THE MODERN AIRPORT TERMINAL

New approaches to airport architecture

Second Edition

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Preface to the second edition

Since the first edition of this book appeared, many significant airport developments have taken place around the world. Major new airports have been constructed and new policies have been adopted to improve the lot of passengers, to help protect the environment and to better connect airports with other transport facilities, notably the railway infrastructure. At any one time it is estimated that half a million people are in the air and another million are waiting in airport terminals. Air travel is now so common, even more so than when the earlier edition was written. Business travel by air is increasing, most Europeans take two overseas holidays a year (one to the sun and another perhaps as a city break) and air commuting for work has dramatically increased as roads and railways have become more congested. In the ten-year period up to 2000 BAA saw a 55 per cent increase in the use of British airports and a 40 per cent growth in the number of flights.[1] Such an increase is above the average growth of the UK economy and above the rise in general living standards. This suggests that air travel is not only popular but part of the mass culture of our society. By 2030 it is expected that the volume of air travel in Europe will triple.

Air travel, once the exclusive pursuit of the leisured classes, is now available to nearly all people throughout the world. Whether in Africa or the USA, travel by plane is the preferred mode of transport for most people for distances over 600km. The questions which need to be asked are:[2]

- Will these passengers find their way round the terminal?
- Will their journey be safe and relaxing?
- Will it be an enjoyable experience?

The answer to these questions is found to a great extent in the arena of airport design. It is the layout and configuration of the airport and its terminal buildings which hold the key to the quality of the journey. Well-designed airports offer the passenger an experience which supports and enhances the journey, a poorly designed airport does the opposite. Since the first edition, many new terminals and even whole new airports have been constructed which we can use as examples of good practice. From these it is possible to reach certain conclusions. First, that as the air travel industry has become progressively de-regulated, the corresponding lowering of fares and expansion of use have made existing facilities increasingly inadequate. There is now congestion in the air, exhaustion in runway capacity, and over-crowding in gate lounges and airport terminals. The task for engineers and designers is not so much the construction of new airports (although this is a significant challenge) but the upgrading of existing facilities. Lowering of fares has meant greater access and a concomitant rise in expectation for other services at the airport. Shopping, leisure and conference facilities are now demanded, and some are provided on a scale which threatens the identity or legibility of the airport terminal itself.

In parallel, there has been a tightening of some controls. Economic de-regulation has been matched by a strengthening of environmental legislation. New standards are expected for sound abatement of surrounding residential areas, for air quality in terminal buildings and outside, for greater recycling of waste and improved energy efficiency. BAA has gone further than most and has produced a strategy for attaining sustainable development. This airport authority now sets environmental targets for itself and the operators which use its facilities. These are significant changes and are discussed in greater detail in the book.

Another change has been the tightening of border and security controls. Airports are now major gateways to continents and to countries. Economic migrants and refugees arrive at airports and are assessed initially within terminal buildings. The customs, passport, health and security checks are required to be ever more stringent especially since the tragic events of 11th September 2001. Somehow the terminal building has to provide smooth passenger movement but to identify and filter out those who are flouting international or national law. Since so many people gather at airports, the terminal buildings themselves have become targets for terrorist attack. Again, this area, where it affects design, has also been expanded.

Changes made to the earlier edition include the expansion of case studies. The revisions are intended to better guide those who commission, design or simply use airport buildings. But through these additions it is possible to draw some important fresh conclusions. First, that the airport is a new type of city, breaking the mould of existing urban areas. Airports start as runways, become a collection of terminals, hangars and control towers, and end up as full urban entities with hotels, parks, business units and even churches. Without noticing it, airports are really new towns which grow at the city edge and eventually threaten the dominance of old centres.

Second, airport terminals are the cathedrals of our age – a huge public space where people gather, wait, eat, sometimes sleep, and usually shop. These are truly twenty-first-century buildings – fluid space for fluid functions using high technology architecture for spatial containment and cultural expression. Like cathedrals, the experience is one of structure and light, and like our grand railway stations, the routes are processional and linear. Herein lies a paradox – the passenger needs a clear sense of direction, a path through chaos and complexity. But the retailer needs dwell time and dwell space – the opposite to fast progression. These are cathedrals in one sense but market places or medinas in another. Guidance is provided on how this conflict can be resolved.

As for landscape design, the airport, like the theme park, is a characteristic post-modern phenomenon. The green deserts between runways, the large turning and security areas, the ghostly lighting and the chain-link perimeter fence are what defines the airport as landscape. So if the airport itself is a new kind of city and the terminal buildings its cathedrals, then the whole assembly sits in a massive sterile green sward isolated from farming and other rural activities. This landscape setting, seen so clearly from the air, provides identity as sharply as the design of the airport buildings themselves. And it is an identity which distances man from nature, itself a metaphor for our age and the very essence of the airliner itself.

It is because of the 'transience, alienation and discontinuity' of the airport, as J.G. Ballard puts it,[3] that architects feel obliged to give shape to these fluid and often chaotic places. If this book helps the reader understand the forces which govern airports and at the same time sketches out a vision of future design aimed at benefiting the passenger, then my efforts as author have not been in vain.

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Introduction

'High tech is the high classicism of postmodernity and the airport is its temple.'

(Michael Sorkin, *Metropolis*, February 1999)

Universality of air travel

Air travel has been described as the defining mode of transportation of the twentieth century.[1] No other form of travel compares with the speed, scale and glamour of contemporary air travel. Flight has opened up continents and allowed mass accessibility much as the railways did on a smaller scale, a century earlier. In the process, air travel has altered our experience of place and time: it has broadened our sense of geography and human experience.

The airport terminal is the central building of the air transport system. Its architecture reflects the glamour, scale and technological prowess of this fast-growing industry. As air travel becomes more popular and accessible, the airport has assumed greater importance as a fundamentally new and challenging building type. Rather like the railway station and theatre combined, the modern airport terminal is a highly charged and symbolic building. It is a miniature city reflecting the values and aspirations of society at large. National image is reflected more directly in the design of airports than in any other building type, with the passenger terminal the key element in public perception.

On the stage of world architecture the airport holds an important place. Airport authorities have been, for half a century, one of the most adventurous patrons of modern architecture. From Eero Saarinen's TWA Terminal of 1959 at Kennedy Airport to Norman Foster's Chek Lap Kok Airport of 2000, airport developers have been consistent in their support of innovative design, whether expressed in formal or in technological terms. The airport of the future will continue to push forward the frontiers of architectural design, creating images and structural solutions that become adopted in other building types. Such is the link between the thrill of air travel and the design of the airport, and between the technology of the aeroplane and that of the terminal, that the next generation of airports will continue to stretch architecture and engineering to its limits.

0.1 Stansted Airport, UK, by Foster and Partners marked the emergence in 1985 of a new generation of airport terminals.

The airport as cultural memory[2]

In many ways the history of the airport is the history of the twentieth century itself. It is the story of modernity acted out in space, speed, light and flight.[3] Within the typical airport there is urbanism based upon rapid movement; large fluid spaces for social exchange; powerful retail, conference and hotel agglomerations; and an architecture which seeks to give identity to an alienating environment. In this placeless world of international companies (airlines, hotel chains, retailers), the designer sometimes struggles to provide physical and cultural orientation. In spite of accelerating globalization, architecture is the means by which geography and history are established. In this transitory environment, the architect creates a gateway to flight and, in the opposite direction, a gateway to continents.

The modern world is increasingly inter-connected physically and electronically. Transport buildings take on a role beyond the utilitarian: they celebrate physical travel and social connections. A review of recent airport designs from Kuala Lumpur to Schipol, confirms the change in emphasis away from mechanistic function to cultural meaning. In the competitive world of the airline business, 'image' is important. A well-designed airport with distinctive eye-catching buildings, attractive interior spaces, planted tranquil areas, and efficient movement systems, serves clients and customers better than anonymous sheds. The trend towards hub airports destroys place, on the one hand, but on the other, makes the need to anchor these structures in the middle of nowhere to some kind of reality. The architectural grammar of modern hubs, captured in the design for the new Schipol airport by Rem Koolhaas, provides an individualized experience in these artificial creations set within placeless landscapes.

We are now witnessing the fourth generation of airport building. Early airports (1930s–1940s) were simple landing strips served by the most basic structures. Second-generation airports (1950s–1960s) had concrete runways, mostly single-storey terminals and distinctive control towers. Third-generation airports (1970s–1980s) were complex multi-terminal places, served by terminal buildings of three or four storeys and road systems which were segregated vertically. Fourth-generation airports (1990s–) are marked by inter-modality (trains, bus, car), terminals which are huge in scale and often linked directly into rail systems (e.g. Chek Lap Kok), and retail is now a serious competing element. A parallel strand of development (logistically quite distinctive) is the growth in hub airports, where a single operator or group of related airline companies fly all passengers to a central point where they are distributed often via smaller aircraft to a number of regional centres. Hubs do not need to be anywhere in particular and their environmental impact (noise and air pollution) means that they are increasingly well away from urban areas. As such, the physical proximity of transport infrastructure to the cities they serve has been broken.

A crisis of urban design

What started as a single exclusive experience (air travel) has over fifty years become a highly complex, socially universal and profitable business. In many airports (e.g. Heathrow), revenue from retail, conference and hotels now exceeds the income generated by travel alone. In this, airport authorities have not always been quick to exploit the opportunities or to resolve problems. Travel by train to airports has often been ignored, the airport estate has lacked legibility and identity, movement for pedestrians has been given a low priority, and the business opportunities for development at both the centre and periphery have been forgotten. Part of the problem has been a lack of vision, especially design vision, part also uncertainty over civic leadership. Since airports inhabit the urban fringe, a kind of in-between space shared with business and retail parks, they are easily forgotten in town planning or urban design terms. Airports have a habit of growing in a haphazard and unplanned fashion and the emphasis of airport authorities (BAA is a good example) is to get the infrastructure right and consider civic design later. As a result, few airports have an urban design framework which defines edges, routes, the nature and configuration of the centre, landscape setting, and how the airport looks from the air. Heathrow in particular is a design disappointment though it generates over £370m a year for BAA.

Herein lies the problem for airport authorities from Stockholm to Sydney. Given the unpredictability of the airline business, how can airport growth be planned on a rational basis and what role does architectural or urban design play in shaping an uncertain future? Airports are, after all, the main global cross-roads between cultural and technological forces.[4] The answer lies in management and design change. Airport authorities need to place designers (not just engineers and project managers) on their boards. Too often, infrastructure engineering drives the future of the airport at the expense of a civilized environment. Runways, taxiing areas and roads are given priority over architectural space, route legibility and passenger satisfaction. Airports are our new cities and need all the qualities we associate with real places. That means a commitment to urban and landscape design, to building as well as interior design, to long-term visions (50 years) rather than short-term goals, and to city-making rather than airport-making.

The airport and sustainable development

Historically, cities which grow are those which are well connected physically. The means of connection was traditionally via water but today it is increasingly by air and rail. The new cities are those on high-speed rail routes and those with major airports nearby. Hence, new cities grow out of places like Heathrow, Roissy and Stockholm-Arlanda – locations which were merely airports initially but which have grown into something much more. Manchester Airport is a good case in point. First seen as a regional airport, it is now a national gateway, a thriving business and conference location, and a magnet around its edge for high tech companies and slightly further afield for new suburban housing estates. Through sensible urban planning and design, these opportunities can be grasped to the benefit of the airport authority and the community at large. Only through the systems provided by town and country planning can the airport play a role in achieving sustainable development at a regional level. Again, few airports have faced up to the demands of sustainability, yet they offer great potential to recycle their waste, to capture and use grey water, to exploit renewable energy (sun and wind), and to preserve pockets of biodiversity. The future will bring sustainable design to bear upon even the sterile estate of the typical airport.

Managing growth requires forward planning which places the airport at the centre of a regional strategy for sustainable development. As airports are major employers (over 58 000 people work at Heathrow and 42 000 at Frankfurt Airport), they provide the opportunity to create a model of social, economic and environmental sustainability. Too few airports come to us from the twentieth century with this agenda, but they will need to face up to these issues to be valid in the twenty-first. Strategic plans are needed to stitch the airport into the physical and social fabric of their regions. Similarly, urban design plans are required to encourage the airport to mature into a city with the airport at its centre. Here the terminal buildings are the 'town centre' – the main public buildings and urban spaces which give identity. This central core of terminals, control towers and linking spaces has to take on a civic dimension with promenades, parks and oases inside and outside the buildings. Since many passengers move between terminals, between modes of transport, and between building types (hotels, stations) the emphasis should be upon routes, movement and circulation. Here the designer needs to handle mass migration, not single movements, and to address perception as well as reality.

The importance of legibility

Distances at airports are often enormous: travel on foot, light rail and travellator opens the airport experience to close attention and much frustration. What is seen from the routes people take at airports often gives them their first experience of a country. The routes need to be legible, attractive to use and periodically way-marked to overcome fatigue. Since the distances are great, the changes of level frequent, and the buildings huge, there is some benefit in designing airport terminals as cities in their own right. Leon Battista Alberti said in 1452 that large buildings were really small cities and this is true, particularly of airport terminals. The typical modern terminal is a huge shopping mall through which airline passengers navigate with difficulty. Rather than design terminals as containers for shops and bars, it is better to restrict retail and commerce to specific areas, as one would in a city centre. Then the terminal can be zoned with streets and squares providing the means of connection to and from the plane. In this urban matrix there can also be interior parks developed as at Kuala Lumpur Airport as green oases within a bigger structural envelope.

Since terminals are places of social exchange as well as movement, space is needed free of retail clutter. The key word here is 'space', for while many terminals are large buildings, their interior sense of space is often lost. Areas for reading, for reflection, for gazing upon the wider environment are needed. Such space, when it does exist initially, is often filled through time, with the result that the architectural experience is eroded (e.g. Stansted). Not only is the perception of volume lost in the process but the physical means of orientation – structural members, roof-lights, long vistas, glimpses of aircraft – are also obscured.

Growth and stress

Airports are economically successful places and the terminal buildings are where the main exchange of people occurs, where customs and control barriers exist, and where passengers and baggage are separated and reunited. Functionally, the terminal represents in the single building what is happening on a bigger scale within the airport itself. Success, expressed as growth and expansion, stresses existing airports and their many buildings. As an organism, the airport is forever having to do more and to work harder within the same space envelope. Airports cannot normally grow outwards and where expansion is inevitable, it takes the form of a fresh foundation. Hence, many world cities are served by a number of airports and within each there are several terminal buildings; most of which are controlled by a different airline. Growth is limited not normally by lack of terminal capacity but by lack of runway space. New runways are needed to handle the growth in air traffic but with the expansion of environmental legislation, many airports are struggling to expand their runway provision. One answer is to reduce the safety margin between flights (currently two minutes at take-off and landing), another is to develop larger aircraft (such as the planned European Airbus super-jumbo with 1000 seats). Another answer is to combine the benefits of flight with high-speed rail by linking modern trans-continental railways directly into airports (the pattern at Frankfurt). However, as travel by plane becomes cheaper and as affluence expands, there is a growth in commuting by air which adds to runway space congestion. Heathrow's recent difficulties with runway capacity highlight the fact that there are limits to growth even with highly successful airports.

When airports experience congestion, passengers experience stress. Terminals are stressful places with periodic bottlenecks – at check-in, security control, customs, and departure gates. Unfortunately, the areas where stress occurs are often the most confined physically. Hence at customs there are queues with space devoid of natural light and adequate dimension. At check-in and the restaurants there are also queues which snake across circulation routes, adding to annoyance. Many of these are the result of air-space congestion reflected on the ground as frustration within the terminal.

As a result, there is a trend towards designing out stress by creating calm places for contemplation away from the bustle of movement or retail activity. Tranquil spaces, acting like parks in a busy city, are often planted with trees and shrubs, and sometimes have fountains to improve air quality and mask background noise. In the competitive world of airports, it is difficult to justify such space on cost grounds, yet the discerning passenger increasingly selects airports and airlines on the basis of the total transport experience. Tranquil environments are needed especially on the airside where passengers may be delayed for lengthy periods.

Airport terminals come in many shapes, sizes and configurations. There are terminals with and without piers, full terminals and satellite terminals, linear and round terminals, and lead airline and multiple airline terminals. All of these are found as single or multi-storey structures. Frequently, terminals which start in one form end up designed to quite a different philosophy a generation later (e.g. Sydney International). The changes stress the terminal internally and exert pressure externally for space in which to expand.[5] Airport designers have the difficult task of providing for growth within the confines of existing buildings while they remain in use. Fundamental re-design is often impossible because of structural limitations, the contradictory agendas of airport operators, and the complex memories locked into former architectural fabric.[6]

Tackling the big picture

Architects almost uniquely have to keep track of the big picture. At airports pressure from aircraft design innovation, from changing management practices of the airline companies, from the airport authority, and from retail and commercial interests all serve to disrupt the clarity of the initial conception. The terminal is pulled in many directions and, as a consequence, the clarity of the initial design is destroyed. The architect has to face four often contradictory challenges:

- the conflict between operational, security and commercial agendas;
- the need to manage artificial environments;
- the need to balance physical and mental states;
- the importance of maintaining cognitive orientation.[7]

In this list, two important principles emerge: that of providing contact with the natural environment (or limiting the artificial), and that of considering mental as well as physical well-being. Sadly, the commercial agenda is usually based upon the maximizing of artificial realities and the operational agenda is based upon quick throughput, irrespective of amenity.

As the go-between representing all the interests at the airport (user, client, retailer, official), the architect has to strike a balance between the demands of permanence and change. This is best achieved by terminals where designs maximize light and space, which use structure as navigation markers, and which allow for commercial colonization without destroying the whole. Under these conditions there are structural, spatial and constructional hierarchies which communicate functional orders, there are movement systems (escalators, stairs, lifts) which correspond with sources of daylight and sunlight, and zones of active and passive activity. Architectural volume and the syntax of structure should defuse tension, offering passengers reassurance through the alienating experience of preparing for flight.

Since architectural space and structure are the key elements of a typical terminal, they should not be neutral. The language of materials and construction has a role in providing sensory pleasure, in connecting with the scale and technology of the aircraft itself, and in making reference to the place where the journey begins and ends. The big picture of airport design is a microcosm of the challenge cities face in a world of global standardization. The science fiction writer J.G. Ballard calls terminal concourses the 'ramblas and agoras of the future – where everybody briefly becomes a true world-citizen'.[8] This may be reality but one where architectural form needs to give particular shape. Terminal design should not lose sight of the particular – of the value of detail, of the place where the airport is located, of the culture it serves, of the climate in which it is located. The challenge is to create the new cathedrals of air travel without them ending up like IKEA stores full of labyrinthine routes within a standardized envelope. Technology and culture can be fused in fresh ways, and without the baggage of older urbanization to cloud judgement, the new cities we call airports can point us to an optimistic future for architecture.

The romance of the airport terminal

Public transport architecture is torn between utility and the romantic. For many people the airport terminal is a functional building which simply provides the connection to the plane. For others it is a place to welcome or bid farewell to friends and lovers, the backcloth to more emotional moments. The volume of the building acts as a container for memories as much as it provides the mere means of access to continents and the growing number of planes that serve them. This is perhaps why the building type has evolved not just into a space of height and volume but into a landscape of romantic and cultural associations.

Elements such as shops, cafés and flower stalls reinforce these non-functional connotations. Even architectural design engages in a dialogue with the spectacular and irrational. The typical terminal is rich in imagery, in chaos and a kind of messy diversity that is a far cry from the functionality of the planes. Airport lounges with their tree-like columns and umbrella roofs suggest a more uplifting moment than the reality of an afternoon glued to the flight departure board.

In a larger airport nearly as many people are waiting for friends as queuing for flights. The non-travelling public drawn to airports by shops and leisure facilities creates a collective audience which challenges the basis of the airport as solely a gateway to the plane. The complexity of people's needs is reflected in an intriguing interactive environment. The human richness supports functional diversity which in turn feeds the multi-coding of space architecturally. The initial simplicity of design gives way to plurality. Order, beloved of certain architects and engineers, erodes into romantic confusion. On the airport estate the roads and swards of cropped grass create a backcloth for mushrooming hotels and business parks whose sense of self-importance is undermined by garish signs and chain-link fences.

The airport terminal is a study in architectural volumes. The check-in hall stands in marked contrast to the meaner departure gate areas. Here smaller and more linear volumes prevail – long spaces designed for queuing or waiting. The lines of passengers reflect in their geometry the long fuselage of modern aircraft. The interaction between contained, yet spacious volumes, and the linearity of gate and satellite piers reflects the basic chemistry of the building type. Added to this, there are often bridges or tunnels to cross the roads and runways. The three elements of the railway station – booking hall, platform and bridge – are repeated in the airport terminal in the form of concourse, lounge and gate, thus confirming Pevsner's theory of the interdependence of transport building types. It is the changing relationship between the three elements which provides a clue to their evolutionary development.

Changes to airports

Since the first edition, changes in regulation and the structure of aviation have greatly altered the airline business. De-regulation has increased competitiveness, bringing down fares, opening up new markets and creating fresh tourist and business demands. This has led to the development of new aircraft with greater carrying capacity and improved energy efficiency and noise performance. It has also led to the expansion of existing airports plus the construction of new ones, and to new concepts concerning the role of airports as conference centres, communication hubs and retail points. At any one time up to half a million people are in the air at one time, travelling for leisure or business. This compares with 2–5 million on trains and 10–12 million travelling on buses. In the past, such travel was rarely connected but in the twenty-first century one talks in terms in inter-modality – of people interfacing between plane, train and bus to reach their destinations.

By 2002 there were twenty times as many airports as in 1940.[9] Looking to the future, the growth of airports is dependent upon the concept of inter-modality – especially the ease with which passengers can move between bus, rail and airport services. The capacity of an airport is determined not by the extent of aircraft movements but by the ease with which passengers can reach the airport. The latter is not a consequence of car access but of travel to the terminal by means of public transport. Hence, the airport of the future will become part of the web of transport infrastructure connecting cities and continents. What makes the airport signification in an age of sustainable development is its role as a potential growth node. The attraction of the airport to business means that the economic power of travel needs to be matched by greater attention to sustainable transport.

New technology has improved the safety and efficiency of airports. Today flights leave and arrive at under two-minute intervals, resulting in 80 flights an hour with an airport of two runways (Oslo) or 90 with three (Chicago). This can result in influxes of passengers of around 10 000 per hour, or about a quarter the capacity of a football stadium. Such volumes are only possible with modern widely spaced runways (usually 2 km apart), with modern methods of baggage handling and people movement. However, whereas new technology on the ground and in the air has speeded up movement bringing turnaround times for aircraft to twenty minutes, greater concern for security has slowed down the throughput of passengers and their baggage. New safety checks, instigated almost universally after 11th September 2001, mean that little passes through to the departure lounge without being subject to an X-ray scan. Speed and security are often in conflict, adding to frustration for passengers and airline staff alike.

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Part one

Airport design

CHAPTER 1 The airport industry

Aviation is a major international industry, which in 2003 carried over 1.3 billion passengers. Of all forms of transport, flying is the most cost-effective, the fastest and increasingly the safest form of long-distance travel. For most international journeys travel by air is the only option, and to make it comfortable and reliable, international standards and regulations apply. These influence the layout, engineering and infrastructure of airports, the design of terminal buildings, and the specification of the aircraft themselves. Civil aviation is therefore a highly regulated and efficient industry, which recognizes few national boundaries or customs. The standardization of operational practices leads to greater safety on and off the ground, and provides an element of uniformity in the criteria that shape airports themselves. Hence runways, taxiing areas, safety zones, passenger piers and terminal buildings all confirm to relatively standardized operational parameters.

The infrastructure of airports consists of five basic zones: the runway, the aircraft fuelling and maintenance areas, the aircraft stands, the passenger piers and the terminal buildings. These are the primary functional divisions that establish the layout and operation of the airport. Secondary areas or buildings may include the flight control tower,

1.1 Marseille Airport, France, extended in 1994 by the Richard Rogers Partnership.

1.2 Kansai Airport, Osaka, Japan: a major public investment in transport infrastructure with private stakeholders. Architects: Renzo Piano Building Workshop.

connecting forms of transport (such as railway stations or light rail systems), the road system, car parks and hotels.

To regulate the aircraft industry, governments have tended to delegate control to industrial organizations in the air transport business. There are three prime international bodies:

- the *International Air Transport Association* (IATA), which represents the interests of aircraft carrier members, such as British Airways and Air Canada.
- the *Airports Association Council International* (AACI), which represents civil airport authorities such as the BAA (previously British Airports Authority).
- the *Institute of Air Transport* (ITA), which represents those other than carriers and airport owners, such as managers, manufacturers and designers.

These three bodies effectively self-regulate and provide a policy framework for the aircraft industry. Because many national governments are little bigger (in GNP terms) than the larger carriers, or generate less wealth than a major international airport such as Heathrow, most governments accept the beneficial influence of these powerful industrial organizations. In addition, there are important national regulatory bodies such as the Civil Aviation Authority in the UK and the Federal Aviation Administration in the USA.

Ownership of airports

The trend these days is away from ownership of airports by the state (either central or regional government) towards either private ownership or partnership between government and private investors. London Stansted is owned by BAA (which is wholly private and quoted on the Stock Exchange), and other major airports, such as Stuttgart in Germany and Milan in Italy, have been denationalized and are now no longer state owned. The reasons are clear: airports require massive injections of funds to adapt to changing regulation, market conditions and commercial opportunity. Only with private capital can the outmoded infrastructure of airports be kept up to date – or so most Western governments believe. In the developing world it is still commonplace for the state or local authority to own and manage airports, but as soon as they become profitable they are quickly sold, often to international organizations. Although many governments cling to the idea that their major airports are part of the state infrastructure of public utilities, in reality the past 10 years have seen a shift worldwide away from government ownership towards some sort of consortium ownership or total private ownership. The prime question, however, is not about who owns the airport, but rather: does the air transport industry exist to provide a public service, or profit for the shareholders? The pattern of ownership throughout the world tends to follow the varying ideologies of the respective governments rather than any obvious regional or subcontinental pattern.

If ownership of airports by governments is declining, there remains a strong group of airports (such as Kansai in Japan) run by a consortium of state and local government, with private companies having a financial stake. Sometimes the airport may be owned by an arm of government, but the principal buildings (such as the passenger termini) are owned, leased or managed by a private organization such as an airline company. The mix of ownership has implications for the operation of the airport and – to some extent – for the design of the parts. Where ownership is vested in government there tends to be a controlling hand over the appearance of the whole airport estate, from hotels to car parks, terminal buildings to control towers. Where ownership is fragmented, or resides in a consortium, there is usually greater pluralism in the approach to design, and often the employment of a wider selection of

1.3 Retail sales now exceed landing fees at most airports. Southampton Airport, UK. Architects: Manser Associates.

architects, designers and engineers. Where there is a split in ownership between the airport and its key buildings (as at Kennedy Airport, New York) the pattern is usually one where different airlines own specific passenger terminals. This allows them to compete with each other as integrated terminal-based services – including ticketing, baggage handling and concessionary shops – all managed by the airline company with which the passenger is flying.

How airports generate income

For the passenger, the airport is a point of arrival or departure – just another stage in the complexity of modern travel – but for the operator the airport is a means of generating income. Generally speaking, there are five ways of earning revenue:[1]

- landing fees
- concessions in terminal buildings
- leasing arrangements with airline operators
- leasing of non-airline operations such as car parks
- equipment rental (such as baggage handling).

Against these earnings. the airport owner has to set two operating expenses:

- maintenance costs (upkeep of buildings, facilities and equipment)
- operating costs (staff salaries, security, utilities costs).

The balance of revenue and expenses determines the profitability or otherwise of the airport. Contrary to expectations it is not the airlines that necessarily generate the bulk of the airport earnings. At Stansted the revenue from the car parks exceeds the landing fees paid by the airline companies, and at Heathrow the money earned through the sale or lease of concessions is one of the principal sources of income, again exceeding the landing fees.[2]

In these balances of profitability, the terminal buildings play a very large part. As an airport expands, generating more traffic flow, the percentage of income from the terminal building itself increases. The increase in throughput of passengers adds greatly to the sale of concessionary and duty-free goods, adding to the fees earned through leasing terminal space to retail and restaurant companies. Growing operational activity is therefore the main aim of the airport operator, who may reduce the fees charged to airline companies (for landing and aircraft parking, etc.) in order to increase the throughput of passengers.

Generally, the larger the airport the greater the percentage of income from the passenger terminal. With small airports (serving up to about 200 000 passengers a year) the landing fees, fuel charges, hangar rentals etc. exceed the revenue from terminal areas by about 25 per cent, but with large airports (serving over 4 million passengers a year) income from the terminal exceeds that of the landing area by 40 per cent.[3] For the typical airport, landing fees account for about 20 per cent of total income, but revenue generated by commercial activities of one kind or another (such as concessions in the terminal building and rents to franchising companies) can approach 50 per cent of total income.

Looking more closely at the sources of income generated in the terminal area, evidence from the USA shows that car rentals, parking fees, restaurant leasing fees and fees from speciality shops generate about 80 per cent of the revenue. The implications are obvious in terms of the design and management of such areas: create as much space in or around the terminal for these secondary activities, ensure that the environments formed are conducive to loitering *en route* to the plane, and (if possible) manage flight departures to maximize 'dwell time'.

Because much of the commercial revenue is the result of duty-free shopping (27 per cent of BAA's total earnings in 1995), a recent trend has been towards providing such shops not only at the beginning of a flight (and during it) but on arrival. Although this allows the airport to exploit both departing and arriving passengers, the move has been resisted by airlines themselves, who derive considerable sales (especially with holiday charter flights) from on-board purchases. However, there is the advantage of reduced congestion and less weight on planes in transferring duty-free to the end rather than the beginning of a journey. For the operator and designer of the terminal building there are implications in re-ordering duty-free shopping. The arrivals area is one of the most congested and controlled of all zones in the terminal building, and customs staff have resisted the change. However, where arrivals duty-free shopping does occur (as at Bangkok and Singapore), the additional income for the airport can be high.

1.4 Even regional airports such as Southampton enjoy the benefit of commuter and international travellers. Southampton Airport, UK. Architects: Manser Associates.

1.5 Airports are increasingly leisure destinations in their own right. Heathrow Terminal 3, London, UK. Architect: D.Y. Davies.

Growth in airport demand

In spite of the slow-down in demand after 11th September 2001, for most of the past 25 years the world air-transport industry has seen passenger numbers grow by about 6–7 per cent per year. From showing the characteristics of an infant industry in the 1960s and 1970s with rapid growth, fast-falling passenger-mile costs and heavy investment in infrastructure, the air transport industry tended to stabilize in the mid-1990s, with growth closer to 5 per cent after 2000. However, while growth rates in Europe and North America have followed this pattern, Asia and the Pacific Rim countries still show higher-than-average rates, with noticeable continuation in investment in new and expanded airports.[4] In some regions, such as western Europe, the development of alternative means of rapid transit (such as the TGV high-speed train) may further retard the growth in air transport, but for many regions travel by air remains the most viable, safe and cost-efficient method of travelling distances over about 1000km. Also, with aircraft manufacturers developing new designs capable of carrying more passengers at less cost through lower energy levels, the cost per kilometre of air travel may again fall, fuelling further increase in demand.

Air travel is a product of four related factors: the supply of people, the need to travel, the resources available to spend, and the existence of an airline transport infrastructure. These four factors operate in different ways in different regions of the world. Whereas in the West the infrastructure exists and an increasing percentage of people can afford to travel, in the Pacific Rim and Asia more people can afford to fly than before but the airport infrastructure is not adequately established to serve their needs. Also, the need to travel is dependent upon the existence of an economy that requires business travel, or a tourist industry that provides holiday destinations served by air. A further factor is the characteristics of the region, especially the distribution of cities and population density.

Forecasting future demand is not simple, and changes in technology can destabilize predictive models. For example, innovation in communication technology may reduce the need to travel, and the trend towards high-speed trains and high-speed ships may further undermine the airline industry's monopoly on reduced journey time. Concerns over terrorism, global warming and other adverse environmental consequences of aircraft travel may also prove a constraint on future growth. However, in spite of this, the UK government expects the volume of air traffic to triple by 2030.

What is an airport?

Airports are large, complex and generally highly profitable industrial enterprises. They are part of a nation's essential transportation infrastructure, which, besides providing thousands of jobs at the airport itself, supports a much wider area in social and economic terms. It has been estimated that for every job at the airport a further one is created in the region. As large industrial complexes airports consist primarily of:

- runways and taxiing areas
- air traffic control buildings
- aircraft maintenance buildings
- passenger terminals and car parks
- freight warehouses.

In the past, the airport structured these five principal activities into airside and landside zones, all enclosed within a security fence and served mainly by car or airline bus. Today, however, the trend is towards more social, commercial and tourist development at airports, with conference facilities, hotels and tourist information shops commonplace. In addition, the airport is seen as part of an integrated transport system, connected not only by car and bus but by mainline or underground railways.

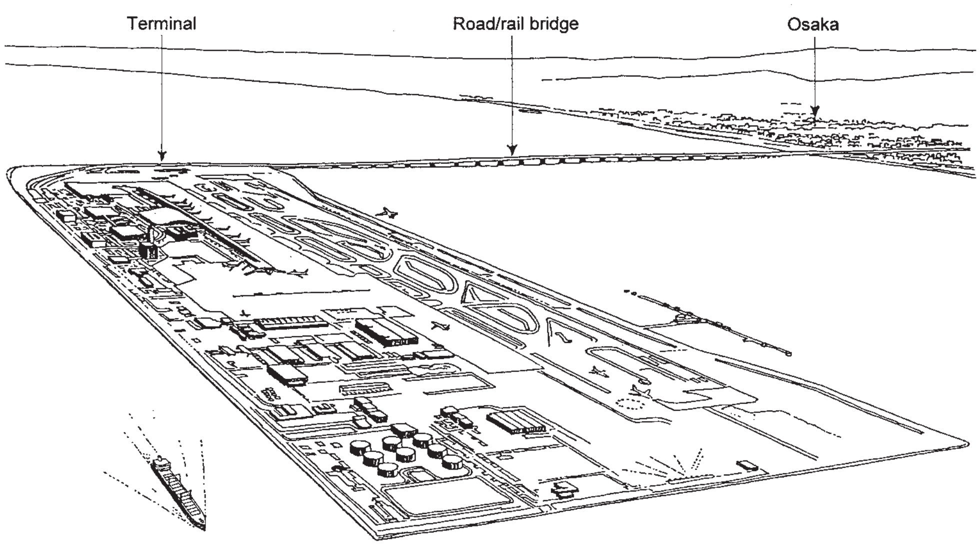
Such is the expansion of facilities at airports that most today are more profitable than the airlines that use them. The major problem for the airline company is the limited services it can provide: transporting people and goods is not as profitable as generating revenue from rentals, concessionary arrangements with retailers or airport landing fees. Heathrow, for instance, in 2000 earned £295 million (about £6 per passenger throughput), which far exceeded the income of British Airways, the major carrier at the airport.

Airports are major transport infrastructure facilities at, above and below ground. They are significant sources of pollution, and of environmental impact near and further afield, and a major concentration of energy usage. They are also cultural, social, economic and commercial points of exchange. In many ways the airport is a microcosm of the city – a satellite that orbits at the edge of a major conurbation but which operates as an urban entity almost on its own.

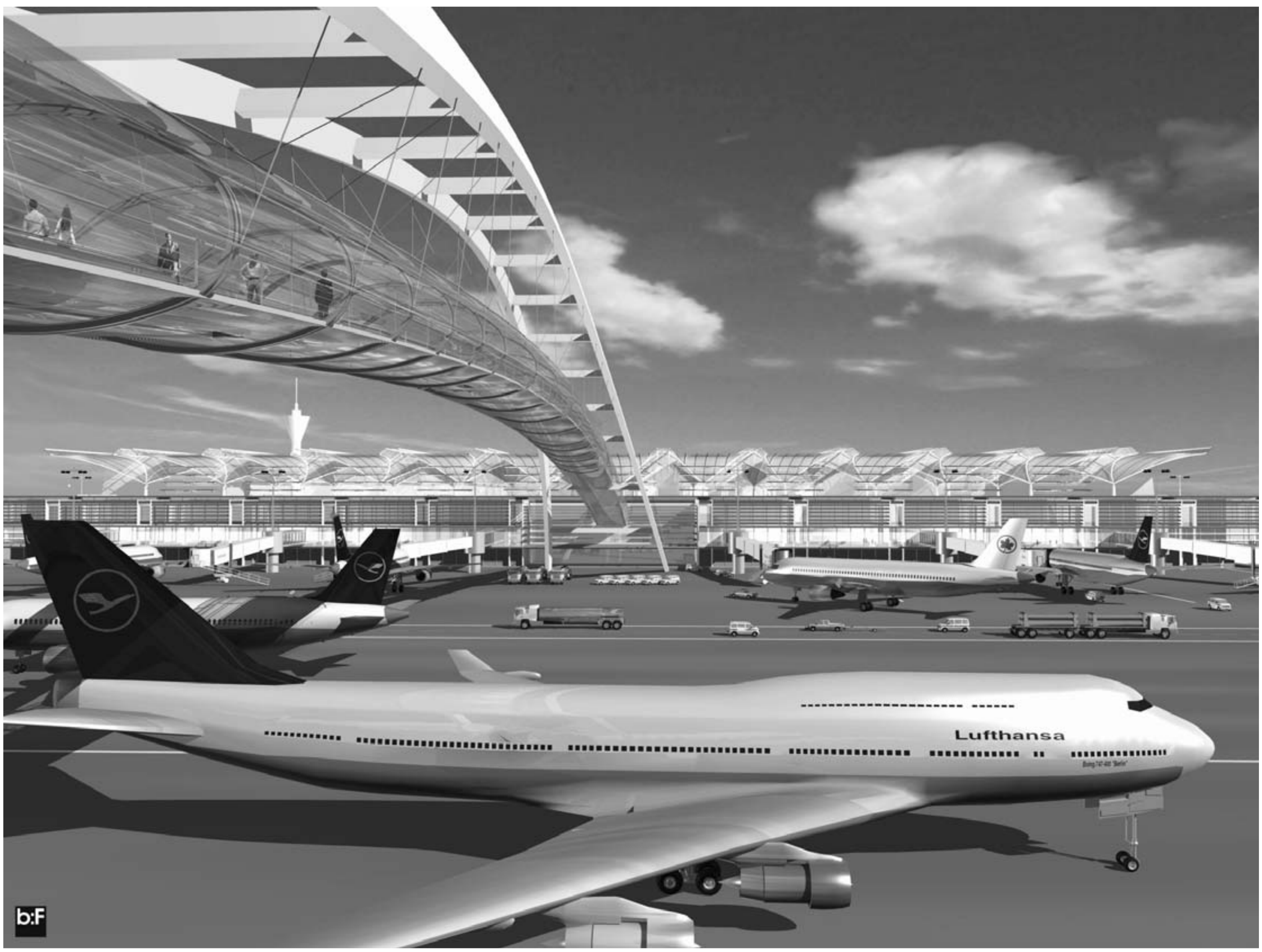
There are three main groups of players at a typical airport:

- the airport company that manages the airport estate
- the airlines that use it
- the passengers.

Those who are encountered at airports are generally represented by one or other of these groups. However, as airports become more complex and more interesting as a destination in their own right, and as they take on more of the characteristics of the city they serve, there begin to emerge other user groups. Mature airports have extensive restaurant, retail and leisure facilities manned and often used by people



1.6 Airports are concentrations of energy use, and have an enormous environmental impact. The trend is to locate airports on offshore islands. Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.



1.7 Terminals celebrate the transition from ground to air. Berlin: Schönefeld Airport. Design by Von Gerkan, Marg & Partner.

1.8 The airport can be seen as a new form of city. North Terminal, Gatwick Airport, UK. Architects: YRM.

who do not belong to the three principal groups. Also, there are security police, fire and ambulance staff. Many large airports have become leisure destinations, attracting people on day trips from further afield. The functional and social diversity of the modern airport leads inevitably to a blurring of the organizational clarity of the buildings – particularly the terminal itself. In some ways a large modern airport performs like a new town. It has enormous economic impact on, and makes large demands upon, the regional infrastructure. Conceptually, an airport is structured like a town, with a centre (where the terminal buildings are located), industrial areas (hangars and warehouses), an effective road system, and residential areas (hotels in the centre, motels at the edges). Many airports ape new towns in their use of public art, landmark buildings and employment of dense corridors of tree planting at their edges and along principal roads.

For the architect, the passenger terminal is the main airport building and opportunity for architectural expression. Other structures, such as hangars and control towers, are technological and structural challenges, but they do not provide the celebratory or processional potential of the terminal. Functionally, the terminal is the building that divides landside from airside: it establishes the boundary between the public realm and the private estate of the airport. This division, expressed directly in the customs and baggage control systems, allows the terminal to be the major organizational and control mechanism at the airport. To cross the line between landside and airside is symbolic of the move from the ground

1.9 Retail and leisure activities can dominate the environment of the terminal. Good design consists of striking a balance between tranquillity and bustle. Terminal 3, Schipol Airport, the Netherlands. Architects: Bentham Crouwel.

Table 1.1 Interaction between the airport system and infrastructure

System	Infrastructure
Airways	Air traffic control
Airports	Runways and aprons
Airlines	Hangars
Aircraft	Terminal buildings
Air passenger	Hotels
Air freight	Car parks
	Warehouses

1.10 Airports, more than most building types, need to cater for unpredictable growth. Hamburg Airport, Germany. Architects: Von Gerkan, Marg & Partner.

to the air. Ticket controls, customs and immigration barriers, baggage extraction and duty-free lounges are all part of this transition. Similarly, the means of reaching the aircraft via passenger piers or light rail systems (as at Birmingham and Stansted) is a further symptom of crossing between landside and airside.

Organizationally, the terminal building is the key element within the airport estate. It is, however, just part of an integrated system, which involves a complex interaction between airline companies, airport authorities and the traveller. The reputation of airports is, however, determined by the quality of its terminal buildings, not just as architectural imagery but in terms of customer needs. Well-designed terminal buildings enhance the reputation of the airline companies that use it, and the airport itself, and ensure that passengers enjoy a comfortable, stress-free start and end to their journey.

If an airport is a self-contained urban entity not unlike a new town at the edge of a city, the terminal buildings are its public buildings. They have much the same relationship to the airport as shopping malls and commercial buildings have to the city. The terminal building is where the travelling public congregate, exchange currency, buy snacks and gifts, use the telephones and Internet machines, and savour the experience of travel. Internally, the shopping and leisure malls provide entertainment for the traveller; externally, the terminal provides the means to spectate upon the aircraft gathered on aprons outside the windows. Inside, the bustle of movement of people from different regions and at different stages of their journey provides a further spectacle. The function of terminals is to celebrate these activities, to raise the spirit, to enhance the anticipation of air travel.

How airports grow

To accommodate the growth in demand for air transportation, which has been at 6–7 per cent per annum over the past 25 years, the infrastructure of air travel needs to grow in five distinct ways:

- More aircraft with greater carrying capacity are needed.
- Airspace and traffic control facilities need to expand.
- New and enlarged runways are needed.
- Passenger facilities need to expand, especially terminals.
- New and more efficient means of reaching the airport are needed.

At different airports, constraint upon growth may be in different areas or combinations. For example, Heathrow's expansion in the late-1990s was curtailed by lack of terminal space and by poor means of reaching the airport by public and private transport, rather than by lack of runways or airspace. In contrast, many North American airports (such as Washington) and Asian ones (such as Tokyo) have their potential expansion limited by lack of runway space.

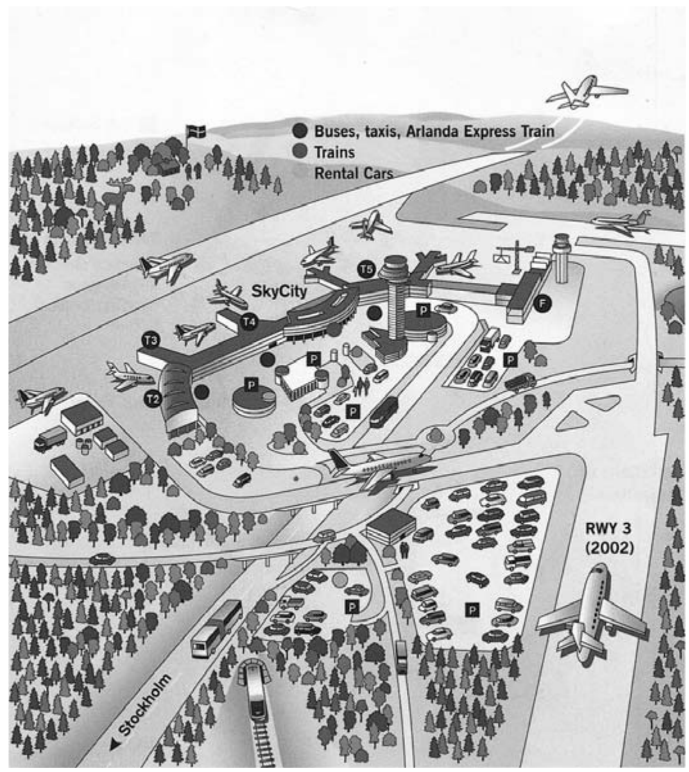
Predicting future demand for air travel and the implications for infrastructure provision, and making better use of existing capacity, are precise arts. Part of the equation,however, relates to aircraft design. As new passenger aircraft are introduced, with shorter take-off and landing lengths, greater capacity and speedier turnaround times, the basis for prediction changes. With Boeing's introduction in 1996 of the 777 (with its greatly increased passenger-carrying capacity), and the further development of STOL (short take-off and landing) aircraft, the relationship between airline company needs and airport provision begins to change.

It was estimated that to meet demand some 4000–4500 extra jet aircraft were built between 1990 and the year 2000.[5] Such a level of increase puts a strain on existing provision across a broad front. Some airports grow by adding new runways (as at Manchester and Lyon), others by building new terminals (as at Heathrow and Stuttgart). However, where space is limited or access is poor there is little alternative than to build a new airport. This was the justification for the development of Stansted, the building of the new airport at Lan Tao Island in Hong Kong, Kansai Airport in Japan, Munich Airport in Germany, and the new airport in Athens. In each of these cases the airport occupied a greenfield site (or man-made island) with, where possible, flight paths taken over water rather than land. In most of these examples, too, the airport is joined to the infrastructure of public transport at the time of construction rather than later.

Most airports expand by building new runways and new terminal buildings. Investment in both is enormous, and each makes demands upon limited space. Gatwick has expanded by a combination of new runways and new terminal buildings, though it was terminal space rather than runway space that was the greater constraint upon growth. Heathrow has seen a similar pattern (construction is underway on the building of Terminal 5), but here the limiting factor is the capacity of roads, motorways and rail services to support the world's biggest airport. Where growth is more moderate it may be possible to expand the existing terminal (as happened at Marseille, Edinburgh and Glasgow) rather than build afresh.

1.11 Terminals usually mark the growth rings of mature airports. O'Hare Airport, Chicago, USA.

1.12 Stockholm-Arlanda Airport shows the complexity of movement on the ground as well as in the air.



If the overall growth in air transport has been between 6 and 7 per cent, the increase in international air traffic has been even more marked. In the 1980s the growth here was 14 per cent,[6] and this sector of the market has continued to expand faster than the domestic sector. International passenger traffic has been most marked in Asia and the Pacific regions, and it is here that runway capacity in particular is under most stress. International flights use bigger aircraft, make greater demands upon runway and apron capacities, and – with their larger passenger loads – put terminal buildings and baggage handling under greater strain. Hence, if airports have the capacity for international traffic, they tend also to be able to cope with national and domestic pressures.

As a general rule, the biggest constraint upon airport growth is lack of runway provision. The environmental problems associated with runways lead to lengthy planning delays, which mean that airports are often behind in their forward provision for growth. Runways cannot easily be expanded without major disruption to the operation of the airport. New, rather than expanded runways are generally more desirable, but overcoming community objections and meeting safety regulations can be a complex and difficult task. However, with new or expanded runway capacity, the next constraint upon growth is usually the passenger terminal. Hence there needs to be integration of provision and a phasing of expansion that allows the airport to grow in a smooth fashion. The history of Heathrow, Orly Airport in Paris and O'Hare Airport in Chicago highlights the problems created by not planning adequately for growth, particularly in the provision of terminal buildings.

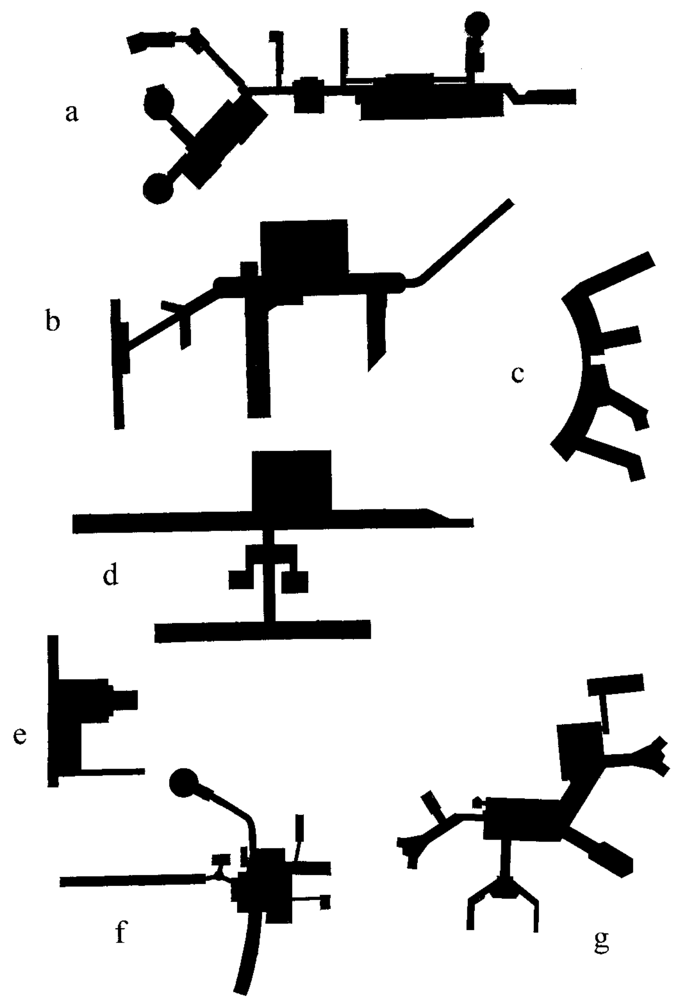
Accommodating growth at airports

Growth in air traffic in the past decade has not been the result of competition between carriers but is rather due to the ability of airlines to cut their costs to the point where they have been able to lure customers from other modes of travel. Airlines now carry passengers who had previously travelled by car, bus or train. As a consequence, growth has tended to be by short-haul carriers who operate smaller aircraft and provide several flights a day. This has led to the expansion of many regional airports which have, in addition, used the availability of cheaper flights to help revitalize the local tourist economy.

New business and leisure travellers tend to put pressure on other aspects of the airport, such as access roads, parking, catering facilities and security systems. More affordable flights have led to congestion as well as prosperity, leading to pressure to create rail links to airports. Over the past decade airports have become not isolated facilities at the edge of cities but part of an inter-connected web of transport infrastructure. Frequent bus and train services to airports mean that airline companies can maximize the benefit of new methods of aircraft servicing at airside which, for example, allows a Boeing 737 to turn around in 20 minutes (as against over an hour for a Jumbo).

Four conditions are needed for the growth of an airport:

- an adequate population base within one hour's travelling distance;
- the ability to expand retail facilities and security on the ground;
- minimal traffic congestion in the sky;
- good public transport connections on the ground.



1.13 Comparison of footprints of mature airports: (a) Detroit; (b) Heathrow Terminal 1; (c) J.F. Kennedy Terminal 8; (d) Heathrow Terminal 3; (e) Gatwick North Terminal; (f) Gatwick South Terminal; (g) Schipol. It is difficult to see the plan shapes as the result of rational growth.

In some ways, low-cost carriers target airports such as London Stansted that meet these criteria rather than compete with established carriers at already congested airports such as Heathrow.

The air transport industry: future trends

In 2000 the air transport industry's impact on gross world output amounted to US $900 billion, creating some 25 million jobs across the globe. By the year 2010 the economic impact is expected to exceed US $1500 billion and over 30 million jobs.[7] Growth rates in the industry, which averaged 7 per cent in the 1970s and 6 per cent in the 1980s, are still expected to be over 5 per cent up to the year 2005. It is anticipated that between 1985 and 2005 the number of people travelling by air will have doubled, putting pressure on terminals, airline companies, air space and runway capacities. In Europe, IATA expects the number of passengers who travel by air to rise from 394 million per annum in 1990 to almost 1010 million by the year 2010.[8] Taking a longer view, the UK government expects a tripling of journeys by air by 2030 compared to 2000.

World growth in air transportation will reach critical levels in terms of infrastructure provision in Europe and North America within the next decade. It is now widely admitted that the growth in aviation facilities cannot keep pace with demand. In the Pacific Rim region it was estimated that 50 per cent of airports were constrained by capacity limitations, even by 1995.[9] In the Asia-Pacific region passenger growth of 8 per cent per annum is the norm, with South Korea's Seoul airport achieving a 14 per cent expansion in passengers.[10]

Aviation infrastructure consists principally of:

- airspace capacity
- airport capacity (runways and terminals)
- surface access to airports (road, rail, metro, etc.).

While expansion of all three is necessary to meet future demand, it is surface access to the airport that is often the most critical and the most frequently overlooked. Links between the city, region and airport need to keep pace – in quality, comfort and convenience – with the growth in customer quality at the airport. Similarly, airspace capacity needs to be expanded (with a corresponding updating of the air traffic control system) if passenger growth increases are to be accommodated. Aircraft stacking in revolving formation above airfields while they wait for available runway space is a regular occurrence these days at the world's busier airports. Runway efficiency is also undermined by different sizes of aircraft using the runway at the same time. Commuter jets and

1.14 The design of aircraft and loading systems tends to determine airport and terminal layout. Hamburg Airport, Germany. Architects: Von Gerkan, Marg & Partner.

1.15 Airport expansion consists in providing new links in each part of the system. Stuttgart Airport, Germany. Architects: Von Gerkan, Marg & Partner.

international flights cannot use a runway simultaneously without causing difficulties for air traffic control, apron services and runway managers. Although mixed traffic causes runway-use headaches, new computer systems being developed by McDonnell Douglas and NASA seek to integrate passenger terminal area use and air traffic management.[11] Congestion in the skies and on the ground are related factors in airport planning. The three elements in the system (airspace, runways and terminals, and surface transport) need to be considered in unison if bottlenecks and inefficiencies are to be avoided.

It is estimated that 10 000 commercial aircraft operate today, carrying about 1 million passengers a day, and that a further 12 000 aeroplanes will be delivered by the year 2010.[12] A third of these will replace obsolete craft, and two-thirds will accommodate growth. The new aircraft will be larger, quieter, ‘greener’ and more flexible to operate than the earlier generation of aircraft. Being larger (average seating capacity of 400–500) they will ease congestion in airspace but add to that in the terminals and in surface transportation. Bigger aircraft result in sharper peaks in passenger throughput, which puts stress on interior space and public transport provision. Having a larger wingspan than earlier aircraft, the new generation of large, high-load, twin-jet aircraft (such as the Boeing 777) require greater manoeuvring space on aprons. Hence groundspace rather than airspace is put under pressure. The same will be true with Airbus Industries’ A380 plane with a seating capacity of 550–650 and a range of 13 700km. These larger aircraft relieve pressure on airspace and air traffic control but shift it to ground facilities, especially apron areas, passenger terminals and the public transport infrastructure serving the airport.

Growing aircraft size is a trend discernible today. Costs, particularly energy costs and airspace congestion, mean that fewer, larger aircraft are preferable to many smaller planes. Speed, however, is another area undergoing change. The growth in the Pacific Rim market has led airlines to ask whether flights from London or New York to Tokyo, which currently take 10 or 12 hours, can be undertaken in half that time. Supersonic aircraft (known as high-speed civil aviation:

1.16 The economic potential of tourism is dependent upon cheap flights and modern efficient airports. Palma Airport. Architect: Pere Nicolau Bover.

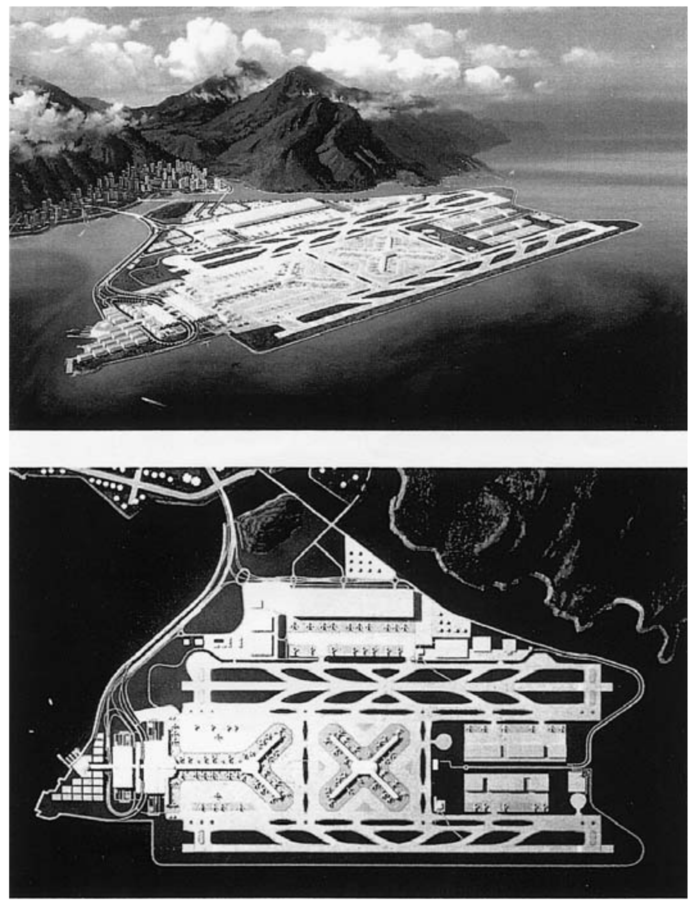
HSCA) could potentially cut journey times by over a half, but the technical feasibility of carrying high passenger loads has yet to be demonstrated. Also, airport and community noise, engine emissions and seat cost remain obstacles to further development.

The future of air transport is dependent upon the provision of infrastructure (aircraft, airports, transport links) and upon airspace availability. Future growth can be met only by the expansion of all the elements in the chain of the airline journey. This means investment in aircraft design and technology, in airport runways and terminals, in airspace provision and traffic control, and in ground transportation links to airports. Satisfying customer needs means keeping the costs down for the passenger while providing comfortable, safe and fast transport. Meeting anticipated levels of growth within ever-tightening environmental regulations and reduced government subsidies is both a challenge and a massive source of employment for aircraft designers and manufacturers, airport architects and engineers, and those involved in the operational management of air transport facilities.

Economic impact of airports

The location and development of airports have a major impact upon economic prosperity. Regional planning and airport growth have to be co-ordinated if the benefits for both are to be realized. Unfortunately, for some regional airports, the growth in hub distribution systems has deprived them of potential development both at the airport itself and in the vicinity. Hubs draw to a single centre the spokes of aviation growth at the periphery with the result that the centre of gravity of economic potential is also drawn inwards. Hence hub airports such as Heathrow become over-heated while the regional edges are, relatively speaking, starved of investment. The advantage of hubs to companies such as BAA is the ability to exploit dwell time and to develop conference and hotel facilities at the airport edge. A hub, whether at Heathrow, Denver or Schipol, draws investment to it at the expense of smaller regional airports. When landing slots are limited, regional links also have to compete with inter-continental services – adding further to the pressure on airports at the periphery of the system. If regional airports in the UK such as Aberdeen or Newcastle are unable to afford landing slots at the European hubs, then there is a loss of inward investment in non-airline business. The reality of regional development in Europe is that good airport links are as important as the road or rail network.

1.17 Off-shore islands can be created for the construction of new airports but for the economic benefits to flow to local communities, cheap surface transport is essential. Chek Lap Kok Airport, Hong Kong.



Except for Manchester and Glasgow, the regional airports in the UK have few direct intercontinental flights. Passengers from the regions have normally to pass through a hub to gain a flight to cities like New York or Cairo. Although connecting flights may exist, the road or rail network may be inadequate. To travel, for instance, from Leeds or Bristol to Gatwick or Stansted would normally entail a poorly integrated ground journey. The lack of co-ordination between aviation policy and ground transport adds further frustration to a typical journey from the UK regions. Without integration between air and land transport, the regions are unable to develop their full economic potential. The dominance of Heathrow as the UK's major hub has led some to call for the splitting up of BAA so that the regional airports can flourish.[13] Without strong regional airports, many economists argue that the comprehensive urban renewal of older industrial centres will not be achieved. And for effective planning to exist, there needs to be a development framework for the growth of the hinterland of the airport based upon the three dimensions of sustainable development – economic, social and environmental.

Limits to airport growth

As the twenty-first century begins, it is apparent that the worldwide growth in air travel is outstripping the capacity of airports and air traffic control systems. The result is congestion in the air, on runways, and in terminal buildings. Growth in demand, if not met by provision, will result in delayed trips, deteriorating quality of service, unacceptable levels of overcrowding in terminal buildings, and diminishing safety in the air. For the passenger, awareness of overcrowding is most evident at the terminal, where queues and delays can undermine customer satisfaction.

The main constraints on expanding airport provision are:

- environmental factors and planning delays
- the availability of suitable land for airport construction
- the willingness of the industry to invest in expensive runway and terminal provision (particularly true of government-owned airports)
- lack of available airspace.

Inadequate scale of airside or landside provision can lead to bottlenecks, delay and threats to safety. Normally it is runway capacity that is the controlling element of the airport system.[14] Runway capacity is dependent upon air traffic control, characteristics of demand, environmental factors, and the number and design of runways. To increase provision one normally has to expand the number, length and orientation of runways, plus the connecting taxiways. Because there are safety criteria for the spacing of aircraft arriving or departing at an airport, the capacity of the system can be calculated. However, the weather plays a large part, and congestion can occur at times when slack exists in the system. The relationship between weather and traffic control is often more critical on a daily basis than runway capacity. However, when the system as a whole becomes heavily used when queuing on the ground and stacking in the air may have to be employed. Predicting when the runway system is approaching capacity requires complex analytical models.

It is less easy to predict when the capacity of a terminal has been reached. Passenger needs expressed as space levels per person are not as scientifically determined as with aircraft on runways. It is evident, all the same, that many airport terminal buildings are unacceptably congested, and that the quality of journeys is suffering. Customer surveys have highlighted overcrowding of public areas and unacceptably long queues as areas of dissatisfaction with terminals, especially at check-in areas and departure lounges. Delays to passengers can lead to delays to aircraft, which puts the air traffic control system under stress.

1.18 The terminal is at the centre of a complex system which requires ever more land and energy. Southampton Airport, UK. Architects: Manser Associates.

1.19 This view of Terminal 2 at Charles de Gaulle Airport, Paris shows the benefit of a strong sense of identity from the air.

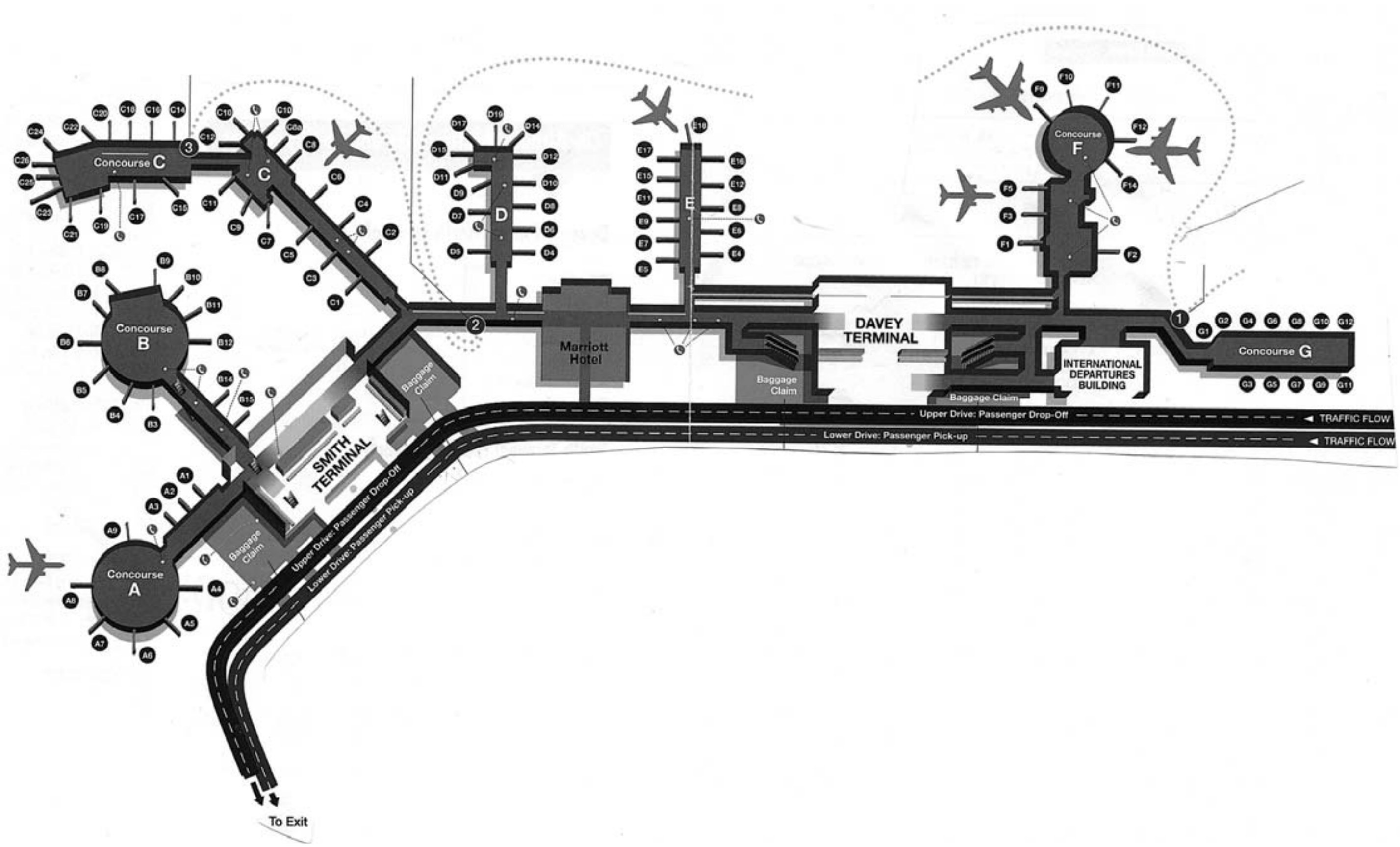
Congestion also occurs at the interface between the runway and terminal: that is, at the terminal apron. This is where the aircraft are parked while being refuelled and serviced, and where passengers and their baggage are loaded or unloaded. Too few 'gate' or 'stand' positions on the apron can limit capacity even when runway and terminal areas are more than adequate for the level of demand. Increasing the area of the terminal apron and the number of aircraft gate positions can give the terminal extra capacity (as with the rebuilding of Heathrow's Terminal 1 with extended piers). Generally, the layout of the terminal provides gates in three recognizable geometric patterns: linear, projecting, and satellite. The clearances required for noise, blast, heat and fume protection, added to the movement characteristics of the aircraft (the angle at which it parks and its turning radius), determine the optimum layout and spacing of gate positions.

The capacity of an airport is determined by the availability of airspace, and by runway provision, apron space and terminal size. Growth in one area normally requires corresponding adjustment in another. Airports tend to carry on growing until they reach capacity, when a new airport is required. To meet the anticipated threefold increase in air traffic movements over the next 50 years airports have to adopt strategies for growth. Because the planning approval, design and construction of major airport facilities can take a decade, operators and carriers have to be alert to changing trends, and be willing to adjust future plans. The history of the airport is one of crisis management rather than the systematic analysis of growth and the expansion of provision.

Flexibility and the sense of the whole

Airports are unpredictable places: they grow often haphazardly and they change their function and purpose over time. What starts as a small regional airport may in a generation become a busy spoke serving a distant hub. Also, what begins as an airport may evolve into a major business location with hotels, conference halls and science parks nearby. These in turn lead to pressure to construct housing, to build schools and colleges, and to locate leisure facilities near the airport. In time, the isolated airport grows into a new town with an infrastructure such as railways and motorways constructed to serve it. In this regard the airport is a new kind of city, one whose seed germinates through the chemistry of business travel and mass tourism.

The problem for the airport planner is to know how to direct the peripheral growth without impeding the development of the core airline businesses. To the French architect Paul Andreu, airport authorities should recognize the importance of a kind of 'open-ended planning' which, in the manner of living organisms 'recognizes the continual possibility of adaptation and development'.[15] Such open-ended planning is based upon Andreu's notion of 'unity' where there is a coherent whole rather than a kit of parts. This requires a masterplan based upon the logic of geometric ordering with space for expansion



1.20 Apron space, terminal facilities, gate areas, baggage and road capacity are in a state of dynamic equilibrium at most airports. Detroit Airport.

provided at the perimeter of each facility whether it is building, runway or servicing structure.

The same principles apply within the terminal building where the demands of growth and change are equally marked. The terminal should be able to expand or adapt itself internally (all rooms less than 3m high, Andreu suggests, can do as they please) as long as there is an architecturally unified and not overly simplified space. The role of construction and materials is to give the terminal its sense of unity and legibility, with each structure at the airport contributing towards the sense of a landscape of buildings. Rather than achieve this by restraint, Andreu argues that the real meaning of such places is realized through light and the colour and movement brought to them by people.[16]

Planning for growth

The UK government forecast in 2001 that passenger numbers could double at UK airports in 20 years. This has led government planners to explore the location of a new major airport in the south-east of England and to plan for significant expansion in capacity at those elsewhere. What was needed, the government argued, was a large flat area with low density of population which is already well served by road and rail surface transport. Low density of habitation is desired because under EU Human Rights Law, residents have the right to night-time silence for sleep (normally seen as 11.30 p.m. to 6 a.m.). What all airport authorities ideally require is 24 hours a day, 365 days a year flying capacity with planes taking off and landing every 3 minutes.[17]

There is, however, a conflict of interest between remote rural locations for airports and other environmental factors. For example, staff travel time, costs and levels of CO_2 emissions increase the greater the distance between home and work. Passengers also have to travel further even though the flight paths are not over residential areas. Locating an airport near to areas requiring economic or physical renewal also has advantages for sustainable development. Remote rural areas for new airports may keep noise disturbance to a minimum, but this does not help regenerate depressed areas such as East London. The airport is an economic magnet which in time leads to social regeneration and physical renewal. Questions of location need to address matters beyond the issue of noise.

Air travel and sustainable development

Some contrast that flying is the most effective means of wrecking the planet. They argue that every passenger on a return journey between Britain and Florida produces more carbon dioxide than the average motorist does in a year.[18] However, this fails to acknowledge the 40 per cent efficiency gain in aircraft engines in the past ten years, or the greater carrying capacity of modern aircraft over their predecessors. Air travel, like all forms of transportation, is a measure of success and of liberation, not just from the forces of gravity, but the stifling effects of geography.

In 2003 the UK government stated it expects a near tripling of the number of passenger journeys by air by the year 2030.[19] The impact on global warming will be enormous, as will be the drain on diminishing supplies of aviation fuel. The growth in air travel since 1960 has been nurtured by governments through assistance to airport authorities and a refusal to levy fuel duty or VAT on airlines. The argument is that air transportation is good business and to some extent promotes social well-being. How the needs of the aviation industry and the protection of the environment are to be reconciled remains to be seen. Although tourists are often active in helping to protect the natural and cultural landscapes they visit, their own journeys are destructive of the very resources they cherish. In this the airport is not a neutral participant but can, through the innovative design of terminals, seek a better balance between the corporate ambition of the airline companies and ecological principles.

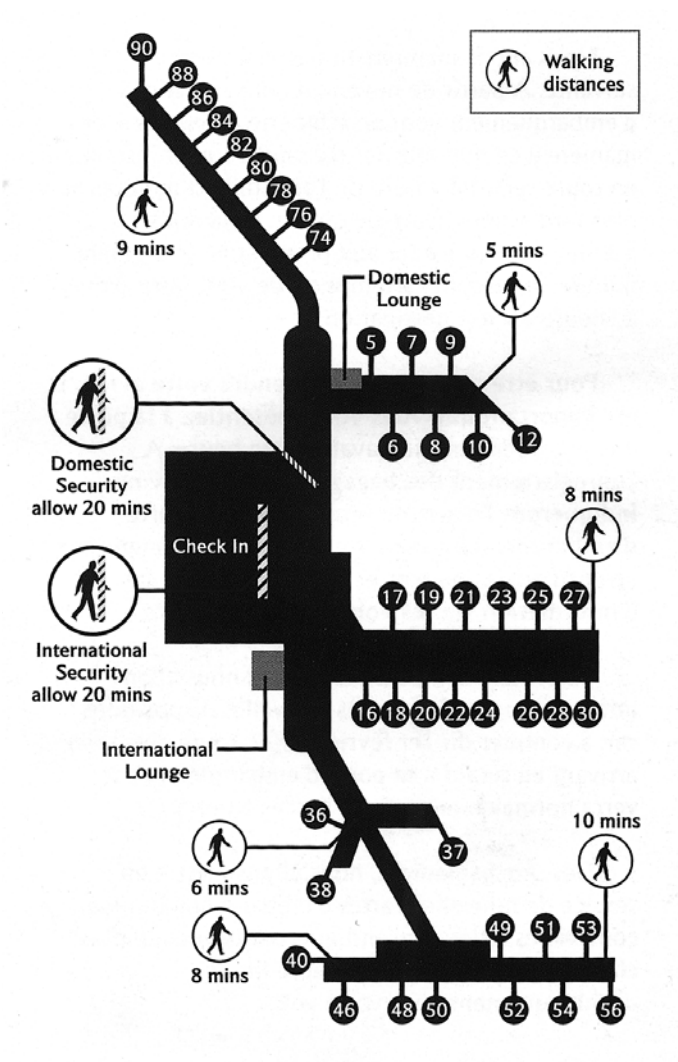
The capacity of airports

There are four factors which limit the growth of airports:

- runway capacity
- terminal capacity
- surface transport capacity
- passport, immigration and security capacity.

Of the four, runway capacity is traditionally seen as the most critical, but new larger aircraft and the compression of the time interval between take-offs or landings have shifted the focus onto the terminal itself. The airport is a system which collects, processes passengers and finally lifts them into the air to be dispersed to countless destinations. It also receives an equal and opposite flow. In addition, a large number of people present at airports are not passengers at all (greeters, airline staff, security personnel) and they add to congestion.

Lack of runway capacity and congested airspace can jeopardize the growth of even efficient, mature airports. Having runways 2 km apart allows the airport authority to operate each runway independently. However, it is common to find an airport with two major runways with a third minor one at right-angles. Sometimes the three runways are positioned to form a triangle with the terminal buildings in the centre and hangars at the periphery (e.g. Stockholm-Arlanda, Sweden). Where two parallel runways exist, the terminals act as a bridging structure between them, often with a railway station beneath (Gardermoen, Oslo, and Chek Lap Kok, Hong Kong). In all cases the airport capacity is a product of the number of runways it can operate at any one time and the safety margin between aircraft. In the past a three-minute rule operated to ensure a sufficient margin of safety between consecutive landings or take-offs, but new traffic control equipment can reduce this to 90 seconds in good weather. However, larger



1.21 Security delays and excessive walking distances can impede the speedy turn-around of aircraft.

planes require a longer safety margin so there comes a point in time when the existing runway capacity is exhausted. Then the only option is to construct a new runway (as at Heathrow) or to accept that the airport has reached its limits. Like a

1.22 Runway and apron capacity have traditionally been seen as limiting factors on airport growth. Sydney Domestic Terminal.

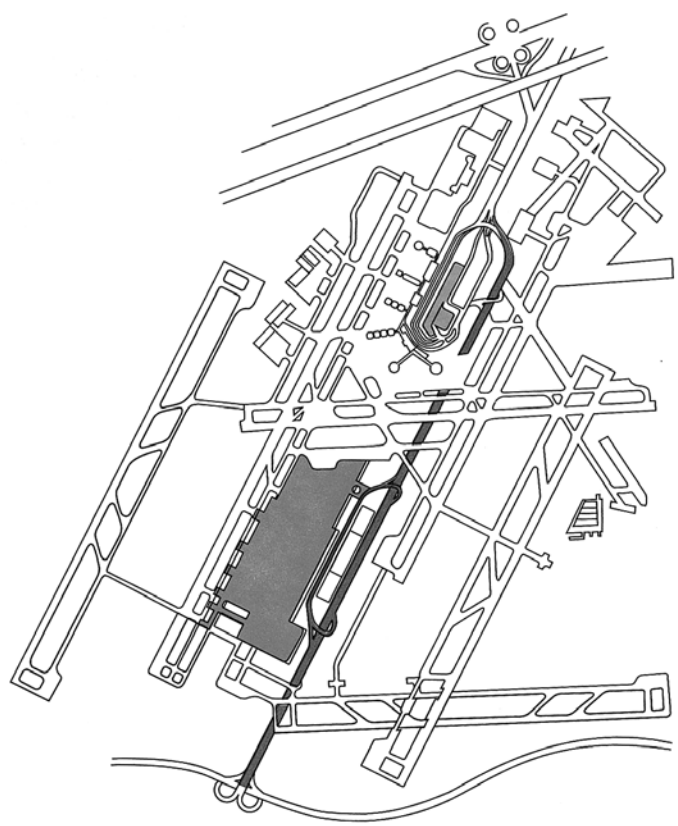
new town, an airport cannot grow forever – there are checks provided by the availability of space and the needs of safety or the wider environment.

The trend of the 1990s towards larger aircraft and reduced safety margins on the runway has naturally stressed the terminal buildings themselves. The space stress is evident particularly in the departure lounge (where flight delays can lead to over-crowding – a problem exacerbated by the growth in retail outlets) and in gate lounges. Sometimes it is not gathering spaces which are most congested but the stairs, lifts, escalators and corridors. Larger aircraft mean bigger floods of people. In the 1980s a typical international passenger flight carried 280 people, by the 1990s the number had risen to 340 and by 2005 the introduction of yet larger aircraft will mean 400–500 people on a single flight. The plans to develop 1 000-seater passenger aircraft mooted by Boeing and Airbus for introduction around 2010 will add further stress to the existing pattern of spaces inside terminals. Whereas an airport authority can develop new runways to meet extra demand and construct new terminal buildings, existing facilities need also to adapt. The ability to carry out new construction while also upgrading existing buildings is a measure of an airport authority's capacity to survive. When both are exhausted, the airport has reached its limits and growth can only be catered for by developing a new airport some distance away.

With two runways in operation an airport can handle 90 movements an hour. Assuming 300 passengers per aircraft, this results in a throughput of 27 000 people per hour. If this throughput is distributed across three terminals, each has to be capable of handling 9 000 passengers an hour through ticket check-in, baggage reclaim, security and passport controls. Such a capacity is over two passengers per second passing through the controls. It is normal to assume that, of the aircraft movements, half are incoming and half are departing flights. Hence, the flow consists of two parallel migrations (outward and inward) leading to the inevitable split between floor levels in the typical terminal building.

Such a throughput of passengers puts a strain also on the surface transport system which serves the airport. Some transport planners predict that the limits to growth are likely to be the result not of congestion in the sky or in the terminal building but in the road and rail systems which serve the airport. As a result, government (and airport authority) expenditure is being directed towards providing new surface links to airports. Many recent airports, especially in Scandinavia, have an integrated system for land and air transport (e.g. Copenhagen Airport) with the trains providing at least 50 per cent of the passenger movements to the airport. BAA has adopted a similar percentage as its target for British airports by 2005. Surface transport inadequacy, particularly in motorway congestion around airports in the USA, is a serious constraint. The problem for the airport authority is that the connecting surface transport infrastructure is provided by other bodies and, unless there is partnership funding between agencies, the road and rail system will not be upgraded in an integrated fashion. The airport will then gradually decline and new airports with better surface links will expand.

The fourth potential limit to growth is in the area of safety, security and government controls. The ability of an airport to provide a safe environment for passengers and staff is of growing concern, especially since the aircraft-generated terrorist attacks on the World Trade Center and the Pentagon on 11th September 2001. An airport which cannot provide security will be shunned by passengers and airline companies. Government controls are becoming ever stricter and the standards expected for international flights have now been adopted for domestic ones. The problem is exacerbated by the rise of international terrorism since 2000 and the growing movement of people as economic migrants or asylum seekers. The latter group, often travelling from what the West considers is the geographical location of terrorist groups (e.g. Afghanistan), pose a particular threat. As a result, terminal buildings contain expanding holding areas for such people, have ever more elaborate safety, health and passport checks, and subject ordinary passengers to more intensive security. The queues and delays are frustrating, and the adaptation of space and systems in the terminal building is becoming more demanding.



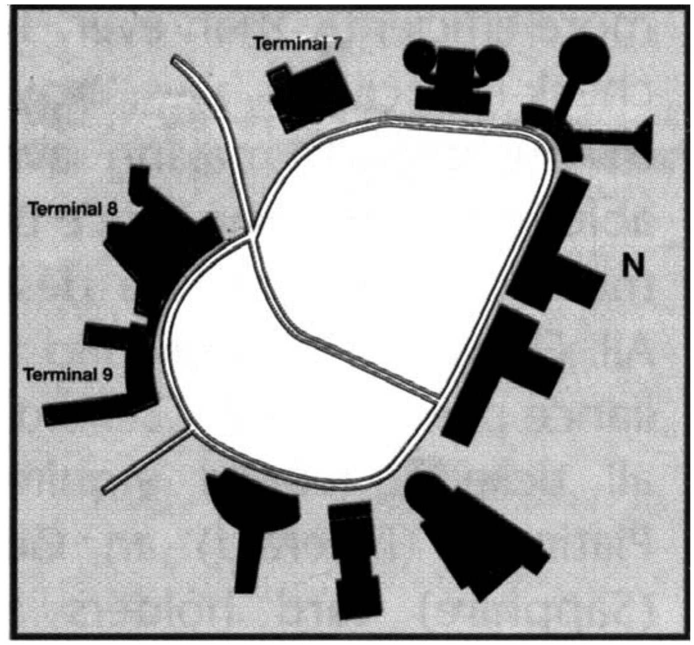
1.23 At Detroit Airport five runways enclose two groups of terminal buildings.

To summarize, 'capacity' is the basis for airport master planning – not regional development. An ideal airport is one where everyone is within an hour's travel distance of the airport, making airports some 50 miles (80km) apart. However, such capacity planning requires inter-agency investment in infrastructure beyond the airport limits. The assumption that runway capacity is the critical factor has been replaced by greater recognition of the consequences of larger and more frequent aircraft on the terminal buildings themselves. In its turn the emphasis has shifted to the capacity of surface transport. While the interaction between these three factors is critical, it is important not to overlook the impact stricter security measures have upon the throughput of passengers. In an age of international terrorism and global people migration (from poor to rich areas, arid to temperate, south to north, east to west), the airport is necessarily a health and security checkpoint to continents.

The airport interchange

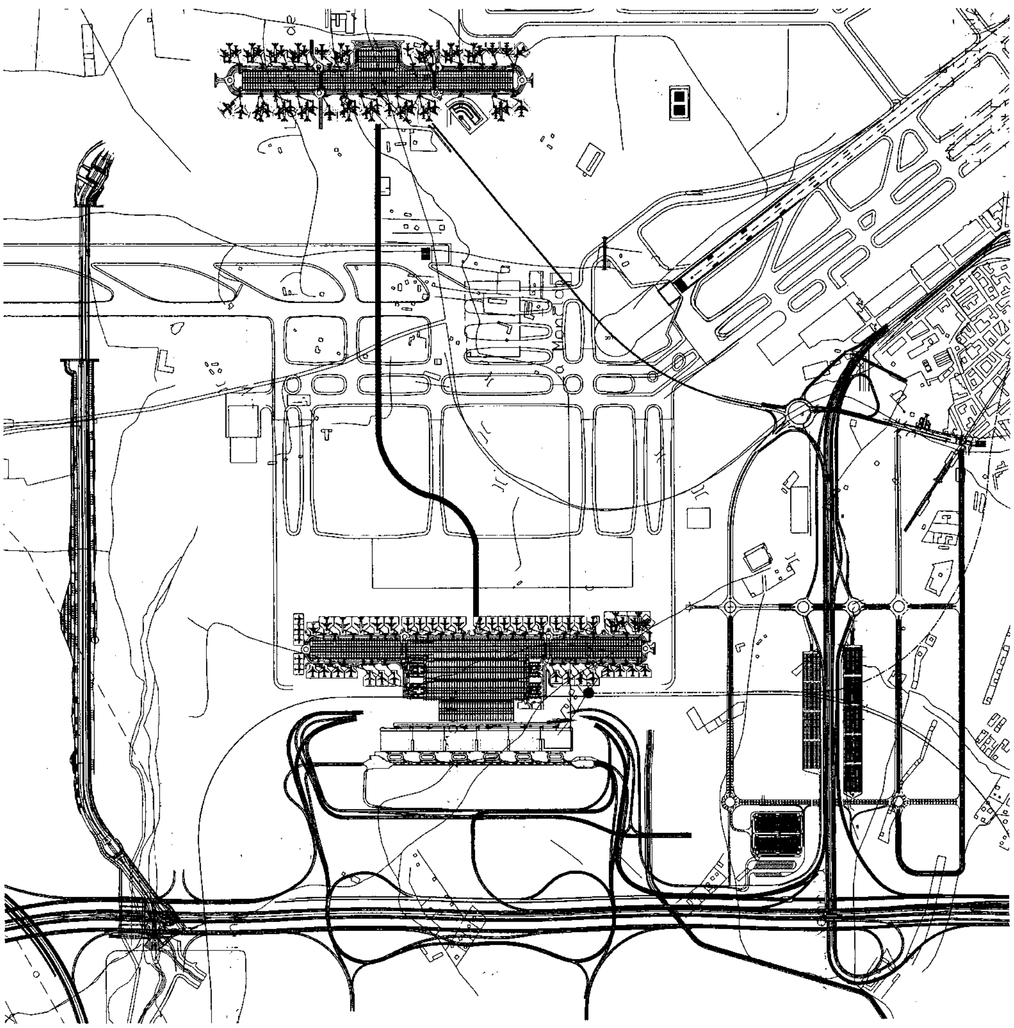
Kipling said that 'transport is civilization' but increasingly it is difficult to plan, fund and deliver an efficient modern transport system. Few governments have an overall vision for national transportation, with the result that airports are often poorly connected to other modes of travel. It also results in the economic potential of airports being under-exploited. For example, in the UK, in spite of planning policy guidelines which seek the integration of land-use planning and civil aviation, there is little connection between the creation of jobs and the growth of airports. Sustainable transport requires not just the integration of modes of travel from air to cycling but also the creation of greater accessibility to work and leisure. Since the airport is an employment, training and recreational hub, its need for spatial and physical connection is high. However, other concepts such as green belts tend to isolate the airport and disperse development away from its edges. As a consequence public transport is difficult to justify financially, distances are too great for walking or cycling, and the car becomes the major means of travel to the airport.

To succeed in the long term, airports need to perform as interchanges rather than merely airports. The connection to rail and bus services is crucial to the ability of an airport



1.24 A ring of nine terminals linked by road and travellator serve John F. Kennedy Airport in New York.

1.25 Palma Airport, Majorca, with bus station at the centre.

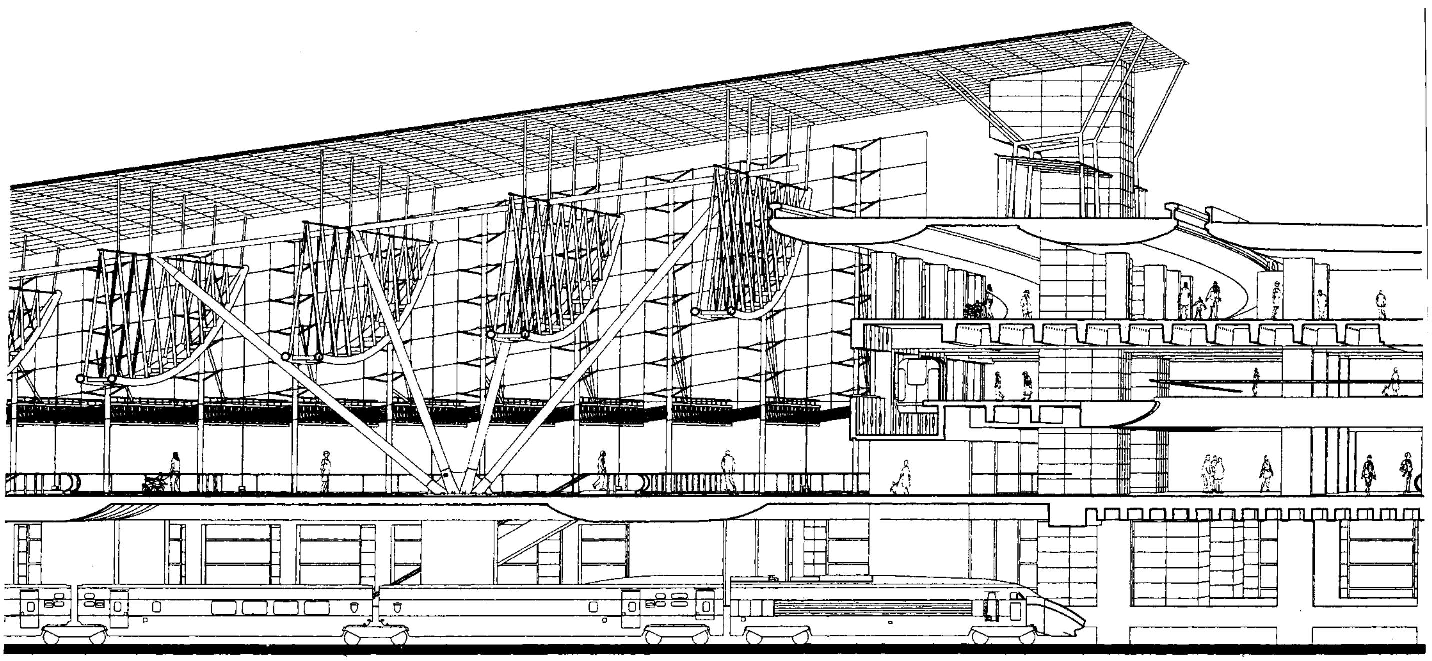


1.26 Site plan, Barajas Airport, Madrid. The main terminal (lower centre) and satellite terminal (top) are joined by light rail to mainline train services. Architects: Richard Rogers Partnership.

to survive in the competitive world of international air travel. Good inter-modal connection facilitates growth in business travel, in using the airport for conferences, in expanding the tourist and leisure market, and in providing a workplace which is easily reached by employees.

Airport interchanges work as a machine of interfaces involving people and their baggage. The ease of connection between types of transportation reduces travel stress and travel time. However, time is not the only criterion of performance: the perception of linkage and of time is also important. The journey between plane and train, or between plane and taxi should be as short, enjoyable and as readily understood as possible. Hence interchanges need to be legible, with the routes clearly defined, the pathways logically disposed, and long distances enlivened by light or art.

In terms of perception, outward-bound passengers need to feel that they are moving towards the mode of travel and



1.27 Roissy Station at Charles de Gaulle Airport. This is one of the few international airports with high-speed train services.

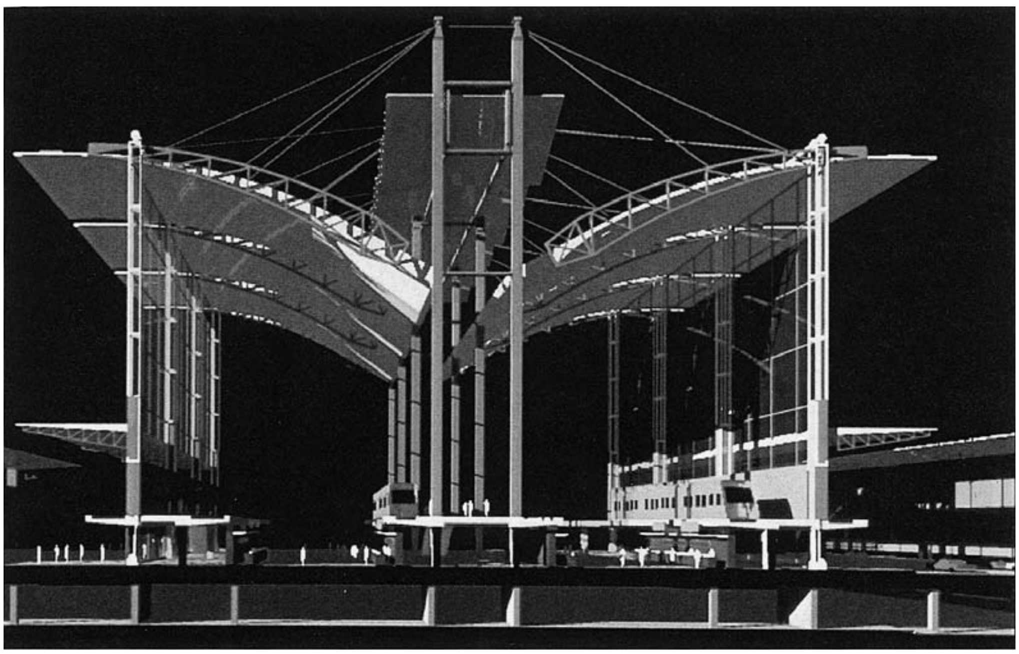
those arriving that they are moving towards the city. In this sense what is visible matters even if the visible is not accessible. The enjoyment of travel is largely experiential: one needs the thrill of flight, the excitement of travel and the pleasure of moving through buildings rich in stimuli. Although interchanges are where people move between types of travel, the exchange should be smooth for people and their baggage.

Interchanges at airports are often places rather than buildings. An airport space connected to bus, rail, car, cycle and plane movement systems may exist with links to a number of closely related buildings. At Zurich Airport, for example, train, tram, bus services and air terminals exist as a loose connection of buildings, joined together at lower level but linked at the ground by public spaces. Here the new airside centre, designed by Nicholas Grimshaw and Partners, acts as a movement catalyst, visually and functionally.

Airport interchanges are sometimes single buildings which give access to different modes of transport arranged on different levels (e.g. Seoul or Schipol). Alternatively, they can be separate but related buildings providing different transportation services in a co-ordinated fashion (e.g. Lyon, Manchester). The interchange is a transport interface for people, not just an interface of infrastructure. People need to understand the geometry of the interface, to comprehend the levels and to perceive the routes. It is not sufficient to join up the engineering of transportation: the linkage has to put passengers first. The problem with Heathrow is not the lack of public transport but the inadequacy of the clues which signal its existence.

By 2020 the European Union anticipate that 50 per cent of Europeans will be over 50 years of age. This means that airport designers need to cater for an ever-ageing population of flyers. Although the cost of air travel is falling and more people fly than ever before, in reality passengers are less able to walk long distances, to view distant signs or to negotiate changes in level. It is against this background that the concept of interchange gains importance, especially the interface between plane and train. Since plane, train, bus and tram services are usually provided by different companies, there is little incentive to

1.28 The Airside Centre at Zurich Airport, provides a transport interchange linked to existing terminal buildings. Architects: Nicholas Grimshaw and Partners.



1.29 Logan Airport Transport Interchange. Architects: Skidmore Owings and Merrill.

co-operate in achieving a smooth integration of transportation systems. The airport authority needs to take the lead in providing interchange spaces which are not excluding in character, frustrating or dangerous in use, or bleak in appearance. They also need to take the lead in maintaining a consistent language of signs, irrespective of the company involved. Single signage, exchange of ticketing between companies and a shared culture of travel information would do much to ease the stress of travel to the airport.

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CHAPTER

2

The airport as a unique twentieth-century building type

The airport is the one unique building type of the latter half of the twentieth century. Like the golf course – its landscape equivalent in terms of modern origins – the airport has no direct parallels in function, scale or form. Though similar to the railway terminal in some respects, the modern airport has a size and intensity all its own. From the airport one ventures into the sky, and in a few hours to distant continents. The airport, with its runways and terminal buildings, has a huge scale, dwarfing most other urban structures. Large international airports, such as London's Heathrow, handle in a year almost the same numbers as those who live in the country. With over 63 million passengers using Heathrow each year (and 80 million predicted by 2013), the airport is a great cosmopolitan centre. As the third busiest airport in the world, Heathrow is a self-contained urban entity, with its buildings, roads and business parks serving a remarkable variety of functions. Heathrow employs more people than the city of Oxford, and has an economic impact as great as that of London Docklands. Trade alone at Heathrow amounts to £250 million per year, with 68 000 direct jobs and 245 000 indirect ones provided as a consequence of the airport's presence.[1] It is clearly more than just an airport; it is a city in its own right, with the terminal buildings its public landmarks. These buildings, plus the hotels, car parks, conference centres and business parks, add up to a fresh kind of twentieth-century city. Culturally, economically and socially the modern airport is a new point of exchange between people, companies and nations.

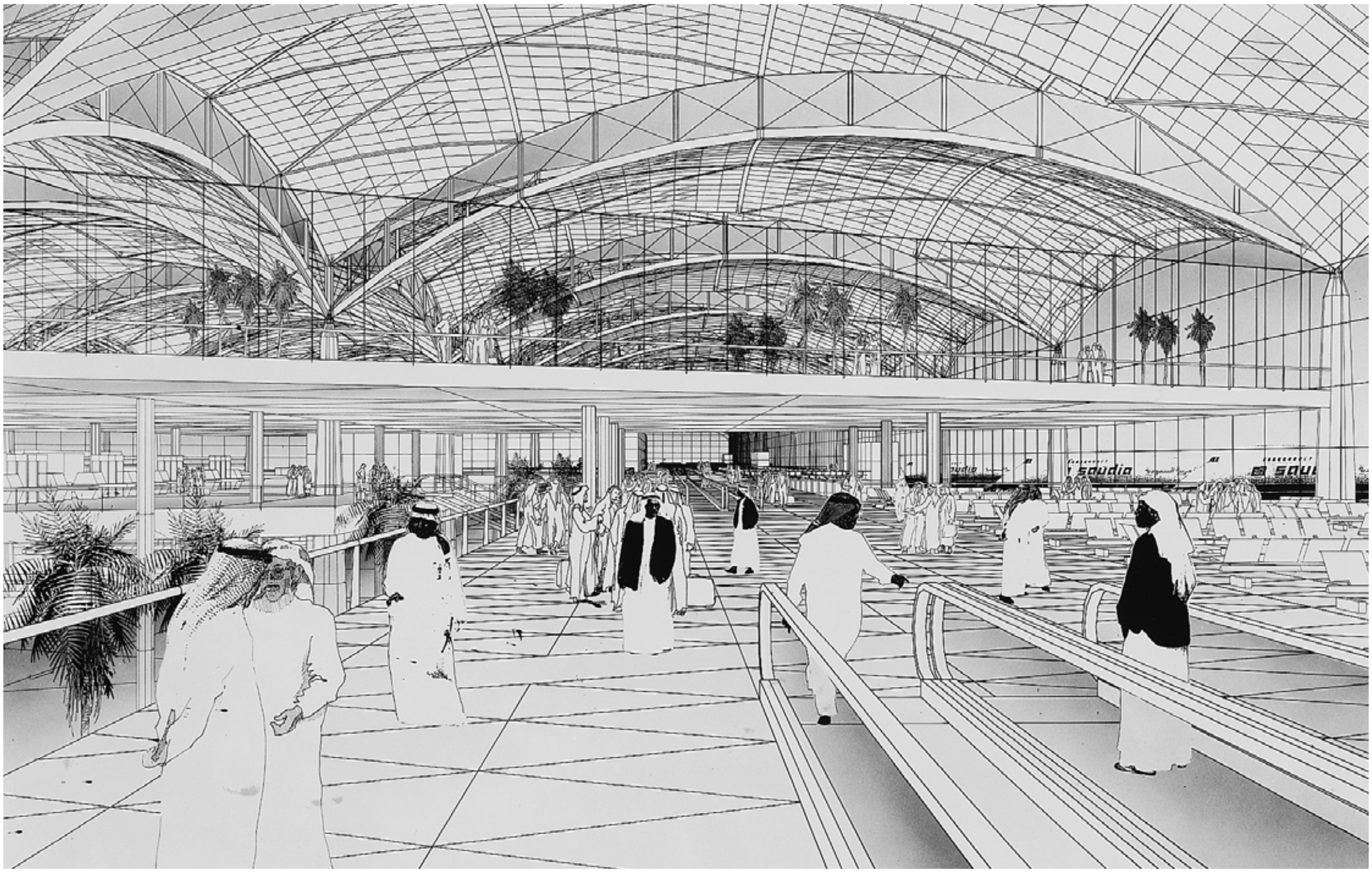
Some argue that airports are a superior kind of city. Martin Pawley, for example, claims that Heathrow is 'not only better than London, it is everything that London isn't'.[2] This assertion is based upon the convenience of airports in terms of the range of facilities provided (shops, business centres, hotels, car parks and travel modes), the feeling of security (lacking in many traditional city centres), and the sense of economic opportunity. The limits on the growth of airports (such as Heathrow and Kennedy) arise, according to Pawley, because they are not recognized as cities, which many airports clearly are in economic, physical and social terms. Large international airports start as airport projects and end as urban entities serving a wide range of

2.1 Heathrow from the air. Heathrow employs more people than the city of Oxford and contributes £1 billion to the UK economy.

non-airport functions. Put simply, they begin as airports and end as cities. Such expansion and change of function is not easily accommodated within an orthodox town planning paradigm.

The international airport is a modern kind of placeless city. It lacks the sense of geographical justification that is evident in most urban areas. The big, busy, multinational airport derives its logic from the distribution of world trade, the spatial pattern of international cities, and the often irrational location of national boundaries. This has led some observers to contend that the airport is a new type of city, perhaps the most coherent of a fresh generation of post-industrial cities. In this the terminal building is its market place, cathedral and municipal town hall all rolled into one.

The architecture of airports reflects the international flavour of modern air travel. There is a sense of technological bravado balanced by national pride in airport design. Countries like to express a modern efficient image through the vehicle of national airports in general and the terminal buildings in particular. While the aircraft are the same, whether in Asia, Europe or North America, the individual terminals often retain something of local cultural identity. The internationalism of air transportation is invariably tempered by regional characteristics in the design of terminals themselves. This is occasionally the



2.2 In the Middle East the terminal is less a retail mall, more a celebration of meeting and travel. King Abdulaziz Airport, Jeddah. Architects: Murphy/Jahn.

2.3 The modern airport is a new kind of city, with the terminal acting like a market hall. Munich Airport, Germany. Architects: Prof. von Busse, Blees, Kampmann & Buch.

result of climate, and sometimes of the traditions of building in a particular area, but often of the sense that airports are great national gateways, where cultural differences have to be expressed. The comparison between London Heathrow and Paris Charles de Gaulle shows how far national characteristics can infuse airport design. While the first is a collection of disjointed terminal buildings set within an apparently haphazard masterplan, the latter is grandly conceived, beautifully executed and infused with Gallic pomp.

Different philosophies apply with regard to the nature of airports in different parts of the world. In Europe the airport is a complex interchange and a leisure destination, while in the USA the airport journey is rather akin to catching a bus. At Chicago O'Hare Airport, for instance, the typical airline passenger arrives by car, parking in a huge open car park, travels by courtesy coach to the airline terminal (not the airport), and boards the plane with generally no passport or customs check. Direct gate ticketing allows the passenger to proceed through the terminal without hindrance or delay. Shops, bars and duty-free facilities barely exist: the airport is a linear functional system, with the terminal – dedicated to a specific airline company – merely an enclosed space through which the passenger hurries en route to the plane.

In Europe, leisure activities and retail sales dominate the architecture of terminals. Airports such as Gatwick, with its separate retail floor at North Terminal sandwiched between the arrival and departure levels, and the burger-bar-dominated

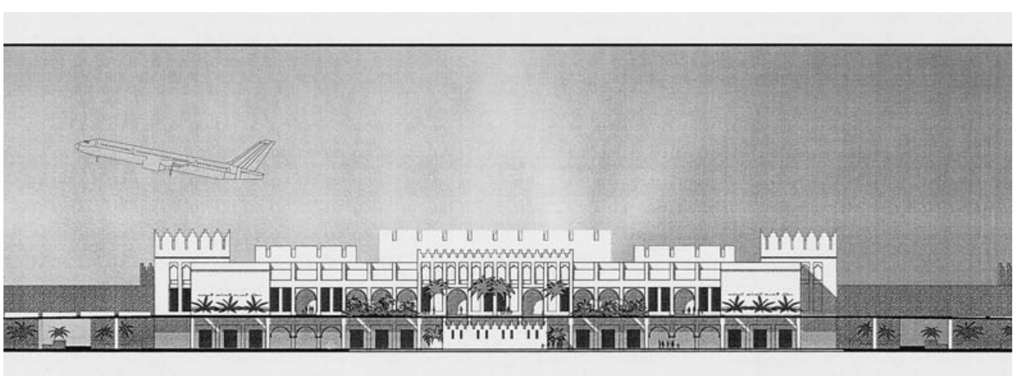
2.4 The European terminal differs from that in the USA, where the experience can be akin to catching a bus. Munich Airport Centre, Germany. Architects: Murphy/Jahn.

'Village' in South Terminal, look and feel more like shopping malls than traditional terminals. In the Middle East and Africa the airport is normally a loss-making, though architecturally distinguished, statement of nationhood. Riyadh Airport in Saudi Arabia is typical of the rather Olympian ideal behind many airports in the Gulf States. Here retail and tourism pressures are kept to the periphery of terminals; the passenger experiences instead a grand processional sequence of public spaces – lofty, well lit and unencumbered. The terminal mirrors the aspirations, wealth and prestige of the country, not the free play of market forces (as in the UK) or ruthless airline efficiency (as in the hub airports of the USA).

The airport is the quintessential building type of the modern age. It is where human and fossil fuel energy are exchanged with greatest intensity. The floods of people arriving and departing, the similar number of greeters who assemble to celebrate the journey, and those who use the airport as a leisure or business destination in its own right, make the terminal building a great modern assembly hall. In a sense the airport is not a single functional entity but an amalgam of activities taking place simultaneously within enormously scaled buildings. To design such structures requires an appreciation of the interculturalism and interfunctionalism of modern life, and a grasp of the dramatic opportunities afforded by the sheer verve of contemporary air travel. Airport terminals are the cathedrals of our age.

The approach to terminal design has changed greatly over the past generation. Writing in 1967, the then chairman of the British Airports Authority, Peter Masefield, said that 'flexible, easily put-up and easily torn-down terminals are the order of the day'.[3] Today, however, the emphasis is more upon the airport terminal as a landmark building. Certainly, it needs to be able to accommodate internal changes on a regular (and hopefully planned) basis, but architects of late have approached the design of the terminal with concepts of permanence in mind. A clearer distinction is now made between fixed parts (structural framework, broad spatial pattern and natural lighting) and the less enduring parts

2.5 Retaining cultural identity is important as airports become globally standardized. Haj Terminal, Jeddah. Architects: Skidmore Owings and Merrill.

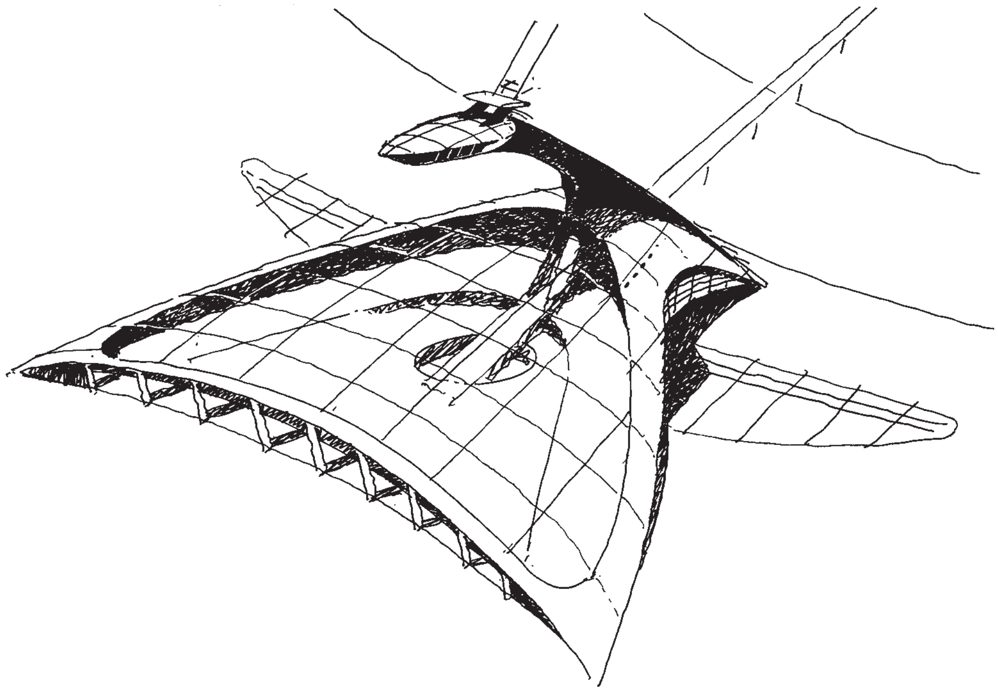


2.6 A sense of national image is required of new airports in the Middle East. New Doha International Airport, Qatar. Architects: Scott Brownrigg and Turner.

(partition walls, mechanical services, retail and leisure areas, baggage-handling system). It is a philosophy that allows the architect to invest heavily in the features that contribute to the character and distinctiveness of a terminal, knowing that the elements that have a shorter life can receive less of the building's budget. Many modern terminals, such as Kansai and Chek Lap Kok, notably follow this example.

The role of meaning, function and form in defining the architecture of terminals

In his *A History of Building Types*, written in 1976, Nikolaus Pevsner places the airport terminal as an adjunct to the chapter on railway stations.[4] The airport is seen as a twentieth-century postscript to the essentially nineteenth-century history



2.7 Interculturalism finds expression in many recent airport projects. Transportation Centre, Seoul Airport, Korea. Architects: Terry Farrell and Partners.

of transportation buildings, of which the railway station is the prime example. To Pevsner the airport terminal is less a new building type than a development of an older, well-established typology. He does, however, refer to one unique characteristic of aerodrome buildings, as he calls them: that is, their ability to be forever growing, with 'cranes and scaffolding never leaving the premises'.[5] Change on its own is not, however, a feature employed by Pevsner to help define building types. Rather, distinctive building types grow from an interweaving of function, materials and styles. By such criteria Pevsner happily classifies the airport terminal along with the ferry terminal, bus station and railway station.

More recent writers have taken a broader view of the taxonomy of building types, noting that the evolution of new types is invariably in response to fresh programmatic requirements and changing technologies. As travel has become faster, the phenomenon of mass transportation has led to the emergence of new forms, of which the modern international airport is an obvious example. Bigger buildings for faster movement lead inevitably to the introduction of new construction techniques, which propel the evolutionary process towards a new building species. Added to this, the concept of perpetual change and dynamic growth (a feature noted by Pevsner) charges the airport building with a responsibility towards structural and spatial change, which further distances the terminal from the railway station. Whereas the station evolved to meet a relatively stable (though unfolding) new functional programme, the airport terminal is conceived as an almost temporary building, given a life of 20–25 years.

2.8 Tectonic construction is a feature of recent terminal design. Paderborn-Lippstadt Airport, Germany. Architects: Von Gerkan, Marg & Partner.

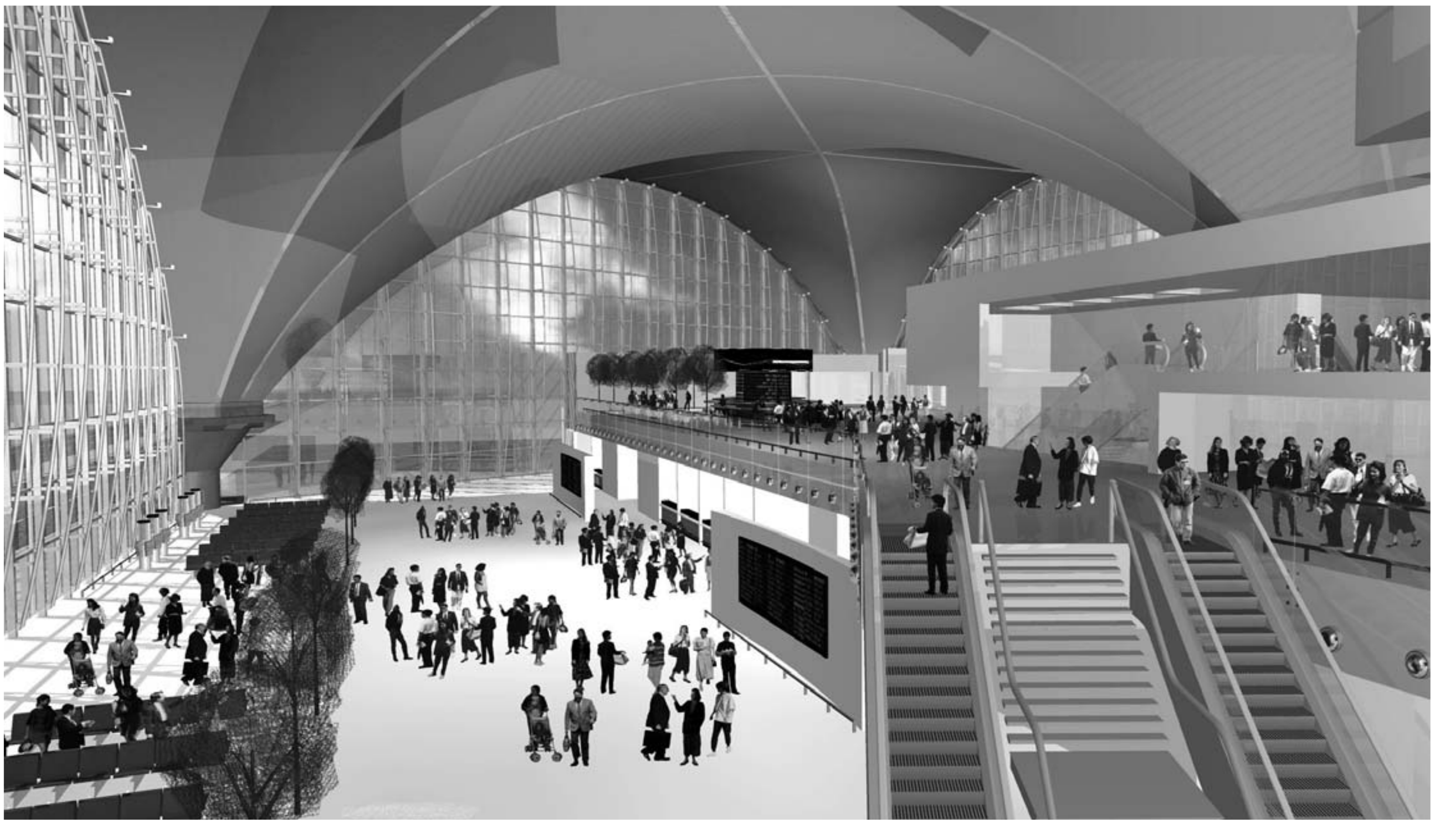
2.9 The geometry of space and articulation of volume is the key to establishing order in the design of terminals. King Abdul Aziz Airport, Jeddah. Architects: Murphy/Jahn.

The unpredictability of airports means that the functional life of the terminal is invariably shorter than the built form it houses. Though airport terminals share certain similarities with the nineteenth-century railway station, they are so much part of the gestalt of early twenty-first century life that they can no longer be considered as a postscript to the former building type.

In understanding the airport terminal as a distinctive typology, it is important to grasp three main formal elements that give it shape: the plan, the design of surfaces, and the handling of light. The plan – the geometry of space, as it is sometimes described – establishes the spatial and hierarchical composition. The medium of plan and section begins the process of defining the airport as a distinctive building type. However, the design of the masses and their surfaces also plays an important part. How the materials are used, and whether the surfaces reflect the functional and socially infused meaning of the airport, are also key factors. Finally, light and the play of light in an optical sense help to distinguish the airport terminal from other related building types such as railway stations. The changing images in the complex movement through a terminal begin, as Markus puts it, to 'coalesce in the mind into a single sensation'.[6] In defining the architectural factors that give the airport terminal its 'airport-ness' – its sense of typological identity – the compositional components of plan, mass and light are of fundamental importance. These combine to give the function appropriate form and meaning, which allow the terminal to be understood by its users, and which permit the terminal to be recognized as a distinctive type of building by those who have yet to enter into it.

This argument also allows function, meaning and form to have social value rather than purely aesthetic value. The term 'airport' or 'airport terminal' is exclusively a twentieth-century one; before the modern age no conception of the airport existed, and hence no preconception of the design of the terminal building had occurred in the mind of architects. By giving the airport a name one constructs a functional narrative, which allows designers to conjure up appropriate forms.[7] Without the naming of a new function there is little basis for design or public recognition of the built consequences.

2.10 The design of Beihai Airport, China, makes a deliberate attempt to celebrate air travel. Architect: Llewelyn Davies.

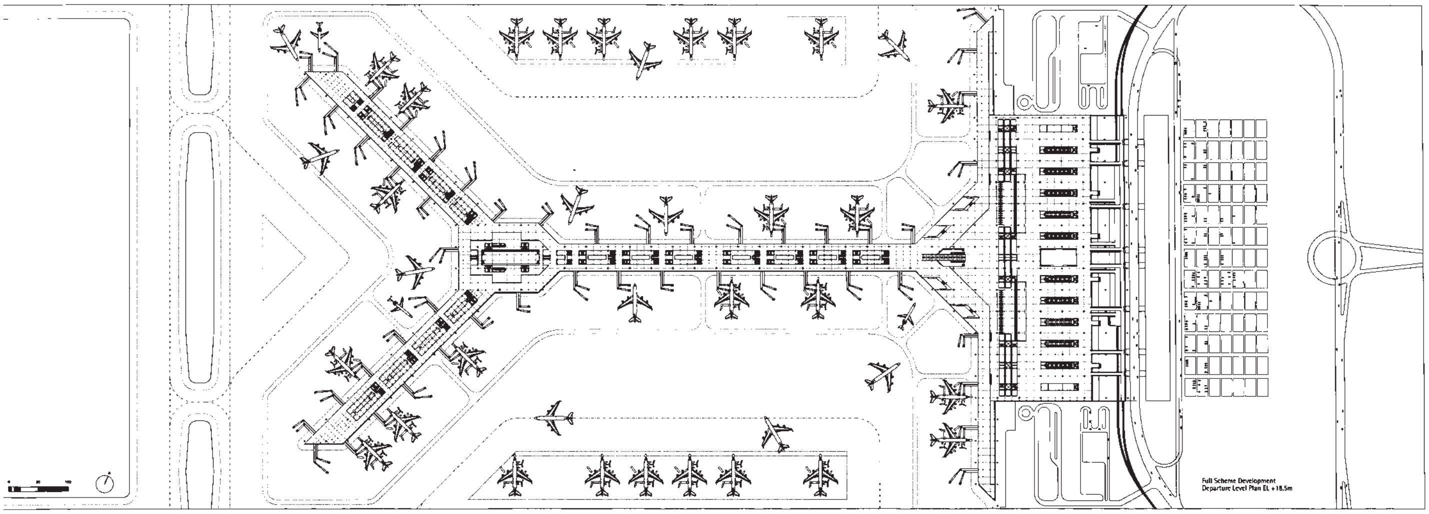


Hence the word 'airport' leads to spatial constructs that themselves carry social meaning. By removing ambiguity through the close correspondence between function, meaning and form, there emerges a recognizable body of building types, which society at large can recognize as airports. In this sense the formal repertoire of architectural elements – plan, masses and surfaces, and light – gives meaning to the built forms. Meaning does not exist within the functional narrative unless accompanied by architectural forms; neither does meaning exist within built forms unless they carry functional legitimacy. The earliest terminal buildings, such as Eero Saarinen's TWA Terminal at New York and his Dulles Terminal at Washington (both designed around 1956), or the more Miesian terminals at O'Hare, Chicago designed at the same time by Naess and Murphy, were important beginnings in helping to define the modern airport in architectural and typological terms.

The maturing of airports as a building type

In the 1950s and 1960s America was the centre for airport development: here new layouts and airport patterns (such as hub airports) were developed, and the typology of the terminal was established. It was in the USA that the standard two-level departures and arrivals terminal was evolved, each level having its own deck of vehicle access. By the 1970s, however, the focus of attention had shifted to Europe, which began to develop airports integrated with other modes of transportation. Deregulation in the 1980s opened up terminals to greater commercial pressure, and it was the UK that refined the notion of the passenger terminal as a huge open retail mall. In the 1980s also the Middle East and parts of the Far East explored the relationship between airports and nationhood, which found expression in grand civic terminals. The relatively straightforward precedent of airports represented by New

2.11 In the Pacific Rim, new airports are part of integrated transportation systems, unlike those in the USA and parts of Europe. Notice the railway station to the right sandwiched between terminal and car park. Hong Kong's new airport at Chek Lap Kok. Architects: Foster and Partners.



York's JFK became by the early 1990s a diverse canvas of different design and management approaches. The extremes are represented by the muscular and expressive Kansai Terminal, on its man-made island in the Pacific, the neutral and refined Stansted Airport in the English countryside north of London, and the tented roof structure of Denver Terminal, evoking images of North American Indian tepees. In each case, though the buildings are undeniably airports, their functional meaning has been enriched by cultural differences.

As the airport has matured into a recognizably distinctive twentieth-century building type, it has also diversified into a range of formal types, whose taxonomy responds directly to different airport management systems. These inevitably reflect the values of the peoples served. Emerging nations have a different view of airports from mature nations, and where the culture of free enterprise is rife, the airport is undeniably a means of making money. What is not always recognized is the role of airports in facilitating knowledge and technology transfer between nations and within countries. New airports in undeveloped parts of the world, designed by global firms and constructed by international contractors, allow new skills and management approaches to be learned. The particular place that airports have in technology transfer and training is pertinent in Africa and China, which looks set to be the arena for airport development in the next century.

The flow of ideas about the nature and design of airports has moved from the New World to the Old, and from the developed parts of the Old to more distant lands. In the process of disseminating wisdom and approaches, the orthodoxy evolved at countless American airports has increasingly been challenged by different geographical and cultural factors. In Australia, Japan and China a new generation of airports is developing, based upon the airport as an element of integrated transportation. Here the role of the airport as a growth centre is recognized, not resisted, within a network of regional airports established (like Shenzhen in China) as a spur to economic, technological and social regeneration. In Australia and parts of Africa the airport is seen as part of sustainable development, bringing in eco-tourists to help preserve endangered landscapes. The environmental battles that accompanied airport expansion in the USA, Europe and Japan have been replaced in the less developed world by greater accommodation with environmental protection. Recent airports too are likely to be designed using local materials and respecting indigenous building traditions. The specifics of place, culture and climate are beginning to balance the universal standards and ideologies of IATA manuals which remain the blueprint for airport development throughout the world.

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CHAPTER 3

Relationship between airports, terminals and aircraft design

With any air transport system, airports, terminals and aircraft are dependent upon each other in giving the passenger a service. The introduction of new aircraft technology, new ways of handling baggage or security, and new approaches to air traffic control, have implications for the operation of the airport and the design of the terminal buildings. Air transportation is a high-growth, high-cost industry, in which advances in technology are rapid and have widespread ramifications for the whole system.

The development by Boeing of the Jumbo Jet in 1970, innovations in short take-off and landing (STOL), and faster, more passenger-weight-efficient planes (such as the European Airbus) have all altered the parameters within which the aircraft industry operates. New, more energy-efficient aircraft engines, larger airframes and quicker aircraft-servicing regimes have all led to real cost savings for the passenger. Cheaper air travel is the main reason why the air transportation industry continues to expand worldwide, even in regions suffering from general economic decline. Because about 85 per cent of the operating costs of the entire air transport system revolves around the aircraft (including purchase price, fuel and servicing), the tendency has been to look to technology

3.1 Modern airport terminals often ape the technology of the aircraft they serve. Xian Airport, China. Architect: Llewelyn Davies.

breakthroughs in aircraft design to reduce overall costs.[1] Hence the airport (runway, terminals etc.) has responded to the planes rather than vice versa.

The introduction of wide-bodied aircraft such as the Boeing 747 in the 1970s resulted not only in the lengthening of runways but also in the enlargement of terminals and access piers to accommodate the influx of passengers arriving in great waves. More recently, the growth in aircraft size has been curtailed not by technological possibility but environmental and operational factors – particularly noise in the neighbourhood of airports, and resistance from airport operators. It is feasible today to design and build aircraft capable of carrying 1000 passengers, but double-decker planes would require double-decked access piers, and greatly enlarged gate lounges and terminals. With rising construction costs and escalating land values, many airport authorities have discouraged plane makers such as Boeing from developing to the full technological potential. Instead, aircraft design in the 1990s has concentrated upon new safety levels, greater comfort, less noise and improved fuel energy performance. Such aircraft have stabilized at seating levels of about 450–550 (as in the Boeing 777) on the advice of airline companies and airport operators alike, though development is under way on the European Airbus A3XX, capable of accommodating 850 passengers and flying non-stop for 14 000km.

While airport runways were being lengthened in the 1970s to accommodate a new generation of aircraft, recently the trend has been reversed. Advances in the technology of producing high lift for take-off has had the effect of reducing the requirement for lengthy runways, particularly in the area of short- to medium-range operations. Shorter runways release land for other possible development at the perimeter of the airport (such as warehousing and hotels), and lessen the impact of aircraft noise in the vicinity of residential areas. However, for larger aircraft runways of 3km are still required, and the new generation of wide-bodied, double-decker aircraft require substantially stronger runways than in the past. A loaded A3XX will weigh 476 tonnes, which is 20 per cent heavier than a 747, adding new stresses to runways.[2]

The interactions between aircraft design and that of the airport itself are necessarily close. The trigger for change is normally that of innovation in plane design, with airports responding (sometimes reluctantly) to new technological innovations in the aircraft industry as a whole. This affects both passenger- and freight-handling policies. Large, wide-bodied aircraft introduced extensively in the 1980s allowed operators to carry both passengers and freight. Air cargo has become a major industry alongside that of passenger transport. Although significant volumes of freight are carried in specially adapted aircraft (mostly formerly passenger aircraft), a large amount – perhaps as much as 50 per cent – is transported in the holds of scheduled passenger services. Freight traffic is growing at a faster rate than passenger traffic, with the belly holds of wide-bodied passenger aircraft providing the capacity. The management of flight turnaround and apron services and immigration controls have all had to respond to what was originally merely the technological breakthrough of wide-bodied aircraft. As a general rule, on short- to medium-haul flights luggage and freight must be loaded and unloaded, and planes serviced and refuelled, in 40 minutes, or 80 minutes for larger aircraft on long-haul flights. The speedy disembarking of passengers is an essential component of efficient flight turnaround.

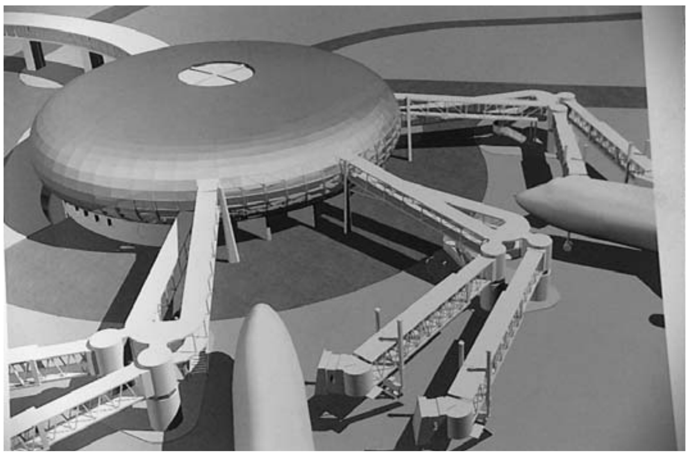
Because aircraft, airports and passengers are part of an interdependent system, we need to know which elements are critical in operational terms. Generally, limits to expansion or operational congestion occur when either

- runway capacity is exceeded, or
- terminal passenger capacity is exceeded.

What determines overcrowding of runways or terminals is dependent upon many factors. With runways it is the size of aircraft, the number of movements, and the type of aircraft: different planes have different climb and speed requirements. With terminal buildings it is not the daily flow of passengers but that at peak times, especially with the arrival of several large aircraft at about the same time. It is this that has tended to curtail the development of 1000-seater aircraft, though the A3XX, capable of serving larger international airports, looks set to corner a niche in the expanding air transport market, especially to the Far East.

Whereas airport capacity was limited in the 1970s by runway capacity, in the 1990s it is more likely to be constrained

3.2 Aircraft design, airport operation and the layout of terminals share a common philosophy. This example is Terminal 2, Charles de Gaulle Airport. Architect: Paul Andreu.



by passenger terminal capacity. At the terminal, capacity may be reached in terms of space per passenger (in the departure or arrivals lounge, the gate lounges and piers), baggage handling, or check-in capacity. Sudden influxes of movement – the result of larger aircraft – also put strain on immigration services and the airport road system. At airside the terminal may reach capacity with regard to apron requirements and access points for aircraft to the terminal. Hence different elements of the system may reach capacity before others, but once capacity is reached in a part the whole system is put in jeopardy.

There is greater understanding today of the nature of the interactions between aircraft design and airport operation. Future trends in plane design suggest that aircraft costs per kilometre will continue to fall in real terms. Cost savings rather than improved speed are what drive innovation in engine and airframe design. The age of the supersonic jet is coming to an end as cost and environmental factors take hold, though some predict its revival in future generations. Passenger kilometres per unit of fuel increased by 25 per cent between 1990 and 2000, making air travel progressively cheaper. Moreover, innovation in fuel-efficient turboprops means that many regional airports dependent upon the short- to medium-haul market will remain viable, and may continue to expand.[3] The airline company, airport operator, aircraft manufacturer and passenger are part of an interdependent system, in which each has profound influence upon the other.

Structure of the air transport system

The structure of air transport falls into one of three distinct models:

- a centralized system with one dominant hub (for example, Heathrow)
- a multi-hub system, as in the USA and Germany
- a dispersed system with only limited hub facilities, as in Italy.

The first is usually dependent upon a major capital city (London in Heathrow's case), the second upon a large country with relatively evenly distributed urban centres, and the third on decentralized air traffic at low levels of usage. Hence geography as well as politics determines the structure of air transport in a country. Where hubs are a central feature they tend to be dominated by one or two airlines (for example, British Airways at Heathrow, Air France at Paris Charles de Gaulle, or United Airlines at Chicago O'Hare). A dominant hub airport also leads to the 'hub and spoke' system of regional airports served mainly by the dominant airline. Consequently, to travel from New York to Newcastle in England involves a change of plane at Heathrow or Birmingham, but the connecting flight is provided by the same carrier.

The structure of the air transport system indirectly influences the structure of the airline industry. As noted, centralized hubs are usually dominated by one or two major carriers. As hub-and-spoke patterns become established, smaller airline companies – who were providers of the spoke elements – tend to be absorbed by the predatory major carrier. The effect is to encourage the growth of megacarriers at the expense of independent smaller airlines. In fact, the survival of small carriers is normally dependent upon the dispersed system of air transport with only limited hub facilities (the third of the three modes listed above). Some companies such as Easyjet and RyanAir have exploited the possibilities of dispersal.

The close relationship between large hub airports and large airline companies (such as Minneapolis St Paul Airport and North West Airlines) means that smaller airlines tend to favour smaller airports. Regional airports are often smaller corporate or financial entities than the airlines that use them, and as a consequence are not always able to measure up to the airlines' requirements. Under such pressures there has emerged a pattern whereby regional airports are served mainly by regional airlines and national airports by national airlines. The only exception occurs where hub-and-spoke patterns place the national carrier as the major user of a regional airport. Here a conflict may exist between national and regional airline companies, perhaps over access to terminal facilities, flight times and preferential treatment in baggage handling.

The hub airport allows the airline company responsible for its development to control the airport gates. This has obvious benefits for a particular airline, because it can establish a brand identity throughout the airport, from assembly concourse to check-in and departure gate. The disadvantage is the lack of competition that single airline control of airports entails. Where the state or airport authority controls the airport (that is, non-hub situations) the airport can offer gate positions to different airlines at fairly short notice. This encourages competition on service and price, to the benefit of passengers. At Florida's Orlando International Airport, which handled 23 million passengers in 1995, the state-owned airport attributes its growth rate (about 10 per cent per year) and passenger appeal (voted the best airport in North America for customer appeal in 1995) to the fact that it controls the vast majority of its departure gates.[4] When a new carrier comes along (such as ValuJet in 1994), the airport can quickly offer access, thereby forcing down competitors' prices or pushing up their standard of service.

As airports became privatized in the 1980s and 1990s, their goals tended to be less aviation oriented. Conflicts can occur between aviation objectives and non-aviation objectives, particularly within the terminal building. Non-aviation management may seek to expand retail, commercial and hotel functions that could conflict with aviation needs. Airline companies may lose their dominant position and role within the terminal, and passenger transport may become only an incidental function of the airport as a whole. Private capital, essential in the eyes of many governments as a means of reducing state subsidy, can have the effect of altering the character and management of an airport to the detriment of the passenger.

Not only are airports subject to the pressures of deregulation and privatization, but so are airline companies. In the West it is accepted that airports and airlines are principally private companies trading openly, making profits and losses for shareholders. In other parts of the world, however, both airports and airline companies are often public or quasi-public bodies. Dependent upon state subsidy, they provide a public service first and foremost. However, they too are subject to increasing pressure to generate secondary income through franchising arrangements with retailers and hotel chains. In the developing world, medium-sized semi-private airlines (such as Air Nigeria) and small private airlines operate out of public airports, with only a few services provided by the private sector. Here too the trend is towards bringing in private capital and managing the airport as a semi-public rather than totally public enterprise.

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Layout, growth and access to airports

CHAPTER 4

The layout of an airport is determined by five basic factors:

- the direction of prevailing winds (the major runway(s) being oriented to the prevailing wind with a back-up runway on a cross-wind alignment)
- the size and number of terminal buildings
- the ground transport system, especially the position of major access roads and railways
- mandatory clearance dimensions between aircraft and buildings
- topography and geology.

Small airports are usually a direct reflection of these spatial and organizational characteristics, but as airports become larger a number of secondary factors come into play, such as environmental controls, the geography of the surrounding region, and the capacity of the local road system. International airports, though their site layout is shaped primarily by wind direction, are increasingly constrained by such factors as community disturbance. As a consequence, their growth and configuration rarely permit simple planning solutions, but are compromised by influences of a regional nature.

Airport as communication node

The airport is primarily a communication node. Located often on a river flood plain, by an estuary or on coastal marshland, the need for a large area of flat ground determines its geographical position. Where no such land exists (as in Hong Kong), the airport may be a man-made island, exploiting (as at Kansai), human refuse and industrial waste to create the necessary flat landscape. The need for effective communications exists on three levels. The first is electronic: airports require 360° electronic surveillance of the skies. Hence, tall buildings, mountains and pylons have to be a certain distance away. The resulting openness of the airport environment is both a virtue since it gives visibility to the airport terminal and a problem since there is a great visual impact. Too often the airport is in a placeless landscape of flat fields, wide access roads and expansive service yards, with little planting or topographical relief to screen the various installations.

The second level requires the linking of the airport to a wide range of other transport systems. To be an effective communication node there needs to be efficient access via road, rail and even cycle systems. Since the capacity of road systems and parking is easily exhausted, the trend is towards full integration with rail in its various guises (inter-city, suburban and increasingly by light rail for internal airport journeys). Bus connection is also important, especially where there is a high leisure or holiday market. The rise in bicycle use (the result partly of topographic flatness) has also to be catered for. The integration of all of these systems (and of course pedestrian movement) determines the effectiveness of the airport as a communication node.

The third level concerns the integration of the airport with other land-uses. The airport as a communication node requires the construction of a diverse range of facilities to allow for the human interaction which is carried in its wake. These include hotels, shopping areas, business and conference venues, recreation and exercise areas. People use airports for a variety of reasons and it is this variety which creates the demand of secondary land-uses. Often these are provided within the terminal buildings, frequently also as separate buildings adjacent to terminals, but increasingly as facilities constructed around the edge of the airport. As the airport expands as a communication node, the need for secondary activities grows. In time, these become major motors of employment, serving the wider community as against the airport itself. As a result, there is then pressure to build new housing estates, schools, even universities, to satisfy expanding demand.

All three forms of communication need to be catered for. Electronic connection (via radar, cable and fibre optics), inter-modal transport linkage and land-use diversity around the airport itself, require the airport authority to plan its growth over long time periods. The normal planning horizon of a typical airport authority (5–10 years) is an inadequate basis for effective forward planning. A time-frame of 50 years is more appropriate, especially if the ambition is to forge the airport into an effective proto-city with the runways and terminal buildings at its centre. This will inevitably entail partnership with other bodies such as utility companies, local authorities, commercial developers and adjoining land owners.

Forecasting airport growth

Airports are planned on the basis of traffic forecasts. These are compiled on the principle not of peak demand but of average sustained demand. Many airports experience passenger or airspace overcrowding for limited periods of the year, but this is not normally taken as justifying expansion. If airports were designed to meet all peak demands then there would be excessive capacity, adding unnecessarily to operating costs. Compiling data on passenger, cargo and aircraft movements is an essential element of the masterplan process. Once the airport has begun to operate, such data need to be periodically checked to ensure that forecasts are being realized by actual volumes.

Typical of the data that need to be gathered are:[1]

- passenger statistics (international or domestic, scheduled or non-scheduled, arriving/departing or transit, weekly, daily or hourly flows)
- cargo statistics (similar breakdown as for passenger flows)
- aircraft (types, international or domestic, passenger or cargo, peak movements)
- visitors (meeters and greeters, airport visitors as non-travelling tourists, shoppers, business users).

In the interrelationship between airport masterplanning and the gathering or monitoring of statistics, three components are of principal concern: passenger traffic, cargo traffic and aircraft movements. These statistics allow the capacity of each of the major elements of the airport to be determined, such as runways, apron areas, terminal, road and railway system, and hotels. Each part, though, will require separate data gathering in order to arrive at a precise idea of usage and hence the implications for layout or design.

For the passenger terminal, operational capacity is dependent upon the performance of the following key elements:[2]

- landside access
- baggage handling

- passenger check-in capacity
- immigration control capacity
- security check capacity
- boarding gate capacity.

The relating of facilities to capacity is a necessary part of masterplanning and, at a more detailed level, of building design. Facility forecasting is normally based on statistics, justified by mathematical modelling and queuing theory employed in such complex areas as the passenger terminal. The architect does not need to know how to undertake such analysis, but it is helpful to understand the principles upon which facilities planning at airports is carried out.

Airport types

There are three main types of airport:

- international airports serving over 20 million passengers a year
- national airports serving between 2 and 20 million passengers a year
- regional airports serving up to 2 million passengers a year.

Such a classification, based upon the level of traffic flow, is a useful guide but by no means infallible. In countries such as Germany, which have a strong hub network of airports, some of the larger regional airports (Stuttgart, for example) have passenger movements that approach international dimensions. Conversely, in smaller countries with single national airports (Oslo Airport in Norway is a good example) passenger movements below the norm for the classification may still justify the inclusion of the airport in the top rank. If the level of passengers is a good general guide, other factors relevant to typological classification include:

- the split between domestic, national and international movements
- the role of the airport as an international centre for aviation or as a distribution hub
- the scale of non-airport facilities, such as other transportation modes, hotels, business and conference centres.

Taking these factors together, it is obvious that Stansted is a national not truly an international airport; that Charles de Gaulle Airport is international while Lyon is national; and that Southampton is regional while Manchester is national. Outside Europe, Kansai Airport at Osaka, John F. Kennedy, Washington Dulles, Newark, Dallas and Denver in the USA are all international, while Baltimore (with passenger levels of 16 million a year in 1996) is rather more national in character (though there are many international flights). Any classification is often confused by airport authorities and airline companies, who have the habit of 'talking up' their airport in order to raise its profile. Birmingham Airport in the UK is one such example; it is named Birmingham International in spite of levels of use of under 10 million passengers a year.

It is important to maintain, conceptually at least, the three-level classification of airport types, because the range of support facilities varies with each type. Generally speaking, the larger the airport and the greater the percentage of international passengers, the more non-airport facilities of one kind or another are needed. International airports cater disproportionately for business travellers, and they require conference and meeting rooms at the airport; they tend also to have top-quality hotels, health and fitness clubs, and perhaps a mini golf course. At the opposite extreme those using regional airports may well be commuters or holiday-makers on package holidays: their needs will be less ambitious. However, regional airports are increasingly seen as focuses for industrial or warehousing growth. In the UK, the manager of Southend Airport openly admits that it is less an airport than 'an industrial estate with a runway'.[3]

A good measure of the status of an airport is the number of alternative transport modes that support it. Both Kansai and Charles de Gaulle Airports are served by TGV or bullet trains as well as local rail and bus services, and Heathrow is busy investing in further underground railways and has plans for intercity rail links. Modern international airports currently on the drawing-board (such as the new airport at Beijing, or Seoul International) are planned with integrated cross-modal transportation and such a wide range of supporting facilities

4.1 The classification of airports reflects passenger movements and architectural ambition. Lyon-Satolas Airport, France. Architects: Curtelin Ricard Bergeret/Scott Brownrigg and Turner/Santiago Calatrava.

that they take on the characteristics of urban areas. Even airports that are well established have to incorporate new transportation systems in order to maintain their position in airport league tables, or to enable them to move from regional to national or national to international airports. So while the earlier classification is helpful in identifying the range and scale of facilities needed, in reality few airports stand still, and most have ambitions to move up the hierarchy.

Airport types are also a clue to security risks. International terrorism tends to target major international, not minor regional airports. The damage to national prestige is greater if terrorists can successfully attack terminals of national importance. The publicity gained for such acts, even if passengers are not hurt, is more widespread and damaging to a country's economic interests if the airport attacked is the nation's principal one. Consequently, while security in the UK is equally strict at Manchester, Glasgow and Stansted Airports, it is Heathrow that is likely to be the terrorists' prime target. Airport staff, policy authorities and terrorists all realize this, with consequences for the level of security-conscious crime prevention in both the design and the management of international airports.

The development of airports is more than the satisfying of aviation needs, no matter how lucrative or demanding these may be. Airports, whether international or regional in nature, need to develop the 'total business' and this 'consists of aviation, retailing, land ownership and integrated transport opportunities.'[4] An example is the new airport at Sheffield in South Yorkshire (opened in 1997), which forms the centre of an expanded business park developed in partnership with the government-funded Sheffield Development Corporation.[5] The business park (masterplanned by Ove Arup and Partners) consists also of offices, industrial and distribution units, and is linked to a golf course, hotel and conference centre, and the national railway system.[6] Here the new airport provides a focal point for development and, in the million or so passengers carried per year, justifies the expansion of retail facilities within the terminal. There are specific facilities for the business community: executives can jet in from different locations, have a meeting in one of the conference suites, and fly home. Business conferencing is an area of growth for regional airports, particularly those away from congested airspace locations.

Gaining access to airports

At many of the larger airports in Europe at least 50 per cent of airline passengers arrive or depart by train. In the USA the figure is much lower. Dependence upon the private car as the main means of gaining access to airports can become self-defeating, and greatly restricts the ability of airports to expand. At busy American airports, such as Los Angeles, congestion caused by private cars means that the relatively space-efficient buses are disadvantaged. The answer adopted with growing frequency is to construct mainline train links to airports or, as in Oslo's case, to site a new airport where existing railway investment can be utilized.

In the past, cost has been a constraint upon joint airport and railway investment. However, the environmental and social benefits of intercity train access to airports has led to the much closer integration of airport and railway construction. At London's Stansted and Lyon-Satolas new airports-cum-stations have been constructed, with the railway costs shared by the state, railway operator and airport developer. As airport usage has grown, the economics of railway links have proved attractive.

As a rule of thumb, 40–50 per cent of airport passengers are destined for the nearby city centre, the remainder for more dispersed locations. At Gatwick, 70 per cent of passengers arriving by plane take the train to central London, but at Heathrow the figure using the underground railway link is merely 30 per cent. The juxtaposition of airport and station provides many benefits, but the economics of train operation require an airport handling about 12 million passengers a year before railway investment can be justified.[7] At this level of usage, capital and running costs based upon a service of about six trains per hour, each of four carriages, should break even. With subsidy from the airport, an operator could make a small profit. Large airports such as Charles de Gaulle, Heathrow, San Fransisco and New York have the passenger capacity to build and run an efficient railway service from airport to city centre without subsidy.

Conventional railway links to airports are well able to met growing demand from rising passenger numbers (unlike roads). As demand grows, the railway operator merely needs to add additional train services or additional carriages. Increasing the number of carriages from four to eight and the frequency of trains from six to ten an hour allows the airport station to handle not 12 million passengers a year but nearly 40 million. With congested airport and motorway roads the train has obvious operational advantages for the effective management of airports. Besides moving large numbers of passengers economically and smoothly, the railway is a vital link for airport staff travelling to work, and for airline crews. As a system, railways can offer a guarantee of transit time that few other modes of transport can achieve.

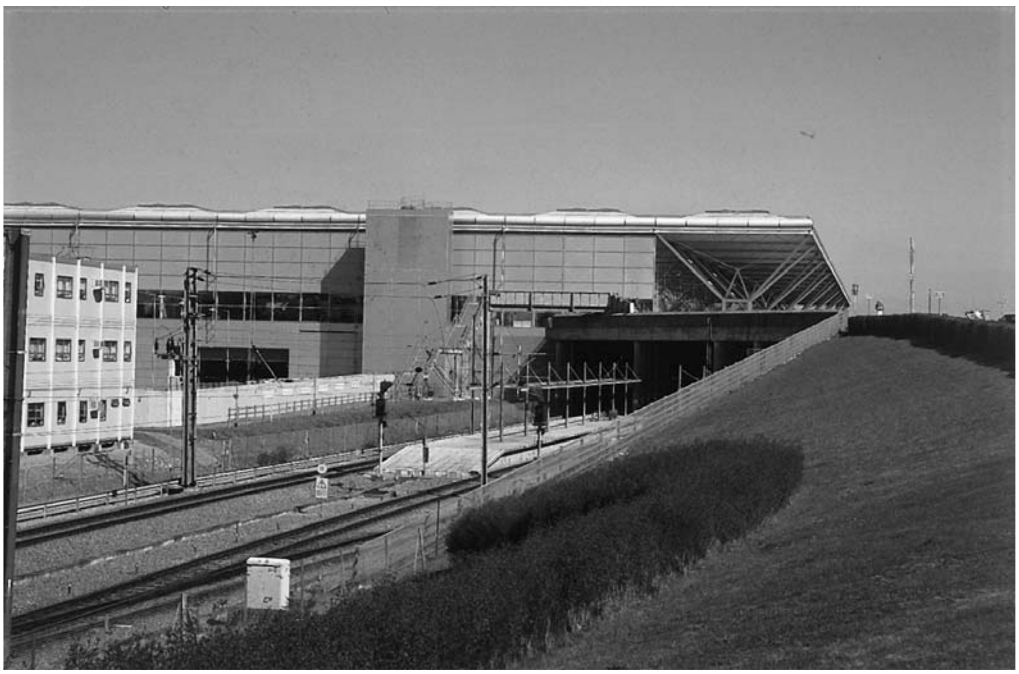
To maximize the benefit of joint airport and railway construction, it is vital that both are considered at the start of the planning stage. Stations should be fully integrated into the complex fabric of airports: their infrastructure needs are, like those of the plane, heavily controlled by safety and operational requirements. Only with effective integration of different modes of transport can the needs of passengers be fully met. As a result, BAA has set a target of 50 per cent of passengers accessing airports by train by 2010.

Rail links to airports

If projected growth in air passenger movements is to be met, then the means of reaching airports have to be improved. The old assumption that travellers can start and finish their air journey by car, taxi or coach has proved to be flawed. The numbers using airports such as Heathrow (63 million passengers a year) mean that the road system, car parks and setting-down points are already overloaded. Rather than expand car access provision within the limited land area of an airport, it is now accepted that alternative forms of surface transport are needed. Of these, rail and underground train systems are preferred, with new railway stations giving direct access to passenger terminals as at Stansted and Manchester Airports.

The design of airports cannot be considered in isolation from the total journey. Surface transport to airports is a vital (and neglected) part of the chain. Compared with the fast, efficient and comfortable flight, the part of the journey at either end can be slow, frustrating and arduous. Improving links to airports means working with planning authorities, state or private railway companies and bus companies. Of the 69 airports in Europe carrying more than 2 million passengers a year, only 34 have existing or planned railway links.[8] The integration of airports into the regional and national transport infrastructure has obvious benefits for the passenger, and in the long term is the only means by which an airport can continue to expand. Bottlenecks in the sky, overcrowded runways or terminals are airport problems capable of being solved by investment, but failure to make corresponding investments in facilities outside the airport boundary can simply transfer the congestion and frustration from the air to the ground.

Improving surface access to airports requires policy coordination between airport owners and the state (central and regional government). The provision of recent TGV rail links to Paris Charles de Gaulle Airport and fast suburban services to Washington National Airport was the direct result of airport and rail operators collaborating within clear national transport



4.2 The integration of trains within the airport terminal poses a difficult design problem both inside and outside the terminal building. Stansted Airport. Architects: Foster and Partners.

policies. Failure to take account of likely traffic growth at Heathrow, in terms of both road capacity (especially the M4 and M25 motorways) and underground railway services, is an example of the way in which denationalization and deregulation have undermined provision frameworks. The Heathrow Express, which began services in 1998, with direct high-speed rail links from London Paddington, came forward only as a result of intolerable surface transport delays. The same is true of the Navita Express in Tokyo.[9]

The Heathrow Express has relieved congestion on the Piccadilly Line underground railway service to the airport. With insufficient track space to provide an express service on the underground the decision was made in 1990 to construct a new high-speed service using British Rail's Great Western main line, which had surplus capacity. A new underground spur running northwards from Heathrow links directly with the InterCity main line, providing the means to provide a service from city centre to airport of only 16 minutes. Looking further to the future, the new tunnel is seen as providing a link in a potential spine of railways running right under Heathrow able to join other main line services south of the airport.

At a cost of £600 million, the Heathrow Express was financed by BAA with a 70 per cent stake and British Railways Board with 30 per cent. Passenger levels of 6 million per year are expected to increase to 10 million when Terminal 5 opens. The service is designed to cater for 20 trains an hour per platform, which is necessary if BAA predictions of 80 million passengers a year at Heathrow in 2016 materialize.[10]

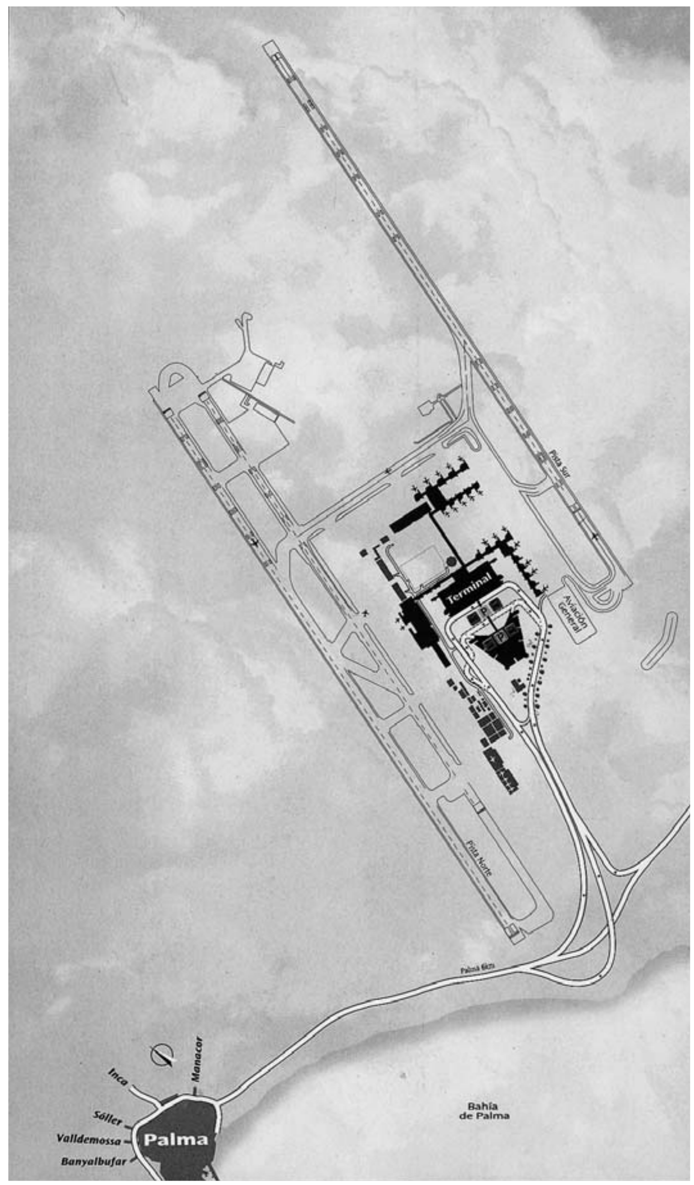
The Stansted SkyTrain offers a similar though reduced service. It uses specially designed trains with sliding doors for easy level access, spacious baggage storage areas, and telephones that accept credit cards, though the journey is slower, taking normally 40 minutes. The design of the station is such that passengers can take their baggage trolleys from the airport directly onto the platform, and the trains act as waiting areas, thereby dispensing with platform waiting-rooms. Served directly by lift, escalator and ramp, the model of air/rail integration at Stansted is one that travellers, according to the BAA, find particularly convenient.

Generally speaking, it can be assumed that 20–30 per cent of air travellers will be arriving by public transport at airports serving over 2 million passengers a year and 40 per cent at those serving over 10 million. The larger the airport, the more serious the problems of surface congestion become, and the greater the environmental pollution. Hence with very big airports the percentage of travellers arriving by train and bus can increase to more than 50 per cent. Passengers will be encouraged to use public transport, especially trains, if the station gives direct access to the terminal building (as at Stansted Airport in London and Schipol Airport in Amsterdam). Where more than one terminal exists this means a different station at each, or at least a transit system of terminal connection (as at London's Gatwick). It is also helpful if the airline ticket includes the rail link to the city centre with, ideally, integrated baggage handling between plane and train. Through-ticketing and baggage transfers require the airport operator, rail operator and airline to cooperate. To be successful in meeting the needs of the airport user (both passenger and airport worker), dedicated rail services need to be frequent, direct and preferably linked to high-speed or intercity services.

The larger the airport, the greater is the distance between buildings and between terminals and satellites. For airport staff this means journeys that are too lengthy on foot, but which may be too congested or prohibited by car. The answer at some airports is to develop internal railway systems (people-movers), or to encourage employees and possibly passengers to use bicycles. Because most flights have provision to carry cycles, a trend is towards young people and backpackers arriving by bike, travelling by plane, and continuing their journey by bicycle at their destination. Provision of mechanical people-movers, cycle roads and cycle facilities at the terminal diversifies the access choices, and relieves congestion on the airport road system.

The life of assets at airports

Because airports are a fast evolving and rapidly changing type of development, where the life span and upgrading of elements are on different timescales, it is important to attach a notional life for the key parts of the airport estate. This is needed for accounting purposes, in order to plan maintenance programmes, and to help predict the replacement of



4.3 The airport is an estate of elements built to last for different periods. The runways are the longest enduring followed by the terminal buildings. Within the buildings themselves there are parts such as shops and check-in counters on quite short time frames. Maintaining coherence in a world of rapid change is one of the hardest problems faced by architects. Palma Airport, Majorca.

operational elements. The life span adopted by BAA for its UK airports assumes the following timescales:[11]

- runways, taxiways and aprons: 100 years
- terminal buildings, pier and satellite structures: 50 years
- tunnels, bridges and subways: 50 years
- terminal fixtures and fittings: 20 years
- transit systems: 20–50 years
- plant and equipment (runway lighting and building plant): 5–20 years
- motor vehicles: 4–8 years
- retail units, bars and restaurants: 3–5 years
- office equipment: 5–10 years.

It is evident that runways are the one relatively permanent feature of airports, followed by the terminal buildings and other major structures. Terminal fixtures and fittings are, however, on a shorter timescale, followed by building plant and equipment, and in turn by office equipment. At a more detailed level one could include carpets, fabrics and furniture (2–5 years). For the airport architect these differing timescales create the need to design terminals that are capable of periodic upgrading without disrupting airport operations. The terminal should be able to adapt to changing and unpredictable management priorities on the one hand and to the predictable needs of building plant and furnishing improvements on the other. However, because much of the space in terminals is leased to concessionaires and retailers, their needs are also important. Retail leases at UK airports are normally on 3–5 year timescales, and this tends to be the framework for phased upgrading of shop units, bars and restaurants. Hence the airport is a complex entity, with differing and sometimes conflicting timescales for the replacement or upgrading of its elements.

The idea of asset life is both a useful accounting tool and a means of giving value to the assorted structures, fittings and components of a typical airport. The runway is as close as anything becomes to a permanent element, followed by the terminal and other large-scale structures such as bridges, underground railways and light transit systems. These are designed to have a useful life of 50 years (as against the 100 years for runways), though the moving parts (rolling stock for transit systems) are given a notional life of 20 years. Inside the terminal there are many timescales influencing the pace of replacement or upgrading. As new priorities are recognized (such as environmental concerns) the terminal will have to be changed, perhaps in a fashion not anticipated by the original designer. As other priorities are given greater weight (such as safety and security) the frequency of alterations here may increase.

The concept of fixed assets with differing timescales for internal alterations means that 'replaceability' becomes as important as flexibility. Terminals and other relatively permanent airport assets are increasingly designed using a restricted palette of parts and components. Standardization of components using a limited range of materials and as few specials as possible keeps the costs down when later changes are undertaken.[12] Two factors encourage this to occur at BAA airports:

- the adoption of best-practice techniques, whereby preselected suppliers advise on the construction details, and make a commitment to long-term quality and ease of replacement;
- the use of systematic auditing of the performance of buildings and other structures to enable the need for change or upgrading to be predicted well in advance.

BAA claims that the extra time spent on design evaluation and pre-planning leads to shorter construction periods, fewer mistakes on site, and more adaptable terminals in the future.[13]

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CHAPTER 5 Masterplanning airports

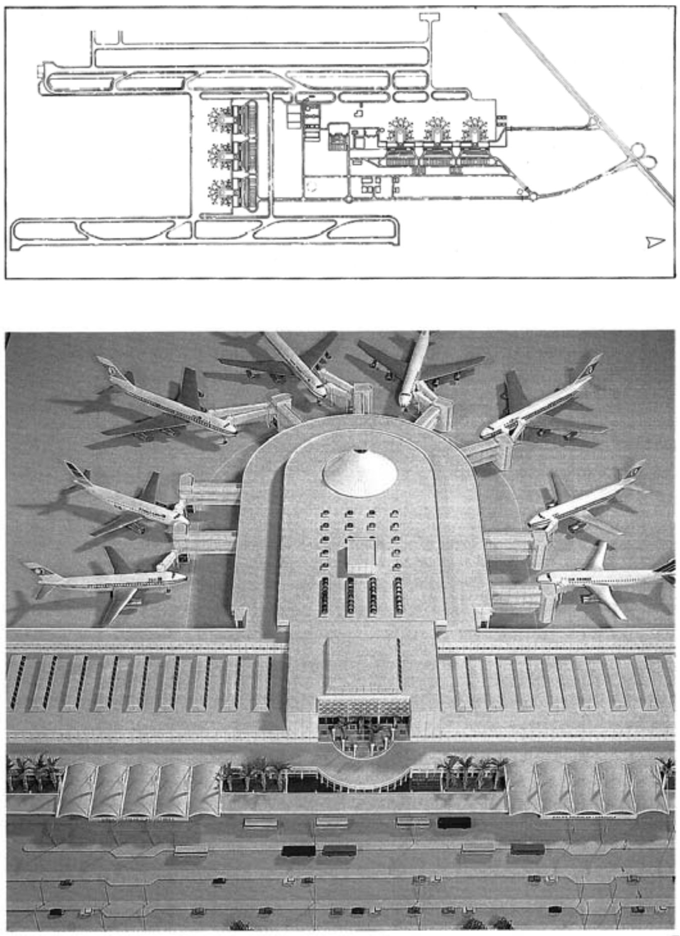
The role of the airport masterplan is to:

- balance the airport system with infrastructure needs
- provide a physical framework for investment
- ensure that the airport estate is effectively managed, particularly with regard to future land, financial and planning needs.

The masterplan is not simply a plan giving an outline of the physical form of the future or expanded airport, but also a description of the financial implications. Necessarily, too, it will deal with the political and environmental ramifications, particularly at the level of infrastructure demands (roads and railway access to the airport) and any planning consents needed. In an industry of rapid change and growth, masterplanning has a vital role in anticipating land, financial and infrastructural needs. It is therefore a crucial element of airport management, though one that has frequently been overlooked in the past: for example, London Gatwick's lack of forethought in runway planning in the 1970s, and Heathrow's in failing to link passenger terminal expansion with public transport provision.

Airport masterplans are usually spatial diagrams of future development options. They necessarily deal with strategic matters, leaving questions of detailed design until engineers and architects are appointed for specific projects. Masterplans need to be flexible in outlook and operation. Changes in aircraft technology, ever-stricter environmental controls, and the altering pattern of the airline industry – all have profound effects upon the airport masterplan. Hence the plan needs to offer an element of tactical flexibility within a graphic framework.

Masterplans should prescribe solutions within varying time horizons. Decisions for short-term capital improvements as well as long-term visions (say, up to 15 years ahead) are both required. Plans need to address different audiences; the public has a right to know of an airport's plans, but so too do the state regulators, the local planning authority, and the financial institutions who may be asked to invest in it. The role of the masterplan is to keep everybody informed, to seek a consensus for the shape



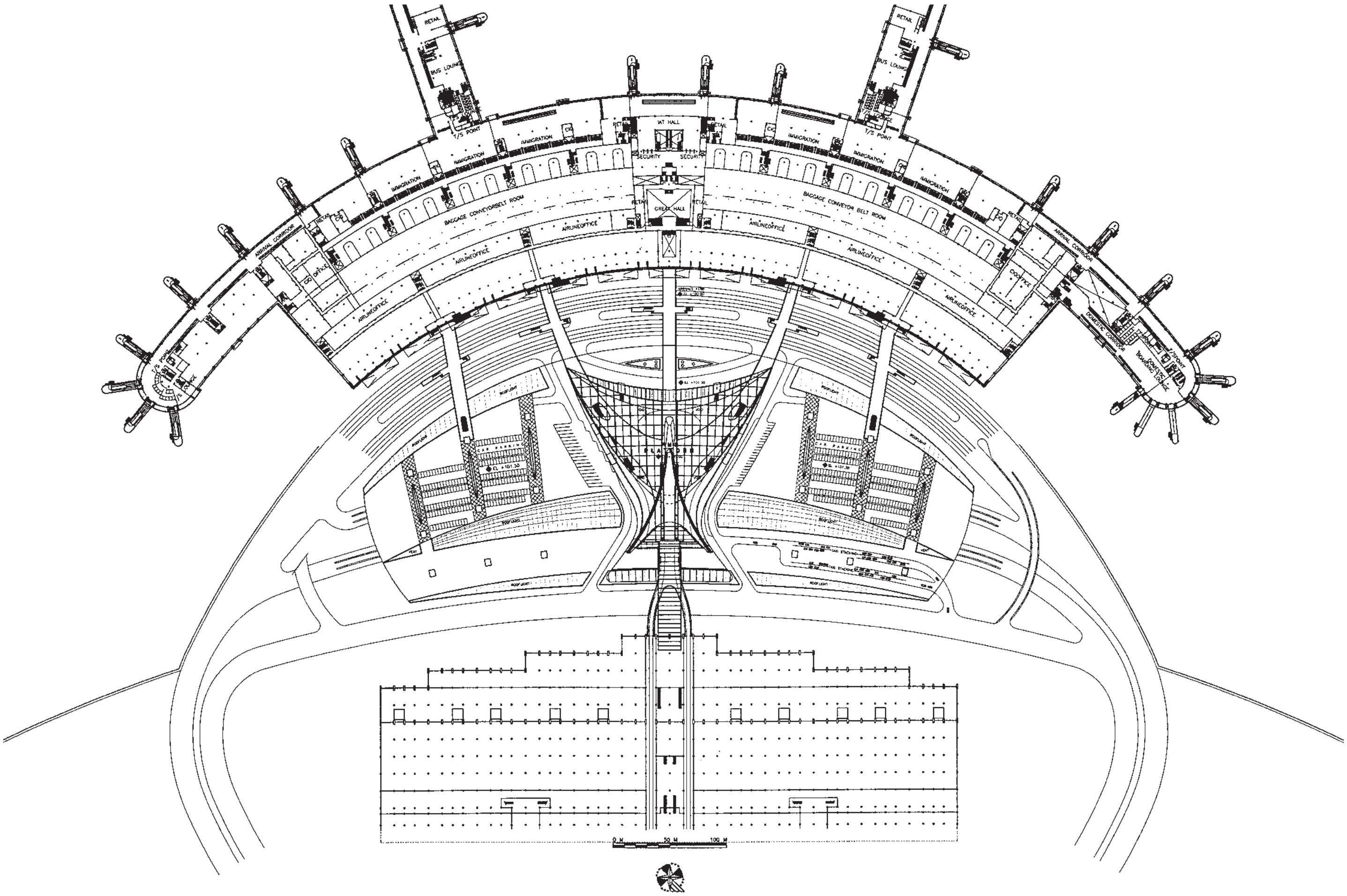
5.1 Conceptual clarity is the key to the airport masterplan. Notice how the geometric order in the masterplan is reflected in the architectural order of the design of the terminal. Antalya Airport, Turkey. Architect: Dogan Tekeli-Sami Sisa.

and scope of future expansion, and to be flexible enough to meet reasonable objections.

As airports transfer from state to private ownership (the result of the worldwide trend towards airport deregulation and removal of government subsidies), the new owners have begun to recognize the importance of the physical masterplan in realizing the land assets at airports. Much land at the perimeter of airports has in the past been poorly used, but under new management the potential for development has tended to be seized. New non-governmental airports tend to see peripheral land as a means of raising cash to subsidize improvements elsewhere, perhaps to terminals or runways. The masterplan helps in realizing the capital tied up in the land itself by identifying surplus land and by creating the right balance of adjoining land uses and infrastructure to maximize its value. The masterplan is therefore both a technical statement of potential and a means of raising expectations and worth, which helps in increasing the valuation of land assets. BAA's use of masterplanning around Glasgow Airport is a notable example of planning-led land utilization and asset enhancement.

The development plan as a final concept will have needed to be assessed technically, politically and procedurally. The formulation of the masterplan, involving a variety of concepts and options, each subject to economic, technical, social and environmental evaluation, will harden into a development plan for consultation. Those who compile the masterplan will, armed with surveys, facts, trends etc., be asked to justify the plan before public inquiries of one form or another. The masterplan needs to be convincing, candid in its analysis of problems, and clear in its forward vision.

Airport masterplans are continually updated documents. In an industry of rapid change, the plan should be monitored and adjusted frequently, perhaps every year. There should be regular adjustment to ensure that changing national laws (on say environmental protection) and altering government policy (on say the balance between road and rail investment) is reflected in the airport masterplan. Also, the plan needs to be adjusted in response to socio-economic conditions, to changes in national air transport policy, to the amalgamation of major airline companies, to alterations to regional land-use policies, and to changes in the design and management of aircraft themselves. As in much forward planning the parameters are subject to change, and this necessarily alters the assumptions from which the masterplan was evolved. In the UK the government White Paper of 2003 on the future of the aviation industry expects a threefold increase in passenger volumes by 2030. This growth in demand requires imaginative forward planning.



5.2 Detailed design needs to exploit the geometry of space to provide incremental growth. Transportation Centre, Seoul Airport, Korea. Architects: Terry Farrell and Partners.

Intermediate plans

The masterplan is a framework for development in space and time. Within the full plan period (usually 20 or 25 years) there should be intermediate plans based upon five-yearly increments. Major development (such as runway expansion, enlargement of a terminal or ground transport provision) should correspond with these intermediate plans, thereby allowing financial and facilities planning to proceed smoothly. The aim is to produce a long-term vision that can be implemented on the basis of well-specified incremental growth.

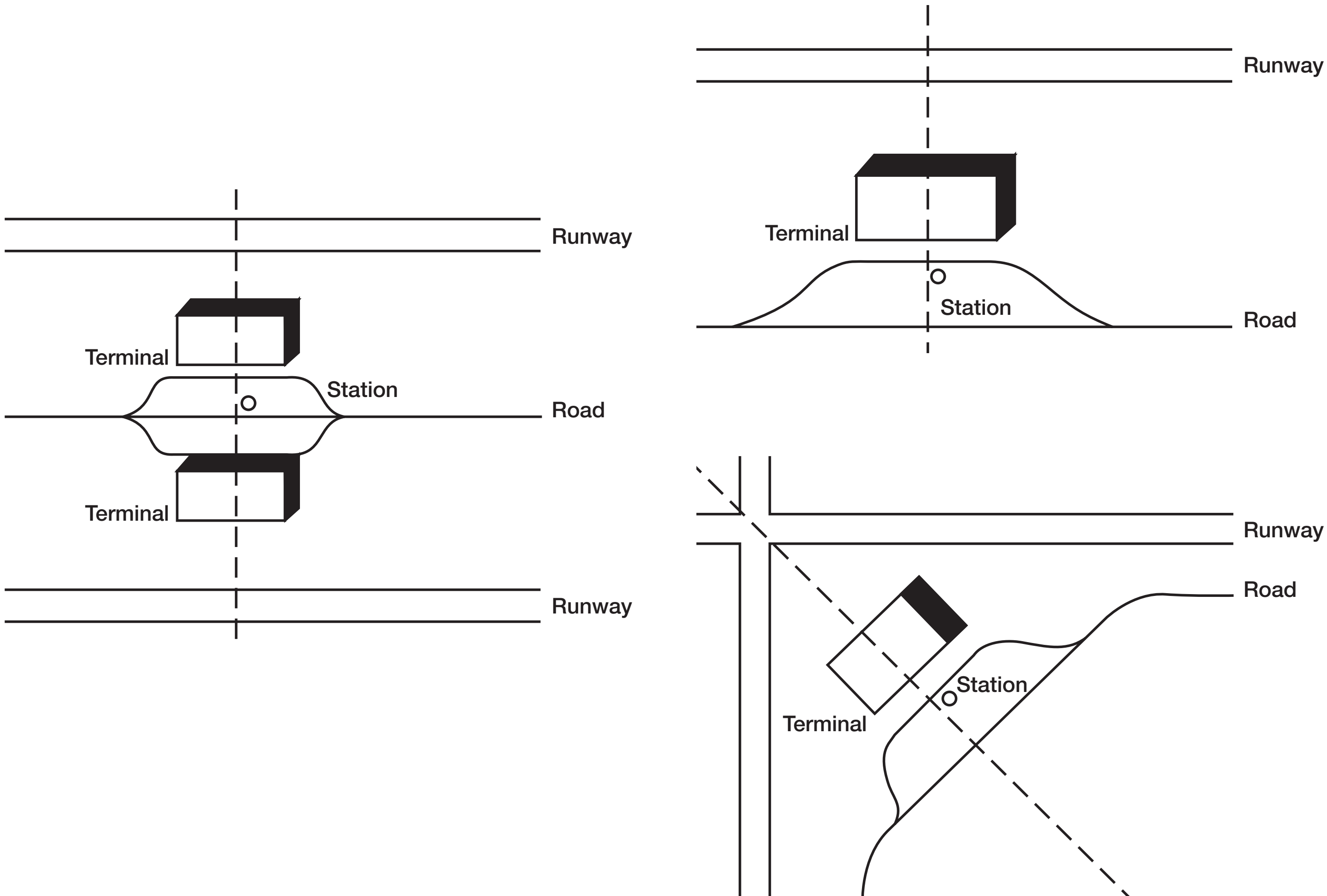
These intermediate plans provide both the framework for airport expansion and the means to monitor and modify the full airport scheme. Over the plan period the assumptions upon which the masterplan was based will have changed. There may, for instance, be a different pattern of passenger use, a new generation of aircraft design, and changes in government policy to air transportation. Hence the staged provision of airport facilities may need modification. The role of the masterplan and its intermediate plans is to ensure that the totality of the airport design is sufficiently flexibile to cater for the unexpected.

Compiling the masterplan

A masterplan is needed for existing and new airports. Both are subject to the same pressures, and will need to follow similar procedures in the masterplanning exercise. Generally speaking there are six stages in airport masterplanning:

1. Appoint masterplanning team and establish parameters.
2. Survey facilities and identify issues.
3. Review aviation forecasts.
4. Evolve and test concepts against environmental, financial and regulatory constraints.
5. Formulate plan and simulation (using CAD) for consultation.
6. Modify and adopt masterplan.

Often the masterplanning exercise is undertaken in order to determine whether an airport should be expanded, or whether it is preferable to build a new facility. Here, the plan needs to be concluded with a policy based upon a thorough analysis of existing conditions and forecasts. Keeping an up-to-date



5.3 Main runway to terminal layout options.

inventory of all the facilities and buildings at an airport is vital if the right choice is to be made between expansion and the construction of a new airport. This is an inventory not only of ground facilities but also of airspace, air congestion and the anticipated growth in air traffic in the region over, say, the next quarter century. The survey will also need to look at buildings and urban areas outside the perimeter of the airport to see how they will be affected. Hence the inventory should contain the location, size and distance from flight paths of hospitals, schools and churches. Noise corridors and cones will need to be plotted, as will historical data on weather patterns in the area.

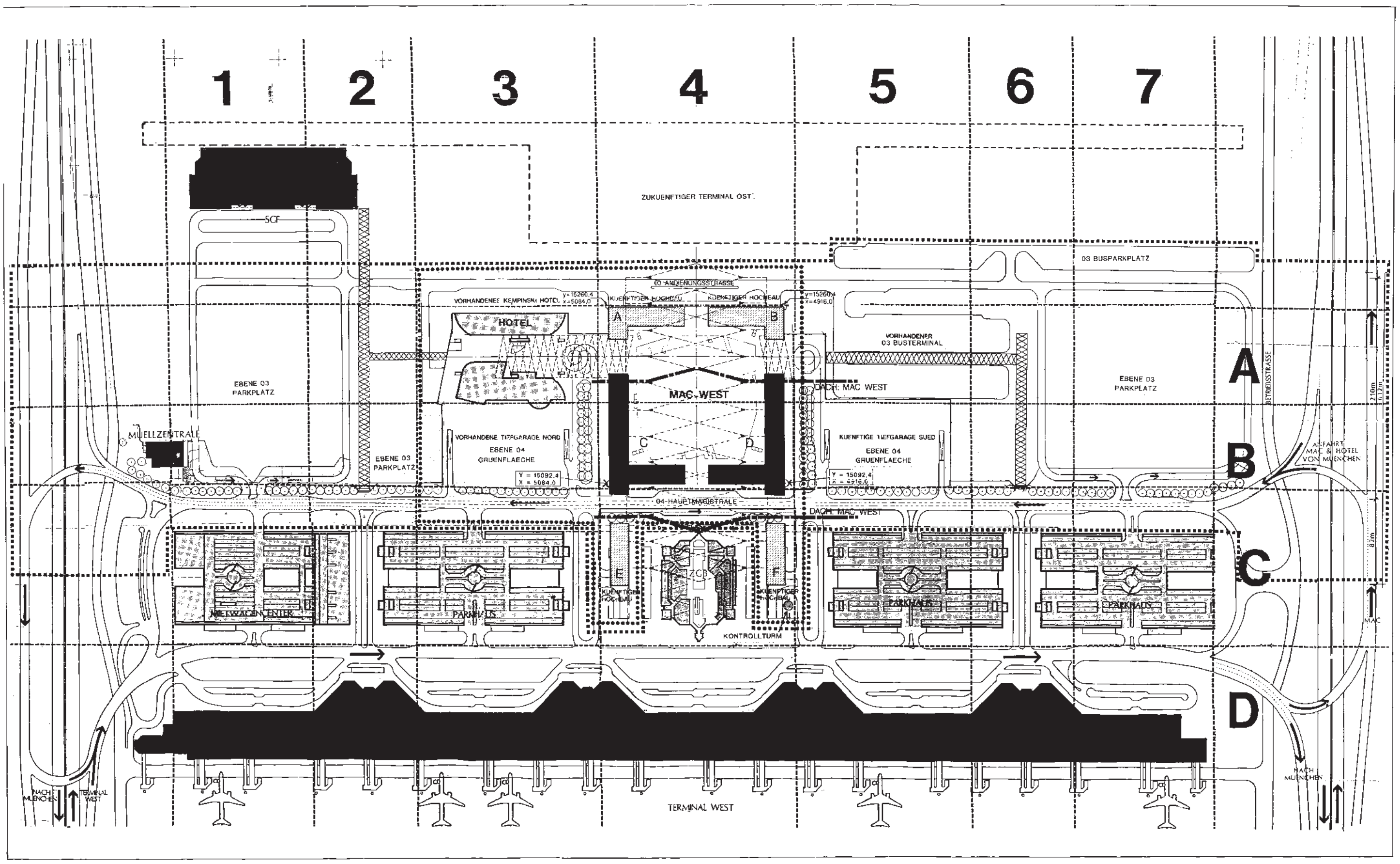
Existing conditions and traffic forecasts are both important areas of data gathering. Understanding the nature of demand, its profile and characteristics, allows a variety of options over different timescales to be evaluated. Once the case has been demonstrated for radical expansion of an airport or the construction of a new one, the type and scale of facilities can be determined.

Airport layout

The layout of the airport is determined by a number of related factors. As in all design exercises there are no precise rules, but rather the balancing of one factor against another to arrive at the best compromise. The principal factors to consider, evaluate and organize spatially are:[1]

- number and orientation of runways (especially with regard to meteorology)
- number of taxiways
- size, shape and organization of aprons
- area of available land
- topography and soil conditions
- obstacles to air navigation
- number and distribution of terminal buildings, hotels and car parks
- external land uses
- phasing of development

5.4 Major and minor grids are often the basis for airport planning. Munich Airport, Germany. Architects: Prof. von Busse, Blees, Kampmann & Buch with Murphy/Jahn.



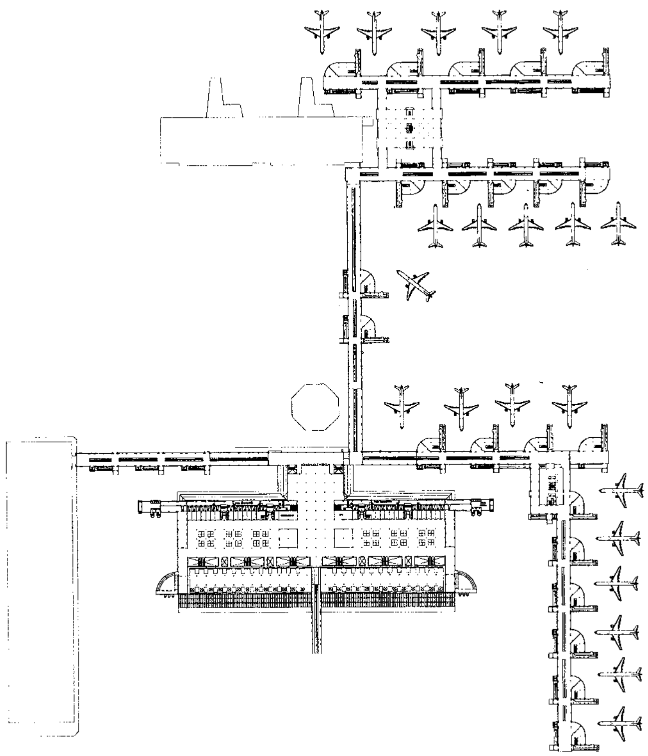
- size and layout of airport road system
- strategy for public transport connections.

The organization of the above factors into a coherent whole then leads to the selection of preferred locations for such facilities as air traffic control tower, aircraft maintenance areas, railway or metro stations, fuel stores, rescue and fire-fighting services, and control gates. The detailed layout of the airport needs to balance conflicting demands, such as public access and security, air freight and passenger needs, and arrival by car or train.

In the normal planning of airports, a number of options are arrived at, evaluated and eventually rejected. The constraints – operational, financial, and in terms of development phasing – add to the complexity of airport layout design. Because airports are subject to rapid change in response to innovations in aircraft design, the masterplan needs to be able to accommodate growth. Both long-term (say 20–25 years) and short-term tactical flexibility (say 5–10 years) need to be provided without compromising the integrity of the whole design.

Runway layout

A key factor in the layout of the masterplan is the configuration of the runways and the relationship between runways and the terminal building. Two main aspects of runways concern the airport designer: their length and their alignment. Length is dependent upon the type of aircraft using an airport, but for the largest planes a runway length of 2–3km is normally required. The length of the runway varies according to altitude,



5.5 The growth of the airport over a 50-year timeframe needs to be accommodated in any masterplan. Here at Palma Airport new satellite terminals are planned well in advance of need.

temperature, wind conditions and plane weight, so for a given aircraft design different runway lengths may be required at different locations. The critical length on a runway is determined by the safe take-off dimensions, not the landing dimensions, which are considerably shorter.

The capacity of runways is difficult to calculate exactly (it is dependent upon the mix and capacity of aircraft and safety regulations in operation at the time). However, as a rule most runways deal with 45–50 operations per hour in good weather and about 25 per cent fewer in poor weather. There is clearly a correspondence between runway and terminal capacity because they both deal with the transport of the same unit of people. To increase the number of passengers handled, airport authorities often extend runways (to allow larger aircraft to land) or build additional runways. These can either be in parallel alignments or more commonly placed at an angle to each other. The advantage of the latter is the greater flexibility in maintaining operations in cross-wind conditions. Where two parallel runways are provided the terminal can straddle them, giving obvious benefit in terms of ready access and economy of airside provision. With angled runways the terminal can sit within the hinge of the runway arms (see Figure 5.3).

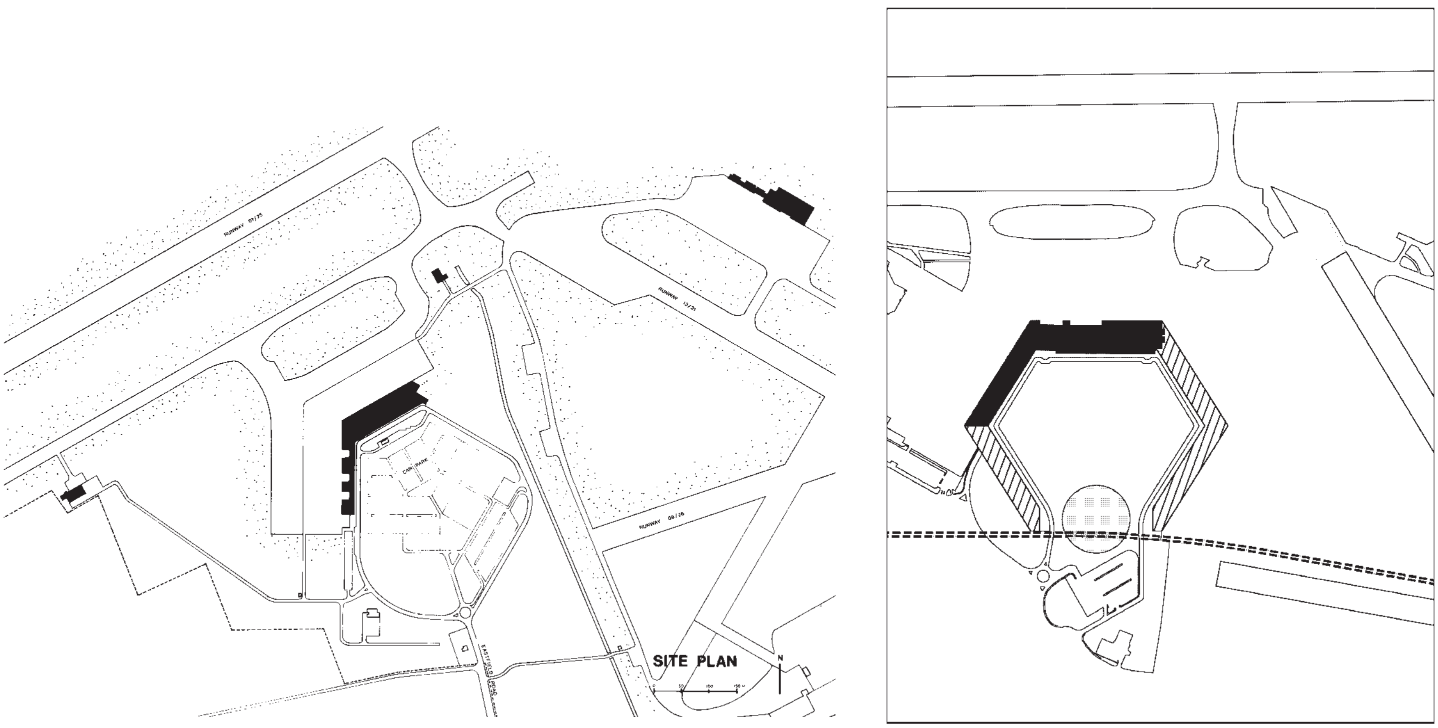
For safety reasons parallel runways are usually required to be 2000m apart laterally, and with angled runways the point where they converge should obey the same dimension. Occasionally runways cross over, but generally divergent runway alignments are preferred. With modern air traffic and ground flight control, airports with two or more runways can handle up to 100 operations an hour, which if translated into passengers (assuming 150 passengers per aircraft) means that the terminal buildings should be capable of dealing with a throughput of 15 000 per hour.

Two or more runways allow airports to cater for simultaneous landings and take-offs. High-density airports, as in the USA, sometimes employ three parallel runways, each linked to a dedicated terminal building. However, the constraint is not so much air space but taxiing space on the ground. Aircraft have to cross the path of those engaged in take-off or landing, posing the potential threat of collision.

The distance that the aircraft needs to taxi between the terminal building and the runway has a large bearing upon airline costs. Long taxi length means longer flight times, increased fuel costs, and the potential for ground traffic delay. The relationship between the location of the terminal and that of the runways (and taxiways) is crucial. Different configurations of terminal buildings, taxiways and runways affect design to a significant degree. There are complex layout issues to resolve, such as airside and landside links (ensuring that smooth connections are made with public transport, for example), and internal environmental conditions to consider (such as aircraft noise, which is more objectionable with jets because of its higher frequency than with turboprops). Where the terminal is placed between parallel runways it can no longer have a clear distinction between airside and landside, because passengers are accessing aircraft on opposite faces of the building. Likewise, taxiways that transport aircraft from the runway to the terminal building and service hangars have to be able to cater for aircraft movements in both directions simultaneously.

Physical elements of the masterplan

Airport masterplanning is a team effort, but the architect or engineer is normally responsible for the physical disposition of the parts. This involves three principal elements:



5.6 Original masterplan (left) for Edinburgh Airport by RMJM and proposed expansion (right) incorporating a railway station and new terminals. Architect: RMJM and Douglas Sherman.

- runways and taxiways
- hangars and service aprons
- terminals

and several secondary ones:

- roads and car parks
- security enclosure
- air traffic control tower
- airport railway stations and light rail system
- hotels, conference facilities etc.
- freight warehouses.

Design is not just a question of the dimensions of the parts in plan but their height and clearance from approach slopes and the like. Similarly, runways have safety zones, and there needs to be cross-wind provision. Terminal buildings are linked to piers and gate positions, thereby determining the layout of aircraft parking and further safety clearances.

The masterplan is a spatial, logistical and three-dimensional graphic plan, which structures investment in the fourth dimension – time. It is important that the vision of the architect and engineer is reflected in the management of the airport and the needs of the airlines that use it. A number of ground rules exist to provide the operational context for the airport and to help integrate airside and landside functions. As a general rule:[2]

Runway areas

- Separate airline, general aviation and commuter traffic on apron.

- Design for efficient and flexible apron-handling operations.
- Minimize taxiing lengths.
- Locate crash and rescue services close to main runway.
- Encourage joint airline use of airside facilities.

Administration buildings

- Locate airport administration close to road and rail system.
- Centralize administration facilities with direct access to landside and airside.

Road layout

- Keep landside road system simple.
- Provide public transport at terminal kerbside and administration building.
- Locate car parks close to terminals or linked by tram system.

Terminal buildings

- Minimize walking distances.
- Facilitate inter-airline transfers of passengers.
- Separate air carrier functions (international, national, commuter) but provide easy interconnections.
- Maximize marketing and rental opportunities.
- Encourage joint airline use of facilities.
- Link terminal buildings directly to public transport.
- Link terminal buildings to hotels and short-stay car parks.

Warehouses

- Accommodate growth in air cargo.
- Ensure efficient segregation airside of passenger baggage and freight.
- Facilitate cargo transfer between airlines.

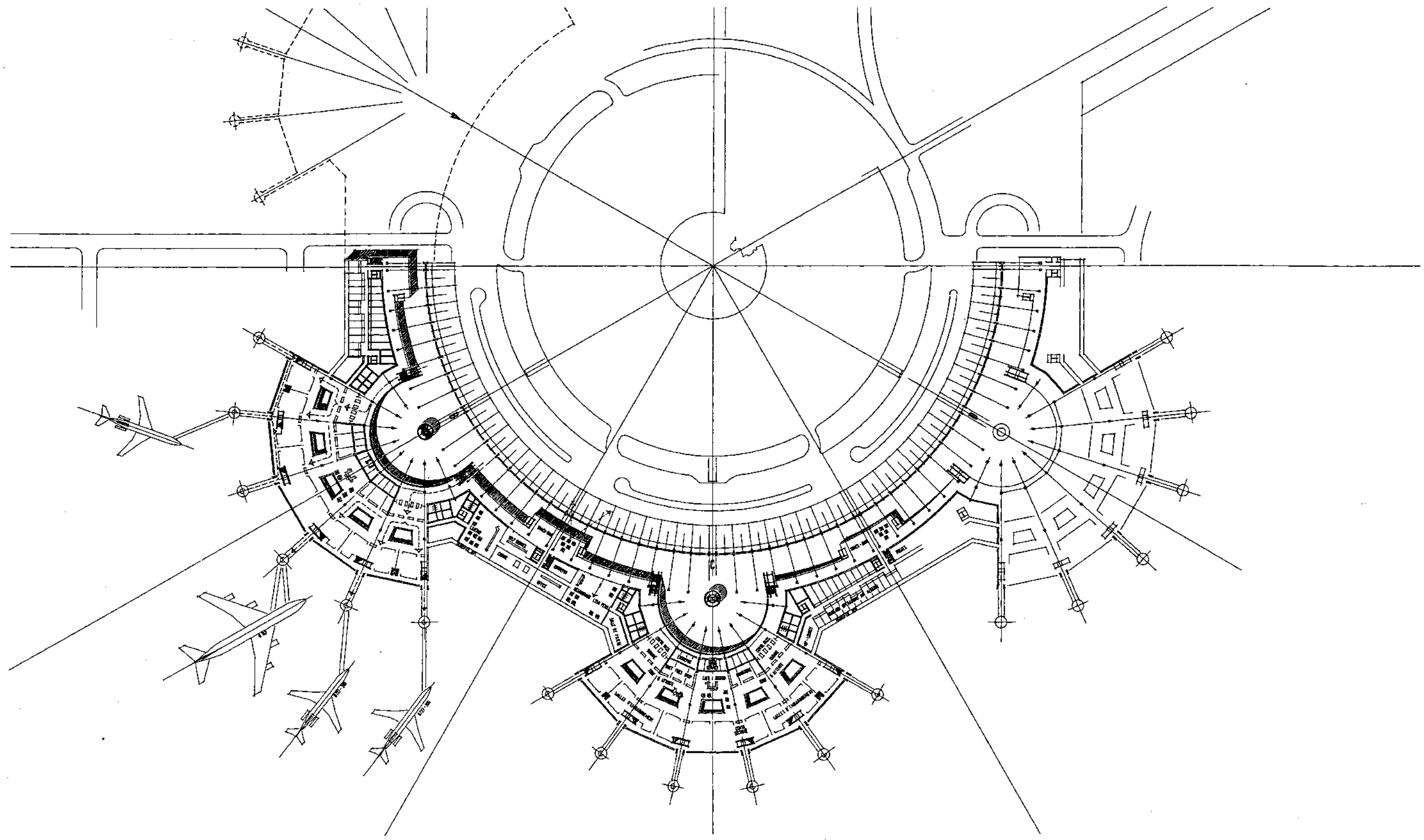
The importance of geometry

The movement of aircraft, service vehicles and people, imposes a geometric order upon the airport. Turning circles, safe distances, flow paths and functional patterns have their own logic in dimension and geometry. Functional order expressed as spatial order is reflected ultimately in structural order. It is characteristic of airports that these orders share common dimensions or physical attributes. Underlying them is a sense of big geometric patterns imposing their will on lesser systems – aircraft turning circles determine the layout of taxiing areas which in turn figure the spacing of gate piers which then position and help give size to terminal buildings.

Behind these patterns lies a system of geometric and spatial configurations which can be readily identified in plan and exploited by the designer. The architect has the primary task of finding clear organizing patterns which can regulate development over time. Such patterns expressed as structural layouts are best evolved with a clear sense of geometric progression. The geometry of patterns of space usage, of people movement and of structural layout, becomes a framework to accommodate the lesser activities (such as retail outlets) and one which can then be extended to accommodate future growth.

A common problem encountered is how to impose this order (essential for economic construction as well as passenger legibility) upon terminal buildings which have grown up in

5.7 This design for Seoul Airport shows the benefit of integrating design and infrastructure engineering at an early stage. Architect: Paul Andreu.



5.8 A clear sense of structural and spatial logic is evident in this design for Algiers Airport. Architects: Von Gerkan, Marg & Partner.

a haphazard fashion. The key lies in organizing traffic flows into a framework of space, structure and light which can regulate both the inherited chaos and impose a will upon the future. Without such clarity the airport would have little identity as a place. Central to the idea of spatial clarity is that of geometry – the simple but harmonious pattern of repeating linear and curved patterns in isolation or in juxtaposition. The use of geometric order allows the functional and spatial to fuse. Not all architects subscribe to a simple repeating order but the demands of a harmonious integrated building outweigh the specific interest of a lesser part.

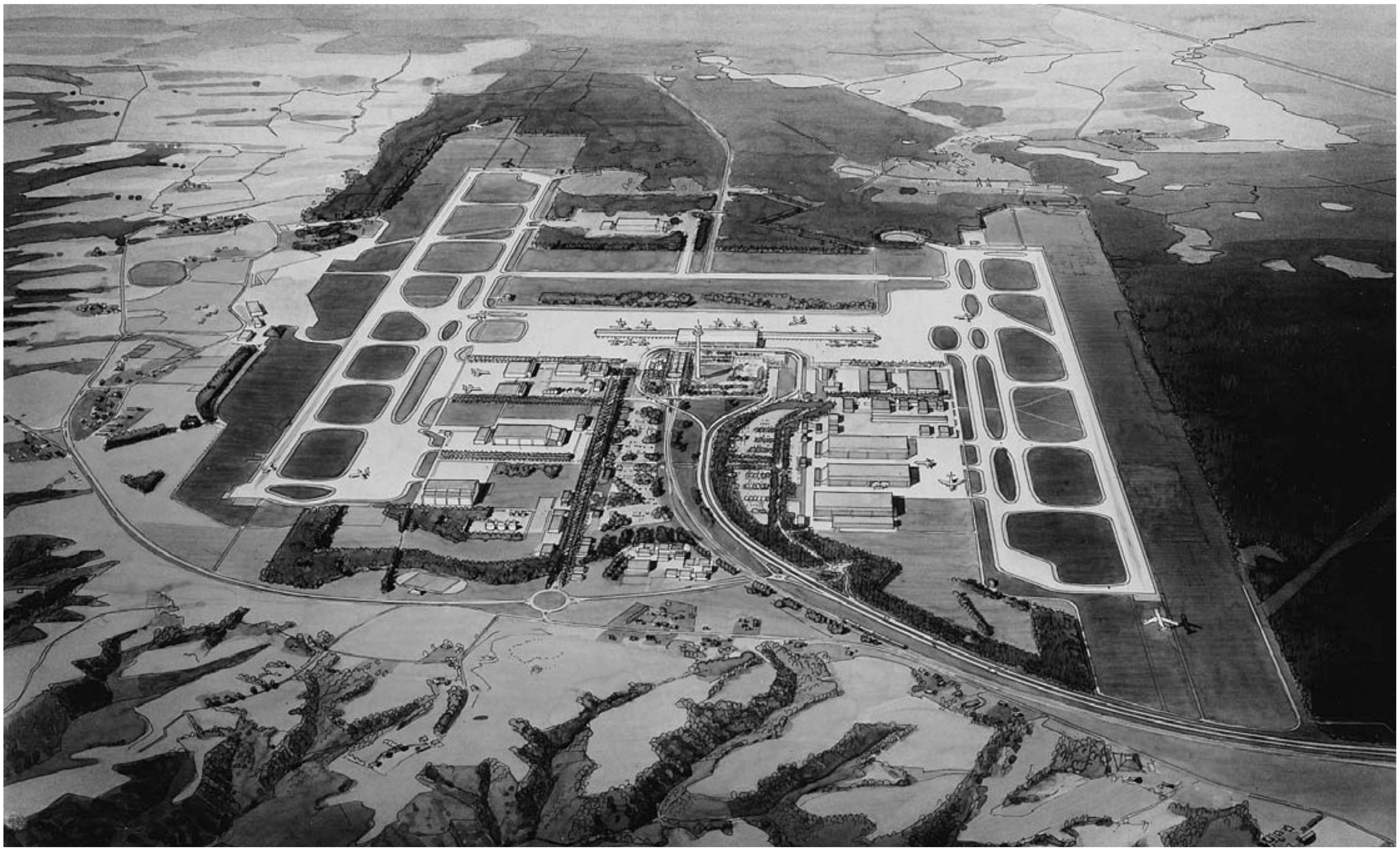
Geometry creates order which aids legibility and image. The construction of a new terminal may provide the chance to link together existing poorly connected structures within a fresh grand conception. This can enhance navigation through the airport and remove the tendency towards an alienating nondescript airport environment. At airports, as in cities, architects have to find solutions which enhance existing situations. Simple geometry provides the chance to generate added value through grand design.

It is, however, difficult to impose an overall vision at some later stage. If the original masterplan for the airport lacks clarity, the opportunity to generate memorable design may be lost. Partial demolition can sometimes allow for the insinuation of missing geometric definition – certainly the architect should consider it when re-designing an airport facility. Such geometric order can exist at many levels: it can fashion large spatial volumes and the smallest construction assembly.

Clarity of geometric conception encourages the airport authority to keep the long-term goal in sight while building in small but coherent portions. It also keeps to the fore the importance of spatial clarity when pressures mount for small-scale functional change. The armature of geometry can be a long-term asset if it is established initially in the masterplan and upheld by those who subsequently commission design changes.

Site choice

It is assumed here that the site for the new airport has been decided, but part of the masterplan exercise often involves the selection of an area for airport expansion. Site selection for a new or greatly expanded airport is fraught with difficulties, so much so that often an ideal site does not exist and a man-made one has to be created (as at Kansai in Japan or Hong Kong's airport at Chep Lap Kok: in both cases physical and environmental constraints were such that an



5.9 The spatial pattern across the landscape reflects directly the operation of a modern airport. Notice here how planting softens the impact of the airport. Oslo Airport, Norway. Architects: Aviaplan AS.

artificial island had to be formed in the sea for the new airport). The site selection process should include an analysis of the following factors:[3]

- operational capacity: obstructions from high buildings and mountains, weather patterns and airspace considerations
- capacity potential: land availability and sustainability
- ground access: infrastructure provision (road and rail), centres of population, parking space
- development costs: land costs, soil and rock conditions, land utilization values
- environmental factors: noise, impact upon ecosystems, air and water quality, cultural impacts, endangered species
- socio-economic factors: impact upon existing communities, public service needs, changes to employment patterns
- planning issues: impact upon land uses, agriculture, forestry and transportation systems.

Balancing the above factors leads to the selection of preferred locations, which can then be investigated in greater detail. Part of the analysis (sieve mapping, contouring and visual simulation) is normally undertaken using computer-aided design (CAD) techniques. Creating an image of the shape the development will take and its wider impacts helps in the final selection of a site. Interactive computer simulation also allows those affected locally to modify the proposals, thereby reducing community conflict at an early stage in the masterplanning process.

Energy and resources

It is important that the site chosen for the airport has sufficient supplies of electrical power and water, and adequate provision for sewage disposal for the full masterplan period: that is, 20–25 years. Airport expansion is dependent upon the ready availability of large amounts of energy and other resources. Future airports are likely also to generate some of their energy needs (by solar or wind power) and to recycle water and waste. The ecological impact of an airport is enormous, and rather than dispose of all wastes the trend will be towards recycling and energy conservation. Heat recovery from the passenger terminal plant, combined heat and power for electrical generation, and exploitation of renewable sources of energy will begin to influence future airport planning.

Within the time horizon of the masterplan it is therefore likely that the airport will begin to move towards a more sustainable pattern of development, with recycling loops applied to water and full life-cycle analysis of the materials used. Rather than being a development that merely consumes large amounts of energy and other finite resources, the future airport will begin to conserve and even generate its own power supplies. The openness of airports provides many opportunities for utilizing wind and solar energy (photovoltaic electrical generation is an obvious possibility), and airports near the sea could exploit wave and tidal power. The masterplan should therefore identify locations for these activities, and hence set the whole airport operation on a sounder ecological basis than in the past.

Environmental problems at airports

Of the factors that limit airport expansion, the protection of the environment is often the most critical. Five major impacts on the environment normally occur, and for each separate environmental statements or audits may be required. They are:

- noise
- air quality
- water quality
- ecosystems
- visual impact.

They are interdependent: changes in water purity from runway run-off may adversely affect local ecosystems, and noise will have consequences for wildlife disturbance. Similarly, air quality may affect rare or endangered species. The masterplan needs to address the impacts of each, and integrate protection policies into airport expansion plans.

Noise

This is a major environmental nuisance at and around airports. Aviation noise extends far beyond the boundaries of an airport in pronounced corridors several kilometres wide, which are the regular runway flight paths. Strictly speaking, outside the perimeter fence aviation noise is the responsibility of airlines, but the public generally equates the noise with airport authority responsibilities.

The impact of noise depends upon the sensitivity of affected areas and the type of aircraft involved. Noise from jet aircraft is more objectionable than that from turboprops because of its higher frequency, even at the same decibel (dB) level. Residential neighbourhoods with schools, universities and hospitals suffer more from the impact of noise than do industrial or agricultural areas. Hence, the development of an airport needs to consider noise corridors, and adjust flight paths or airport location accordingly. Because airport noise and that of approaching or exiting aircraft has become an issue of growing importance, many modern airports are constructed in positions where flight paths are taken over water rather than land.

There is a reciprocal relationship between airport noise and land-use activities. Where planning consent is granted for a new or greatly expanded airport, the aviation noise corridors (for take-off and landing) may limit land uses over a large area. Zoning regulations may be needed to ensure that development on the ground is compatible with the anticipated noise levels.

At airports where night-time flight restrictions operate, measures are taken to ensure that airlines do not violate local planning regulations. The airport authority as landlord has an important role in helping to police pilots' adherence to noise restrictions. Because noise nuisance is mainly perceived as a night-time problem, the normal practice is to restrict the number of flights during the night hours (generally defined as between 11.00 p.m. and 6.00 a.m.) and, where night flights do occur, to ensure that quieter jets are used by imposing a noise points system.

The airport authority has an interest in keeping within noise regulations, because disturbance to local communities can prove a headache when future expansion plans are under discussion. Good public relations – an important consideration for the modern airport operator – can be easily undermined by airlines that break statutory or advisory noise limits. It is the airport authority that tends to monitor noise levels and has the power to impose fines upon airline companies that break the rules. At London Stansted a noise points system operates based upon the take-off and landing noise levels of different types of aircraft. Noisy aircraft, such as an ageing DC9, may incur a noise points score 16 times higher than that of a modern turboprop. This means that 16 quiet night flights receive the same score as a single noisy one. Airlines are given a certain noise points quota level (to meet unexpected weather or flight conditions) against which every night-time flight carries a quota count. Once the quota level has been exceeded, the airline company faces a fine, which can be as high as £1000 per violating flight. At Stansted, these fines help to fund community and environmental projects in the area.

The system at Stansted applies in modified form at all BAA airports. Local regulations define the restricted period for night flights, and set decibel levels (89dBA at Stansted) for departing flights that are unavoidably delayed. The dual system of time restriction and encouragement through the noise quota scheme to use quieter aircraft has been gradually introduced by the UK Department of Transport to all major airports. By delegating the monitoring of noise levels (mainly night-time, but increasingly also daytime where 97dBA limits are imposed) to individual airport operators, the Department has brought greater local accountability to the issue of aircraft noise. This in turn has placed airline operators, agents and flight crews under greater scrutiny to obey noise regulations.

Noise preferential routes are the selected flight paths for each runway. Again, aircraft that fly outside the prescribed corridors are subject to fines, because facilities on the ground (such as terminals and hotels) and those in the wider neighbourhood (such as schools) will be subject to noise nuisance. Airlines that have a poor track record of obeying the regulations may find their operating licence withdrawn or conditions attached to continuing to use a particular airport. Again, referring to Stansted's experience, the prospect of gaining planning consent for a second runway is seen, in part at least, as depending upon the airport enjoying good relationships with the local community. Here noise nuisance is often the most crucial factor, and one that the airport operator, rather than the airline company, has the greater interest in avoiding.

Air quality

Airports suffer from poor air quality because of the concentrated burning of fossil fuels: aviation fuel, diesel and petroleum. The aircraft, servicing vehicles and road traffic all contribute towards a build-up of pollutants of one form or another. The combination of emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen can be more damaging than the various air pollutants in isolation.

Many airports are islands of high-level pollution; the air quality is noticeably poorer than in adjoining areas. Poor air quality adversely affects human health and that of other species that exist at the airport: this is particularly noticeable in the lack of vigour displayed by trees and shrubs planted along airport estate roads.

Poor external air quality means that buildings suffer from poor internal air quality, and may stain prematurely on their outsides. With smoking still permitted (and even encouraged by the presence of duty-free shops) in designated areas inside terminal buildings, the environmental conditions within buildings are far from ideal. As a consequence, most airport buildings are air-conditioned, either in whole or in part, adding at least indirectly to global health problems elsewhere through the use of CFCs and high levels of fossil fuel use.

Water quality

Airports produce a great deal of groundwater contamination, mainly through fuel spillage and run-off from runways and apron areas. Normally, treatment is required to intercept and purify the polluted water before it is allowed to enter local rivers and streams.

Water pollution occurs also with de-icing fluids and detergents used to clean aircraft at the servicing turnaround. Also, in the construction phase, soil erosion can lead to large amounts of pollution entering watercourses. As with air pollution, water quality should be embraced within the environmental statement that accompanies the masterplan. An inventory will be required of existing watercourses, their quantity and quality, and an assessment of how these will be affected by the proposed airport.

Ecosystems

Because of its physical size and environmental impact, an airport alters the ecosystems of a large area. An inventory and assessment of quality needs to be undertaken of all habitats

5.10 Reducing the visual impact of terminals by varying the roof profile and stepping at the edge helps to absorb large buildings into the open landscape of airports. Heathrow Terminal 5, UK. Original design by Richard Rogers Partnership.

affected. The biotic health and degree of biodiversity of wildlife sites should be catalogued and understood. This will then form the datum point for assessing or predicting future changes. As with other environmental factors, a distinction needs to be made between the quantitative inventory of existing conditions and the qualitative assessment of impacts at both the construction and operation stage.

Visual impact

Visual impact is an important environmental consideration. On the one hand the view of an airport identifies its location, and gives a good impression of its scale and national standing; on the other hand the appearance of the airport may jar with the open countryside in which it stands. Good design is essential if a favourable impact is to be made, and if the apparent scale of operations is to be reduced. Computer-aided graphics can help greatly in explaining the likely visual impacts and in reducing the romantic notions that often accompany artists' perspectives. CAD-generated drawings or TV monitor displays also allow interaction by the viewer with the subject, thereby permitting some detailed exploration or modification of the proposals. As the presentation drawings of Heathrow's Terminal 5 confirm, the use of advanced computer graphics can present reliable and attractive images to reviews such as public inquiries.

The visual impact of airports embraces the whole complex infrastructure, from terminal buildings to control towers, runways to hangars, and car parks to hotels. Reducing impacts may involve using one set of buildings or structures to screen another. At Terminal 5 it was decided to develop a coherent set of structures, and to give the effect of a family of designs without jarring elements. The different parts are united by design philosophy as well as constructional, surface and colour elements with the urban design relationships well developed.[4] Part of the strategy is to conceal larger buildings behind smaller ones, thereby stepping the design composition as a whole. The intention is to reduce the visual impact of the main terminal from afar by using terraced car parking, lower buildings and landscaping as a screen, while opening up dramatic close views framed by adjoining structures.

A physical strategy for sustainable development

Sustainable development necessarily impacts upon the location, land-use planning and design of airports. Some 8 per cent of global carbon dioxide emissions are the result of air travel and transport to airports. Besides energy use, airports are big users of other resources and large takers of land, much of it of prime agricultural value. As a result of this consumption, airports are producers of considerable volumes of waste, pollution (air, water, noise) and long-term land contamination (from heavy metals). Potentially, airports could be models of sustainable development with their own ecological needs, areas where renewable energy could be farmed (solar and wind) and their own patterns of buildings and landscapes aimed at reducing fossil fuel dependence and maximizing recycling. Additionally, the airport could be seen as a means of transferring new skills (in IT and resource management), in developing new partnerships with higher education, and in exploring new slimmer technologies. If environmental sustainability is necessarily at the core of the strategy, it is important for airport authorities to integrate resource conservation with policies for social and economic sustainability.

The combination of buildings and green space gives the airport the beginnings of a land-use and layout strategy which can exploit the inter-dependences inherent in sustainable development. For example, the waste cycle requires areas for separation, for digestion and re-use by composting and incinerating waste into the resource chain. The green areas at airports provide the opportunity to compost waste, farm energy crops and process water on a large scale, exploiting solar and wind sources.[5] Planting at the edge of airports also provides the opportunity to exploit bio-mass and handle organic wastes.

The green areas necessary at airports because of the growing length of runways (typically 3.3km long and 2km apart) provide ample space for ecological and amenity treatment. Although sight-lines have to be protected and bird strikes militate against the development of wetlands, there is still much opportunity for wildlife enhancement. Further afield the airfield could be seen as green parkland with a town in the centre (the terminals, hotels and car parks), the whole surrounded by housing, business parks, leisure and educational buildings, and green wedges. Such peripheral areas will need to be integrated neighbourhoods, not monocultures of single land-uses. Beneath the flight paths there will be restriction of what can be built but, in between, much potential exists to exploit the airport as an economic magnet.

The key to unlocking the potential of peripheral growth lies in the presence of public transport. Where the airport is well served by a train service, it is easier to construct sub-nodes of development along its corridor (e.g. the development axis created along the new train route serving Hong Kong Airport). There begins to emerge a pattern, sustainable in spirit, where the airport is at the centre of a hub of relatively closely spaced communities benefiting from the airport's economic impact. Such communities, if well designed, could enhance social welfare and economic progress, and help introduce low-energy strategies in the design of housing and schools by the example set at the airport itself. The three-dimensional nature of sustainable development (environmental, social and economic) well suits the airport as a system of inter-dependent activities. Unfortunately, few airports have exploited the opportunities provided, partly because airport authorities rarely own the land beyond the perimeter fence, and local authorities are generally more intent upon banning growth (by establishing green belts) than manipulating it to foster sustainable development.

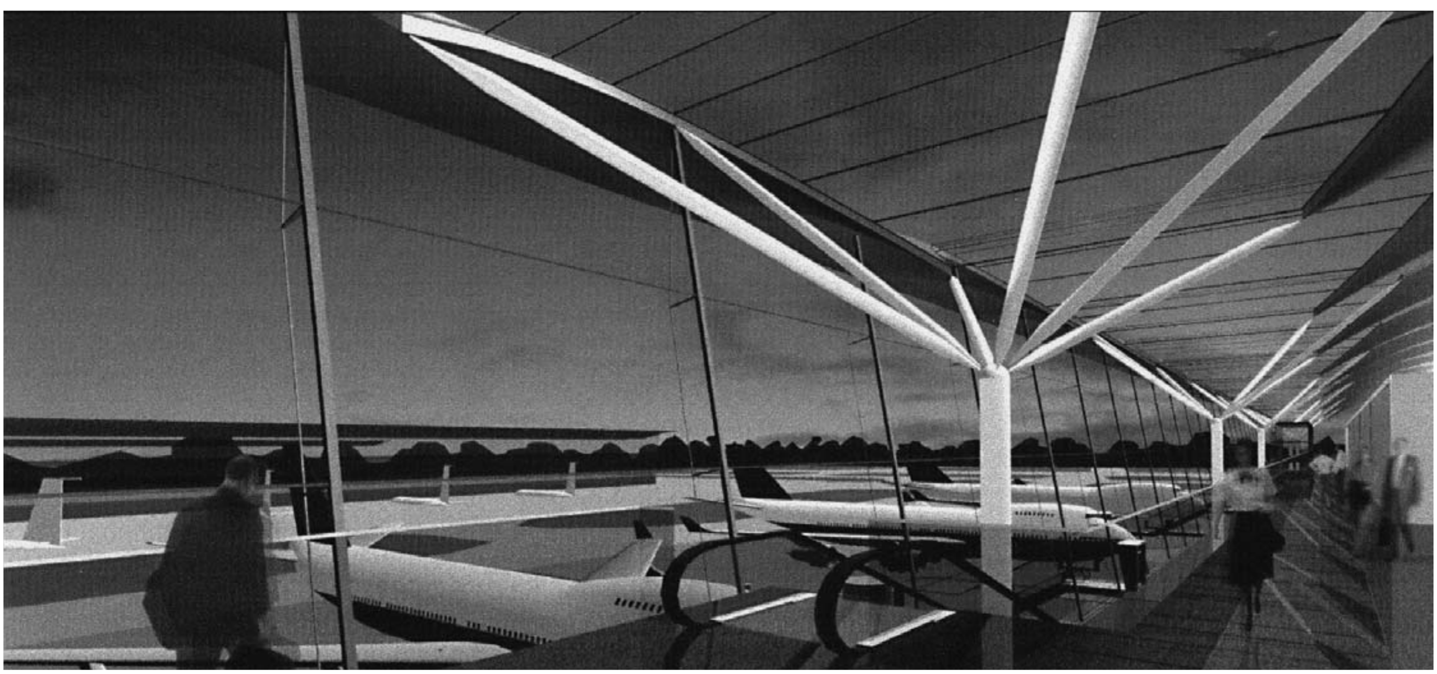
Reducing environmental impacts: a case study of the original design of Heathrow's Terminal 5

Heathrow's Terminal 5 was subject to both an environmental impact assessment and correspondingly to a public inquiry. The latter considered the former in some detail, because the environmental consequences of the development were one of the chief grounds for objection by local authorities and community groups. At the inquiry the inspector required BAA to submit details of the design and its likely visual impact for examination, arguing that the scope and scale of the buildings were a 'material consideration'. In response BAA presented evidence explaining both the planning and design criteria for the new terminal, with 'illustrative and likely' views of what it would look like.[6] BAA was careful to hedge its bets at that time, arguing that the design by the Richard Rogers

Partnership was not 'a commitment but can reasonably be used for assessment purposes'. As the inquiry has unfolded, the concept design with accompanying computer animations and sketch plans has become rather more firm with regard to appearance, scope, scale and technical performance. The effect of the inquiring has been to bring into the public arena the nature of visual impacts involved. The employment of the Rogers' office ensured a high profile for the design which eased planning consent difficulties.

The development of Terminal 5 consists of a core terminal building, three mini satellite terminals, maintenance hangar, aprons, taxiways, car parks, office and hotel. The main terminal is rather more a transportation interchange than a traditional passenger terminal, providing links to underground and main line railways and bus services. Dimensionally it is very large, measuring 432m by 195m, and 40m high to the ridge and 29m to the eaves. The interior concourses are also lofty, with a clear height of 20m specified by BAA for the departure lounge.[7]

The materials and architectural forms have been selected to reduce visual and environmental impacts. The inclined glazing on the east and west elevations and the large overhanging canopies on the north and south elevations are intended to reduce the reflectivity of the building, especially when the sun is at low angles. An undulating roof shape has been selected to reduce light spillage at night from the large rooflights, thereby minimizing night-time sky pollution and potential hazard to pilots. In the choice of materials BAA's architects have striven to absorb the building into the airport environment. The predominantly glazed walls, set in frames and panels of neutral greys and pale greens, allow the building to blend with the apron areas and adjoining grassland. The roof's wavy profile and soft metallic finish also apes the tones of an English sky. The colours of the terminal, car parks, office



5.11 Virtual development in the form of CAD simulation has been a feature of the public inquiry into Heathrow's Terminal 5. Original design by Richard Rogers Partnership.

block and hotel are all in the range of off-white, grey and silver with, if the visualizations are to be trusted, touches of light green and pale blue.

To reduce the apparent scale of the collection of new buildings, a stepped profile is adopted. The visually dominating terminal has a sweeping, oscillating roof, which is lower at the outer edges giving – superficially at least – the appearance of land undulations. In addition, the different buildings nearby (such as car parks, hotel, offices and satellite terminals) are stepped in height to allow the main terminal to appear as an urban grouping with the terminal at the centre. Stylistically, there is an attempt at aesthetic integration of the different building parts by using a family of materials, construction and landscape details and a consistent design philosophy. Planting (trees, hedges, shrubs and grass banks) plays a key part in reducing the environmental impact of the whole development. The parapets of each level of the car park, as well as the hotel and office roofs, are to be planted with creepers, which tumble down the walls and clothe the concrete frames. From the landside the appearance sought will be one of greenery masking the peripheral buildings, with the predominantly glazed main terminal set within a more formal space.

Landscape is not only used to screen and soften the different buildings, it is also employed at a broader infrastructure level. Between the formal landscape associated with the buildings and the informal agricultural landscapes of Middlesex, the intention is to introduce transitional planting, which acts like layers integrating the development with the wider environment. The effect of the strategy, aided by stepped and layered buildings and planted bulbs along roads, is to allow the massive development to be absorbed into the landscape. Care has been taken with the selection of species of tree and shrub to avoid the attraction of larger birds, which can pose a hazard to aircraft. Again, to reduce the scale of the different structures, many are designed with one or two storeys beneath ground, either enclosed or hidden behind 7m high planted embankments.

The formal language of design for the different buildings embraces the play of primary shapes and geometries. The car parks are designed as cubes or rectangles with semicircular ramps 18m in diameter placed on the outsides of the buildings. These curved ramps, which provide vertical circulation for cars, are complemented by square stair towers and lifts placed on the outside of the structures. The juxtaposition of the square and circular elements gives interest to the design, and avoids the visual monotony associated with car parks. Similar plays of cubes and cylinders make up hotels and office buildings. Strong geometric forms, and large-scale planting, have been employed to reduce the apparent scale of the development. The revised design for the airport following the public inquiry is described on p. 198.

Extent of the masterplan

It has already been noted that the impact of an airport extends far beyond its physical boundaries. Two types of masterplan are commonly encountered: that which structures the airport estate only (but with a statement of wider impacts), and that which structures both the airport and adjoining areas into an integrated development proposal. The latter is increasingly adopted as airport developers, working usually with adjoining landowners and civic authorities, recognize that integrating neighbourhood land uses with airport expansion is mutually beneficial.

An example of the wider impact of airports upon the regional infrastructure is that of Stansted. The airport's growth from its opening in 1991 with 4 million passengers a year to an expected 15 million within the decade has resulted in a planned increase in the workforce from 3500 to 14 500. The increase puts pressure on roads, public transport provision, health care, education and housing. The latter is a point of particular contention in this area of still largely agricultural Essex. Essex County Council identified in its Structure Plan Review of 1994 the need for 2500 new houses to satisfy Stansted's anticipated growth. Following a public inquiry into objections from local councils, the government inspector recommended the expansion of existing villages rather than the construction of a new town on the former American air base at Little Easton as proposed earlier. However, local people, faced with the expansion of villages such as Felsted and Takeley from about 200 houses to over 500, continued to object and took the issue to the High Court in London.[8] The case illustrates how wide the economic and social impacts of major airports are, and masterplans need to plan for growth and environmental protection way outside the boundaries of the airport.

The physical and environmental planning of an airport and its hinterland should seek to ease community conflict (from problems such as noise and imbalanced local communities) and realize the potential of development alongside the airport. The growth in services such as air cargo has led to an expansion of warehousing facilities near to airports. Similarly, business parks have grown up near to major airports (for example, Stockley Park near Heathrow) because of the proximity to the transport infrastructure, and the presence of modern hotels and conference facilities. Airport expansion should therefore recognize that much growth occurs outside the perimeter fence, and that both need to be structured in time and space to ensure that infrastructure demands (water, drainage, transport) and environmental impacts are anticipated and addressed. Where the airport authority owns adjoining land, it makes great sense to maximize its development potential in tandem with airport needs.

References

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2. Adapted from Ashford and Wright, *Airport Engineering*, p. 126.
3. *Ibid*., pp. 28–29.
4. Josephine Smit and Antony Oliver, ‘Time for T5’, in Jackie Whitelaw (ed.), *21st Century Airports*, supplement of *New Civil Engineer/New Builder*, May 1995.
5. Brian Edwards, ‘Future directions of airport architecture’, *Arkitektur*, vol. 5, no. 101, August 2001, pp. 10–11.
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7. *Ibid*., p. 7.
8. *The Guardian*, 16 April 1996.

Part two

Terminal design

CHAPTER 6 The terminal as part of the airport system

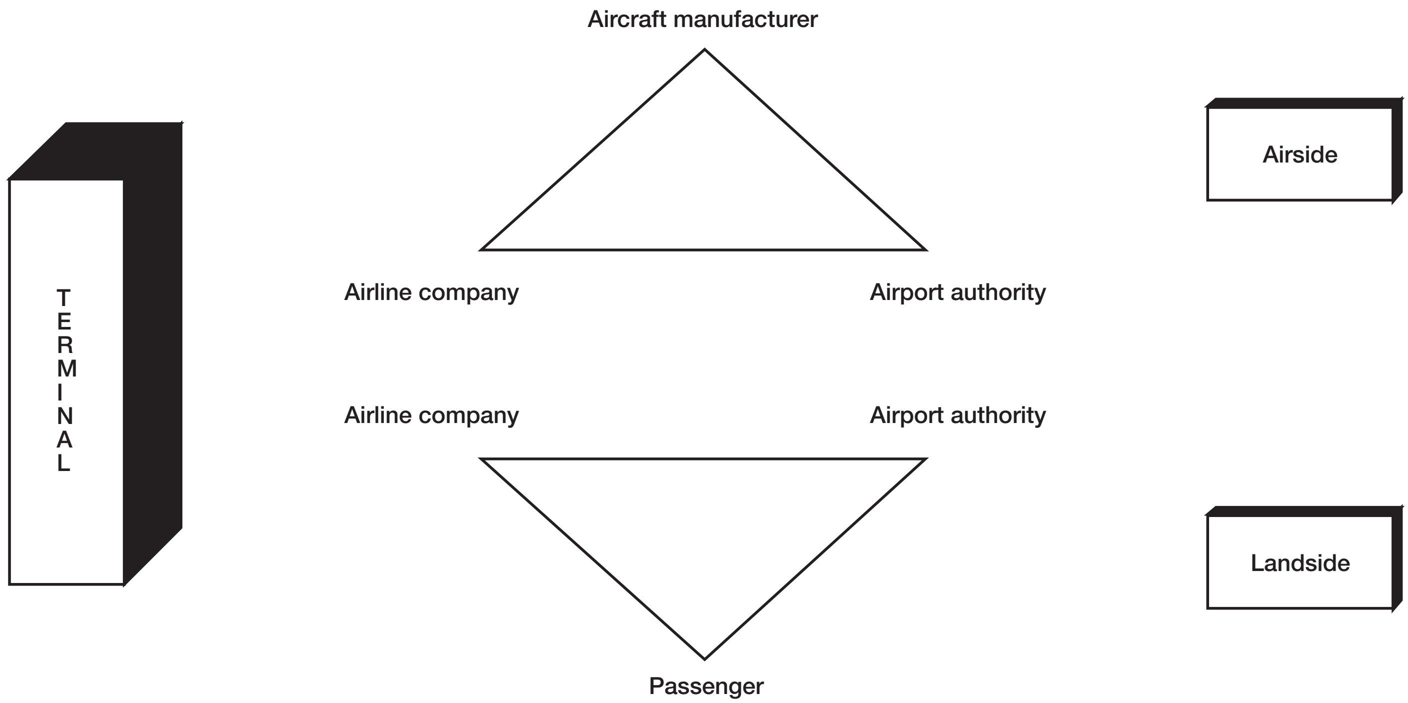
Aircraft types and passenger terminal design

The four main scales of air transport – intercontinental, continental, regional and commuter – are each served by their own type and category of aircraft. Transport by the first is in such aircraft as the Boeing 747 (with seating for about 400), the second by say the European Airbus A310 (seating about 250), the third by the Boeing 737 (seating 150–200) and the fourth by the SAAB 340 (seating about 35). Each scale of jet has its own apron, servicing and terminal design needs. Though there are overlaps between the four main categories of aircraft, the designer of the airport knows that if each scale can be accommodated, then those planes between the capacity bands will fit comfortably into the system. As a general rule, journeys over 3000km are seen as intercontinental, between 3000 and 1500km as continental, under 1500km as regional, and under 300km as commuting.

While the intercontinental and continental market is met by jet aircraft, the lower end of the regional scale and commuter market is increasingly served by turboprops. The new generation of turboprops offer distinct advantages over jet aircraft: they are less noisy, can operate at lower altitudes, have reduced emissions, and shorter take-off and

6.1 The growth in commuting by plane poses particular difficulty for security of the apron area.

6.2 Key relationships at airports.



landing needs. The growth in commuter journeying by plane is being met not by small noisy jets but by relatively quiet and fuel-efficient turboprops such as the SAA 2000. In fact, while larger jet aircraft are increasingly constrained by environmental regulations of one kind or another, the new generation of turboprops with their improved performance readily meet international standards. This is further fuelling a growth in commuter journeys by plane, which changing work practices and regional politics (such as the integration of Europe) are also promoting.

The increase in commuter aircraft journeys is most marked in North America and Europe, where the majority of the 9000 commuter aircraft in the world operate. However, it has been estimated that over the next 20 years an additional 17 000 aircraft will be needed to meet demand. While this is not a large volume in financial terms (compared with growth in larger aircraft), it suggests a significant increase in such traffic, which terminal design will need to accommodate. The main problem here is access from the terminal building to the plane; the usual pattern of elevated telescopic gates will not suffice. Demarcation for commuter flights is normally directly over the apron alongside the terminal or by bussing to locations further afield.

Where large numbers of commuter passengers regularly use a terminal, there needs to be provision for direct and easy access to the apron area from the departure lounge. This poses security and organization problems, because the departure lounge is normally at first-floor level. Also, because about 70 per cent of commuter and regional traffic is provided by small independent carriers, the major airlines operating at a terminal may be reluctant to sacrifice their own operational efficiency (and security) to meet the needs of this specialized market.

The terminal building has to be capable of accommodating all four scales of commercial aircraft listed earlier. The most problematic area is normally with regard to commuter aircraft, where smallness of size, the need to take off and land quickly, and unusual aircraft design features put terminal, gate lounge, runway and apron facilities under greatest strain. However, looking further to the future (10–20 years), a new generation of aircraft now undergoing technical investigation may require wider modification to airport design. Two trends are emerging that, if realized, will alter the assumptions under which the airline and airport industries operate. The first concerns the re-emergence of supersonic passenger aircraft. Design and technological research is being devoted to a new generation of supersonic aircraft based upon the experience of Concorde. Several manufacturers are collaborating to develop a quieter, faster, more fuel-efficient and larger-capacity supersonic jet. With business travel growth still buoyant, and the world's biggest trading nations at opposite geographical regions, aircraft designers realize that very high-speed travel has commercial advantage. The age of mass supersonic commercial air transport will probably occur well within the lifetime of airports currently being designed (that is, 50 years). The second innovation concerns very large (as against fast) aircraft, perhaps capable of carrying 1000 or more passengers. Airbus Industrie, Boeing and McDonnell Douglas are all developing prototype designs in this field. For the passenger terminal the implications for the organization and distribution of space, catering, ticketing and baggage handling will be profound. To meet such future demand, terminal design needs to be robust in concept and capable of multiple adaptation over time.

The life of an airport terminal, at about 50 years, is two or three times as long as that of the aircraft it serves, and frequently longer than the life of an airline company. In an industry of little stability, the airport is the one permanent feature. Even the airport, though, does not stand still; it evolves new runways and passenger terminals, it replaces obsolete ground transport systems, and regularly upgrades air traffic control facilities. At Heathrow there are now four terminals (with a fifth on site), while Terminal 1 has been substantially rehabilitated and extended at least twice in its 40 years of life. These changes are driven by two main factors: the increase in passenger numbers, and the evolving nature of aircraft design. Innovation in aircraft design triggers a chain reaction throughout the industry, which airline management, airport operation and passenger terminal design have then to meet. It is against this background that changes in aircraft design (the new breed of turboprops, second generation of supersonic planes, very high-capacity aircraft) and their effect upon terminals should be seen. The passenger terminal has to be capable of meeting change, but the architect is rarely able to anticipate what specific shape or direction that change will take. Flexibility, expandability and functional adaptability are the obvious design philosophies to adopt within the constraints of structural robustness and aesthetic appeal.

Energy consumption, payload and the effect upon terminal design

Energy is consumed in enormous quantities at airports. Fossil fuel is used to lift aircraft into the sky; to transport people, freight and baggage to airports; and to heat, light and ventilate airport buildings. Airports are one of the greatest energy-consuming centres per square kilometre on our planet. For every plane that travels from New York to London the amount of energy used is roughly equal to that of an ocean liner.[1] Large jet aircraft consume about 9600 litres of fuel per hour in flight, and about 2400 litres on take-off. On a long journey a typical jet burns about 40 tonnes of fuel. This leads to a great concentration of air pollution at airports, and the obvious need for extensive refuelling facilities on apron areas where spillage occurs. Pollution affects air conditioning of buildings and the choice of materials used in the construction of airports. Advanced turboprops are far more energy efficient per tonne of aircraft than turbojets, consuming about two-thirds less fuel per tonne-km. As a consequence, regional airports, which make greater use of turboprops than of jet aircraft, suffer less air pollution. In total, aviation accounts for 6 per cent of world oil consumption and 20 per cent of all oil used in transportation, contributing some 5–6 per cent of the gases leading to global warming.[2]

For the airline company the factor that determines operational efficiency is not so much fuel consumption but payload. This is a factor determined by the revenue-producing load: that is, the carrying capacity in terms of passengers and freight. Jet aircraft are used where large numbers of people need to be carried. As a rule of thumb, payload represents about a fifth of the total aircraft weight. Payload and aviation fuel are the two variables in aircraft weight, and both must be carefully calculated to ensure that safety regulations are met. On long journeys fuel may account for a third of the total weight of the aircraft and payload only a sixth, but more typically fuel weight and payload are about the same (at roughly 18 per cent each of average weight).[3]

Payload is the revenue-generating function of air transportation. But with modern aircraft design it is often not weight that is the limiting factor, but space. On passenger flights it is rare for payload weight to reach the maximum permitted under international safety regulations, because seats and aisles take up so much space. Airlines compete on quality of journey where leg-room and seat width are critical factors. As a consequence, payload limits are rarely reached except at the lower end of the market (holiday package tours, for example).

There is a relationship between aircraft carrying capacity, runway length and the design of passenger terminals. Few aircraft journeys exploit the limits of payload because of passenger space expectations. This means that most terminals have to cater for many flights slightly below their passenger-carrying capacity, rather than fewer at the weight limit. This tends to even out the peaks and troughs of aircraft movement. However, as larger and more powerful aircraft are introduced (such as the Boeing 777), the troughs are tending to be filled. Bigger aircraft mean longer runways and larger payloads. Longer runways mean modification to the design of the airport itself; larger payloads mean changes in the layout and passenger-handling methods employed at the terminal. As payloads increase (25 per cent payload weight to aircraft weight is becoming the norm, compared with 18–20 per cent a decade ago), check-in, baggage handling and lounge space are put under stress. Aircraft design and terminal design are directly related.

Large aircraft with heavy fuel loads and high payloads require long runways, wide apron areas and plenty of taxiing space. This means that passengers spend a lot of time on the ground in the aircraft before and after take-off. Hence the passenger arriving at the airport after a long journey is often jaded, and does not readily accept additional delays at baggage reclaim or customs clearance. Terminal design has to ensure that passengers are not unduly subjected to changes in level, long corridors, overcrowded arrival lounge areas, and disorientating movements. It also means that seats should be provided within movement flows; that interior design should relieve stress, not add to it; and that daylight and tranquillity should temper movement through the terminal.

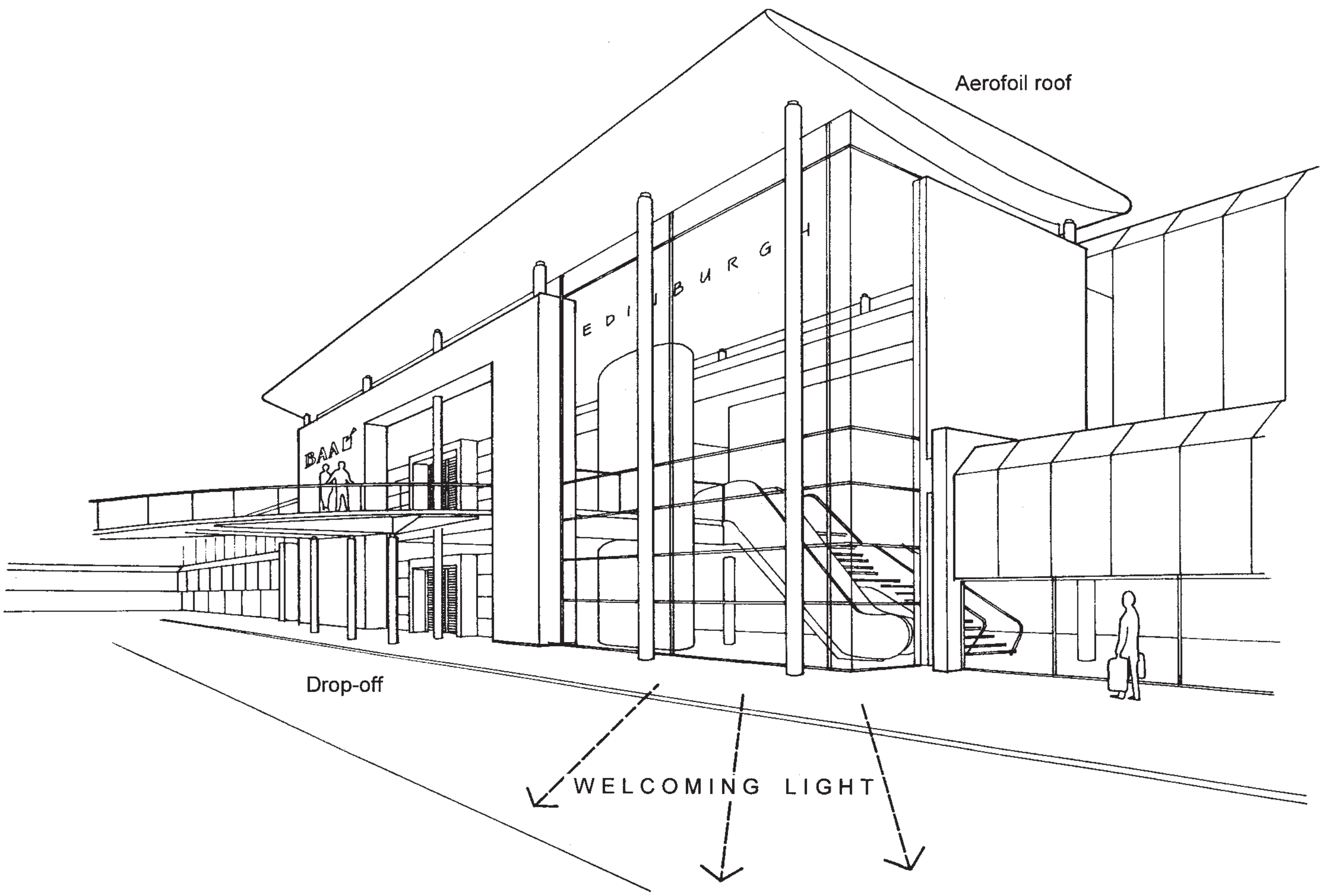
6.3 Stansted marked the transition from second- to third-generation terminals. Stansted Airport, UK. Architects: Foster and Partners.

Relationship between the mission of BAA and terminal design

Recognizing the value of good design has its roots in the mission statements of more progressive airport authorities. For example, the six-point mission adopted by BAA lays the foundation for the pursuit of quality in the design and management of its airports. BAA's mission can be summarized as follows:[4]

- Give safety and security the highest priority through risk auditing, and best-practice management systems.
- Provide a good and safe working environment for employees.
- Ensure that passengers and airlines receive excellence and good value for money.
- Concentrate on the core airport business while fully developing property and retail potential.
- Encourage shareholders to believe in the company by giving them consistent growth in earnings and dividends.
- Recognize the concerns of the local (airport) communities, set challenging environmental targets, and audit performance against them.

Of the six elements of BAA's mission, three have a direct bearing upon airport design and two further influence the quality of physical development indirectly. Two strands of the mission statement are, however, worthy of special mention:



6.4 Light, space and gateway are key elements of BAA design philosophy as in this proposal for extending Edinburgh Airport, UK. Architects: Parr Partnership.

safety and security, and environment. The first is crucial to successful terminal design, especially as perceived by passengers and airport managers. Without safe and secure buildings, the airport journey is fraught with potential hazard and – equally important – fear of danger, which undermines the passengers' sense of security. The expression of environmental concerns also signals changing priorities over the past decade. Airports are designed today to minimize environmental and ecological impacts, both in their design and construction and in day-to-day operations.

Because BAA is the world's biggest private airport operator, the mission of the company has more than local relevance. The range of concerns expressed – from safety to good working environments for staff, from a culture of excellence in the provision of airport facilities to maximizing property and retail earnings – all point towards the difference between first- and second-generation airports. The sense of evolution evident say in the difference between Heathrow's Terminal 4 and the published designs for Terminal 5 can be traced to the revised mission adopted by BAA in 1992 when Rogers was appointed.

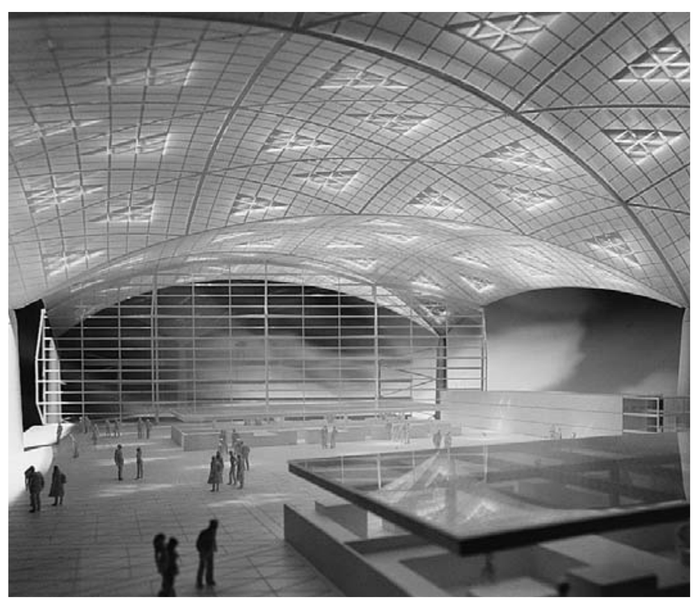
BAA owns and operates seven UK airports used by 177 million passengers per year and has management contracts for the operation of all or part of a further 12 outside the UK (including Indianapolis in the USA, Melbourne in Australia and

Naples in Italy). BAA is the leading airport company in terms of passenger capacity and in setting design standards. The company's policy is beginning to influence the culture of competitors and to raise standards generally. Also, as federally owned airports throughout the world are sold either in whole or in part to the private sector, it is BAA that is emerging as a lead contender to take them over. Hence BAA's mission of excellence, customer quality and reduced environmental impact looks set to have international application.

One can trace many recent developments at UK airports to the influence of the mission statement. The Flight Connections Centre that links Terminals 1 and 2 at Heathrow followed concerns over passenger transfer difficulties (the new Centre includes opening up views of the airport runway, showers, slumber zone and children's play area). The new international departure lounge at Terminal 1 was also in response to the pursuit of excellence in facilities expressed in the mission. Growing congestion at Terminal 1 led also to Europier (designed by the Richard Rogers Partnership), which combined expanded retail facilities with more extensive direct boarding of aircraft. Similar plans are afoot to build a three-storey extension to Heathrow's Terminal 2, which will double the size of the departure hall. The improvements also include: modernized check-in desks; new seating areas, escalators, lifts and stairs; baggage-sorting improvements; and a new, centralized security facility.

The question of safety and security has led to many changes in the design and operation of terminals. BAA employs 3000 staff specifically in the field of airport safety and security.[5] New technologies introduced progressively at Gatwick and Glasgow Airports have speeded the electronic searching of baggage, and hand-held metal detectors for body checks now supplement traditional screening. As new safety technologies are introduced, the arrangement of security screens and waiting areas at ticket control points has had to be adapted. Physical upheaval is inevitable in an industry noted for innovation. When changes to airports are planned, either alterations to the fabric of terminals or modifications to management processes, the corresponding designs are subjected to a standardized risk assessment procedure. Designing for safety is one of the biggest differences between first- and second-generation airports.

6.5 Sondica Airport, Bilbao, signals the importance of design image to the airport authority. Architect: Santiago Calatrava.



6.6 Architecture has an important role in creating a gateway to the sky. King Abdul Aziz Airport, Jeddah, Saudi Arabia. Architects: Murphy/Jahn.

Table 6.1 Examples of airport layout concepts (see Chapter 7 for layout configurations)

Airport	Concept	Architect
Dulles International Terminal, Washington, USA	Transporter concept with 2-storey terminal	Eero Saarinen
Dulles International Terminal (Phase 2), Washington, USA	Transporter concept converted to satellite pier with enlarged terminal	Skidmore, Owings and Merrill
Fargo Airport, North Dakota, USA	$1\frac{1}{2}$-storey linear terminal	Foss Associates with Thompson Consultants
Heathrow Airport, Terminal 5, London, UK	Multistorey terminal with detached satellite piers reached by underground rail	Richard Rogers Partnership
Kansai Airport, Japan	Terminal with long parallel finger pier	Renzo Piano Building Workshop
King Khaled International Airport, Riyadh, Saudi Arabia	Triangular compact module units joined by moving walkways	Hellmuth, Obata & Kassabaum
Nashville Metropolitan Airport, USA	Radiating pier finger with multistorey terminal	Gresham, Smith and Partners and Robert Lamb Hart with Thompson Consultants
O'Hare Airport, United Terminal, Chicago, USA	2-storey linear terminal with end satellites	Murphy/Jahn with A. Epstein and Sons
San Francisco International Airport, USA	Combined radiating pier/finger with satellites	Gensler & Associates
Southampton Airport, UK	Single-storey linear terminal without piers	Manser Associates
Stansted Airport, UK	2-storey terminal with detached satellite piers reached by light rail	Foster and Partners
Tehran Airport, Iran	Radiating pier/finger with multistorey terminal	Tippetts, Abett, McCarthy, Stratton
Los Angeles Airport, Tom Bradley International Terminal, USA	Square pier/finger with multistorey terminal	Pereira, Dworsky, Sinclair Williams with Thompson Consultants

The mission statement highlights the importance now attached to the environmental impact of airports. BAA, the Civil Aviation Authority in the UK and the Federal Aviation Administration in the USA all recognize that they have a role in reducing the damage to the environment caused by airport operations. Airports are integral parts of local communities, and those communities' concerns have been given fresh urgency. No airport can ignore the damage to local ecosystems or the visual and noise intrusion of their operations. BAA instils in its airport management the need to be environmentally responsible neighbours. The new awareness is expressed in the way in which airport buildings are designed to work more with nature (Terminal 5 at Heathrow is an example), the management of the wider landscape to promote ecodiversity, the development of environmentally related educational projects with local schools and colleges, and a scheme of funding noise insulation measures for houses near airports (7000 homes near Heathrow have been improved, at a cost to BAA of £10 million).[6]

Redressing the balance between passenger and airport needs

Airports are extraordinarily complex facilities – perhaps one of the most sophisticated and complicated forms of development engineered by man. However, passengers should not be exposed to the complexity: their experience of the airport should be one of simplicity and serenity. A well-designed airport is one where routes are clear and simple to use, where the images are uplifting, even romantic, and where the jaded

6.7 Positioning the escalators against the glazed façade helps uplift the spirits of tired passengers. Extension to Edinburgh Airport. Architects: Parr Partnership.

passenger ferried from building to plane and terminal to gate can find tranquillity and peace. Hence there are two parallel perceptions of the airport: the facilities manager wants a well-organized, finely tuned airport operation, while the typical traveller needs protection from the workings of the airport and requires instead quiet efficiency of passage. The dialectic between the two perceptions provides the basis for ordering typical airports into landside and airside facilities, into public and private routes, into openly accessible and security sterile areas, and into arrivals and departures flows. It is also the foundation for the split of passenger from baggage as near as possible to the terminal entrance, and for the undercroft of baggage and building services facilities found in most airports. It is the basis too for the use of different floor levels to accommodate cross-flows, and the logic of general retailing split from duty-free facilities.

Complexity at airports is resolved, identified and reconciled in plan and section. Airport managers and passengers need to be able to read and exploit the terminal in three dimensions: managers because of the demands made by airline companies, security staff, immigration controls and retailers; passengers because of their need to recognize the meaning and direction of places and routes within the labyrinth of a typical airport. Three-dimensional complexity is a feature of modern terminals: it derives from the scale of intermodal transport links provided today, from the extent of retailing at modern airports, and from security demands. Early terminals were relatively straightforward single- or double-level buildings, but today's airports (such as Kansai) are on four main levels, and future ones (such as Seoul International) will be on six or more levels.

If complexity is a necessary measure of size and the contemporary approach to the multifarious airport, the passenger needs some protection from its ramifications. But airports should not become dull, sanitized and neutral environments as a consequence (the problem perhaps with Stansted). The airport remains a building type with romantic overtones; its imagery requires an uplifting, technologically inspired architecture language. The crisp transparent spaces filled with sunlight and daring engineering of contemporary terminals (as at Stuttgart) allude to an airport atmosphere without subjecting passengers to the full functional paraphernalia of airport operations. The shielding of passengers from the complexity of the modern airport allows the drama and expressive possibilities of the major public terminal spaces to be exploited. The dialogue of the passenger with the concourses allows the airport architect to engage in the uplift of tired spirits, and to create legibility within intrinsically complicated and confusing buildings.

The airport designer has two distinct but parallel perceptions of quality to satisfy: the airport authority and the passenger. In the past, design manuals such as that issued by IATA emphasized functional solutions at the expense of aesthetic ones. Certainly, the modern airport needs to operate smoothly, be profitable and viable in the short and longer term. But from the passenger viewpoint, it needs to offer a great deal more. The current concern with large, theatrical interior airport spaces, with tree planting inside and outside terminals, with legibility and waymarking of routes, with natural light and ventilation, represents a shift in balance between airport and passenger priorities. Some more enlightened airport developers (such as BAA) began to put the physical and psychological needs of passengers to the fore in the early 1990s. Their example is becoming standard practice worldwide, with consequences for the whole approach to airport design. Though technical standards are still needed, they do not have the primacy of old. By putting the passenger needs alongside those of airport managers and airline companies, a new architectural culture has begun to emerge.

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4. The list is adapted from BAA, *Shaping up for the 21st Century*, BAA Annual Report 1995/96, London, p. 1.
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Procurement and management of terminals

CHAPTER 7

Design standards and briefing: the example of BAA

As a major provider of airport facilities in the UK, and the world's biggest airport operator, BAA has a key role to play in questions of design quality. Through its briefing instructions to architects, the method of procurement adopted, and the cost yardsticks applied, BAA has a central role in providing terminals that satisfy customer needs on the one hand, and raise architectural standards on the other. BAA spends about £500 million a year on construction services of one kind or another. This represents nearly 40 per cent of its annual turnover.[1] In order to keep costs down, and inspired by the Latham Report of 1994, *Constructing the Team*, the BAA has set a target of achieving a 30 per cent cost reduction per unit of construction over a three-year period.[2] Such a large reduction in unit costs, justified according to BAA Chief Executive Sir John Egan by world airport cost comparisons, is to allow BAA to compete effectively within the global economy.

How such a reduction is to be achieved is outlined in Table 7.1, but concern should perhaps be expressed over the effect of such extensive cost saving on design quality. Whereas the Latham Report promulgated a wider vision of greater teamwork, improved productivity and new working practices to reduce unnecessary litigation, all in order to achieve cost savings for the UK construction industry of 30 per cent over a 10-year period, BAA has more immediate plans. Pointers have been identified by BAA that allow the savings to be achieved more rapidly under six headings:

- Reduce changes to design.
- Optimize specifications.
- Improve design cost-effectiveness.
- Apportion risk efficiently.
- Improve productivity.
- Reduce waste.

With the development of Heathrow's Terminal 5 by the Richard Rogers Partnership on site, such changes in briefing and project management have implications for architectural quality and design freedom.

Table 7.1 BAA's six pointers towards achieving a 30% cost saving on construction projects.

Reduce changes	Improve customer/market research Brief effectively Use prototypes
Optimize specification standards	Match standards to needs Review code standards Review 'institutional specifications'
Improve design cost-effectiveness	Increase use of standard designs and components Use 3-D design technologies to automate design and create building prototypes Use IT/electronic data interchange to improve communications efficiency Involve suppliers early in design process Develop supply partnering arrangements
Apportion risk efficiently	Use single project insurance Use industry-wide standard warranties/guarantees/bonds Develop a more flexible lease structure
Improve productivity	Develop off-site/on-site logistics Design for construction Use more standard designs and components Develop project team workflow processes
Reduce waste	Use 3-D technologies to test designs for errors, fit etc. Use off-site manufacturing and assembly

Source: Jackie Whitelaw (ed.), *21st Century Airports*, supplement of *New Civil Engineer/New Builder*, May 1995, p. 24

Raymond Turner, BAA's Group Design Director (at the time of writing), has the task of coordinating design standards mainly through the issue of design guides and project briefing to consultant architects. His principal task is to ensure that new buildings fit the company's mission statement, with its emphasis upon customer satisfaction, cost competitiveness and quality of experience. BAA is anxious to standardize design solutions from concept design to detail. This is the main mechanism by which building costs can be controlled. It also

Table 7.2 Key elements of design management at BAA

Standardize 50% of components used in terminals
Use preselected contractors for a wide range of site and construction work
Adopt a culture of no design changes once the building is under construction
Adopt a common design management process, with BAA's project managers taking the lead
Build teams based upon the repeated use of a small number of designers, suppliers and constructors
Involve customers in design development at early stage
Develop 'framework agreements' with suppliers

Source: *Shaping Up for the 21st Century*, BAA Annual Report 1995/96, pp.15–66; and Jackie Whitelaw (ed.), *21st Century Airports*, supplement of *New Civil Engineer/New Builder*, May 1995, p. 20

means that replacement components can be readily obtained, and that one terminal design develops logically from the experience of another. It is partly the use of prototypes with limited developmental variations that led to the similarities between Foster's Stansted design and that by Rogers' office for Heathrow's Terminal 5.

The culture of standardization has led BAA to insist that 50 per cent of the parts of a new terminal are made up of standardized components, provided and installed by pre-selected contractors under 'framework agreements'.[3] Not all products reach BAA's new standards, and one role of appointed architects is to help develop components or designs that can then become part of the standard specification. As Turner notes, not all architects are happy with the imposition of such standardization, or with the primary role of BAA's own staff in selecting finishes and products such as carpets or seats for new terminals,[4] but the avoidance of unnecessary variation is seen as essential for cost and quality control. Framework agreements also allow suppliers to develop new products without undue risk, and to enter into competition on the basis of quality standards as well as of cost.

Table 7.3 BAA's construction process

Inception	→	Defining the business need
↓		
Feasibility	→	Project board
	→	Optimize business solution
↓		
Concept	→	Design team
	→	Optimum design solution
↓		
Co-ordinated design	→	Getting it to fit
↓		
Production information	→	Standard components
	→	Pre-planned construction
↓		
Construction	→	Build as planned
↓		
Operation and maintenance	→	Audit

Source: *Shaping Up for the 21st Century*, BAA Annual Report 1995/96, p. 15

Having tackled common specifications, BAA is also seeking to standardize design management processes just as the Latham Report proposed. BAA's briefing guide has two parts: a common procedure for design and briefing for BAA's own staff of project managers, and standard guidelines for the appointment and briefing of external consultants. Both depend upon a universal set of design deliverables (as the BAA puts it), which are needed by certain stages so that the design can be reviewed and evaluated by BAA and potential customers before decisions become too fixed. Turner admits that the process has shifted some of the design decision-making away from designers towards project managers and contractors, adding wryly that 'design is too important to be left to the designer'.[5] Just as BAA has sought to standardize the choice of materials and specification for new terminals, it has also used its powers as client to impose a common management ethos controlling the whole design and procurement process.

The brief for Southampton illustrates the relationship between quality, cost and design standards. BAA required its new terminal (designed by Manser Associates) to 'set new standards for regional airports, both in quality of service and in cost-effectiveness'.[6] The internal layout was to be 'simple and efficient' in order to achieve the 'maximum income from the available commercial space'.[7] Hence the architect had the task of achieving design excellence in an abstract sense, and of creating a building that achieved the highest possible level of secondary income generation. Added to this, the design had to give the best 'value for money' as measured against BAA's own procurement quality standards, while also being functionally efficient within a single shell.

At a detailed level, the terminal had to be cooled to not less than '3 °C below outside ambient temperature to obviate thermal shock to users'.[8] Because aircraft engine fumes can lead to internal air pollution, the brief also required that air-chilled water coolers be of PVC-coated aluminium fins or copper coil construction to avoid corrosion.[9] Architectural design has therefore to achieve both broad operational efficiencies and detailed standards of comfort or health. The various briefing constraints shape terminals far more than is generally realized. Only with effective and enlightened briefs can truly innovative airport architecture emerge. (See p. 233 for a description of Southampton Airport.)

Managing terminals

There clearly needs to be a correspondence between the design and management strategies of airport terminals. As management approaches change, there are inevitable effects upon the use and distribution of space within terminals. As has already been noted, one of the current new directions for terminals is in the retail, leisure and conference fields, and this trend is supported by the growing use of private sector airport management companies. There has appeared recently a willingness to split the ownership of airports from the management of key services. Although certain facilities, such as baggage handling and apron services, have traditionally been carried out by specialist companies, this approach has spread to the management of the terminal itself. Today, airport authorities have begun to realize that the successful exploitation of the huge passenger flows within terminals requires the assistance of private sector companies.

7.1 Following the UK's example, many American airports have begun to adopt the BAA model of diversifying income through retailing. This example is Skidmore Owings and Merrill's design of the arrivals terminal at John F. Kennedy Airport. Architects: Skidmore Owings and Merrill.

One airport operator that has begun to exploit the dialectic between ownership and management is BAA itself. Having led the retail and leisure industry expansion of UK airports in the 1980s, the company established BAA International in 1990 to take the approach and expertise further afield. By 1996 BAA International had secured contracts to manage two American airports (at Pittsburgh and Indianapolis), and had formed joint venture companies to exploit opportunities in the Asia Pacific region and in Australia. In each case, BAA working with local private sector and state partners was invited to form a joint venture to manage airports, or in the case of Melbourne, Brisbane, Adelaide and Perth airports to take over the ownership and management of the whole enterprise.

BAA's approach is to apply the lessons learnt principally at Gatwick and Heathrow to overseas airports. Working generally within 10–15 year management contracts, the company's priorities include the introduction of BAA's terminal management processes, the adoption of their Quality of Service Monitor, the implementation of a new retail strategy, and the development of property potential inside and outside the terminal.[10] As the company's culture is adopted, the airports it manages inevitably change, creating opportunities for architects and interior designers. For example, at Pittsburgh Airport, where terminal management was taken over by BAA International in 1992, 1500m^2 of additional concession space has been created, and the money spent per passenger

7.2 Retail sales help to justify refurbishment of older terminals. South Terminal, Gatwick Airport, UK. Architects: Chapman Taylor Partners.

passing through the terminal has risen from $2.30 to $6.68. Nearer to home BAA undertook a detailed assessment of Naples Airport, with a view to operating the airport when it transferred from state to private ownership in 1997.

Private management of airports, either in whole or in part, opens up airports to market forces. These in turn create change and opportunity for designers of various kinds (including shop and restaurant designers, graphics and furniture designers, and facilities managers). It has also resulted in the diversification of different management cultures at airports, leading in turn to different styles of organization and design within the terminal. As Asian airports, for example, are expanded, British, American and German management skills and designers are brought in. One challenge for companies such as BAA International is how to recognize and respond to the subtle cultural differences between nations, to ensure that a standardizing management approach does not stifle regional distinctiveness at airports.

Although the pattern varies from country to country, there is growing consistency in the way in which airport authorities own and manage terminals. The key trend already noted is the privatization of airports and the contracting out of important services, especially in the baggage handling, retail and leisure fields. Income for the airport operator at the terminal varies according to the type of service. For example, income from retailing (amounting to about 40 per cent of BAA's total profits at UK airports) is turnover related: that is, BAA takes a percentage of the retailer's sales. However, with car parking, advertising and duty-free shopping the airport operator is paid a fixed fee by the lessee irrespective of the level of sales.[11] Such contracts between the airport authority and private companies are normally on a three- to five-year timescale, and this in turn generates the timescale for the internal adaptation of terminal space.

High levels of retail and ancillary sales mean that airports are relatively cheap for airline companies. Airport and traffic charges for airline companies account for only 35 per cent of BAA's income, the low rates being possible because of the high levels generated by retail sales in the terminals themselves. As a result, Heathrow and Gatwick are amongst the cheapest major airports for airline companies in the world.

Keeping abreast of expanded passenger facilities requires high levels of expenditure by the airport operator. Using BAA again as an example, the company in 1996 spent over £1 million a day on improving the quality of facilities for its passengers (over 60 per cent of total retail earnings for the year). Quality enhancement involving physical upgrading of terminals is essential if passenger standards and revenue targets are to be met.

BAA's management strategy for terminals has the following elements:

- using market research to establish customer needs
- increased competition in products and services
- a commitment to providing high levels of customer service
- offering value for money
- introducing international brand names to the airports
- providing a wide range of high-quality products
- creating quality retail environments
- working in partnership with retailers to meet customer needs profitably.

The management strategy, with its emphasis on retail expansion, has implications for the design and upgrading of terminals. The culture of regular market research carries the corollary that terminals will be frequently refurbished to meet the changing needs and taste of passengers. As witnessed in the upgrading of Gatwick's South Terminal to form 'The Village', and at Heathrow's Terminal 2, this entails the introduction of daylight into existing retail malls or the exploitation of new views over runways to provide tired passengers with interesting panoramas. The quality of the retail environment is an important factor in retail sales; in fact some international retailers (such as The Disney Store) require a certain standard before they will consider locating at a particular venue. Hence BAA's ambition for greater retailer growth requires investment in the physical environment of terminals to allow this to materialize.

The role of the Quality of Service Monitor (QSM)

To ensure the smooth operation of airports, BAA adopts a standard method of monitoring the performance of its terminals. Using seven main headings (cleanliness, mechanical assistance including such things as trolleys, procedures, comfort, congestion, staff helpfulness and value for money), each airport is subjected to QSM. The assessment focuses upon passenger experience but includes the monitoring of the views of other stakeholders, such as airline companies and retailers.

7.3 Terminals represent national values. Here at Schipol Airport there is an air of measured civic provision, not the bustle of a retail mall. Schipol Airport, the Netherlands. Architects: Bentham Crouwel.

The surveys are undertaken without prior notice. Airport managers are encouraged to maintain vigilance and to regularly raise standards by the presence of QSM. The areas where surveying tends to concentrate are at check-in, security, baggage reclaim, immigration and departure lounges. Where low scores are achieved (the rating is 1 to 5, where 5 is

Table 7.4 Revenue by function earned by BAA at UK airports in 2003

Type	£m
Retail	763
Airport/aircraft traffic charges	665
Property	266
Car parking	140
Other (cargo subsidiaries, etc)	43
Total	1937

BAA Annual Report for 2003

excellent), this may be because of ineffective management or lack of investment in physical improvements. Regular low scores recorded at Heathrow's Terminal 1 (which handles 22 million passengers a year) led to a number of new facilities being constructed in 1995–96, such as the Flight Connections Centre, a dedicated international departures lounge, and Europier for direct flight boarding. So, while QSM is a management tool, its use helps to identify shortcomings, which leads to new physical investment in airports.[12]

Manipulation of space and time in the terminal

The management and, as a consequence, the design of terminals increasingly exploit space and time to increase revenue sales. They exploit space in the sense that passenger flows are interrupted by periodic banks of shops, bars, cafes, flower stalls, currency dealerships and car rental points – not just in the departure lounge but in the arrivals lounge as well. Every stage in the journey through the terminal is manipulated by commerce in one form or another. Even before reaching the check-in desks, passengers are being persuaded to part with their money, or are being exposed to sales advertising. They exploit time in the sense that airlines set extensive check-in times (up to two hours) to ensure that passengers are exposed to as much commercial distraction as possible. Boredom drives frustrated airline passengers into the shops and bars that predate upon their movements. Modern airports, especially in the UK and the USA, exploit time and space to extract maximum commercial advantage from the traveller. In other countries such as France and Japan, and often in the

7.4 The new airport at Shenzhen provides ample space for passengers. Architect: Llewelyn Davies.

developing world, the airport terminal is seen as part of the national infrastructure – like roads and hospitals – rather than merely as a means of making money. Here commercial exploitation of the traveller, who may be isolated in the airport for long periods, is less obvious. In place of burger bars and amusement arcades one finds spacious, well-planted lounges and wide, uncluttered corridors. Although national television may be playing in the background (as in many African airports), there is little commercial manipulation.

Terminals in the developing world

Airports are expensive undertakings – amongst the most expensive infrastructure projects for governments. Inevitably, state investment seeks to provide a service and, eventually, a profit. Normally, governments plan to earn an income from airports in 8–10 years, but with low levels of usage (as is the case in most developing countries), the state is unlikely to see a return for a much longer period, if at all. Unprofitable airports are viewed by governments in the developing world (especially Africa) as an essential public service, and also to some extent as a symbol of national prestige. Profit is not normally the prime objective; it is merely sufficient that the country has an airport able to bring in businessmen, conference delegates, international tourists and, as a last resort, to receive food aid in times of crisis.

There is a wide discrepancy between the perception of airports in the West and in emerging countries. New economic areas (such as Africa, South America and parts of Asia) see the airport as a loss-leader in purely economic terms. Hence governments are willing to subsidize airports from the national treasury, and to pay for relatively lavish terminals as a symbol of state prestige. While European and North American airports normally operate at a profit (or at least balance national subsidy with commercial earnings), in the developing world aid agencies play an increasingly big role in the provision and subsidizing of airport operations, especially in regional rather than national airports.

As a rule of thumb, airports that handle under 1 million passengers a year are unlikely to be profitable. Over 1 million passengers, the profit and loss account is likely to be neutral, but under 1 million, large losses can be expected. Most regional airports operate at a loss in the developing world, not just because of operating costs but because there is insufficient traffic to exploit commercial revenues. In regional airports in the Third World, it is rare that 'named' food outlets are present, or that extensive duty-free shops exist. Such airports are mainly public and social facilities, there to serve a dispersed rural population in the fashion of a regional hospital or college. It is not only scale that undermines the profitability of regional airports but the nature of the traffic. With few international flights, there are not the wealthy international passengers available in numbers sufficient to generate non-aeronautical revenue. As noted earlier, airports are rarely profitable on airside operations alone; concessions, leasehold agreements, rents and parking charges are the mainstay of airport income.

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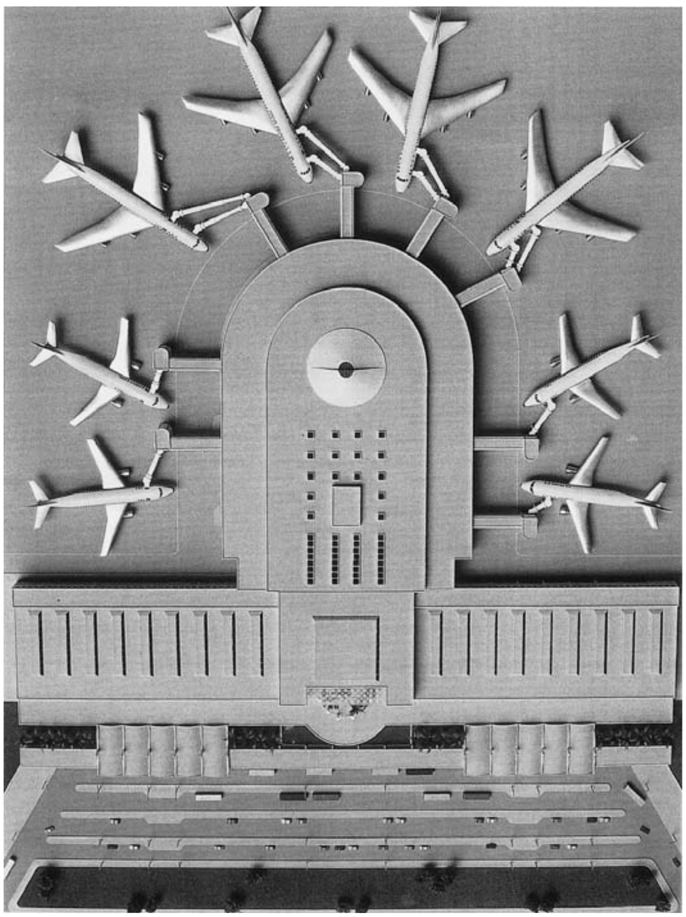
Flexibility and permanence in airport design

CHAPTER 8

Within the functional pattern of an airport, the only basic and relatively stable element is the runways. Every other part is subject to change: the aircraft themselves, the apron areas, the piers and jetties, and not least the terminals. Hence when a new terminal is proposed (as at Heathrow with Terminal 5), every part of the airport has to adapt except the runways. Although runways may be lengthened, widened or strengthened, their basic alignment and presence do not alter. Terminals, in contrast, have to be capable of extension in all directions and their relationship to the aircraft stands has to be altered as new generations of aircraft are introduced.

The motor for change tends to be the design of aircraft. As new types, sizes and patterns of aircraft are introduced, it is the terminal that has to adapt, not the runway. New, larger aircraft impose changes on the capacity of departure lounges, airside corridors, telescopic piers and access jetties. Terminals are as a consequence designed to be as flexible in operation as possible, with internal changes as frequent as at 18-month intervals. According to Graham Jordan, BAA's head of airport planning, the speed of change at terminals will quadruple into the next century.[1] A culture of change means that airport terminals have to accommodate 'infinite flexibility', and will be designed increasingly as aggregations of modular units, whose arrangement is determined by 'long-life facility management systems'. The elements of permanence in the terminal will be the primary order of main structure and circulation routes. Even views, such as to the aircraft, and daylight may be sacrificed in the pursuit of flexibility.

The pace of change has posed a dilemma for architects. First-generation terminals were an architectural experience of some magnitude: in fact some of the world's most important twentieth-century landmarks are early airports (for example, Washington Dulles Airport of 1962, with its sweeping roofed terminal and sculpted control tower). However, managing the accelerating pace of change and expressing it in second-generation terminals has tended to erode the architectural quality of the building type. Airport terminals have become either bland but flexible Cartesian containers designed for growth, or somewhat mannered landmarks in the tradition of earlier buildings. The former



8.1 The design of Antalya Airport, Turkey, is based on repeating six times a standard terminal module (see top of Fig 5.1) Architect: Dogan Tekeli-Sami Sisa.

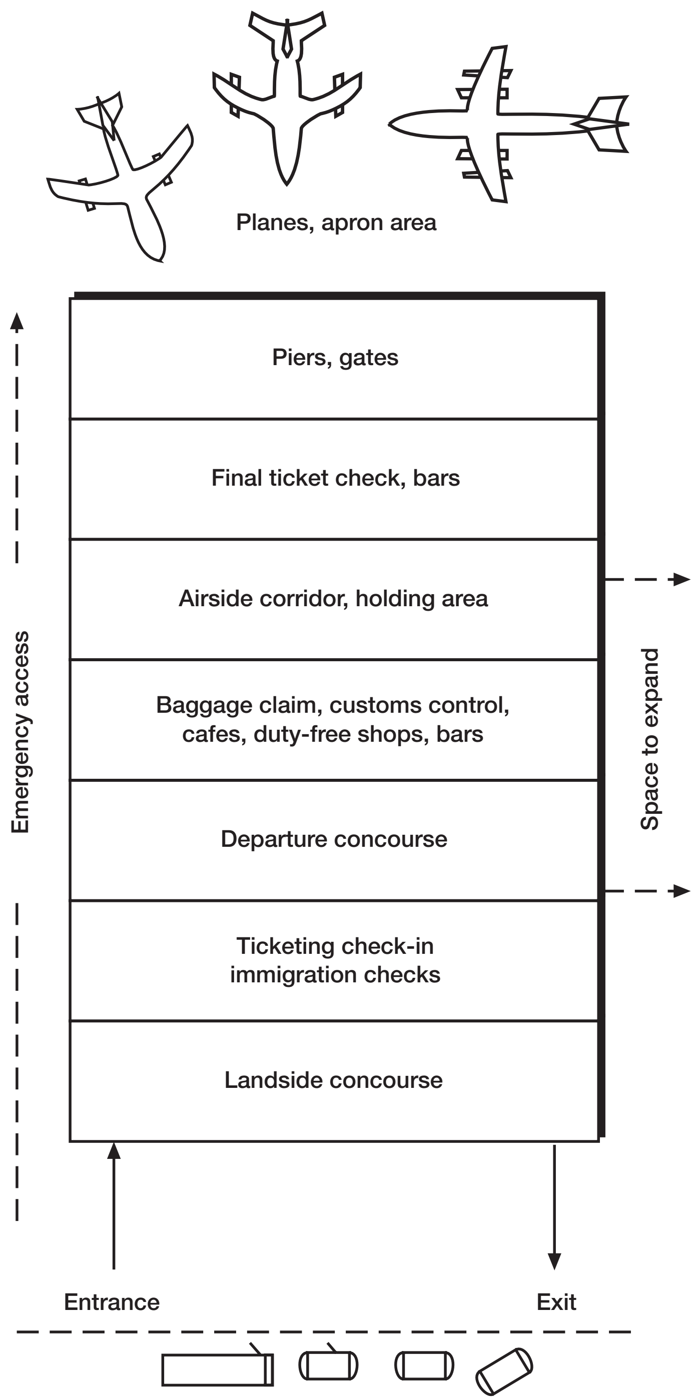
– represented by Manchester's Terminal 2, the redeveloped Heathrow Terminal 3 or the United Airlines Terminal at Chicago O'Hare – are worthy and at times elegant buildings, which perform effectively in all conditions. The latter – represented by Kansai Airport, Sondica Airport and Terminal 2 at Paris Charles de Gaulle – continue a heroic, if operationally more inflexible, tradition. In some recent designs – such as Heathrow Terminal 5 – which balance between the two positions, their architects have endeavoured to give the passenger a memorable experience while meeting the growing demand from airport clients for great flexibility.

Airport authorities cannot influence aircraft design. Innovation in aircraft design is driven by the big plane manufacturers, such as Boeing, European Airbus, McDonnell Douglas and SAAB. Though airports represent a bigger investment in infrastructure than the cost of the aircraft that serve them, airport owners and airline companies are forced to modify their operations when a new generation of aircraft is introduced. Change is inevitable at terminals as long as aircraft manufacturers carry on innovating. Bigger aircraft with higher passenger capacities tend to have larger turning circles (which alter the jetty-to-apron relationships), and more demanding servicing requirements; they impose extra strain on departure lounge space, and stretch baggage-handling systems. Terminals have to be capable of accommodating these changes perhaps as often as every five years while still remaining in operation. The scale and pace of change at airports are fundamentally different from those of railway stations. New stations are designed within standard track gauge and platform dimensions determined by trains whose measurements and capacity vary little over long time periods. Airports, in contrast, are subject to the unpredictable innovations of aircraft designers and their manufacturers.

Flexibility and terminal design

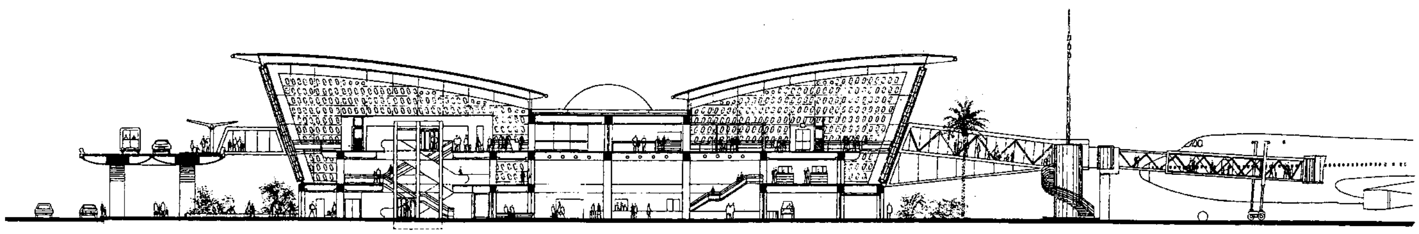
The terminal today is a far different building from those of a decade or two ago. Airline deregulation, the ever-present threat of international terrorism, and the need to exploit revenue from non-airline activities at airports, have jointly altered the assumptions upon which terminals are designed. Deregulation (introduced in the USA by the Airline Deregulation Act 1978, and in the UK by the Airports Act 1986) has had a profound impact. It has reduced the price of airline tickets, thereby spurring a growth in demand. The spirit of deregulation has encouraged airport authorities to expand income at the terminal from concessionaires and franchisees, and has reduced the scope of government controls, which were once written into design briefs. Today's airport is a loosely regulated parcel of infrastructure aimed at making the maximum amount of money for its private owner.

8.2 Schematic plan of terminal building.



Because the airline industry is undergoing rapid management and technological change, there are few formulas for architects to use. The old assumptions upon which the design of terminals was based have been largely swept aside by industry deregulation or by advances in aircraft design. Airport terminals need to be flexible, yet capable of being worthy national landmarks in their own right. Although space standards exist (see Chapter 13), the use and distribution of space inside terminals remain static for only relatively short periods (say 10–15 years), though the structure and external enclosure may survive for 50 years. In the fluid culture of airports, architects need to be able to offer aesthetic quality and operational flexibility. Even within the terminal concept adopted (see Chapter 11), much alteration in internal layout and probably also building footprint will occur. The terminal may need to adapt to the demands of a new airline company operating out of the building, the dictates of a fresh generation of planes (which will have altered the airside relationship between terminal, apron areas and taxiway), changes in security, ticketing or baggage-handling policy, and new ideas about corporate or brand identity. Deregulation has removed boundaries and opened airports up to ideas whose origins are to be found in retail parks or the leisure industry. The architect has, on the one hand, to provide buildings of high quality to satisfy growing customer expectations and, on the other, to accommodate changes that can rarely be anticipated. Because airport buildings are subject to some abuse by the tenants who occupy the space on relatively short timescales, it is obviously important to raise the design standards as high as possible at the outset. The design of the terminal needs to be able to meet the demands of tenants (such as airlines and franchisees), but not by compromising the key architectural elements of space, structure, procession and light. At Stansted Airport, Sir Norman Foster's elegant design has been successively undermined by management policies apparently indifferent to the original aesthetic values.[2]

Under such pressure the architectural design of terminals is tending to distinguish between long-term elements (building structure, daylight, processional routes) and short-term alterations (such as repositioning of walls, and changes to ticket counters, shops, bars and signs). This policy allows the



8.3 Aircraft determine the layout decisions at airside just as passengers do at landside. The terminal is where the two systems interface.

8.4 Changes in aircraft design trigger alterations to gate design. Munich Airport, Germany. Architects: Prof. von Busse, Blees, Kampmann & Buch.

8.5 Architectural quality at airports helps to establish national standards of design. Athens Airport. Architect: Paul Andreu.

airport to survive as a recognizable entity yet still adapt to management changes. Making a clearer distinction between primary factors of design and secondary ones allows the terminal to meet the future without compromising the essential permanent character of the building. If this character is not present at the outset then the terminal will be less able to provide the organizational clarity and ease of orientation that passengers expect.

The facilities that tend to be altered at fairly regular intervals are:

changes every 3–5 years:

- ticket counters at gate lounges
- check-in desks
- security systems
- signs and advertising
- shops, bars and restaurants;

changes every 10–15 years:

- baggage-handling systems
- building services (heating, ventilation and lighting)
- toilets and kitchens;

changes every 30–50 years:

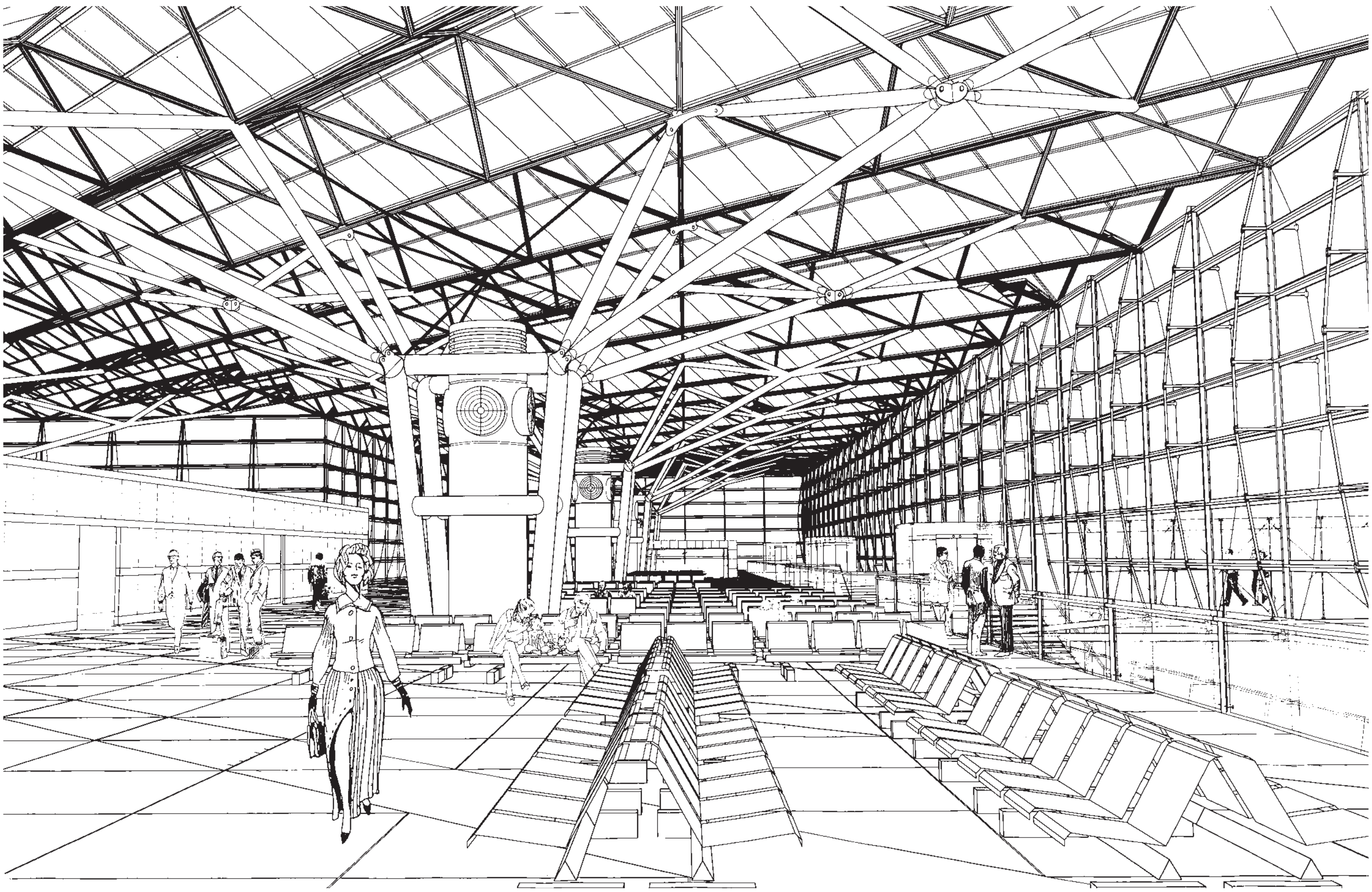
- building structure
- building envelope
- stairs, lifts, travellators and escalators.

Hence there are three lifespans (and even more with finishes) for every external renewal. However, even where the structural and perimeter frame remains static, many airports accommodate change by outward expansion (for example, Marseille by Richard Rogers Partnership). Airport terminals grow by extending lengthways, by adding additional floors, or by constructing new finger or satellite piers. Expandability, linked to internal flexibility, is the policy normally adopted. Of course, once the terminal is saturated, there is little option other than to build a new terminal, which too will mature in the same fashion.

Interactions between plane, passenger and terminal

The need for flexibility at airports is the result of the complex interaction between airline companies, aircraft design and airport authorities. This triangular 'tug of war' (Figure 8.7) explains the ever-changing parameters in which designers operate. The terminal is subject to pulls from all directions: airport authorities who want to maximize profits; airline companies that want to assert their presence or change passenger-processing arrangements; aircraft designers whose innovations make airside arrangements obsolete. The designer of the terminal has to meet all their needs, both present and anticipated.

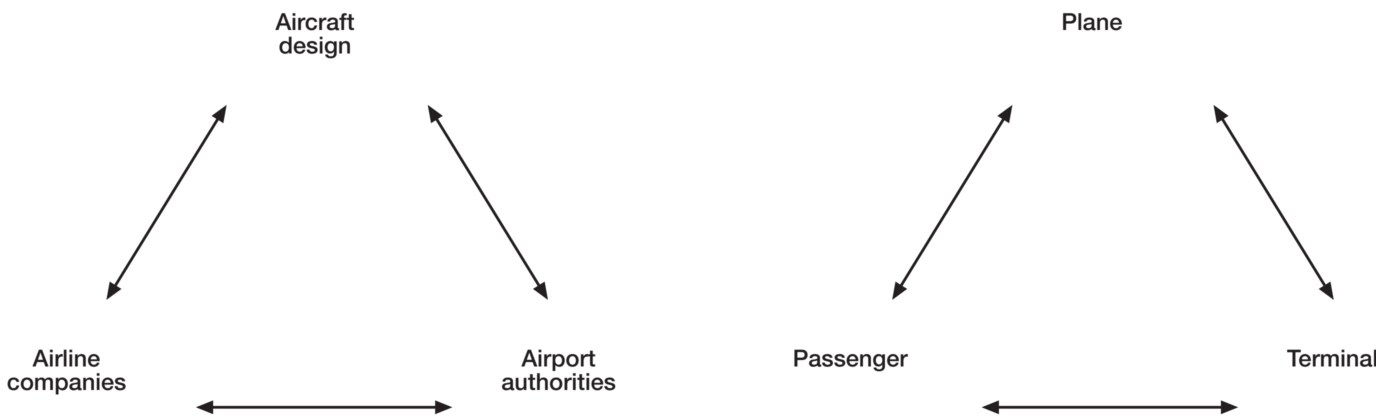
The practice of developing hub airports and independent satellite piers allows airlines to assert their identity and control, at the expense of airport authorities. Certain plan configurations are inherently more flexible than others, but as a general rule flexibility is at the expense of architectural quality. Satellite piers and unit terminals allow a direct relationship in imagery and quality control between building fabric and airline company (hence their popularity with airlines). The arrangement leads to airports that lack a strong central design identity, because the different terminals are designed by different architects working for different clients (Chicago O'Hare is a good example). Airline



8.6 Space, light and structure are the enduring elements in terminal design. Cologne/Bonn Airport extension, Germany. Architects: Murphy/Jahn.

companies that are successful enjoy the luxury of being able to shape the design language of their part of the airport while also taking advantage of central facilities. As the airline company prospers, it can upgrade its satellite or unit terminal, thereby attracting more passengers away from other terminals or even airports in the region. In this sense, architecture directly serves airline company ambitions, because the satellite takes on the characteristics of an independent terminal, with its own ticketing, retail and concessionary arrangements. It also makes evident to the passenger the relationship in quality of service between the terminal experience and that in the air.

The major problem of satellite and unit terminals is the lack of facilities for transfer passengers. As the terminals become more popular they end up attracting increasing numbers of transit travellers, who – instead of ending their journeys – are merely changing planes. In the USA as many as half the passengers at unit or hub airports are transfer passengers. Whereas the central terminal may have enough space and



8.7 The triangular tug of war between different interests.

baggage handling for both destination and transfer needs, this may not be the case with unit and satellite terminals. Overcrowded space, congested escalators and baggage reclaim may end up reflecting poorly upon the airline company that operates out of the terminal.

In the past decade, terminal buildings have been constructed to accommodate a collection of shops, bars and duty-free outlets, but today there are new pressures. The modern airport has become a business destination in its own right, providing conference, computing, fax and telecommunications facilities. While the 1990s saw the terminal building become a kind of shopping mall from which you could catch a plane, the year 2000 saw the emergence of the terminal as a conference venue. Today you can attend a business meeting or hold a conference at the airport, send a message on the Internet, catch up with email messages, and catch a plane home or to your next destination. As with retail changes, the terminal has had to adapt to wider changes in society.

How terminals expand

The history of the airport terminal is one of growing expansion, functional change, and increasing complexity. Terminals rarely remain static for long; the need to respond to fresh management ideas and new sources of income generation leads inevitably to internal changes, expansion at the edges and eventual rebuilding. How terminals respond to increases in passenger numbers and commercial pressure is well known. More and more floor space is given over to retail use; lofty internal volumes are sacrificed (as at Glasgow Airport) to build new floors; perimeter walls are taken down and extra bays constructed. Within time (perhaps as little as 20 years) the strain of these trends cannot be resisted without a new terminal building being constructed. At Frankfurt Airport the old terminal was taken down in 1990 and the present one designed by Helmut Jahn built, but more commonly the earlier terminal buildings are kept and a succession of new ones built. At Heathrow construction is under way to build Terminal 5 (to designs by the Richard Rogers Partnership) but Terminals 1–4 remain as a testament to changing technological and commercial dictates. The same pattern of a necklace of terminals within a collection of runways is found at Chicago O'Hare and JFK, New York (Fig. 1.24). The older the airport, the more passenger terminals normally exist. Space (and noise) is, however, a constraint on perpetual expansion, and in the 1990s plans were afoot to relocate some of the world's biggest airports onto greenfield sites. Again, Chicago and Denver (both among the world's busiest airports) are developing plans for new airports to take the strain off existing facilities.

Airports behave like the cities they serve. They expand gradually and systematically, but are finally constrained by space and environmental factors. They then cease to grow, and expansion is met by a new airport, which (like a satellite new town) expands to its environmental limits. In its turn its expansion is limited, and again a new airport on another site is constructed. Taken together, these airports (and London is a good example) are like new cities growing, maturing and then stabilizing. They begin life as a means of facilitating movement and end up as self-contained centres of economic and social activity.

How terminals adapt

Terminals, like most buildings, adapt and renew themselves in specific ways. The inexorable and accelerating march of technology expresses itself in pressure to replace obsolete windows, doors, building plant and whole structural systems. Changing management ideals create an equal momentum for internal space modification. To serve its purpose the terminal has to learn fast and adapt.

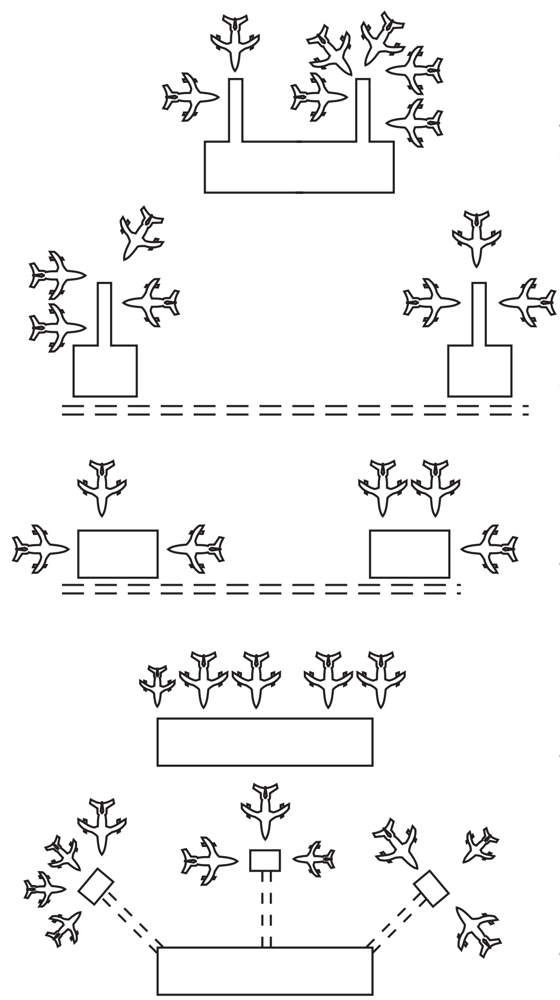
The modern terminal represents the contemporary condition whereby the functional life of a building is on a different timescale from the structural life. Though certain recent terminals (Stansted, for instance) have sought to ensure some sort of fit between the two by adroit design, most accept that the interior design of terminals is a world quite divorced from the architecture of their exteriors. Frequent interior revision reflects the commercial pressure that terminals are under, but the changes made on the inside mirror less visible and slower changes made to the building skin, structure and services. In fact, different parts of terminals change at different rates, and to understand the process one needs to see the building as a series of layers. The principal layers in a conceptual sense are:

technological change

- infrastructure
- building structure
- skin
- services

management change

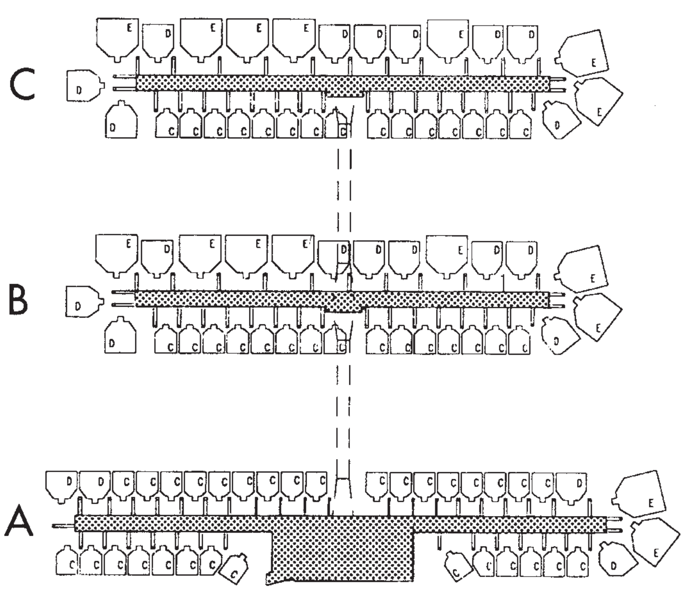
- retail areas
- interior space
- finishes
- furniture.



8.8 Typical terminal types.

Evidently, each layer is on a distinctive timescale, and their condition reflects both the initial capital investment and that spent on maintenance. However, one feature of terminals (as for many modern building types) is that as each layer is renewed it tends to disrupt the whole. These 'shearing layers

8.9 Conference facilities adjacent to terminals allow the airport to serve business needs. Munich Airport Centre, Germany. Architects: Murphy/Jahn.

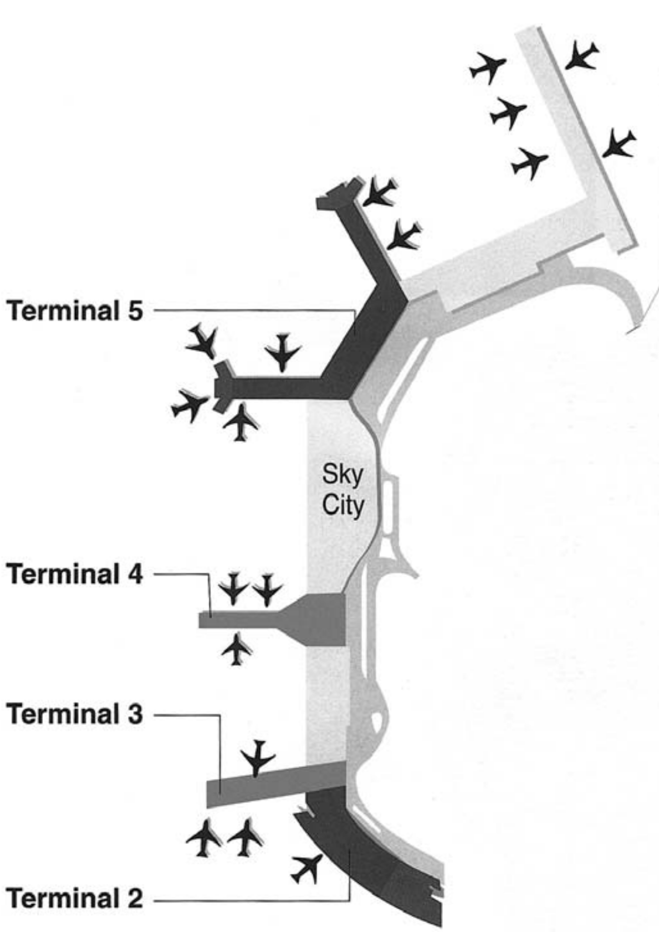


8.10 Phased growth of satellite piers B and C at Oslo Airport Terminal (A), Norway. Architects: Aviaplan AS.

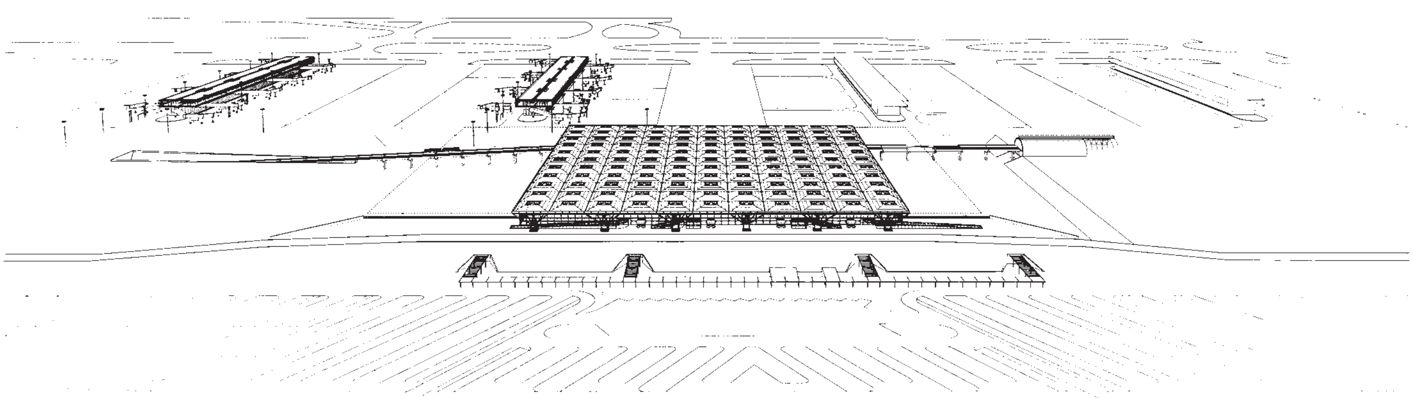
of change'[3] have to be managed and anticipated by good design.

So, while the initial architecture of terminals matters, a key element in their continuing to look good is the management of the time equation. The use of terminals over time is not just a question of facilities planning but of designing terminals so that the separate layers can be renewed with-out undue disruption. Changes in building technology (use of energy, new materials etc.) tend to dictate alteration to the outer layers, management policy changes to the inner layers. Design therefore needs to address both the technology of terminals and airport management, especially the way in which space planning alters over time.

Terminals are functionally turbulent places: the pace of change is greater than in almost every other type of building. Architects have a responsibility to manage change by designing buildings that accommodate it from the outset. Recognizing the separate layers that make up a typical terminal allows some disconnection to be made between the parts. By keeping 'structure' free from 'skin', and 'interior space' separate from 'services', the necessary elbow-room is formed



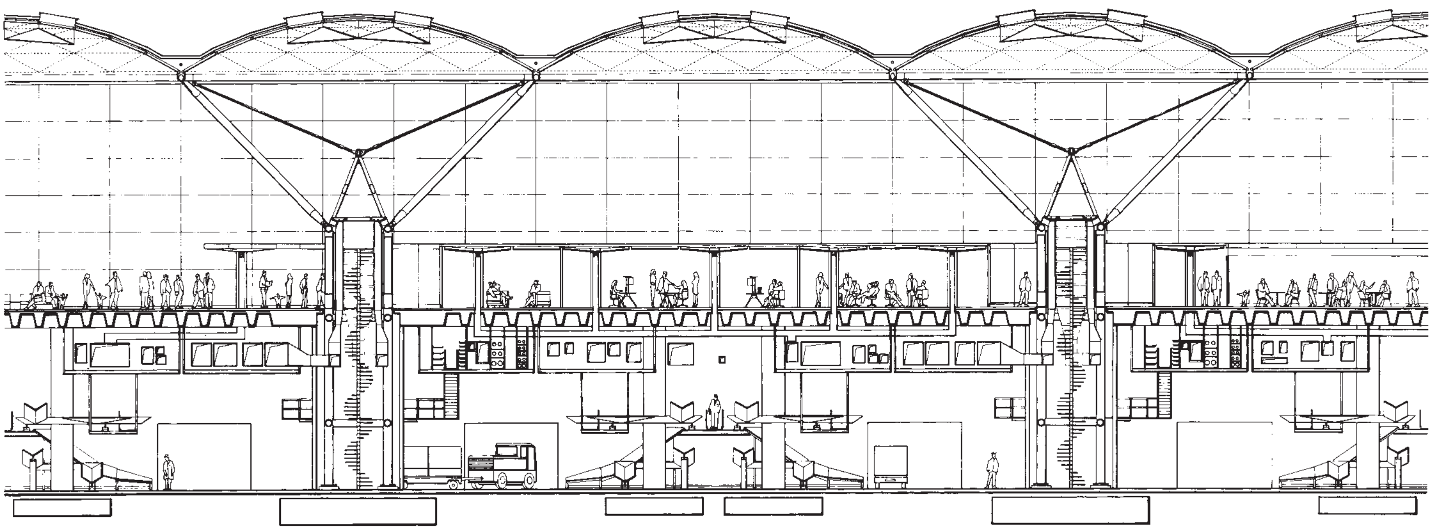
8.11 Growth of Stockholm-Arlanda Airport from 1950–2000 showing the expansion from a single terminal to a network of linked terminals.



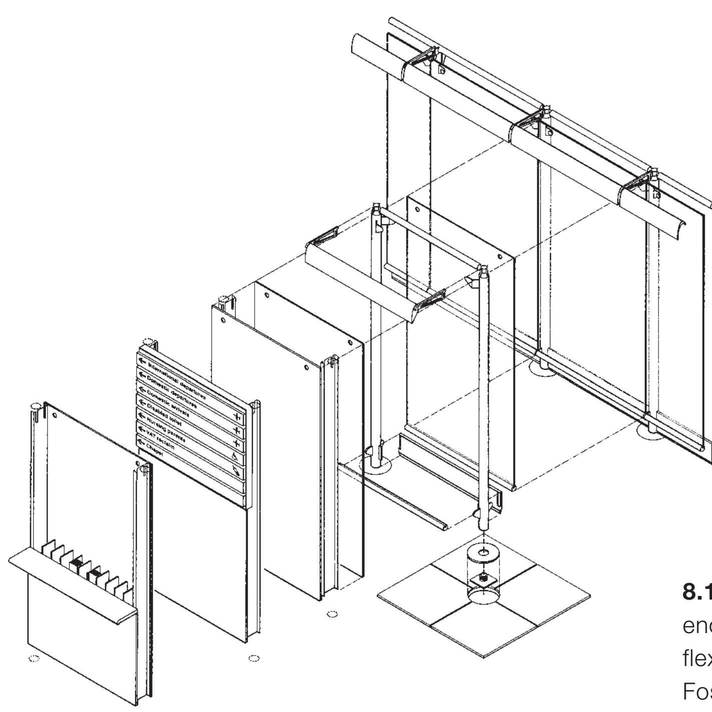
8.12 Stansted Airport, UK, with original position of satellite piers with two more planned. Architects: Foster and Partners.

to allow the building to renew itself. The thin slice of space between structure (which has a life of 50 or 60 years) and skin (with a life of 20 years) is not just important as part of architectural expression; it facilitates change. The deliberate disjunction of the key layers allows accommodation of the inevitable changes over time. In this sense, space and time are related in the maturing of the terminal as a dynamic, interactive learning building.

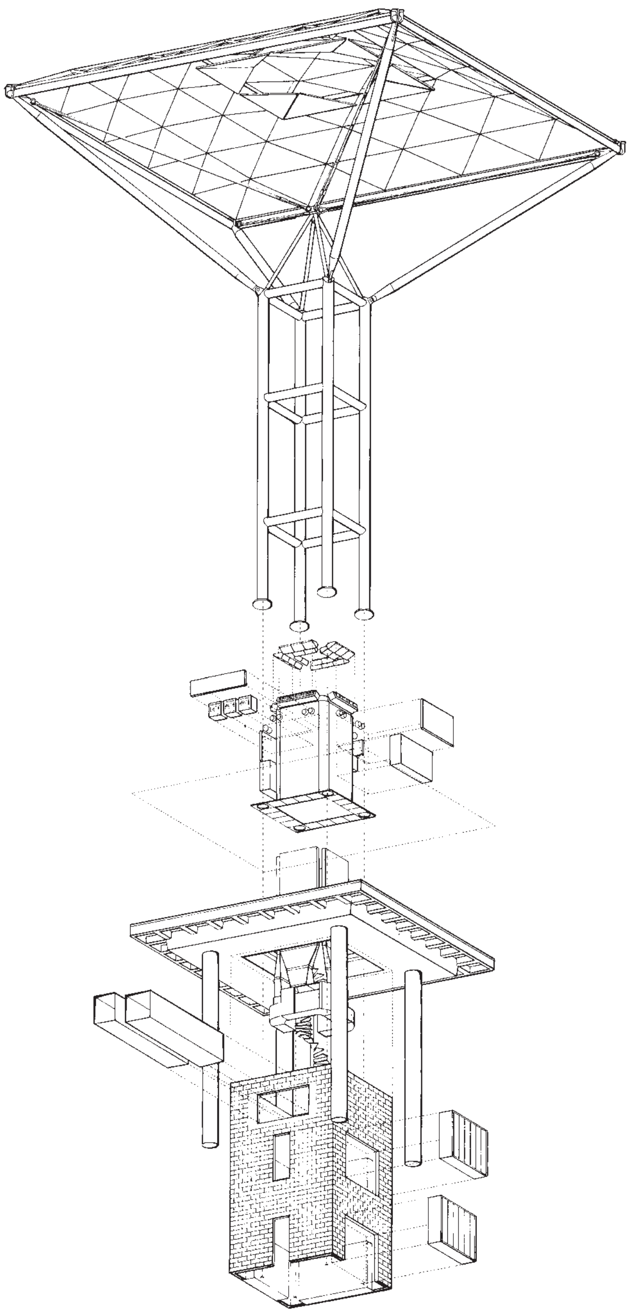
But it is evident also that the terminal has a hierarchy of change, with – generally speaking – the slow parts (site or structure) dominating those, such as finishes, that are renewed more frequently. For example, to change the layout of a



8.13 Airport terminals that distinguish between primary and secondary functions accommodate large-scale change without undue disruption. Section through terminal, Stansted Airport, UK. Architects: Foster and Partners.



8.14 The 'kit of parts' approach encourages replaceability and small-scale flexibility. Stansted Airport, UK. Architects: Foster and Partners.

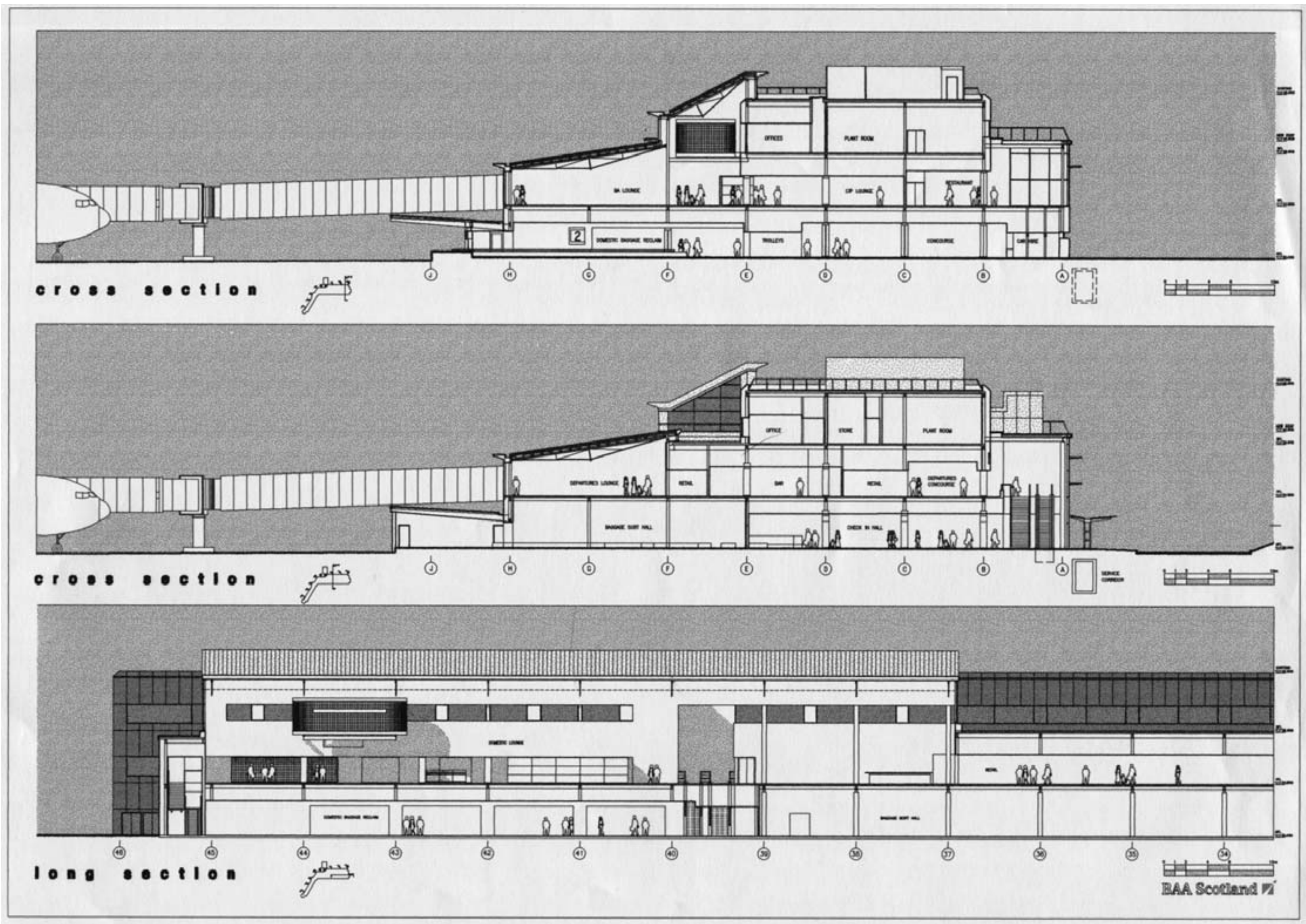


8.15 Separation of structure and building services within an integrated system. Stansted Airport, UK. Architects: Foster and Partners.

8.16 Structural separation used to define functional zones at Schipol Airport, Amsterdam, the Netherlands. Architects: Bentham Crouwel.

departure lounge means accepting the placement of columns and the position of the terminal skin. These more senior parts of the system of layers tend to be in charge, since they are not changing as fast as the more visible junior elements.[4] There does, however, come a point when so many rapid changes are called for that the airport authority decides that a new terminal is needed, or an existing one has to be extended.

Viewing the terminal as a series of layers, and the activities within it as a system, allows the designer to anticipate change even when its exact shape is not known. Terminals need to be robust in character yet resilient enough to flex with internal change. They are like arms with muscle, bone, veins and skin – each performing a distinctive function within a flexible interactive system. The immutability of some parts and the expendability of others is the basis for some recent terminal designs such as Kansai. Here, the architect Renzo Piano sought inspiration from ecosystems, with their different rates of change within balanced communities.



8.17 Growth of main terminal at Edinburgh Airport. The original building from 1972 has been extended to the left (pitched roofs) and to the right (stair). Architects: Parr Partnership.

References

1. Personal communication with the author, 24 July 1996.
2. Kenneth Powell, 'Stansted revisited', *The Architects' Journal*, 29 August 1996, p. 26.
3. Stewart Brand, *How Buildings Learn*, Viking, New York, 1994, p. 13. Brand acknowledges Francis Duffy as the sources of his ideas on 'layers' and the variable pace of change.
4. *Ibid*., p.17.

CHAPTER 9

The terminal as a movement system

Passenger movement

Airline terminals are essentially movement systems. Two main flows occur – passengers and baggage – and both move in two opposing currents: outwards and inwards. It is important that architects recognize the imperative of movement in the allocation of space, the ordering system of structure, and the handling of light. There is increasing pressure to obstruct, deflect or slow the pace of movement in order to exploit services of one kind or another. Revenue earned from concessions and other facilities provided in the terminal should not be allowed to undermine the clear ordering of passenger concourses and other key routes. Balancing the demands of architecture and commerce requires a sharing of values between designers and airport managers. Bottlenecks in flows inevitably occur at peak times, but it is better if these are the result of security checks or immigration control rather than obstruction caused by poor design. On the journey through the terminal the passenger is more likely to accept interruptions that stem from public interest concerns than those that are caused by predatory retailers.

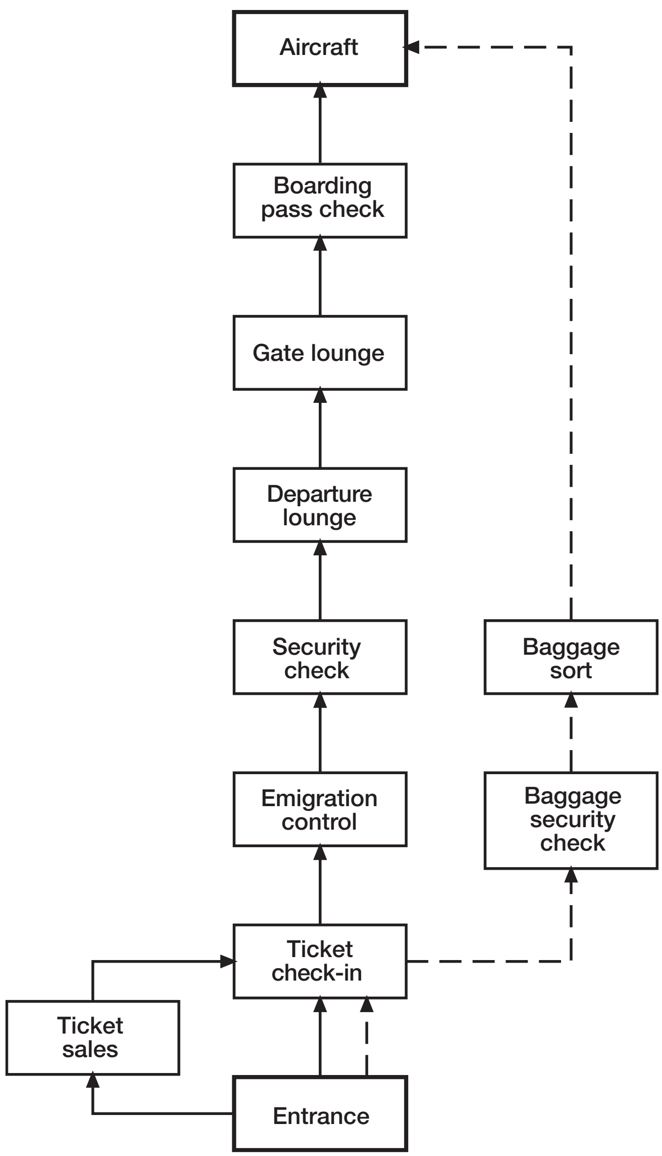
Movement through the terminal needs to be landmarked. There are four principal ways to achieve this: by space, by structure, by light, and by object.

Space

The definition of routes using different sizes or volumes of internal space helps the traveller to know whether a particular corridor or concourse is a major or a minor one. The hierarchy of routes through the terminal and the size of spaces need to correspond. Hence spacious internal volumes such as the landside concourse gesture towards major gathering-spaces used by all passengers passing through the terminal, while narrow corridors of single height clearly mean emergency routes or access to toilets. The orchestration of space into several recognizable hierarchies allows passengers to find their way around with the minimum of fuss.

The size and position of staircases and escalators should follow the same rules. Major routes will ideally be marked

9.1 Departures flow diagram.



by wide gracious staircases, with escalators facing the direction of flow. The angle of flights, going and width of stairs and escalators should indicate the degree of publicness or privateness of that particular route. Stairs with sharp doglegs, that are poorly lit and meanly proportioned imply minor not major airport routes.

Internal space and the positioning of stairs and escalators are related factors. The correspondence between them should both direct travellers along the principal routes of a terminal and take them from one concourse level to another without confusion.

Structure

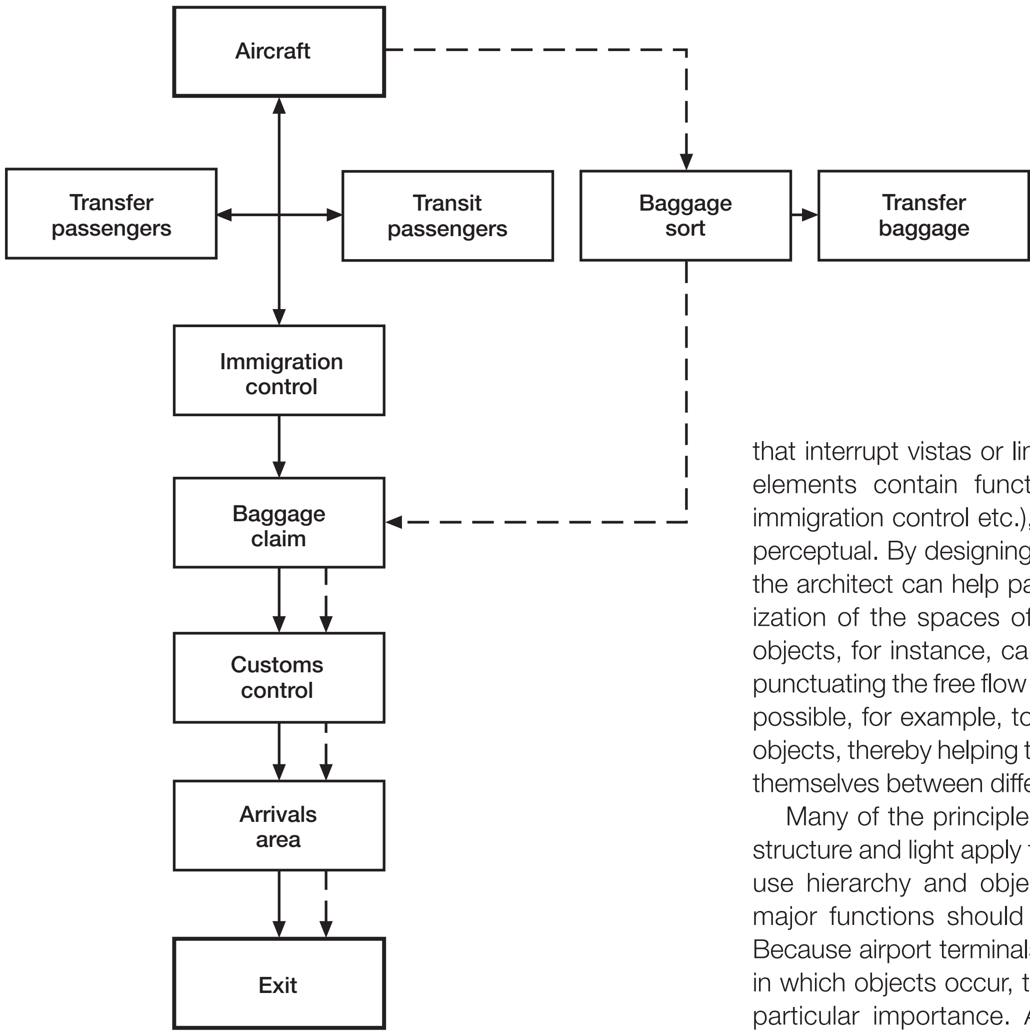
The role of the primary elements of structure – columns, walls and beams – is both to support the terminal physically and to support the perception of major routes psychologically. A row of columns in a concourse is doing more than merely holding up the roof: they are guiding passengers through a complex space. Beams too can be used to indicate a direction of flow or to provide scale in a large public area. Architectural structure is a means by which direction can be indicated and the rhythms of movement can be articulated.

The relative scale of structural elements should, like the management of interior space, reflect directly the movement or use hierarchy of that part of the terminal. Large columns obviously indicate large public spaces, small columns smaller ones. The principal route through a terminal from landside to airside should be accompanied by structural elements that, as at Kansai Airport, hint at the progression from ground to air. To exploit the aesthetic as well as structural possibilities is to see the column, beam and wall as useful elements in defining and articulating movement systems.

Light

Because they are detached buildings set in open landscapes, terminals are able to exploit light more than most building types. Light, like space and structure, is a major tactile material in its own right. Light to the terminal designer is more important than a question of lighting levels alone. Light – that is, daylight and sunlight – should be moulded, manipulated and directed with the sensitivity of a sculptor. Used in the correct fashion, light can be a solid, expressive material to guide travellers through the complex changes of direction and level encountered in a modern airline terminal.

In exploiting light, the designer needs to be conscious of the path of the sun. The orientation of the terminal building



9.2 Arrivals flow diagram.

should, wherever possible, allow sunlight into the core of the building. Sunlight and structure used together (as at Southampton Airport) allow the main concourse to be a central point of orientation for all those using the airport. Light helps to articulate space and animate the structural elements of a terminal, helping passengers in their perception of the building and uplifting their spirits.

The issue of hierarchy mentioned already in the context of space and structure applies equally well to light. The degree of light intensity helps to distinguish major routes from minor routes through the terminal. Daylight and sunlight can both be exploited to signal a principal staircase, the main departure lounge, or the central concourse.

Object

Object is the converse of space: the word is used to denote solid volumes within passenger terminals. Objects embrace banks of check-in counters, enclosing walls of various kinds, free-standing kiosks and lift shafts. Designers need to see 'objects' as orientating elements: solid points of reference that interrupt vistas or limit the edges of space. These solid elements contain functional space (staff offices, toilets, immigration control etc.), but their role in the terminal is also perceptual. By designing the solid parts as positive features, the architect can help passengers to understand the organization of the spaces of the terminal building. Certain key objects, for instance, can be treated as sculptural elements punctuating the free flow of space in the concourse. It may be possible, for example, to design the lift shafts as 'landmark' objects, thereby helping travellers to find the lifts and orientate themselves between different parts of the building.

Many of the principles relating to the handling of space, structure and light apply to objects. The relationship between use hierarchy and object meaning needs to correspond: major functions should be landmarked by major objects. Because airport terminals are mainly large volumes of space in which objects occur, the design of the solid elements has particular importance. Areas enclosed by walls (such as customs offices) have a function in defining the limits of concourse areas, in directing people in the desired flow, and in establishing navigation points in complex buildings.

Public art is, in many ways, a means by which space orientation can be reinforced (see Figure 9.8). The use of free-standing sculpture in concourse areas can establish a point of reference, particularly if it is located at, a crossroads in the passenger flow. Similarly, a mural attached to a wall can give that wall extra significance in the perception of interior routes. Major volumes in the terminal can be landmarked by a combination of light, structural expression and art. In combination, the elements should leave passengers in little doubt about the hierarchies of route and space in the terminal.

Integration of space, structure, light and object

The prime object of terminal design is to use all four elements together. The architect needs to orchestrate space, structure, light and object to express in the mind of the airport user the organization in plan and section of the building. The difference between Stansted and Kansai Airports, arguably two of the most important airport buildings of the past decade, is that only the latter combines these elements into a pattern that expresses the movement and space hierarchies. Stansted, in spite of its technical prowess, has a relatively uniform grid of columns and even distribution of light, which disguises rather than reinforces the pattern of passenger movement.

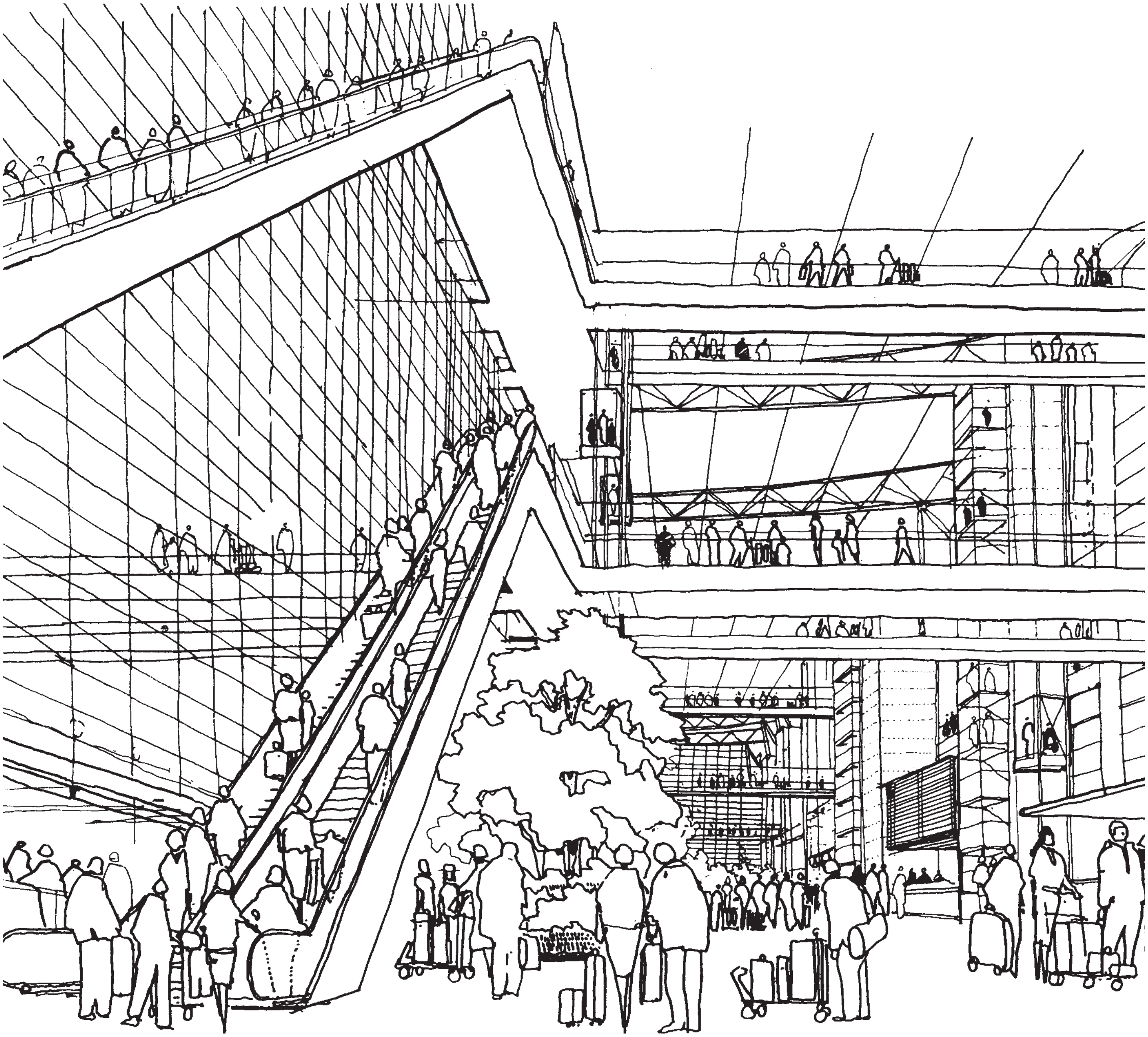
The design of Heathrow's Terminal 5 by the Richard Rogers Partnership successfully integrates the four key elements. Here a largely glazed curved roof above the central concourse bathes all below in diaphanous light. The disposition of columns directs passengers through the major concourse areas. There is an eloquent dialogue of volumes made up of suites of offices and shops and great voids of interior space. Three main orders of space are employed: large public volumes for people gathering, smaller but still spacious routes that connect principal functional areas together, and essentially private and utilitarian spaces expressed as small pod-like units. In such a design there is little need for directional signs: architecture alone provides the guidance.

Principles of passenger flow at large complex airports

The needs of passengers should be paramount in the design of terminal facilities. Passenger and baggage flows should be as smooth, well marked and flexible as possible. Ten design principles should be followed:

- Concourse routes should be as short and straight as possible.
- Areas used for passenger flows should not be obstructed by concessionaire, airline or government facilities.
- There should not be cross-flows.
- Routes should be capable of being used safely and comfortably by disabled travellers.
- Changes in level should be kept to a minimum but where needed should be accessed by lifts, escalators and stairs.
- All flow areas should be capable of multi-airline use unless they are dedicated terminals or piers.
- Multiple routeing should be provided to give passengers a choice of passport and customs control positions.
- Flexibility of layout should be provided to cater for the unexpected.
- The design of check-in areas should allow for processing passengers individually and in groups.
- Flow routes should be capable of operating under reverse conditions.

9.3 Terminals need to use architectural means to distinguish between major and minor routes. Hamburg Airport, Germany. Architects: Von Gerkan, Marg & Partner.



9.4 Space, volume and circulation are carefully orchestrated in this early sketch of Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.

Reasons for control

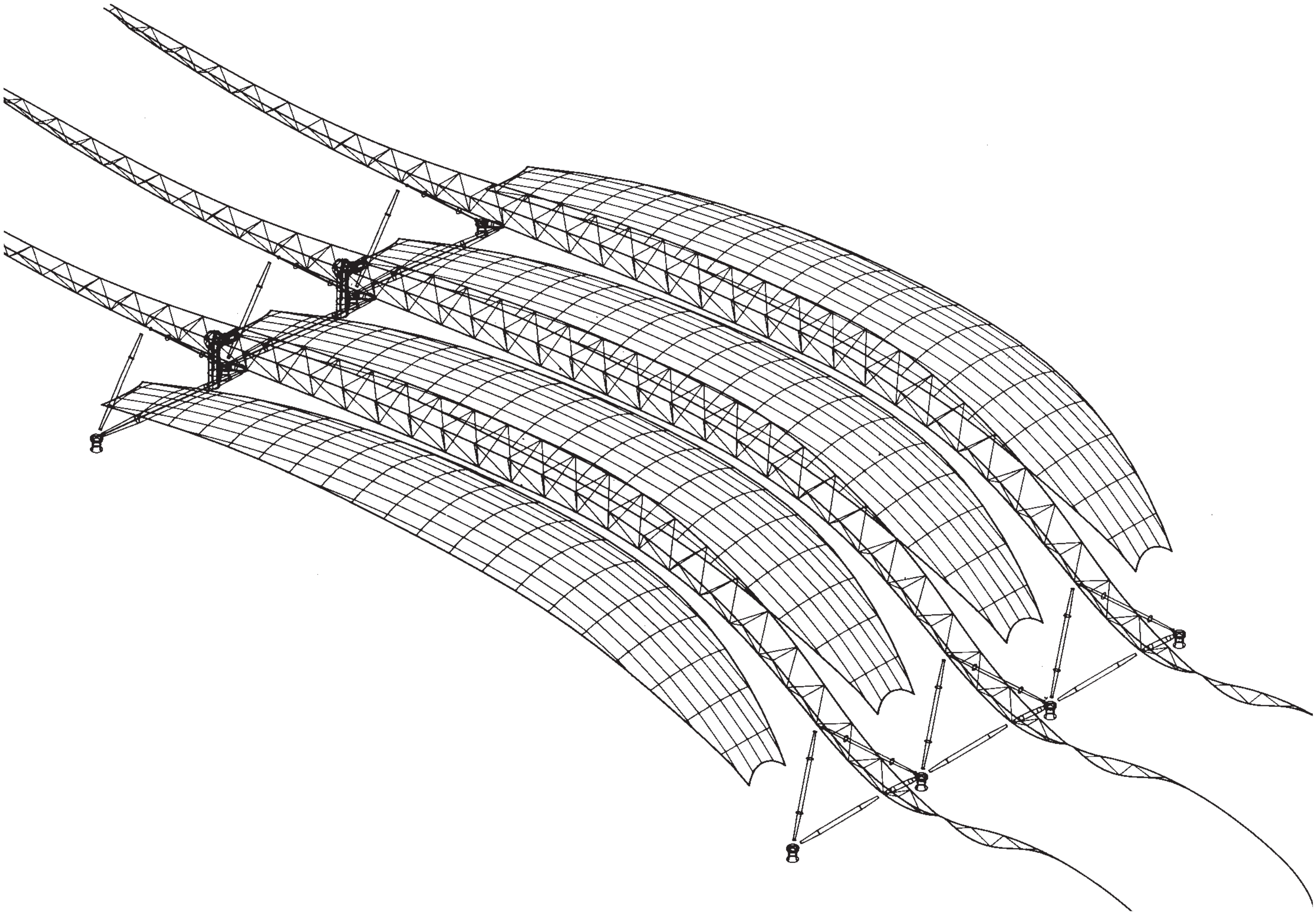
Much of the control mechanism at airports is the result of government requirements. Immigration, health and customs controls require the careful screening and routeing of passengers. Airports that cater exclusively for domestic flights do not display the same internal complexity as international terminals. The challenge for the architect is to provide clarity of route for the passenger who necessarily is herded through government control points.

On the outward journey there are two or three deliberate interruptions to the journey from land to air:

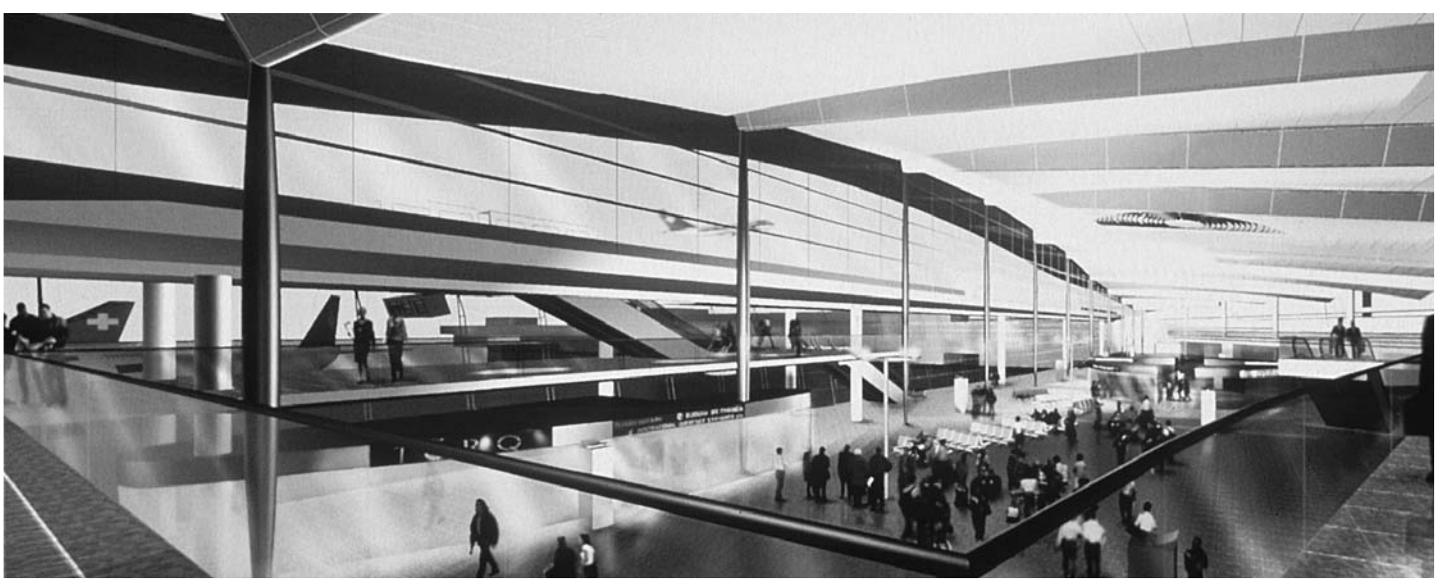
- ticket check-in (when passenger and baggage are separated)
- immigration control (outward)
- flight check-in.

On the inward journey there are three interruptions for international flights, and one usually for domestic:

- immigration control (inward)
- baggage reclaim (optional)
- customs control.



9.5 The roof structure at Kansai Airport helps to define the direction of flow. Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.



9.6 Daylight helps to orientate passengers in the confusing environment of modern terminals. Zurich Airport 2000, Switzerland. Architects: Nicholas Grimshaw & Partners.

9.7 Sunlight helps to animate structure and route. Glasgow Airport extension, UK. Architects: Parr Partnership.

9.8 Sculpture used to aid orientation in the terminal interior. Terminal 3, Schipol Airport, the Netherlands. Architects: Bentham Crouwel.

As a consequence, the smooth flow of passengers becomes a series of filter points where those travelling are segregated from terminal visitors, domestic and international passengers are channelled into separate streams, those with baggage are divided from those without, and those of national origin are split from non-nationals. How these filters and physical barriers are designed greatly influences the smooth running of an airport and how the passenger feels about the experience. Lengthy delays may be the result of a poorly managed airport, but the frustration can be alleviated by well-designed waiting areas and concourses.

Because the filter points often contain bottlenecks it is important that areas adjacent to them be provided with seating for tired travellers, the elderly and those with young children. Such areas should be attractively proportioned, well lit and restfully designed. Ideally, those waiting at baggage reclaim, check-in and immigration control should be provided with pockets of space away from the thrust of airport flows that are scaled for family groups rather than the individual.

Location of barriers

Where the segregation occurs is clearly important. At arrival, international and domestic passengers should be separated at

9.9 Stretched canopies, structural steelwork and pools of sunlight combine to create a vivid image for the initial design of Terminal 5 at Heathrow, UK. Architects: Richard Rogers Partnership.

the airside of the terminal, often by the use of a segregated airside corridor. For security reasons, arriving and departing passengers are also normally separated on airside of the immigration control barrier. The need to introduce physical segregation is translated by many terminals into different floor levels. The requirement for government controls at airports (immigration, health, customs) and the need for operational flexibility are often in conflict. Over-rigid regulations can lead to compartmentalized terminal buildings, which lack architectural qualities. The interpenetration of large volumes of space, views and plenty of daylight is often compromised at terminals by the rigidity of government regulation. Here, the management's need for flexibility and the designer's aspiration for an open democratic terminal are in conflict with security policy.

Assisted passenger flow

As a general rule, passenger flows should be as straight and short as possible. Cross-flows of movement, lengthy and tortuous routes, and many changes in level should be avoided. Main passenger flow routes should also be landmarked or waymarked using architectural means.

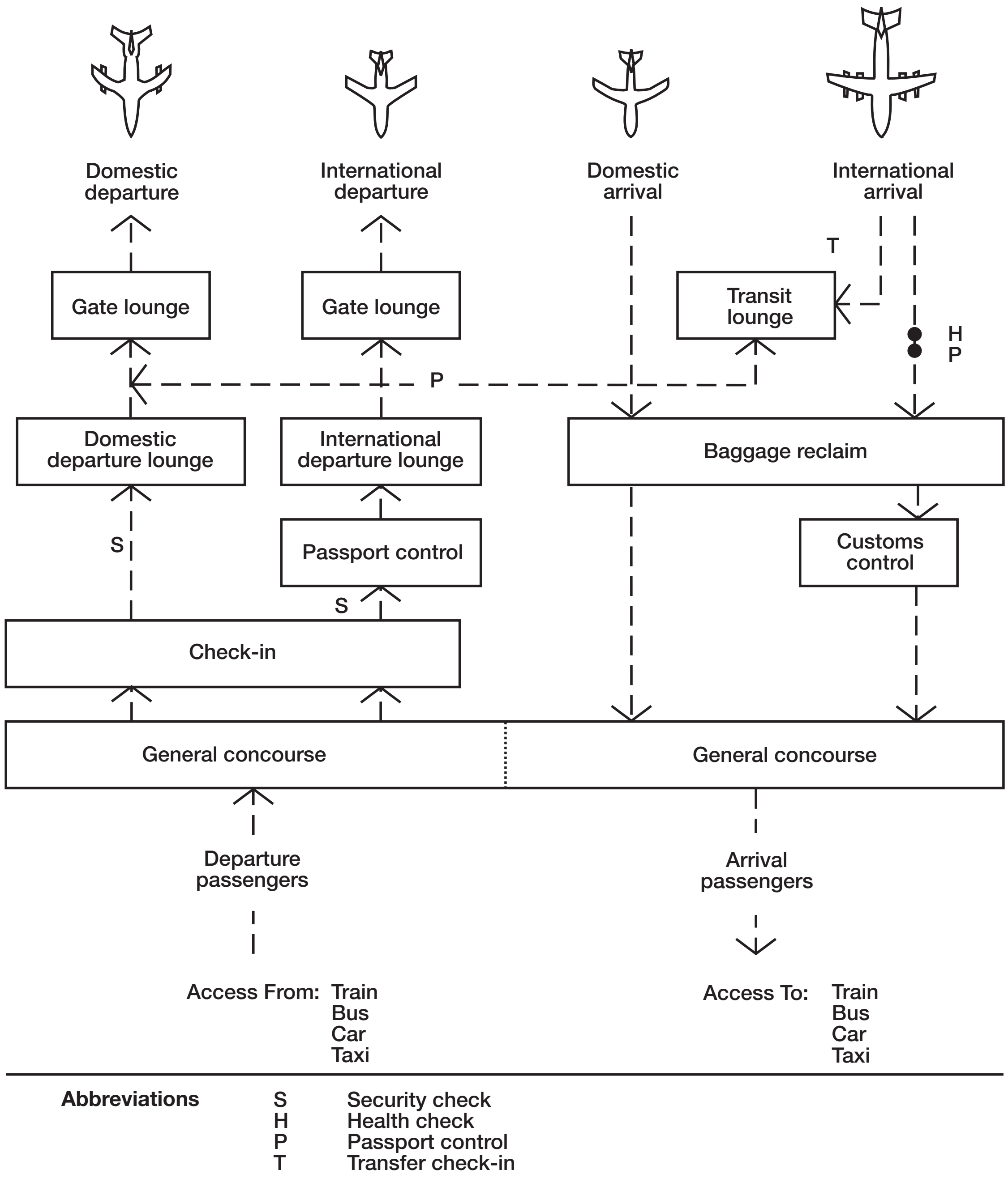
However, with certain passenger terminal layouts (such as finger piers, satellite piers and multi-terminal airports) long walking distances are inevitable. Under such conditions the airport designer needs to consider how to assist the passenger. According to IATA manuals 300m is the accepted maximum walking distance between the point of check-in and aircraft boarding without some form of mechanical assistance. People-mover systems, whether by travellator, light rail or airport buses, are expensive to provide and maintain. Compact terminals that require no assistance to be provided to horizontal movement are preferred. Assisted vertical movement is, of course, commonplace whether by escalator or by lift. With both horizontal and vertical assisted passenger movement, the designer needs to know whether baggage needs to be transported as well. If so, the facilities provided should be capable of catering for passengers and trolleys together.

Two main systems of horizontal assisted movement are found within terminals and between terminals and gate lounges.

Travellator

This consists of a deck of moving pavement set at about the speed of brisk walking. Travellators are normally wide enough to allow two passengers with their trolleys to pass side by side (hence the width is about 1.4m). The width of the travellator is, however, dependent upon the volume of traffic. The length of the travellator is determined by safety and maintenance factors (these normally result in a length of about 60m). Hence long routes consist of several units of travellator divided by short lengths of static floor space.

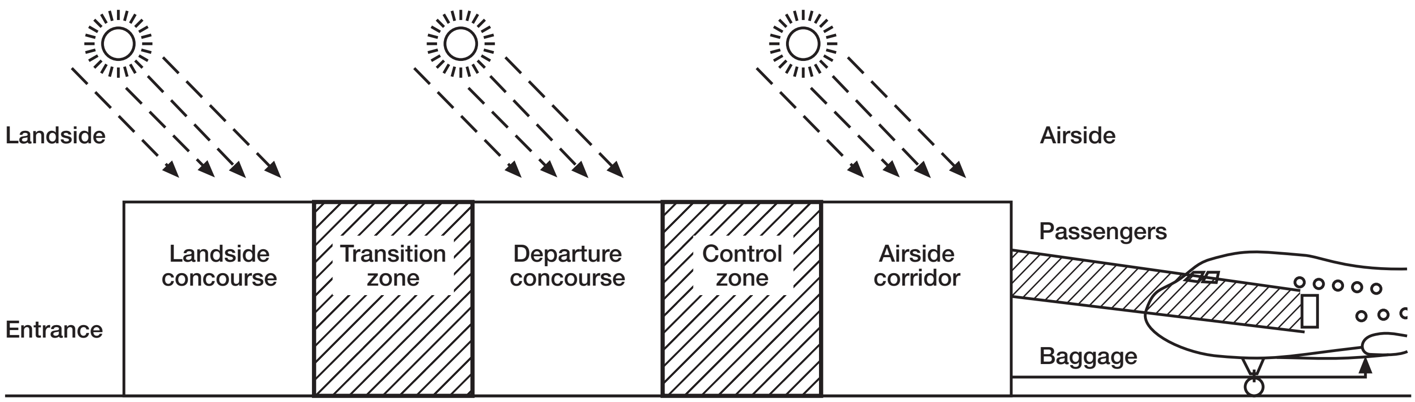
Travellators are moving walkways, which carry passengers over longish distances and up or down shallow inclines (up to about 1:15). Travellators come in single, double or triple widths and in varying lengths. They are normally designed



9.10 Baggage and passenger flow at a typical terminal.

to suit the layout of the airport using manufacturers' standard dimensions. Because travellators move people relatively slowly and in the same direction of flow they would have taken walking, passengers are rarely disorientated. However, as the speed is gentle it is important to provide visual stimulation either in the form of visibility over the apron areas or by advertising or public art provided nearer at hand.

Walking lengths over 1200m should not be met by the provision of travellators. The time factor is limiting: passengers become bored and flights are unduly delayed. Above this



9.11 Typical section of terminal. Notice how sunlight can be used to help define the concourse areas from control zones, providing an alternating sequence of light and dark areas *en route* to the plane.

9.12 Travellator linking Terminals 1 and 2 at Manchester Airport. Notice how the option to walk is generously provided.

9.13 AEG Westinghouse light rail system at Stansted Airport, UK. Architects: Foster and Partners.

distance some form of fast mechanical transport is required, such as the light rail systems used at Stansted and Detroit Airports. Light rail or bus transport between terminal building and gate pier allows the airport to exploit the benefit of lateral dispersal. Consequently, with such a system the terminal is normally designed upon the basis of distant satellites (as at Stansted) or of apron boarding of aircraft. A combination of travellators and rail systems frequently occurs as well, especially at large airports (such as Gatwick).

There is clearly a relationship between the design strategy for the airport and the means chosen to move passengers and their baggage. Small simple terminals at regional airports can dispense with people-movers, but large international airports cannot function without them. As aircraft become larger and air travel becomes cheaper, the more airports will have to adapt their terminals to mechanical forms of moving passengers.

Rapid people-movers

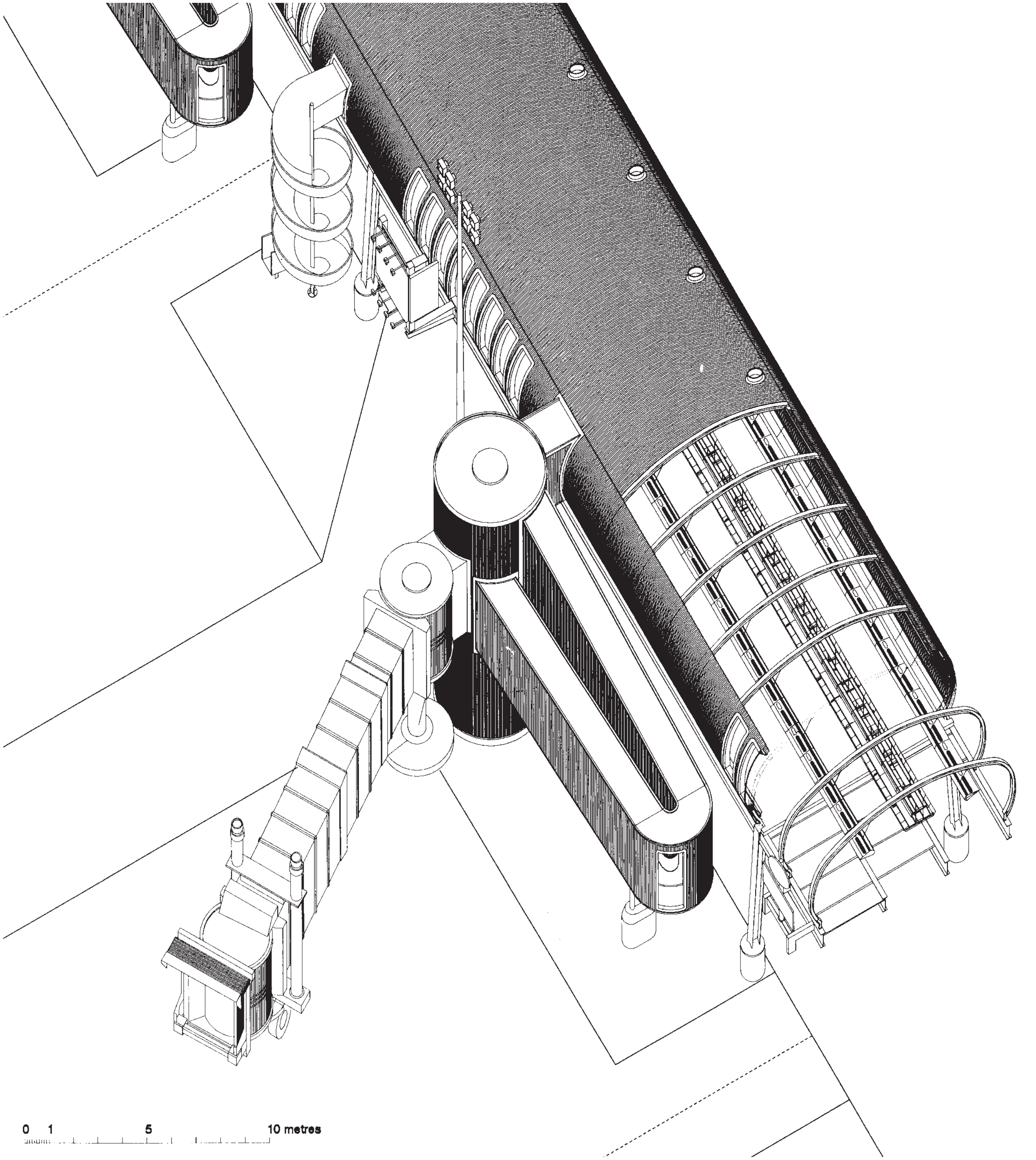
The limiting factor in the provision of travellator-type movement systems is time and effort. Beyond distances of about 1200m faster forms of people-mover are needed. These consist of various types of micro-transportation (known as personal rapid transit, PRT), from light rail to minibus and air-cushioned train systems. Between about 1 and 4km PRTs are required. The system adopted is usually dependent upon cost (capital and revenue), the number of passenger journeys required, and capacity. Minibus systems are fine for small groups of up to 15 passengers, but for large airports the capacity of each train should approach that of the bigger aircraft (about 300 people). Light rail systems with two or three carriages, each carrying up to 100 passengers, begin to approach this figure. A recent example is at Kansai Airport, where each gate wing (in total about 2km in length) is served by a light rail system with six stations.

With light rail and other tram systems the provision needs to be at departure floor level. This allows a smooth transition between airport terminal and the gate pier or jetty giving access to the plane. Changing levels along the journey should be avoided. Some systems, however, operate beneath ground level, thereby leaving apron and terminal airside areas free for service vehicles, baggage trolleys and parked aircraft. Elevated rail systems have the advantage of leaving the apron level free for service vehicles, and because they are at the height of airport doors, passengers do not have to undergo disorientating changes in level.

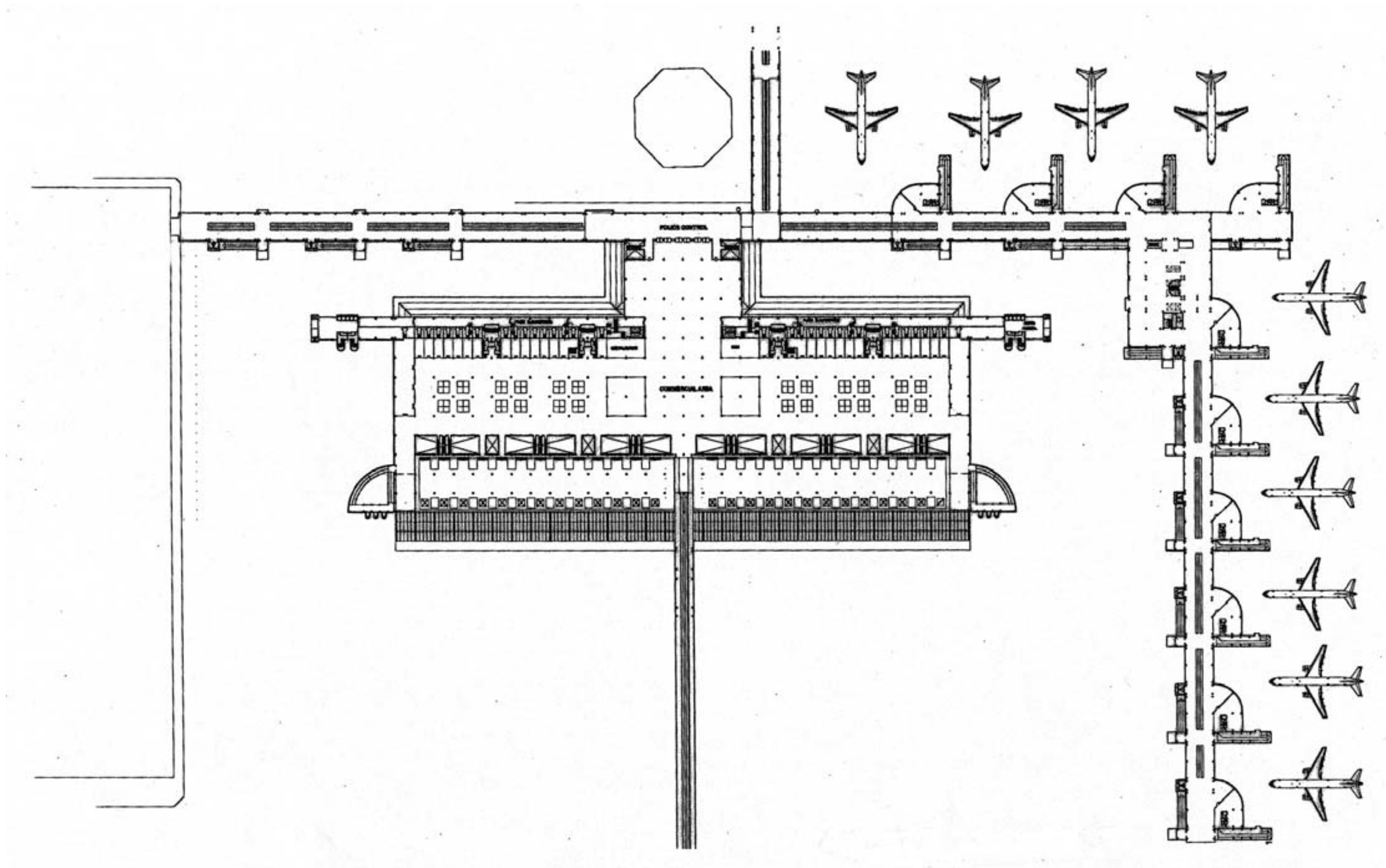
Passenger-loading bridges

Passenger-loading bridges (or jetties as they are sometimes called) provide elevated access directly from the terminal building to the aircraft. Depending upon the terminal layout, they give direct access from the airside corridor or departure gate lounge to the aircraft standing on the apron. Passenger-loading bridges add greatly to the comfort and convenience of passengers, and avoid the need to use mobile apron stairs. For the airline company, direct loading via enclosed bridges is faster, smoother and more secure than the use of apron vehicles or apron stairs. For the airport operator, passenger-loading bridges allow quicker turnaround of aircraft and hence potentially higher earnings. The more extreme the weather at a particular airport, and the greater the passenger turnaround, the more likely it is that loading bridges will be employed.

Because aircraft come in different sizes with varying height of passenger door, loading bridges need to be capable of elevational and directional flexibility. They work upon pneumatic



9.14 Telescopic or mobile loading bridge at Pier 4, Heathrow, UK. Architects: Nicholas Grimshaw & Partners.



9.15 The geometry of passenger loading bridges is determined by the size of aircraft. Palma Airport. Architect: Pere Nicolau Bover.

telescopic principles, with clearly defined docking points for different types of aircraft. Two main forms of loading bridge exist: fixed and mobile. The former consist of a bridge in a permanent position relative to the apron, with a flexible, telescopic nose capable of limited vertical and horizontal movement to suit different heights and positions of aircraft door. The latter consist of wheeled loading bridges anchored at the terminal end but still capable of fairly large rotational as well as vertical movement. Mobile loading bridges are more expensive to build and maintain, but offer greater operational flexibility. Some loading bridges have two or three lengths to allow for the large level changes needed in segregated airside corridors.

With both mobile and fixed bridges the accuracy of aircraft docking and the relative tolerance of the loading bridge system need to correspond. Aircraft docking guidance, aircraft parking, the mating of loading bridges and apron servicing (refuelling etc.) need to be considered as an integrated operation. Normally, a single loading bridge is sufficient for aircraft as large as the Boeing 747, but at busy airports where turnaround time is critical two loading bridges may be needed. Certainly two or even three will be required when aircraft capable of transporting 600 passengers come into operation around 2005. Corridors linking the loading bridge to the terminal should be at least 2m wide, and 3m where two bridges converge into a single corridor.

Table 9.1 Some aircraft passenger door sill heights

Aircraft type	Aircraft passenger door sill height (m)
Airbus A310	4.48 (average)
Airbus A320	3.41
Boeing 737-300	2.70 (average)
Boeing 747-400	5.00 (average)
Boeing 777-200	4.71
British Aerospace 146-300	1.88
McDonnell Douglas DC-8	3.32 (average)
McDonnell Douglas MD-90	2.30 (average)
Tupolev TU-154	3.26 (average)

Source: Christopher J. Blow, *Airport Terminals*, 2nd edn, Butterworth-Heinemann, Oxford, 1996, pp. 208–11

Baggage handling

CHAPTER

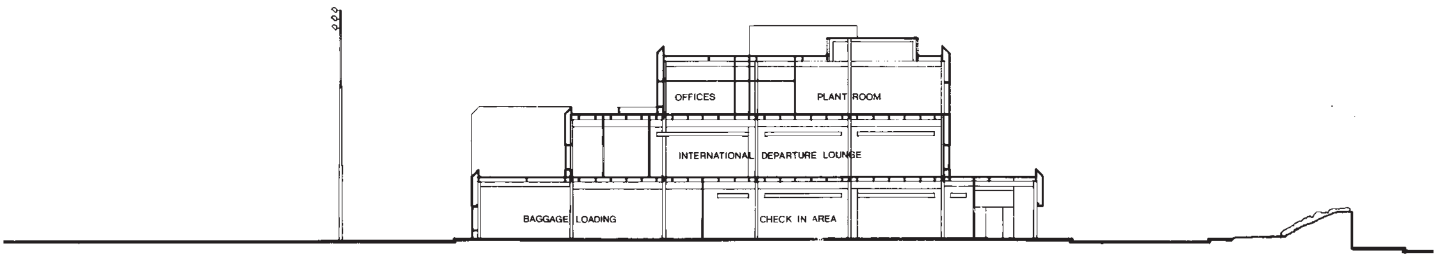
10

One of the principal reasons why terminals are multilevel is to deal with the complexity of baggage movement. Baggage is loaded onto aircraft at apron level via baggage holds, while the passengers board the aircraft at nearly 4m above apron level. The difference in height between the aircraft passenger door and the baggage hold requires all but the most simple terminals to split passenger levels from baggage levels soon after check-in. Quite how and when the segregation occurs varies according to the layout of the terminal, the proportion of destination and transit passengers expected, the balance between domestic and international flights, and how passengers arrive at the terminal – air, train, coach, mini-bus etc. Also, the needs of arrival and departure passengers vary: those arriving tend to enter the terminal in large groups, those departing singly or in small groups. Baggage handling is one of the most complex and, in terms of passenger perception, most critical factors in the success of a terminal.

The passenger load factor (the passenger flows that result from the number, size and frequency of aircraft) determines the baggage-handling capacity required. Not all passengers are terminating, however. Many, especially at hub airports, are merely transferring to another flight. Their baggage should transfer from one aircraft to another as smoothly as the passengers. Large aircraft mean large surges in baggage-handling needs. Hence even with existing terminals there is often periodic upgrading of baggage facilities to match innovations in aircraft design, or changes in security arrangements.

Baggage handling is an integral part of passenger terminal operation. Though rarely seen by the passenger after check-in, baggage movement is one of the processes that order the interior spaces and distribution of floor levels at the terminal. Different baggage-handling systems exist, from fully automated computer-controlled systems using driverless electronic carts to simple conveyor belt systems. The terminal layout and the needs of baggage handling should be integrated at the design concept stage. Baggage movement is not a bolt-on after the terminal has been designed, but a central ordering system as important as passenger flows.

10.1 Typical section showing baggage handling in a split-level terminal. Edinburgh Airport, UK. Architects: RMJM.



Six guiding principles should be adopted in baggage handling:

- Minimize the number of handling operations.
- Ensure that the baggage-handling system is consistent with the characteristics of aircraft movement (type of passenger, size of aircraft, frequency of flights).
- Avoid turns and level changes.
- Ensure that conveyor belt slopes do not exceed 15º.
- Avoid baggage flow crossing passenger flows, aircraft flows and air freight flows.
- Place baggage-sorting areas adjacent to the apron.

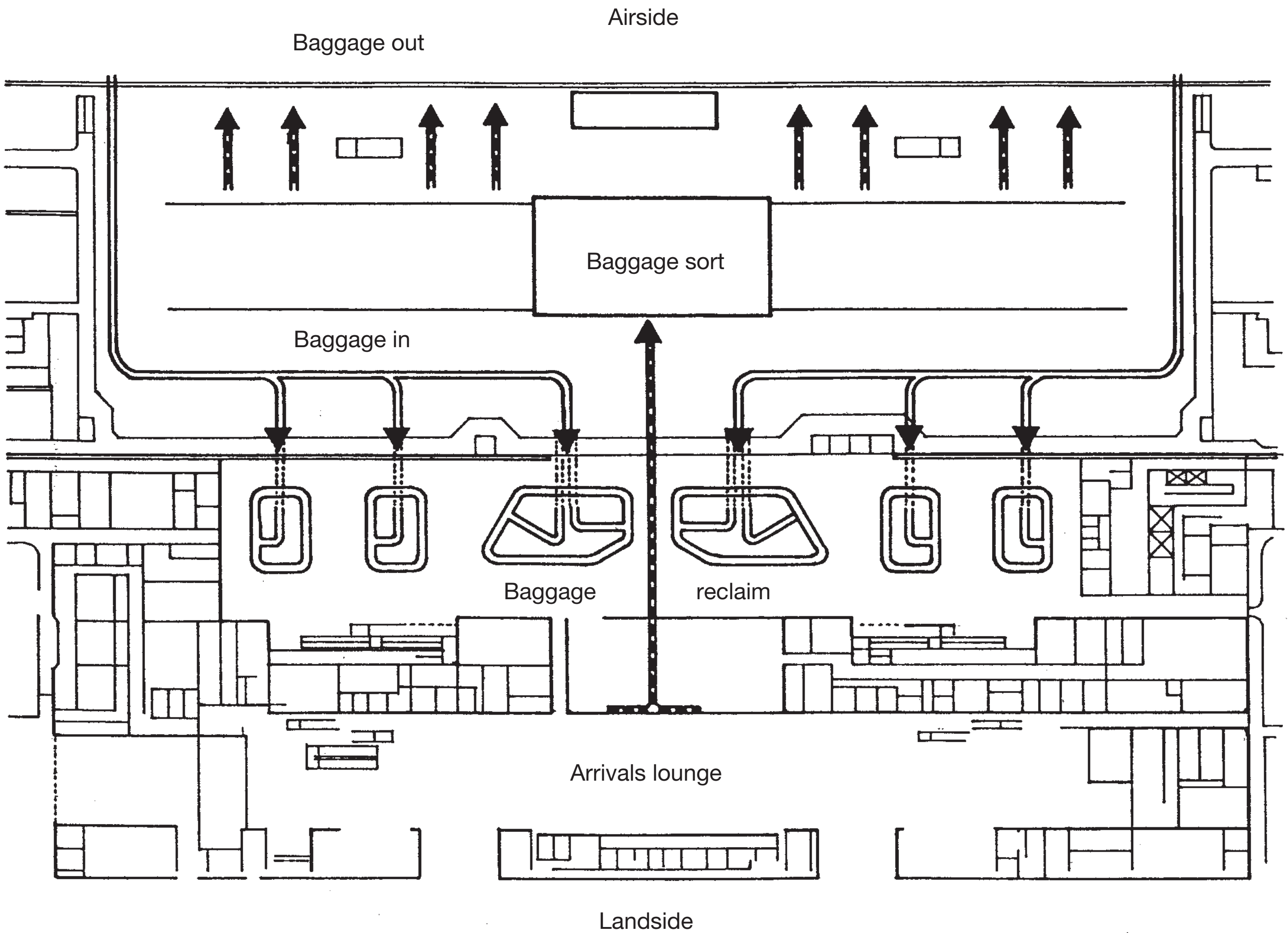
Baggage flow, unlike passenger flow, should be as rapid, direct and simple as possible. Whereas passengers are encouraged to loiter, shop and stop in bars en route to the plane, speed is of the essence with baggage handling. Because many passengers are likely to be transferring, baggage systems need to be flexible and reliable to ensure that passenger and baggage arrive together at their destination. Baggage movement is a two-way process. While with departing passengers there may be a longish period (up to 2 hours) between check-in and flight departure, with arrivals the passenger expects to be reunited with baggage in a matter of minutes (in 14 minutes with Manchester Airport's quality assurance scheme).

Baggage needs to be planned on a linear flow basis. Baggage and passengers are parallel currents, which pass through the terminal in a disciplined logical order. The two flow systems (passenger and baggage) are related but operate on parallel paths, separating at ticket check-in and reuniting at baggage claim at the end of the journey. Because it is a flow system, abrupt changes in direction or level should be avoided. Normally a conveyor belt transports baggage from the passenger check-in to be sorted in the departure baggage area. Here it is loaded onto baggage carts or small containers for transporting by electric or diesel vehicles to the holds of aircraft waiting nearby on the apron. Baggage flow, like passenger flow, is critical in terms of time. Any baggage-handling system needs to be capable of catering for peak as well as normal flows, for interruptions due to adverse weather, for security checks, for equipment breakdown, and for last-minute passengers reporting directly to gate positions.

Arriving baggage has different characteristics from those of departing baggage. Customs clearance requires incoming passengers and baggage to pass through control mechanisms together. Passengers need quick reacquaintance with their baggage if they are carrying duty-free goods purchased on the plane, and transfer baggage needs to be sorted from arrival baggage before the baggage claim area. Speed and clarity of operation are key factors in meeting passenger and airline needs.

Between the aircraft and baggage claim conveyor belt there is normally a baggage-sorting area. It is here that the baggage of transfer and arrival passengers is separated. Because transfer baggage is likely to be destined for a number of different locations, sorting needs to be done efficiently and speedily, especially where transfers are between airline companies. At 'hub' airports such as Heathrow, where 30 per cent of the 63 million passengers a year are transfers, the logistics of baggage handling require sophisticated solutions. Normally, the procedures for handling baggage are jointly devised between airport authorities, specialist handling companies such as ServisAir, and airline companies, with the airport facilities manager translating the system into briefing instructions to the architect. Because the life of baggage-handling systems (and customs regulations) is normally far less

10.2 The movement of baggage is a major factor in the layout of terminals. Terminal 4, Heathrow Airport, UK. Architects: Scott Brownrigg and Turner.



than that of the terminal itself, periodic upgrading is the norm. This of course has implications for apron procedures on the one hand, and for terminal design on the other.

The baggage-handling system

Baggage handling is normally a service provided at the terminal by the airport authority or subcontractors rather than the airline company. With unit terminals or dedicated satellites, however, greater airline control of the baggage-handling system occurs. Normally, the airport authority provides a shared service for a number of airline companies with, occasionally, private baggage-handling contractors operating part or all of the system. Where contractors are employed this may consist of baggage sorting or more frequently baggage transportation across apron areas to the aircraft.

The choice of baggage-handling system (and its subsequent upgrading on a 5–10 year timescale) is normally decided by the airport authority in collaboration with the airline companies operating out of a terminal. Most airports use a shared system, rather than an airline-dedicated system linked to a quality assurance guarantee. Baggage handling is an increasingly automated computer-controlled system, using bar-coded tag identification (common in supermarkets). Breakdowns due to failure of the mechanical conveyor system or power supplies can bring the operation of the airport to a standstill. Most terminals are designed with a bypass capability to allow manual handling of baggage in emergencies.

Between 1995 and 1998 BAA invested £42 million at Heathrow in a new baggage-handling system. Using a system tested initially at Dallas Airport, the baggage at Heathrow travels the 1.4km between terminals 1 and 4 in a specially constructed tunnel 4.5m in diameter and 20m underground. Special carts transport baggage at a rate of 42 bags per minute at a speed that allows transfer baggage to move from terminal to terminal in a maximum of 18 minutes.[1] Because British Airways is the main beneficiary of the new system (BA operates 90 per cent of flights from Terminal 4) it contributed towards the construction costs, and has taken a lease on the new facility over a 10-year period. Hitherto baggage was transported between terminals by road, taking as long as an hour and frequently delaying the departure of flights.

The normal method of baggage handling is by means of conveyor belts in the terminal, linked to container or trolley transportation of baggage across the apron. The conveyor belt system is usually designed on the basis of a belt 0.9m wide with a headroom clearance of 1m.[2] Mechanical deflection (usually tilt operated) of the baggage is also needed to allow checked-in baggage to move from one belt system to another depending upon the destination flight. Special provision is needed at bends in the conveyor belt and at changes in level. Bends, which consist of double conveyor belts, require the inner belt to be set at a slightly lower speed to avoid baggage snagging. Level changes are best accommodated by setting the belts at shallow angles (up 5°) rather than by using escalators, lifts or metal chutes.

The system employed needs to be able to cater for peak demand, not just typical flow levels. It also requires a capability to distinguish baggage between airlines, flight number, destination and class of passenger. The system also requires the ability to handle abnormal baggage such as bicycles, surfboards, skis, golf clubs and pets. Normally such items are segregated at flight check-in with special containers or trolleys used.

The departure baggage area is where the sorting and loading into baggage containers occurs. Up to this point most baggage will have been transported by conveyor belt directly from the check-in desk; beyond this point baggage is placed in containers or on trolleys for transportation to the aircraft. The process is a movement flow, with each transfer point capable of dealing with peak demand in order to avoid bottlenecks. The critical parts are normally baggage check-in, baggage sorting, baggage loading, and aircraft loading. The degree of automation present normally reflects the volume of baggage to be handled. In modern sophisticated systems baggage sorting and baggage loading is a combined operation where bar-coded baggage is mechanically directed (via computer-controlled deflectors) to designated carts, trolleys or containers.

The baggage make-up area is a vital part of the baggage departure area: it is here that containers or carts are loaded for transportation across the apron to waiting aircraft. Separate entry and exit points are required for the electric or diesel-driven vehicles, which tow usually three or four carts at a time. Detailed design is important: the conveyor belt should be at a comfortable working height, lighting should be high and of an even standard to allow staff to read the tags readily, ventilation should be provided to disperse vehicle fumes or those from battery recharging areas, and flooring needs to be non-slip (when wet and dry) yet able to provide non-skid conditions for wheeled transport without tyre noise. Dimensional clearances required are 3.2m height and 3m width for baggage carts or containers.[3] In operational terms it is advisable for departure baggage make-up areas and arrivals baggage breakdown areas to be practically side by side, thereby permitting the easy transfer of containers and carts. The usual plan is to have two lanes of baggage carts (an offload lane and a bypass lane) each 3m wide and separated from the conveyor belt by a work area 0.9m wide.

Baggage handling requires staff to be fully informed of airline and apron operations, and airline operators to be equally informed of the minute-by-minute flow of baggage through make-up and breakdown areas. Closed-circuit television in baggage-handling areas ensures that airport management staff and airline operators have up-to-date information on the state of baggage operations. This leads to early recognition of problems, and helps with the security of baggage. Flight information boards, large clocks, telephones and intercom are also required in the baggage-handling areas.

The design of the baggage system and that of the terminal are closely related. Centralized terminals require different baggage-handling systems from decentralized and satellite arrangements. Similarly, hub airports have different baggage characteristics from mainly destination airports. As a rule of thumb it is better to keep baggage-handling systems as simple as possible, with manual sorting and cart loading preferable to

10.3 Airside view of passenger handling at rear of terminal. Paderborn-Lippstadt Airport, Germany. Architects: Von Gerkan, Marg & Partner.

expensive and vulnerable fully automated systems. However, beyond certain baggage-handling capacities mechanical systems are unavoidable, but again manual back-up is required in order to keep the airport operational in the event of system breakdown.

Security controls and baggage handling

After 11th September 2001, all baggage, domestic or international, has had to pass through a security check before entering the aircraft hold. This consists of an X-ray examination, manual checking of suspect baggage, and additional spot checks on certain high-risk flights (such as London to New York). After clearance, baggage enters a sterile area, where any contact with non-secure personnel or non-screened baggage must be avoided. Like a hospital, the airport operates with sterile and non-sterile zones where physical interaction can put at risk passengers, airport personnel and the aircraft themselves. Just as contact between security-screened and non-screened passengers is not permitted, so too with

10.4 Baggage handling in the terminal and on the apron needs to be well co-ordinated to avoid security risk.

baggage. Because suspect baggage may prove to contain a bomb or incendiary device, there needs to be a secure storage area where it can be placed before being made safe.

One important safety principle of baggage handling is that of ensuring that both passenger and baggage travel on the same flight. Baggage must not be allowed to enter the aircraft hold without an accompanying passenger on board. After the Lockerbie bomb in December 1988, security was tightened in this regard. The difficulty is greatest with transferring passengers: here there is the risk that a passenger will deliberately miss the flight connection on which his or her baggage (possibly filled with explosives) has already been loaded. To avoid this, baggage and passengers are paired on computers held at check-in, baggage sorting, gate check-in, and baggage aircraft loading. By using an electronic bar-code on the passenger boarding pass and baggage tag, there is little possibility that baggage will go astray or travel unaccompanied. Also, laser bar-coding of baggage speeds up operations, allowing up to 60 bags per minute to be sorted without loss of security.

Before the bringing down of Pan Am flight 103 over Lockerbie with the loss of over 300 passengers, baggage transfer from connecting flights was assumed to have been

10.5 Typical baggage belt in reclaim area at Glasgow Airport, UK. Architects: Sir Basil Spence. Recent extension: Parr Partnership.

checked at the original airport. Because not all airports operated the same security standards, the Lockerbie bomber was able to exploit poor security at one airport to place a bomb on a plane flying out of another. The subsequent policy change to screen all baggage prior to departure, including that transferring between flights and airlines, placed a considerable burden on busy airports such as Heathrow, where over a quarter of passengers are transferring between flights. After Lockerbie the US scanning equipment specialist Vivid Technologies developed a system for BAA that detects explosives, drugs, weapons and currency without direct visual contact.[4] Using advanced X-ray techniques, the system identifies 'suspect' baggage for further scans and direct visual examination by a member of the security staff. The system has the capacity to examine 1200 bags per hour, second-level scanning for suspect baggage takes a further 10 seconds, and for the less than 1 per cent of baggage that is still suspect, manual inspection can be undertaken (always with the owner of the baggage present) in a couple of minutes. From a terminal design point of view, the system requires additional space for equipment and conveyor belts, as well as rooms for the temporary storage of suspect baggage. Though largely invisible to the passenger, the expensive new security checks have led to safer air travel, but they add to the cost and complexity of baggage-handling procedures.

Baggage reclaim

Once the aircraft has arrived, baggage is dispersed via cart, trolley or container to the breakdown area, where it is divided between destination and transfer. The operation is largely manual, with airport staff unloading carts or containers and placing baggage upon the appropriate conveyor belt. Up to four carts can normally be parked alongside a work area, which is served by a conveyor belt that takes baggage via a loop system to the baggage claim area. Four carts or containers would normally contain the baggage for about 80–100 passengers, so for a large aircraft two or three conveyor belts are needed for each arriving flight. The plan arrangement consists of a sequence of baggage claim peninsulas (normally about 10–15m apart) served by offload areas with bypass lanes for vehicle access.

The passenger reclaims baggage in the baggage claim area. A variety of methods are used to allow passengers to spot and then retrieve their baggage within the general mêlée of such areas. The plan shape of the conveyor belt can be linear or circular, or a combination. With recirculating baggage claim the passenger can remain stationary, but in smaller airports the baggage is deposited in one place (normally a long low counter), and the passenger moves along until the appropriate bags are located.

Baggage claim belts should be at a convenient height for passengers (0.45m for a sloping belt and 0.35m for a flat belt[5]) and operated at a speed of 23m/min. As with departures, baggage provision should be made for manual handling of bulky baggage (such as folded bicycles). Once the passengers have retrieved their baggage they require ready access to personal baggage trolleys. These need to be stored near to the conveyor belts in staging areas. Two complications often occur. First, not all baggage is claimed, and secure storage areas are needed nearby for unclaimed (or suspect) baggage. Second, transfer baggage may arrive by mistake in the baggage reclaim area. Facilities need to exist to identify and rectify the mistake so that subsequent flights are not delayed.

Once passengers and baggage are united they may proceed to customs control or, if on a domestic flight, directly to the arrivals lounge.

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2. IATA, *Airport Terminals Reference Manual*, 7th edn, International Air Transport Association, Montreal, Canada, 1989, pp. 3.51.
3. Christopher J. Blow, *Airport Terminals*, 2nd edn, Butterworth-Heinemann, Oxford, 1996, p. 152.
4. Oliver, *op.cit.* p. 68.
5. *Airport Terminals Reference Manual*, p. 3.58.

Terminal design concepts

CHAPTER 11

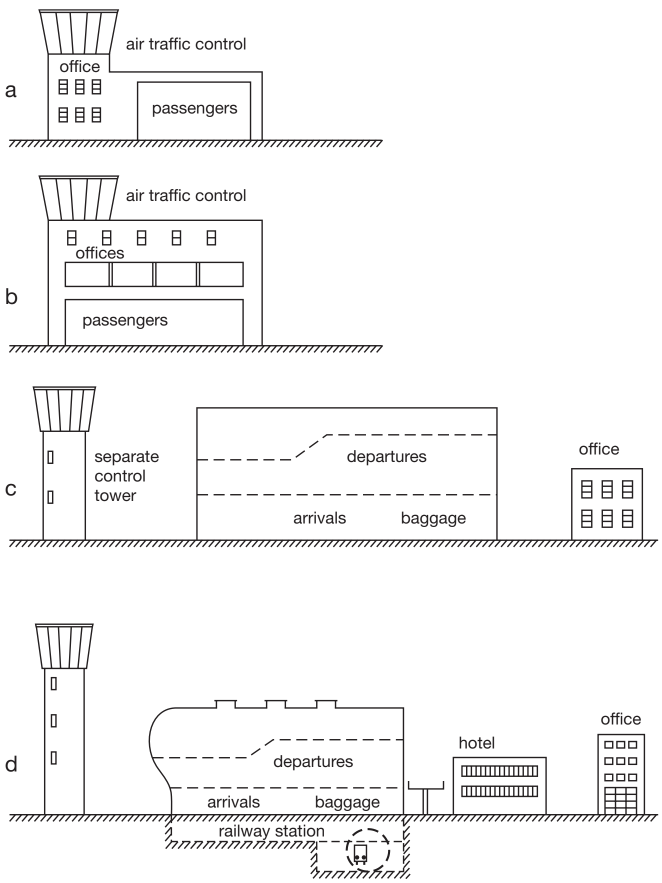
The terminal building contains the various facilities that passengers and their baggage need between landside and airside, and for those transferring between aircraft. The transition is in two directions (arriving and departing), with an equal number of passengers involved in each flow. Hence the terminal building should provide a welcoming approach from both landside and airside.

Because the terminal building is part of a larger system of airport elements (including roads, apron areas and aircraft taxiways), its position is determined precisely by the masterplan. This will prescribe a specific location, the means by which connections are made to other facilities, and the extent of the footprint and height of the passenger terminal building. The geometry of the terminal building reflects in a direct fashion the wider geometry of the airport: a point that designers need to bear in mind if passengers are not to become disorientated.

Six basic criteria should be observed in the design of passenger movement in the terminal building:[1]

- easy orientation for the travelling public
- shortest possible walking distances
- minimum level changes
- avoidance of passenger cross-flows
- built-in flexibility
- separation of arriving and departing passengers.

Two basic philosophies have been adopted for terminals in the past. In the centralized concept all the major elements are grouped together into a single multilevel building; in the dispersed system the functions are spread into a number of buildings, each often under the control of a separate company or airline. Hence in the first philosophy passenger and baggage handling, aircraft stands, car parking and railway station are housed in a megastructure (as at Kansai Airport, Japan); in the second the various facilities are decentralized and dispersed geographically across the airport (as at Manchester Airport). However, the design concept is the result of many factors, including: the nature of traffic demand; the number of participating airlines; the traffic split between international and domestic, charter and



11.1 Changing pattern of airport design: (a) 1930s; (b) 1950s; (c) 1960s; (d) 1980s.

scheduled flights; site characteristics; access modes; and financial arrangements.[2]

Changing typologies

Since its inception as a building type in the 1930s and more substantially in the 1940s, the airport terminal has undergone many transformations. These have concerned the organization of the terminal in plan and in section, and in the relationship between three key elements – the public concourse area, private offices and the control tower.

Early terminals combined the three elements in a single structure but by the 1950s the control tower had become a self-contained building and by the 1970s the same was true of airline company offices, especially at larger airports. These generalizations are true of bigger airports where the trend towards segregation of functions is most marked. The capacity of a single building to absorb runway control functions with administrative and passenger ones is determined by the scale of flows. With over a million passengers a year, segregation is unavoidable and many airports (such as Heathrow) reached this figure in the early 1950s. Typologically speaking, physical segregation into self-functioning units resolves the security and management conflicts inherent in integrated terminals. Another common strategy is to zone the terminals into distinct domestic and international areas, arrivals and departures, airside and landside. Each zone is physically contained (for security reasons) and often situated on a separate floor. So as airports become larger, terminal buildings become more complex in plan, section and organization. There comes a point when the scale of complexity threatens efficient operation and here the answer is normally to place non-public functions (such as air-traffic control) in their own buildings.

Alternative terminal design layouts

Today five distinct terminal and pier concepts exist (see Figure 8.8), each with its own advantages, and each appropriate for different situations:[3]

- central terminal with pier/finger (centralized terminal)
- open apron or linear (semi-centralized or decentralized terminal)
- remote apron or transporter (centralized terminal)
- central terminal with remote satellites (centralized terminal)
- unit terminal (semi-centralized or decentralized terminal).

The facilities manager and designer of the passenger terminal will select the system that best suits the airport in question, but if the airport is being expanded (rather than developed from scratch) the choice is often less open. For instance, if a terminal is facing periodic enlargement it is likely that an open apron or linear concept will be adopted, or a unit terminal. The central

11.2 Linked terminals at Lyon-Satolas Airport, France. Architects: Curtelin Ricard Bergeret/Scott Brownrigg and Turner/Santiago Calatrava.

terminal with pier/finger, though it is popular with airport authorities, airlines and government authorities, and is the most numerous configuration, is inherently inflexible when it comes to future expansion.

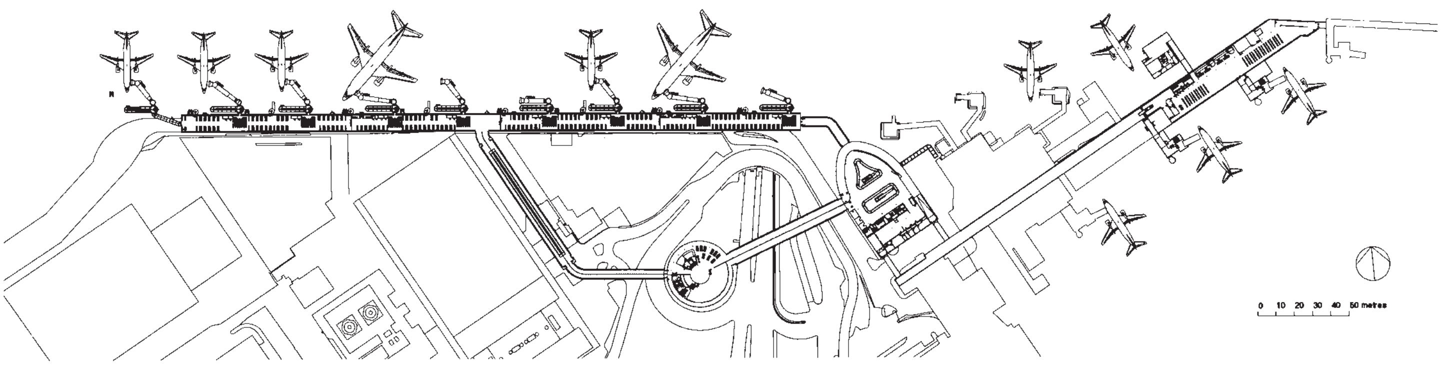
Central terminal with pier/finger

This is a much employed layout (e.g. Amsterdam Schipol Airport, Kansai Airport), with a central terminal serving a radiating, orthogonal or linear group of gate piers that give direct access to aircraft. The main advantages are the centralization of facilities (shops, duty free, restaurants, immigration control, check-in) and the clear, visible relationship between terminal and departure piers. Because the terminal serves a large number of piers, it can be an economic arrangement in terms of building and apron costs. The disadvantages, however, include congestion in the terminal at peak times, lack of car parking space at the terminal entrance (for the number of passengers), long walking distances from terminal to gate, reduced manoeuvring space for aircraft alongside gates, and the need to separate arriving and departing passengers on different levels. In addition, this arrangement involves extensive baggage conveying and (normally) the need to provide travellators. Also, the geometry of the layout makes expansion difficult. To overcome congestion in the terminal, a variation involves constructing a mini-satellite at the end of each pier, with its own restaurant, retail and direct check-in facilities for domestic flights.

Open apron or linear

This consists of a long terminal with semi-centralized groups of check-in counters forming nodes within a linear building. An example is Munich Airport which has four international departure units.[4] Aircraft park directly alongside the terminal (on the opposite side to the landside entrance), usually without the construction of piers. An airside corridor provides access along the full length of the building to the departure (and arrival) gates. The main advantages are: the short walking distance

11.3 Linear gate pier linked to a central terminal at Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.



11.4 Example of finger piers at Heathrow's Terminal 4, UK. Architects: Nicholas Grimshaw & Partners.

between the terminal and gate, and the correspondingly short journey for baggage handling; simple separation of arriving and departing passengers (can be via an airside corridor rather than different levels); easy passenger orientation (aircraft can be seen on arrival at the terminal); and long kerb lengths, which allow plenty of space for setting down and picking up passengers. The disadvantages are: the duplication of facilities and services (check-in, shops, restaurants, immigration control, flight information boards, etc.); long walking distances for transfer passengers; high capital and building running costs; and lack of flexibility for catering for different aircraft designs.

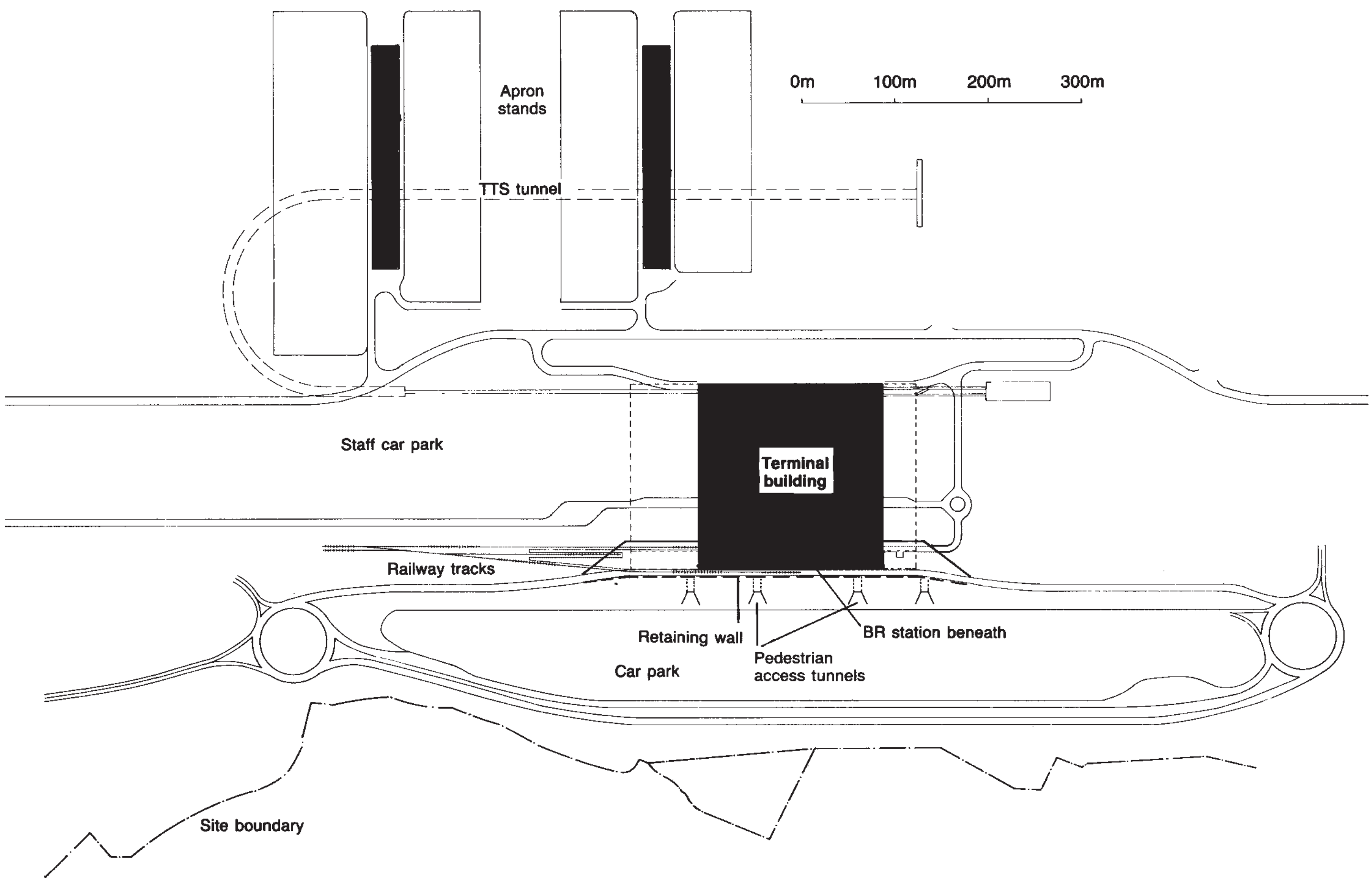
Remote apron or transporter

This system consists of a centralized terminal with dispersed aircraft-loading positions on the apron. An example can be seen at Mirabel International Airport, Montreal. The aircraft are parked on the open apron and reached by transporters, which serve as mobile lounges and gate hold rooms. Baggage too is transported to the aircraft on separate mobile apron equipment. The main advantages are flexibility of operation, reduced costs of the terminal building, ease of separating arriving and departing passengers, and reduced walking distances. However, this system has serious disadvantages: vehicle breakdowns or lack of mobile equipment can lead to poor levels of service in aircraft loading or unloading; maintenance and operating costs are high; the system is vulnerable in industrial disputes, and slow in transporting passengers from terminal to aircraft; and there is a need for additional airline and security staff.

Central terminal with remote satellites

The layout here consists of a central terminal building and a number of satellites around which aircraft are parked for receiving passengers. An example is Stansted Airport, where the satellites are reached by a rapid transit system. The terminal and satellites are joined above or below ground by travellators. Baggage is separated from the passenger at the central check-in and transported usually by vehicles operating across the apron. The main advantage of the concept is the centralization of facilities and services, though further shops or duty-free outlets are often provided in each satellite. It has the added advantage that security checks can easily be carried out at the entrance to each satellite. The system also allows further satellites to be constructed without causing great disruption, if demand grows. Usually, a single airline company is responsible for each satellite, thereby reinforcing a sense of brand identity and allowing passengers to change planes without having to pass through the terminal. The disadvantages are: high capital, running and operating costs (the configuration is relatively expensive compared with, say, the open apron or linear concept, travellator costs are high, baggage handling is expensive, and staff costs are high); limited expansion of the terminal (as against satellites); and long distances, necessitating early check-in times, and making transfers between

11.5 Satellite piers with space for expansion at Stansted Airport, UK. Architects: Foster and Partners.

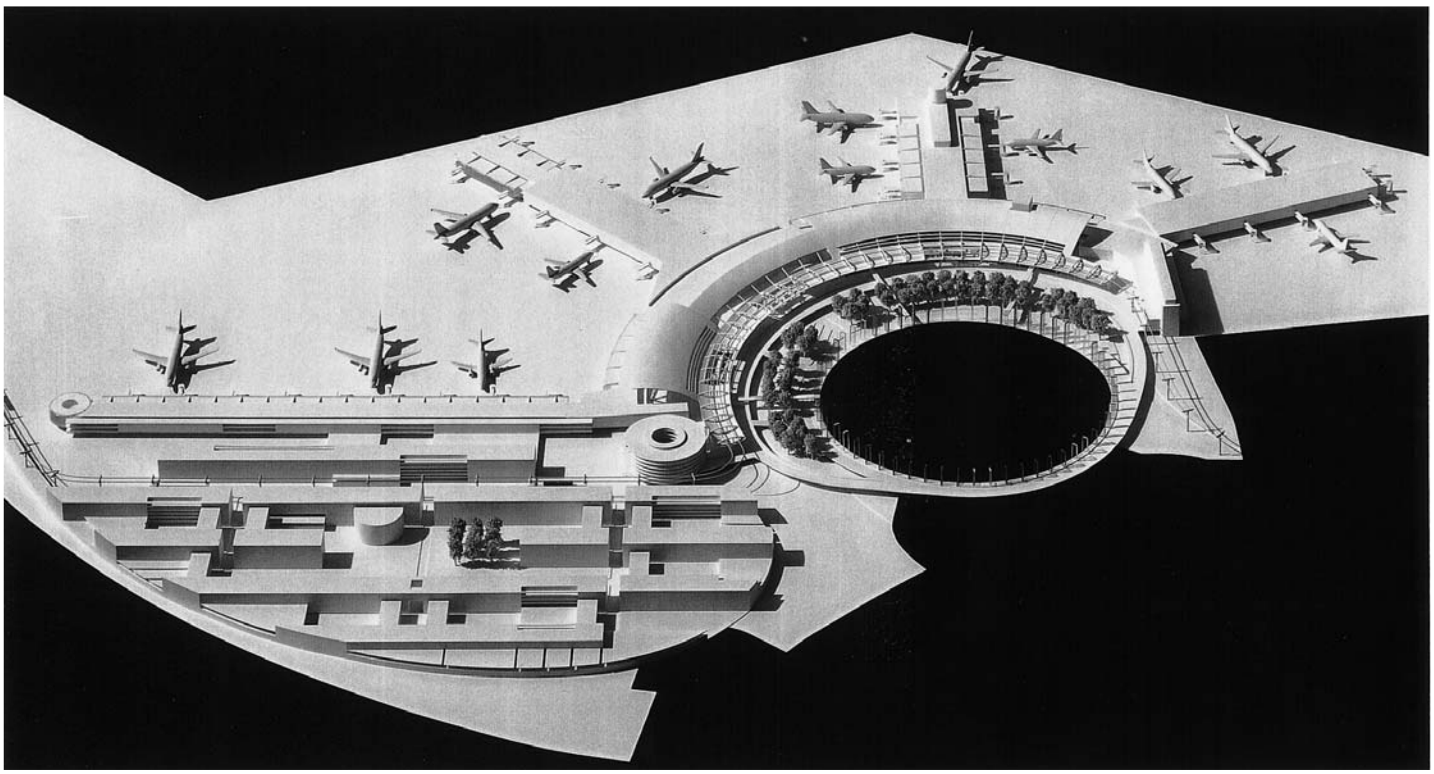


airlines difficult (though not between planes at the same satellite). However, the arrangement is considered sufficiently attractive to be the basis of Heathrow's new Terminal 5.

Unit terminal

This concept is based upon a number of terminals linked by the airport road system, underground railway or pedestrian travellator. A particularly good example is John F. Kennedy, New York, where there are nine terminals, each managed by a different airline. Each terminal provides integrated passenger and baggage facilities, with flight stand and gate check-in close by or incorporated into a single service. It is an arrangement that allows airports to grow incrementally, with different airline companies taking a major stake in each terminal. The main advantages are the short distances between check-in and aircraft (and hence late check-in times), and the relatively low cost of construction. The disadvantages are the difficulty experienced by transfer passengers, the need for elaborate flight information and signposting, the duplication of staff and facilities in different unit terminals, the difficulty of providing public transport links, and the need (eventually) to join each terminal by people-movers. However, an interesting design that overcomes these difficulties is Seoul, Inchon International Airport by Terry Farrell and Partners. Here a large transportation centre, where rail, bus, car and taxi services congregate, is

11.6 Düsseldorf Airport, showing a combination of linked terminals and radiating gate piers. Architects: Von Gerkan, Marg & Partner.



directly linked to two new terminal buildings: one for domestic and the other for international flights (Figure 11.7).

These five basic organizational patterns allow airports to serve different regions, patterns of demand and management systems. In the developing world, where demand may be uncertain and political stability by no means assured, the airport needs to grow in stages, and this leads to the adoption of the unit terminal concept. In regions where air travel is the main means of business and leisure transportation (as in North America), the more centralized systems (such as central terminal with pier/finger or satellites) are preferred. Mature airports (such as London Heathrow or Chicago O'Hare) may display a combination of concepts applied in varying shapes and geometries. Here a number of terminals are encountered, each built according to the needs and priorities of the time. As new terminals are built they accommodate changes in aircraft design and management practice. Hence large and mature airports (Paris Charles de Gaulle is another good example) start out as single-terminal facilities but finish as complex unit terminals, where each adopts a more sophisticated arrangement of piers, fingers and satellites.

Many airports adopt hybrids of the classification outlined. Here the advantages of different systems are combined in fresh ways to meet the circumstances at a particular location. Kansai is a good example: it is cited here as adopting the central terminal with finger/pier arrangement, but in reality it combines the characteristics of this layout with the advantages of the linear concept. Another example of a hybrid is the United Airlines terminal at Chicago O'Hare, which combines the central terminal idea with a single remote terminal joined by a subterranean road under the apron area. Unlike earlier examples, however, aircraft can be boarded from both terminals, which face each other across a shared apron and runway.[5]

11.7 Multi-modal transportation centre and control tower between Terminals 1 and 2 at Seoul, Inchon International Airport, Korea. Architects: Terry Farrell and Partners.

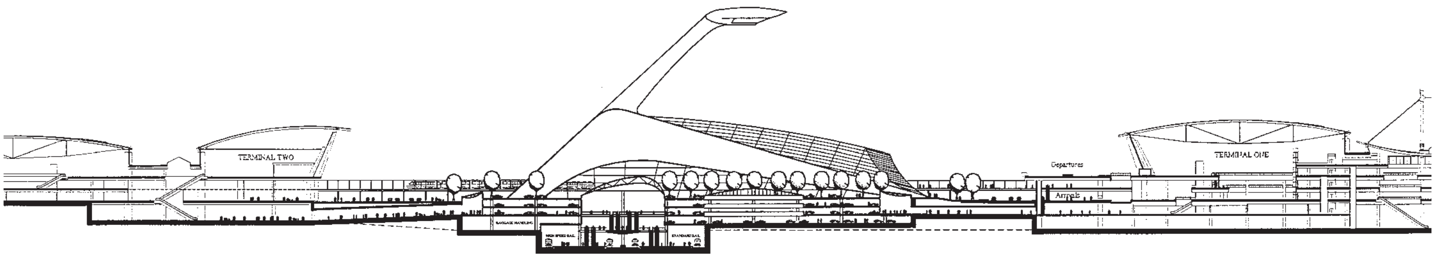
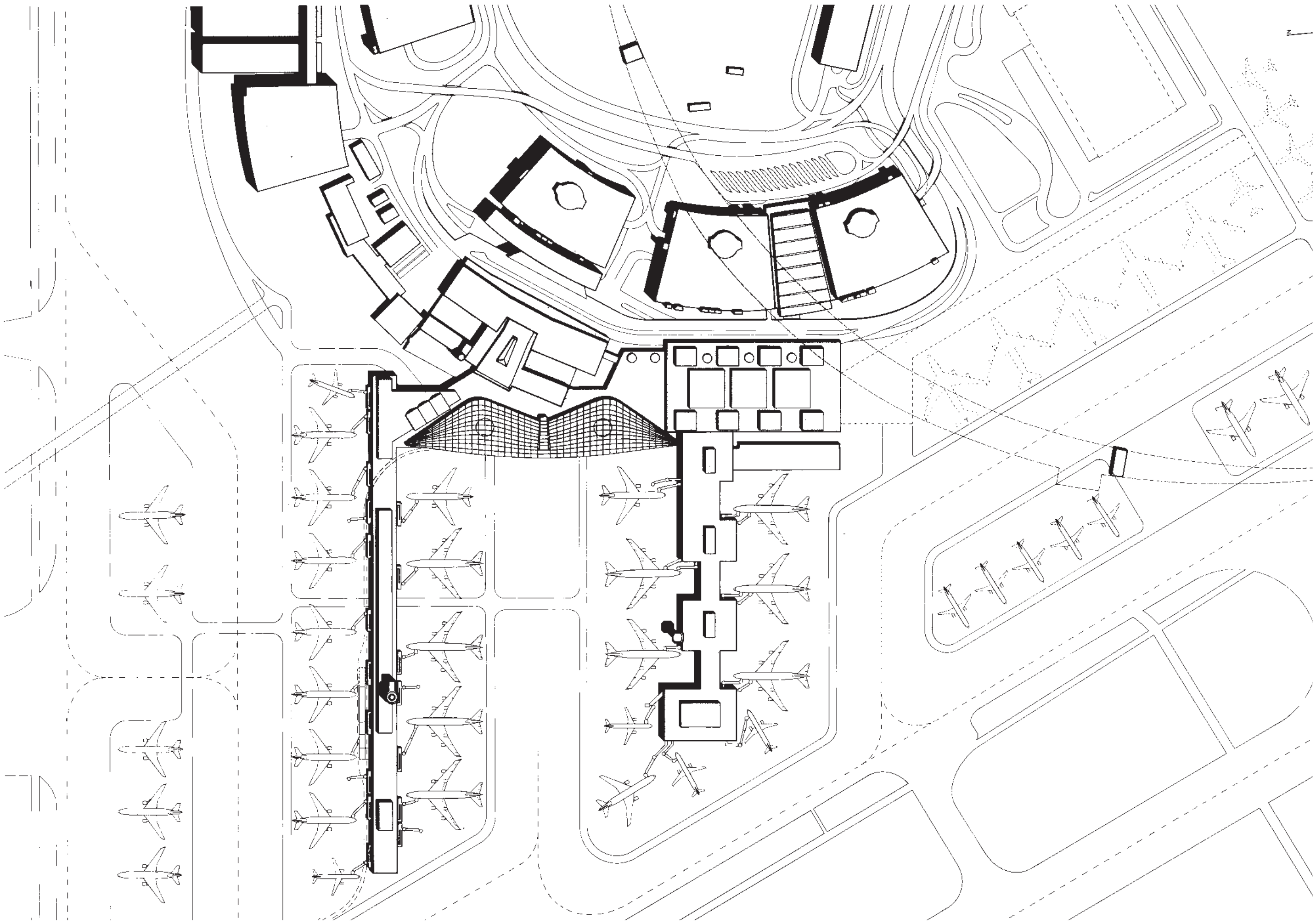


Table 11.1 Different perceptions of airports

Passenger viewpoint	Airline viewpoint	Airport viewpoint
Easy access from road or rail	Terminals that provide efficient space use	Masterplan that provides orderly expansion
Short walking distances from station or kerb to check-in, check-in to gate	Runway layout that minimizes taxiing distances and maximizes capacity	Layout that maximizes runway charge profits
Attractive architecture		
Short queues		
Aircraft depart on time	Runway and apron layout that is energy efficient	Layout that satisfies airline needs at airside and landside
Efficient baggage delivery	Efficient layout for baggage and cargo handling	Attractive airport environment, which smooths community relations
Ample baggage trolleys		
Clear signage		
Good variety of retailers	Attractive and healthy working environment for staff	
Attractive lounges		
Moderately priced eating establishments	Good airport shopping and eating facilities	Regional infrastructure that provides good access to airport
	Low airport charges	Terminal design that maximizes retail income
Safe and secure environment	Effective security controls	Airport design that supports safety and security
		Design and operation with lowest environmental impact

Sources: Adapted from IATA, *Airport Development Reference Manual*, 8th edn, Montreal, Canada, 1995; BAA Annual Report 1995/96; British Airways Annual Report & Accounts 1994/95



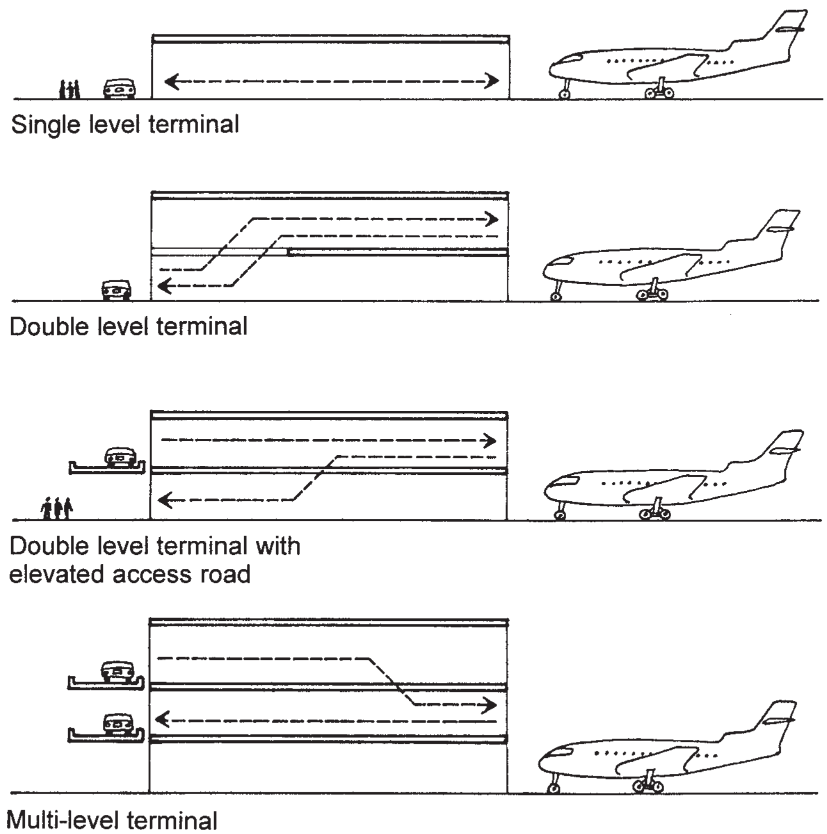
11.8 Zurich Airport redevelopment with hybrid terminal types. Architects: Nicholas Grimshaw & Partners.

Changes in level

The concept in plan and the arrangement in section of the terminal building have a close correspondence. Certain plan types necessitate passengers changing level in order to distinguish between those arriving and departing. Level changes also help with baggage handling and security, which is often provided by a private intermediate floor between the two main terminal levels. Four basic plan/section arrangements are commonly adopted (see Figure 11.9):

- single-deck road, single-level terminal, and apron access to aircraft
- single-deck road, one-and-a-half or double-level terminal, and elevated access to aircraft
- double-deck road, double-level terminal, and elevated access to aircraft
- elevated double-deck road, double- or triple-level terminal, and elevated access to aircraft.

The four basic section layouts are each designed to separate passenger and baggage arrivals from departures. The use of each system, or a combination, is largely the result of capacity: high levels of passenger flow require greater separation in plan and section than low-level flows. It is clear – in the fourth layout in particular – that the design of the terminal, with its elevated



11.9 Vertical segregation in typical terminals.

road system, requires both horizontal and vertical zoning. The different passenger-processing systems are applicable to any airport-planning concept, but the more complex the terminal the more likely it is that several changes in level will need to be employed. Clearly, moving passengers up or down a level has implications for the airport as a whole: the double-deck road system requires elaborate interchanges; the two-storey terminal may require double-height piers, gate lounges and satellites; and intermediate floors may be needed for transporting baggage. Also, the more levels that are adopted, the less flexible the terminal is in terms of internal changes and outward expansion. However, the advantage of two-level road systems at landside is that passengers are already vertically zoned before they enter the terminal, thereby simplifying interior planning. With large volumes, multilevel terminals are inevitable, and because departing passengers require more space than those arriving, the combining of arrivals facilities and baggage handling onto a single lower level tends to be the norm except in the biggest airports.

Single-level elevated piers are often used in conjunction with multilevel terminals (Kansai Airport is a notable exception). The normal arrangement is to have public concourses along the upper pier level, with airline and baggage-handling functions below at apron level. However, security poses a problem on single-level piers, and unless domestic and international passengers are separated and transferring passengers are subject to security checks, two-level operation of piers becomes inevitable. Hence for the larger international airports the pattern adopted tends to be three-level terminals (often involving intermediate gallery levels, as in the design of International Terminal, San Francisco) and two-level piers.

Although many hybrid systems exist, there is a direct relationship between plan arrangement and section type. For example, the Nashville Metropolitan Airport (lead architect Gresham, Smith and Partners) adopts the pier/finger layout with a centralized three-storey terminal; the King Khaled Airport in Riyadh, Saudi Arabia (designed by Hellmuth, Obata & Kassabaum) uses the modular layout with two-storey

11.10 Palma Airport, Majorca, is a good example of a central terminal with gate piers parallel and at right angles to the main building. Notice the way gate lounges provide views over the apron.

terminals; and the United Airlines Terminal at Chicago O'Hare International Airport (designed by Murphy/Jahn) uses a hybrid centralized/linear concept with a two-storey terminal entered at the upper level and terminated at both ends by satellites.[6]

Certain plan concepts suit particular airport operational patterns. The most common configuration of terminal design – a central terminal with long piers placed parallel to its axis or at right angles – is relatively economical to build and operate, and suits both large international and smaller regional airports. Examples include Terminal 4 at Heathrow, North Terminal at Gatwick Airport, and Palma Airport, Majorca (Figure 11.10). Conversely, the modular unit terminal concept suits hub airports, because it allows a separate airline to establish an identity within the whole of the terminal. Such an arrangement can be seen without piers at King Khaled Airport at Riyadh in Saudi Arabia, and with piers at Tehran Airport. Airports that plan for subsequent expansion often adopt the unit terminal layout because of the ease with which additional terminals can be added. Large, mature airports, in contrast, tend to adopt the central terminal with pier arrangement.

Management practice, the nature of the flights taken at an airport (tourist, business, commuter, transfer etc.) and the age of an airport tend to lead to the adoption of different terminal layout concepts. As mentioned earlier, unit terminals are popular with hub airports, because each airline can 'adopt' a terminal, further units can be added without greatly disrupting the life of the airport, and parking can be accommodated

11.11 Airports increasingly support a variety of terminal designs. Here at Cologne/Bonn Airport, Germany, there are multilevel, unit and satellite terminals forming a harmonious composition. Architects: Murphy/Jahn.

directly alongside the terminal. In contrast, centralized terminals with satellites or piers allow the terminal building to provide plenty of space for retail, leisure and business functions, which have the advantage of supplementing an airport authority's income.

Choosing between single-level and multilevel terminals

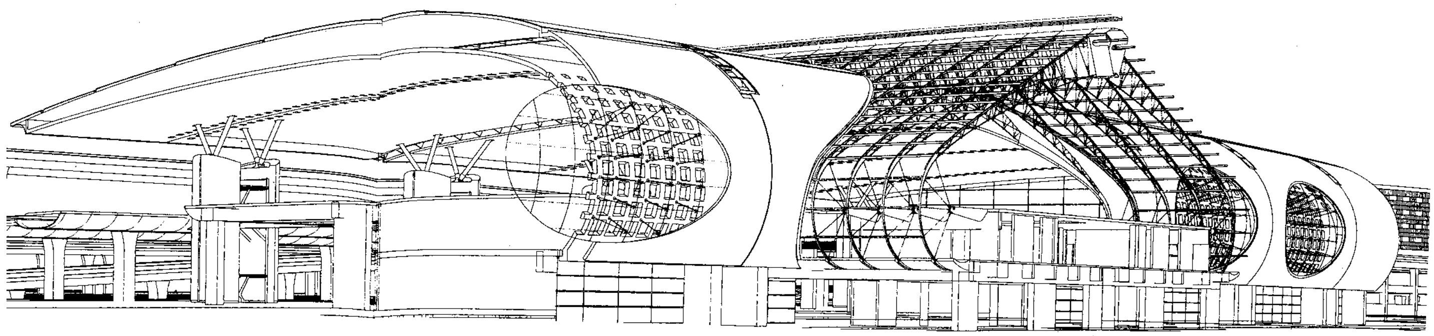
The main function of level changes at terminals is to improve the operational efficiency of passenger and baggage movement. There are four main factors to consider in deciding between single, double and multilevel terminals:

- the volume of passenger flow
- the mix between destination and transfer passengers, and between domestic and international
- the relationship between walking distances and airport capacity
- the type and size of aircraft using a terminal.

Two-level terminals reduce the distance that passengers need to travel, and allow direct access from the upper floor to the aircraft door. Because the aircraft door is normally 4m above the ground, most airports use this figure or slightly more (5 or 6m) for the height between ground and first-floor level.

The smooth movement of passengers and their bagage is the main factor determining the sectional profile of the terminal. Structural elements, such as columns, windows and walls, contribute to the aesthetic appearance and help to define the flow patterns through the terminal. Space and facilities for the general public should be subordinate to passenger space and passenger facilities.[7] The interaction between passenger flow, terminal space and structure is an important one. The organization of the building in plan and section is the primary factor that determines all other decisions. Design and the method of construction need to support the passenger's perception of the flows through the building. They also need to support the organization of the building in terms of airline staff. The functional path followed by passengers at ground- or first-floor level and baggage on the same or a different level is a system reinforced, not impeded, by architectural design.

Because multilevel terminals are by their nature confusing buildings, the task of design is to establish efficient movement patterns and give a sense of orientation. Design should encourage passengers to use architectural clues to find their way around. This means exploiting daylight and sunlight as navigation aids, using the main structural elements to gesture the presence of major routes and concourses, and using the design of interior volumes to signal the flow patterns. Critical points in the flow, such as main entrances, ticket check-in and customs control, should be marked by changes in design. The choice of materials, colour, texture and profile of surfaces needs to signal the presence of important events in the movement through the terminal.



11.12 The complex cross-section of Hall F at Terminal 2, Charles de Gaulle Airport, provides an uplifting space for passengers. Architect: Paul Andreu.

Standard plans, irregular sections

The layout of terminal buildings is becoming globally standardized. The spatial requirements of various activities, the flow path of tasks such as baggage handling, the organization of ticket check-in, security and much else are now universally consistent. What British Airways requires at Heathrow and Air France in Paris is exactly the same as both require in Hong Kong or Sydney. The layouts do not vary no matter what the airline company, airport operator or retailer. The McDonald's or WH Smiths bookshop require a similar floor area, layout and access to building services no matter where it is constructed in the world. The space standards for airline operators are laid down by international bodies (e.g. the Civil Aviation Authority), whether it is in the terminal building, on the apron or the runway, and for retailers by their own global templates. In this world, difference is not a virtue but an inconvenience and a potential inefficiency.

Consistency in space planning is not, however, matched by standardization of terminal buildings in cross-section. One has only to look at the different profiles in section of recent terminal buildings to discover the rich and varied translation of planning need into the spatial dimension. If order and organization are to be found in the plan of terminals, then beauty and event are created by the different applications of structure, space and light in section. It is the sectional profile of terminal buildings which distinguishes them from each other, not their plans. Kansai was one of the first large terminals to exploit the section to produce drama and a memorable spatial sequence from landside to airside. Many recent terminals (notably Terminal 3 at Copenhagen Airport and the design of Terminal 2 at Charles de Gaulle) have developed this theme.

Standardization in plan is the result of the needs of large global players in the air transportation business. The richness and complexity in section reflect the effects of two rival forces. The first is climatic: we may have a global economy of carriers and aircraft but the particular needs of climate vary according to geographical location. In Norway, the new airport in Oslo has to deal with snow loading, sub-Arctic winter temperatures and long sunny days in high summer. The section of the terminal building responds to these climatic imperatives just as that for the new airport in Kuala Lumpur does, but in a different fashion. In both cases, the shape of the roofs, the area of glazing, the angle of walls and the internal profile of floors are adjusted to achieve the best conditions for that geographical location. It is this difference, driven increasingly by the agenda of sustainable design, that leads to variety in section. Climates cannot be ignored, even in an industry governed by international rules and regulations.

The other factor which gives variety to the section is essentially cultural. Different regions have different ways of reading space. The linear progression through western terminals presupposes mechanistic thought. The flat-roofed, air-conditioned airport terminal is efficient in moving people but it does not uplift the spirit or celebrate the transition from land to air or recognize cultural differences. By adjusting the roof profile, by exposing columns and beams as signals, by expanding routes periodically into massive volumes, it is possible to reach people's inner souls. This Jungian internal sense of self needs to connect with the external reality of architectural space. We perceive space differently according to cultural conditioning and airports are beginning to respond in terms of interior design.

So it is clear that while the ground plane is determined by others, the architect still controls the section. And it is the section which gives the terminal its beauty, not the plan. Not only is the floor level dictated by non-architectural forces – efficient passenger flow, profitability for franchisers, security – but its demands vary over time. As a consequence, the plan is forever in a state of flux, fluctuating to the whim or demands of space-hungry commercial activities. The walls also become colonized by advertising posters as further subdivisions of architectural space occur. The syntax of progression or order

11.13 Even with standard layouts in plan, the section provides the opportunity to celebrate travel. Xian Airport, China. Architects: Llewelyn Davies.

is gradually eroded and only the section, especially the upper reaches of terminal space, are unaffected. In this, the roof, particularly the structural members and how the space is lit, becomes critical. The loss of control of the ground plane shifts the architectural emphasis to the roof plans. Here the clues to orientation are to be found in the direction of structural members, in the play of natural light (daylight and sunlight), and in the orchestration of space, light and construction together. The architect of Munich and Stuttgart Airports, Meinhard von Gerkan, likens the task to that of the medieval carpenter who decorated the church roof with elaborate feats of engineering intended to raise the eyes to the heavens.[8] It is important, he claims, to design the roof of the terminal so that it absorbs the changing activities below.

References

1. Adapted from IATA, *Airport Terminals Reference Manual*, 7th edn, International Air Transport Association, Montreal, Canada, 1989, p. 3.26.
2. Norman Ashford and Paul Wright, *Airport Engineering*, John Wiley & Sons, New York, 1991, p. 293.
3. Adapted from Ashford and Wright, *Airport Engineering*, and IATA, *Airport Terminals Reference Manual*.
4. Christopher J. Blow, *Airport Terminals*, 2nd edn, Butterworth-Heinemann, Oxford, 1996, pp. 96-97.
5. *Ibid*., pp. 105–106.
6. These and other examples are taken from *Progressive Architecture*, 3.87, pp. 96–104.
7. IATA, *Airport Terminals Reference Manual*, p. 3.32.
8. Meinhard von Gerkan, 'Airport architecture', paper presented at the conference on Airport Architecture, Lund University, Sweden, 29–31 August 2001.

CHAPTER 12

Conflict between function and meaning in the design of terminals

Design characteristics of passenger terminals

Airport terminals need to be outstanding, satisfying and memorable buildings, which benefit all users or stake-holders:[1]

- passengers
- airport staff
- airport authorities
- airline companies
- the country in general.

As a functional and building planning exercise, terminals are an organizational, logistical, resource and architectural challenge. Because they are particularly complex building types their design needs to eliminate ambiguity and confusion, addressing instead questions of clarity of use, functional legibility and route identification. To remove stress (one of the biggest complaints about modern airports) terminals should provide:

- calmness and tranquillity
- the presence of nature in public areas
- natural finishes and materials wherever possible
- spatial and organizational clarity
- structure and light that express the patterns of use and functional hierarchies.

Because airport terminals are subject to much internal change and external growth they should also:

- be designed for operational flexibility
- be extendible in part and in whole, preferably in more than one direction
- be designed so that the major spaces and activities can be changed without compromising the operation of the whole
- address safety and security in a flexible manner.

In order to meet these constraints the typical passenger terminal normally consists of three main parts or elements, each with its own form and pattern of uses:

12.1 Tranquil departure lounge at Paderborn-Lippstadt Airport, Germany. Architects: von Gerkan, Marg and Partner.

- the main terminal
- piers that give access to aircraft
- ancillary buildings such as railway stations, control towers, car parks and hotels.

Factors that tend to distinguish the present generation of airport terminals are:

- design for flexibility and extendibility
- passenger and user friendliness
- safety and security by design, surveillance and electronic means
- an environmentally friendly approach to the selection of materials and means of providing building services
- architectural quality that addresses the management and perception of value
- cost efficiency through the standardization of finishes, materials and components.

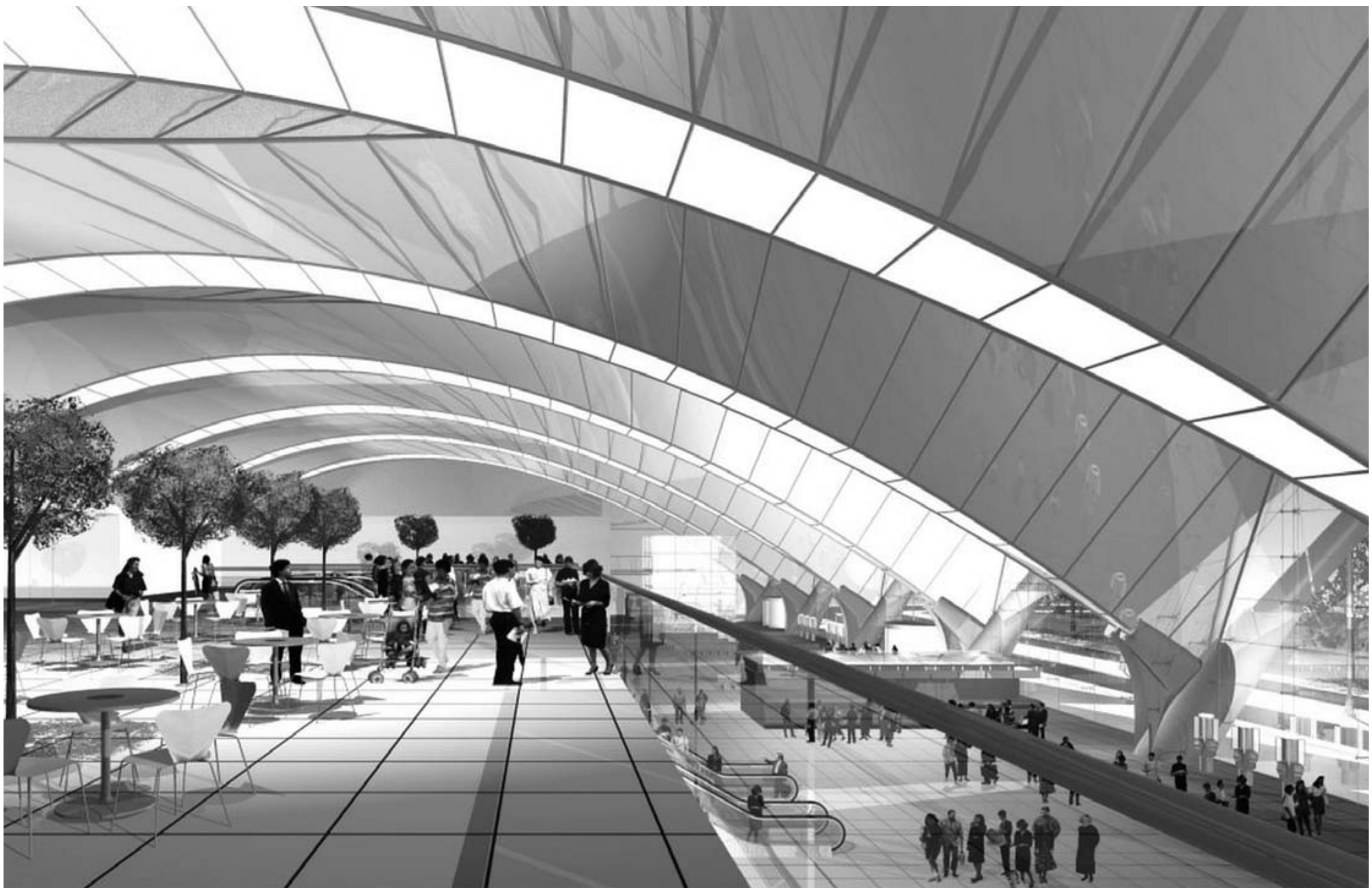
The four key functions of the terminal

The functional design and architectural design of terminals need clearly to correspond. In simple terms the passenger terminal performs four main functions:[2]

- It facilitates a change of transport mode (from train to plane, from car to plane, etc.).
- It processes passengers (ticket check, customs clearance, immigration control).
- It provides passenger services of various kinds (shopping, toilets, eating, meeting and greeting, business and conference).

Table 12.1 Functional areas and activities in terminal

Movement	Activities	Space
Departures	Check-in	Check-in concourse
	Commercial areas	Departure concourse
	Customs	
	Security	
	Shopping	Departure lounge
	Eating	
	Gate check-in	Gate lounge
Arrivals	Immigration	Arrivals waiting area
	Security	
	Baggage claim	Baggage hall
	Customs	Customs hall
	Meeting	Arrivals concourse
	Refreshment	
Transfers	Security	Departure lounge/ Transfer lounge
	Customs	
	Immigration	

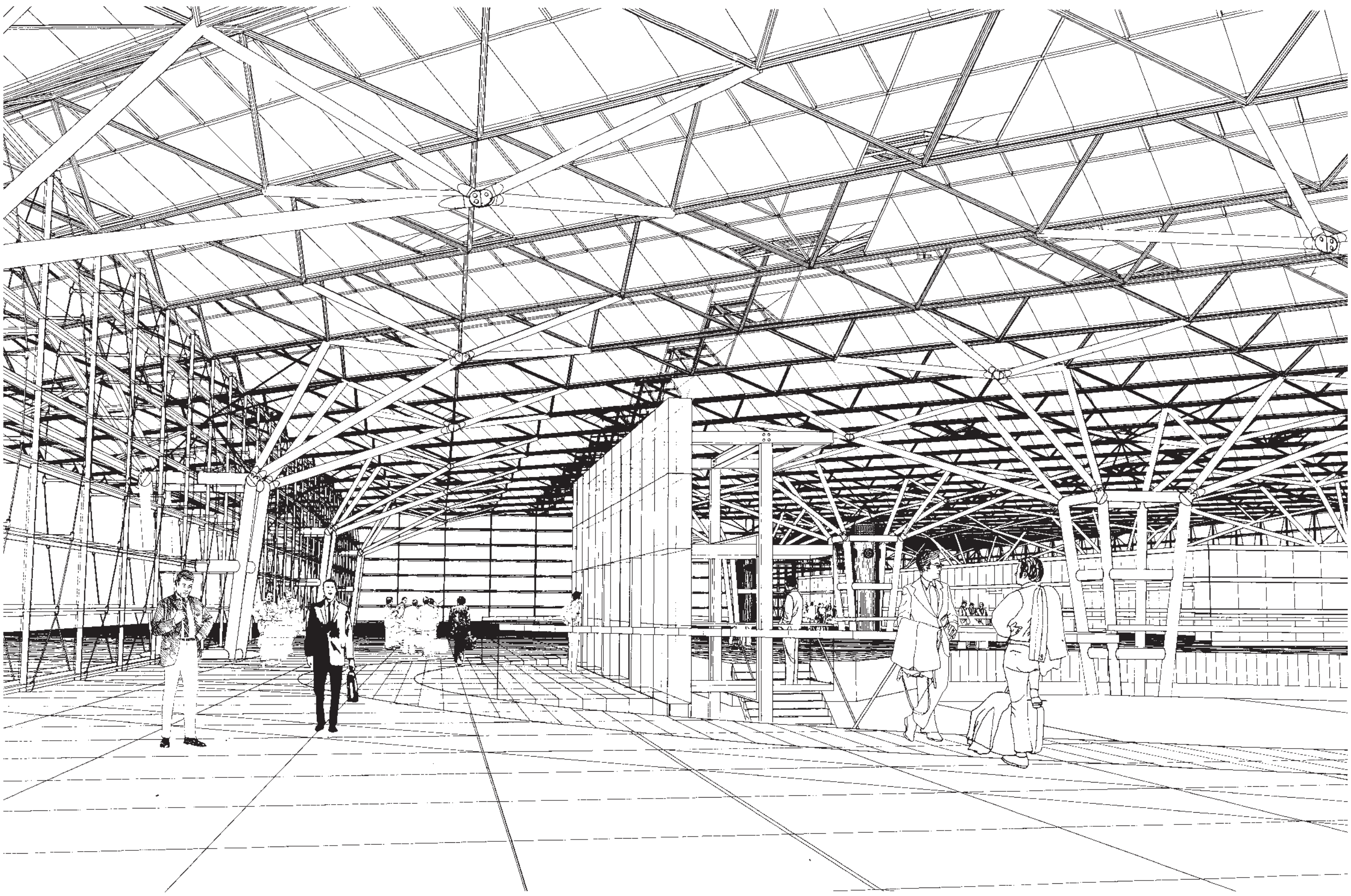


12.2 Clarity of circulation is an important aspect of terminal design. Beihai Airport, China. Architect: Llewelyn Davies.

- It organizes and groups passengers into discrete batches ready for journeys by plane.

These four functions interconnect and interchange. Because the terminal handles movement in opposing currents the space allocated has, to a degree, to be capable of working in reverse. This is particularly true in the gate lounges.

Taking these four primary functions together it is evident that the passenger terminal has to provide space and clarity of use for circulation, processing, secondary services of various kinds, and gathering. In fact the extent of circulation and gathering is such that the typical airport consists mainly of space, not rooms. This means that space is used for a variety of functions (processing, gathering, servicing passenger needs, batching of passengers into flight grouping) with the consequence that the architect has to give particular areas of space the necessary cues to allow passengers to understand the intended purpose. Although open space exceeds enclosed volume, the terminal has to define by design means how an area of space is to be used. Rooms can have nameplates to distinguish their function, but this is less easy with space. Hence the terminal designer has to give functional meaning

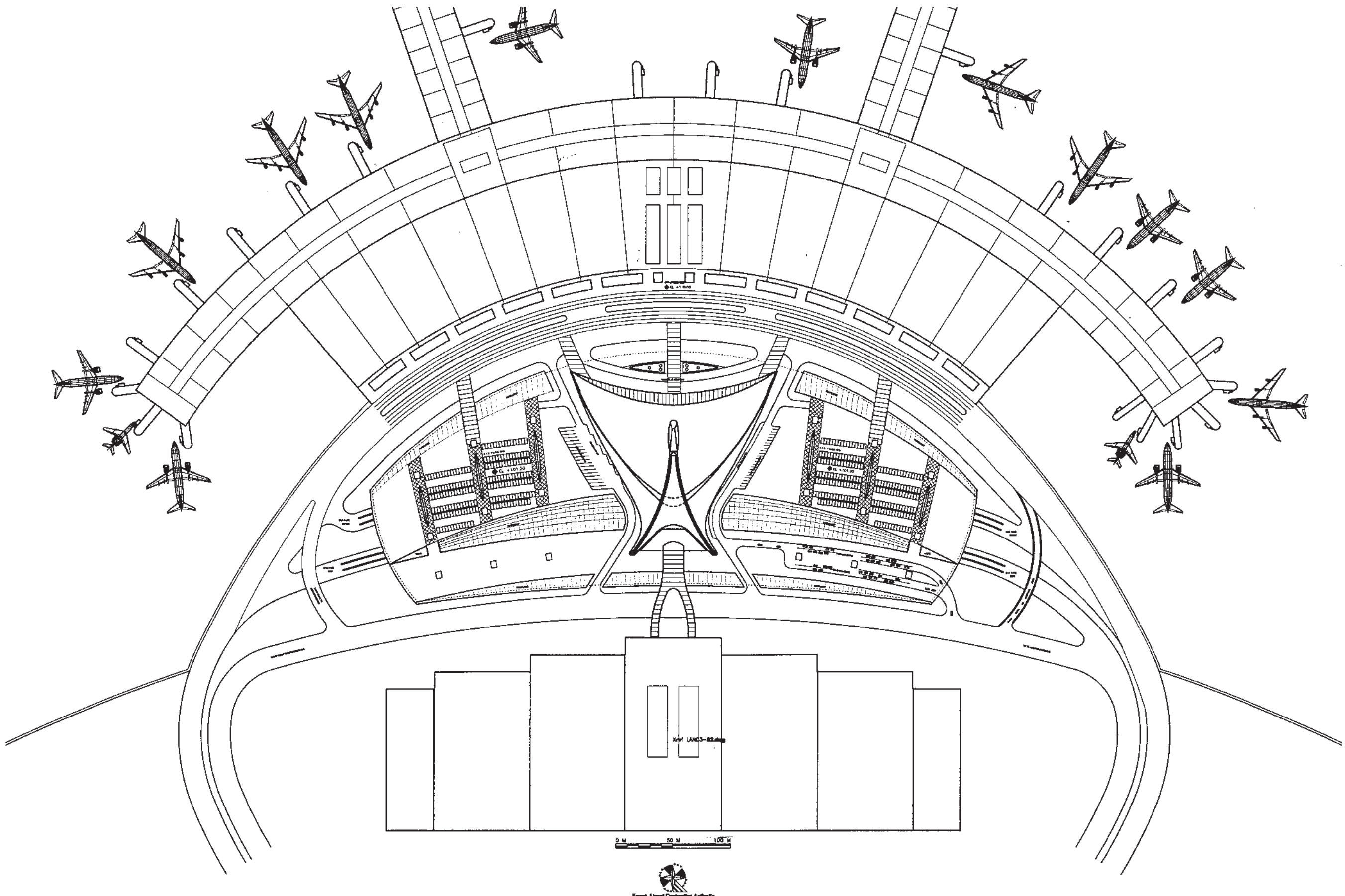


12.3 Tectonic structure, large interior volume and light provide the means of creating airport atmosphere. Extension to Cologne/Bonn Airport, Germany. Architects: Murphy/Jahn.

to the interior volumes, and here the size of the space, the gesturing of structure, the handling of light and 'atmosphere' have all to be exploited.

The four primary functions need to be capable of operating smoothly throughout the total design life of a terminal: that is, 50 years. The trend is for the secondary functions (such as security) to increase at the expense of the primary ones. Also, within the four primary functional orders, passenger services (retail, banking or conference, for example) tends to expand at the expense of processing efficiency. As the balance of importance changes, the use of space in the terminal alters too. Hence, while the terminal must be capable of meeting current functional patterns, it must also be able to adapt to future ones without putting the operation of the airport in jeopardy. Whereas the terminals of old catered exclusively for passengers, the current generation of terminals are designed to attract non-travellers to airport facilities. This too compromises the simple functional pattern outlined earlier.

12.4 At Seoul Airport the transportation centre sits between the two terminals. Transportation Centre, Seoul Airport, Korea. Architects: Terry Farrell and Partners.



Change of transport mode

This function is of growing importance as modern terminals seek to accommodate a wide range of public transport access provision. Architects are increasingly required to provide convenient and legible connection at terminals to rail, metro, bus and private car access. The integration of airports with the regional and national transport infrastructure places particular strain upon the terminal building itself. Some recent airports (such as at the new Seoul Transportation Centre) give prominence to the intermodal function, relegating the terminal proper to a secondary role. At Seoul a huge triangular transportation centre serves two terminals attached one at the apex and the other at the base of the triangle.

Processing passengers

The processing of passengers involves airline staff in baggage and ticket checking, and government officials in security, health and immigration controls. While ticketing is becoming easier as the airline companies introduce smoother passage through check-in controls, the governmental controls are tending to become stricter. The rise in international terrorism, in drug trafficking, the spread of disease, and the increase in political refugees, all mean that ever-tighter controls are needed. Generally, the processing function consists of:

airline function

- ticket check-in
- baggage handling
- gate check

governmental function

- health control
- passport control
- immigration control
- customs control
- security check.

12.5 Directing and grouping passengers is a function of the terminal. The clarity of signage is important. O'Hare Airport, Chicago, USA.

Passenger services

There has been a marked increase in the range and scale of passenger services over the past decade. Generally speaking the terminal may need to provide the following passenger facilities or services:

- retail sales, including duty-free
- restaurants and bars
- banks, post office and currency exchange shops
- business and conference support
- leisure and tourist information
- amusement arcades
- museum (of flight)
- information points, especially for disabled travellers
- health club
- VIP facilities.

The need to provide these facilities should be balanced by the legitimate demands of other passengers for tranquil spaces away from the noisy bustle of retail malls.

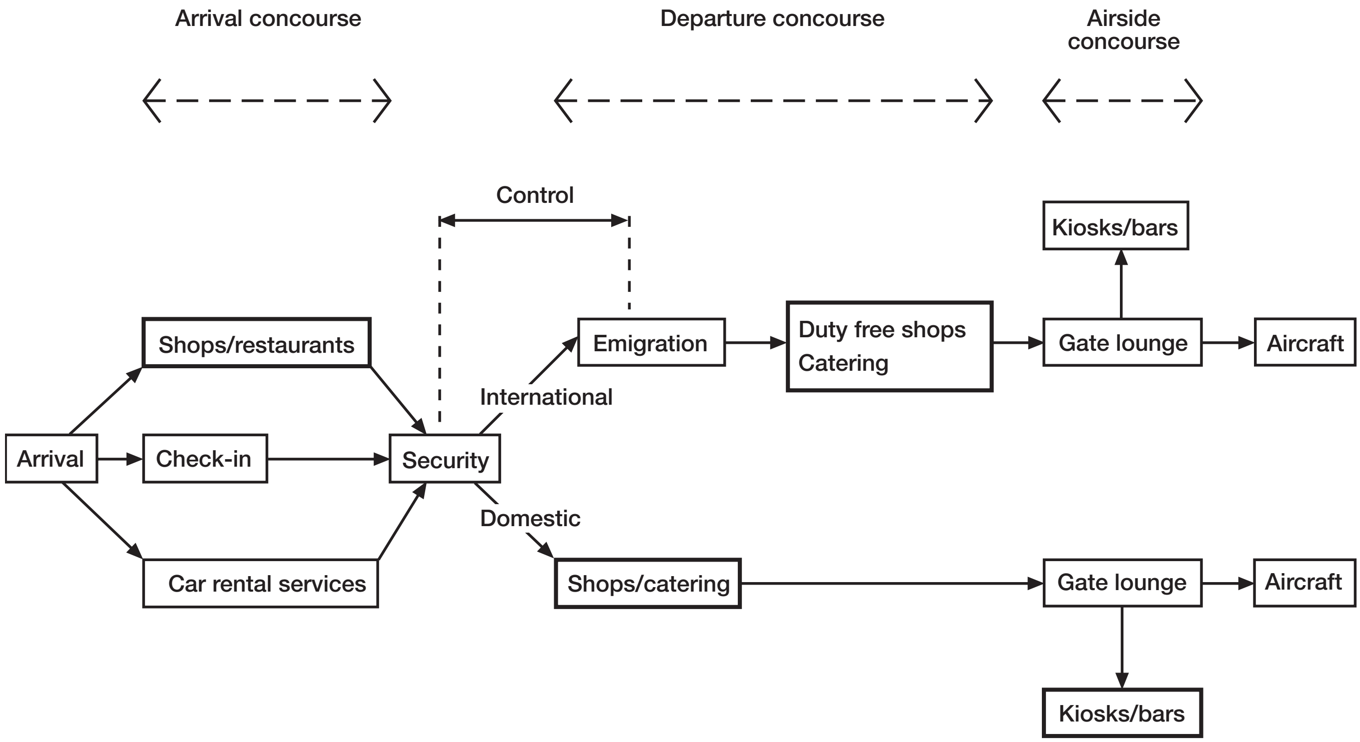
Organizing and grouping passengers

Part of the function of the terminal is to organize passengers into logical flows. This consists in segregating them into arriving and departing currents, in distinguishing physically between passengers and non-travelling visitors, in forming holding areas, and in distinguishing between airside and landside movements. The architecture of the terminal plays an important part in defining the organization of movement. Space, enclosure and barrier are essential ingredients in functional differentiation. The typical terminal contains the following key holding spaces:

- passenger lounges, including general concourse, departure, arrivals and gate lounges
- airside corridor or lounge
- observation deck or lounge
- baggage reclaim area.

The areas are usually served by restaurants, bars and shops of various kinds, arranged as perimeter attractions, galleries or islands.

12.6 Diagrammatic structure of retail facilities at terminal for departure passengers.



Key qualities

The key qualities of a terminal building are functional efficiency, legibility of space, and architectural image. Functional in the sense that the terminal has a job to do and we can measure how well it does it. Legibility and quality of space are also important because passengers spend a great deal of time in terminals. Architecture matters too since it provides, through materials and construction, the immediate experience of the building. These general qualities are not enough, however, to form the basis for the complex and value-laden decisions which have to be taken by airport authorities and their designers. A further list of criteria could include:

- capacity (baggage, terminal, car park, etc.)
- delay (on ground and in the air)
- comfort (for passengers, greeters and staff)
- safety (of planes, terminal buildings, passengers and staff)
- security (on the ground and in the sky)
- orientation (for passengers)
- aesthetics (the image and values projected)
- noise (at airports, in terminal buildings, for neighbourhoods)
- air pollution (at airport, inside buildings)
- convenience (for passengers and staff)
- surface transport (by train, bus, car).

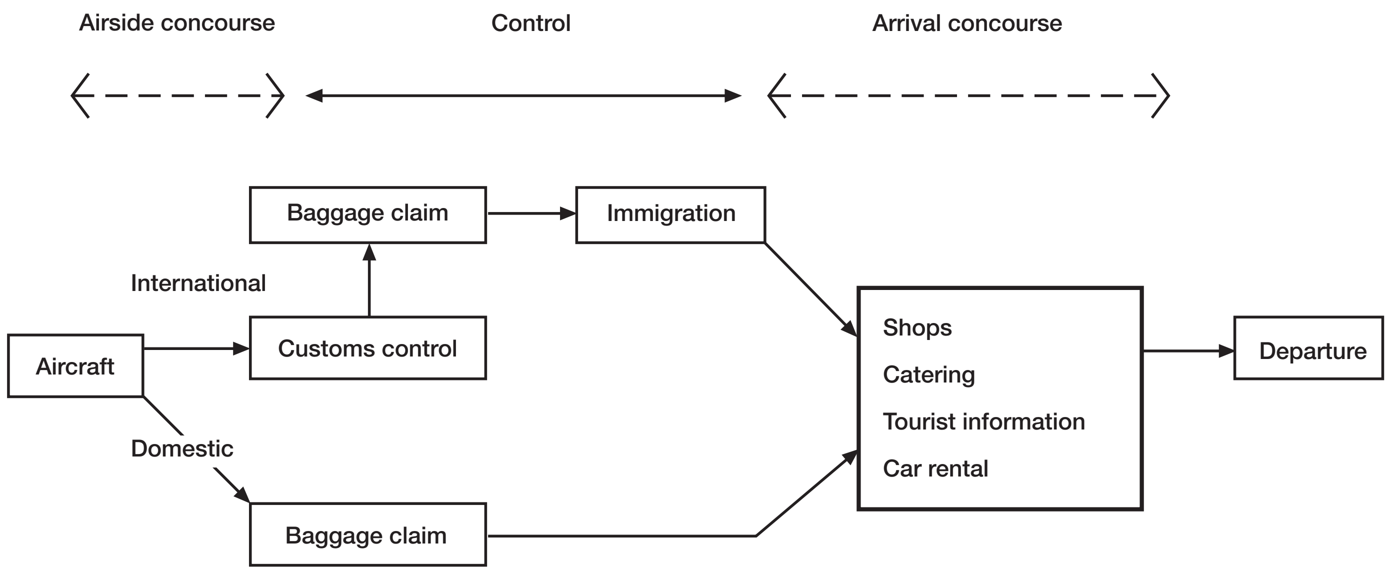
In addressing this fuller list, an assessment strategy is required to reach the optimum resolution of conflicting demands. Four approaches are useful:

- cost/benefit analysis
- cost effectiveness of options
- winner/loser relationships
- limits/values of stakeholders.

The first equates the cost and benefits (or disadvantages) of each choice. This allows a computation of advantages to be drawn up. The second examines the cost effectiveness of different options – setting value for money as the prime objective using techniques such as Value Engineering. The third employs a system of winners and losers, setting targets against positive and negative scores. The final assessment approach examines the limit of action (or inaction) against the values held by an airport authority or airline company (as tenant in a terminal building).

Taken together, the list of key qualities and functional issues, when set against a variety of assessment approaches, provides a strategy for deciding on the size, location and design of airports. It also provides the basis for designing the core components of a modern airport such as a terminal building. It is important to remember that decisions are not value-free. Many of the most complex choices require an appreciation of values – whether they are ethical ones concerned with staff or passenger welfare, or whether they are in the arena of sustainable development. Ultimately, airports like all human development, are not free of the burden of adopting appropriate values which can then fashion the functional and technical decisions required.

12.7 Diagrammatic structure of facilities at terminal for arrivals passengers.



Functional elements of the terminal building

The basic organization of a terminal can be separated into two parallel functional patterns of passenger and baggage movement: departures and arrivals. Both shape the profile in plan and section of the terminal. In addition, there are private facilities that support or regulate the public passenger flows relating to airport, airline and government functions. Their offices and facilities play an important but minor role in shaping the design of terminals.

The terminal consists of two main public spaces: the departures concourse and the arrivals concourse. Each is a key spatial element, which needs to be separately identified. Although the departures and arrivals concourse may coalesce at the airside corridor, the two concourses should not meet after kerbside. There may, however, have to be provision for crossover to serve the needs of transit passengers, and the possibility of either being used in reverse flow.

The departures concourse consists of:

- circulation areas
- waiting areas, including departure lounge
- shops, bars and restaurants
- telephones and business facilities
- information points
- toilets, rest-rooms and first aid
- ticket sales
- passenger and baggage check-in
- immigration control.

The flow relationship, with retail facilities highlighted, is shown in Figure 12.6.

The arrivals concourse consists of:

- circulation areas
- waiting areas, including arrivals lounge
- limited shops and bars
- telephones and toilets
- baggage claim
- customs, health and immigration control.

The flow relationship, again with retail facilities highlighted, is shown in Figure 12.7.

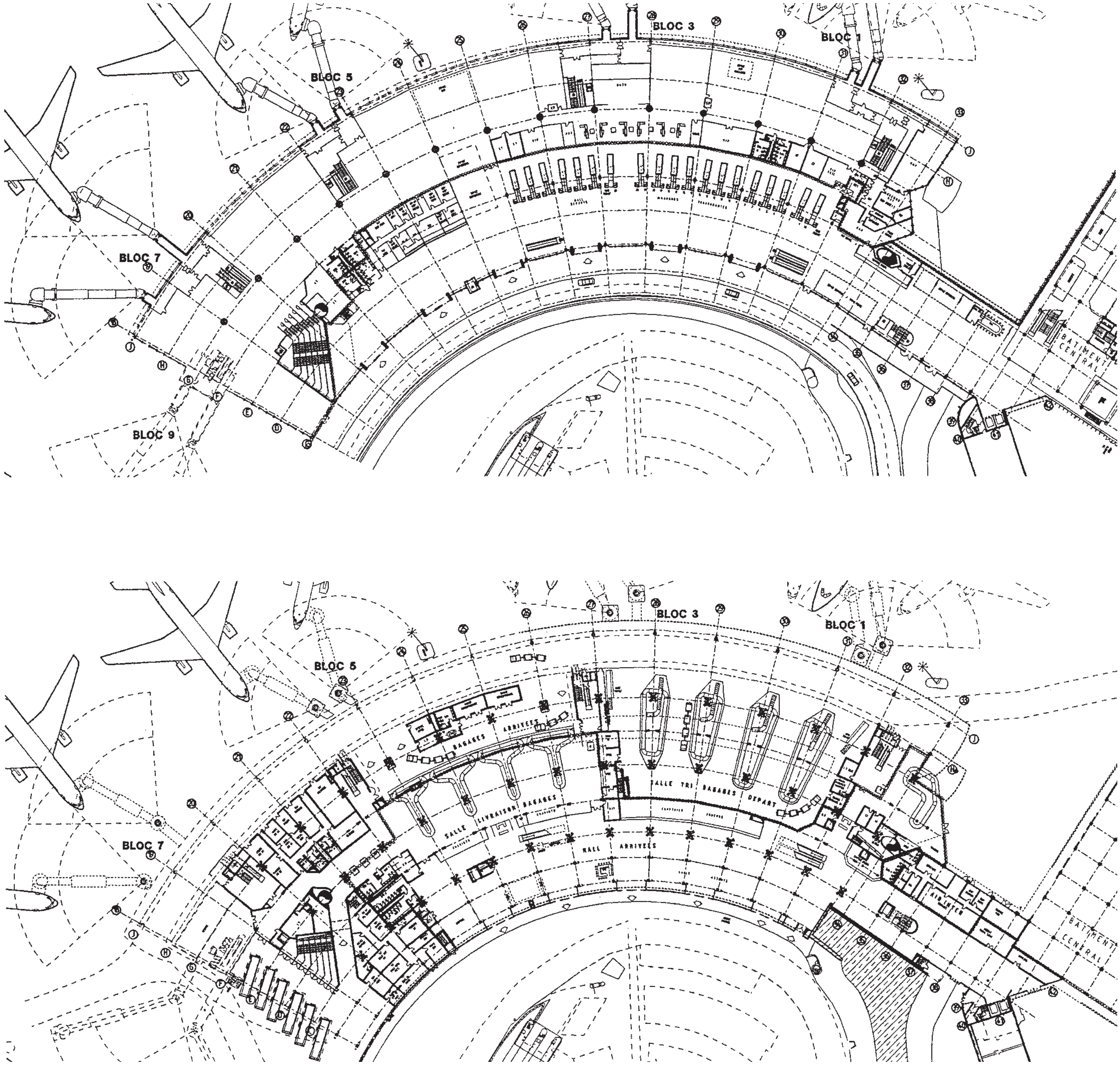
In addition, the terminal building may contain passenger accommodation and facilities that are shared between the departure and arrivals concourses. This includes:

- a common kerbside lounge or concourse (known sometimes as assembly, entrance or general concourse)
- an airside corridor or concourse
- common, transit lounge.

Terminals also contain a wide range of offices or facilities devoted to the passenger movement function, such as:

- airport offices
- airline offices
- customs offices
- immigration and health offices
- baggage-handling services.

The terminal building can be seen as containing three broad functional groupings of accommodation, devoted to departures, arrivals and shared facilities respectively. The triangular relationship between the three – exploited occasionally in triangular-shaped terminals such as King Khaled



12.8 Detail of arrivals floor (below) and departures (above) at Lyon-Satolas Airport, France. Architects: Curtelin Ricard Bergeret with Scott Brownrigg and Turner.

International Airport at Riyadh, Saudi Arabia – leads also to three-level terminals where offices and baggage handling occupy an interstitial level between the departures and arrivals floor. Such terminals provide a clear split in accommodation between public and private facilities, and between governmental ones and those of airline companies.

The terminal designer has the task of giving form to these functional divisions. The airport is a complex play of organizational systems, and the architect has the prime responsibility of shaping and providing meaning to the various parts.

Within each subdivision of accommodation there are a number of variables and options available, depending upon the size and operational characteristics of a particular airport. Planning solutions that work well in one terminal building may not function so smoothly in another. Some of the more complex design issues are listed below.

Circulation areas

The major circulation area occurs between the landside facade and the ticket check-in area. This normally consists of a parallel concourse immediately behind the glazed front of the passenger terminal. Known sometimes as the 'landside concourse' or 'assembly concourse' this area is shared by the general public and the travelling public, and in some layouts by departure and arrivals passengers. Because shops, car rental outlets, bars and restaurants, and ticket sales are found in this area, as well as meeters and greeters and those accompanying departing passengers, there are many flows involved. The circulation areas need to be wide enough to accommodate the various activities, yet of dimensions and shape that guide passengers in the direction of flow.

Facilities such as toilets and flight information boards intended for those travelling should be arranged to prevent the general public from obstructing routes or visibility. Space utilization in the landside and departure concourse should promote efficient and uniform use of the circulation areas, bearing in mind the uneven flows of use that stem from flight departure times. Zoning facilities, and making a clear distinction in the design of space between public and private, and between passenger needs and those of the non-travelling public, can greatly promote the smooth use of concourse areas. Similarly, ticket sales for those who intend to fly but have not purchased a ticket should be provided near to the passenger flow route but should not obstruct it. This is particularly important where, as in much of the USA, self-service ticket machines are provided.

Passenger check-in

The check-in counters and adjoining queuing area are, for the airline company, a crucial zone in the departure concourse. The area is normally part of the shared landside and departure concourse, though on occasions the two areas are partially split (as at Manchester Airport Terminal 2). Check-in is where passengers are allocated a seat and their baggage is transferred to an automated handling system. After check-in, the passenger can idle through the concourse relieved of baggage trolleys, and proceed to customs and flight security checks.

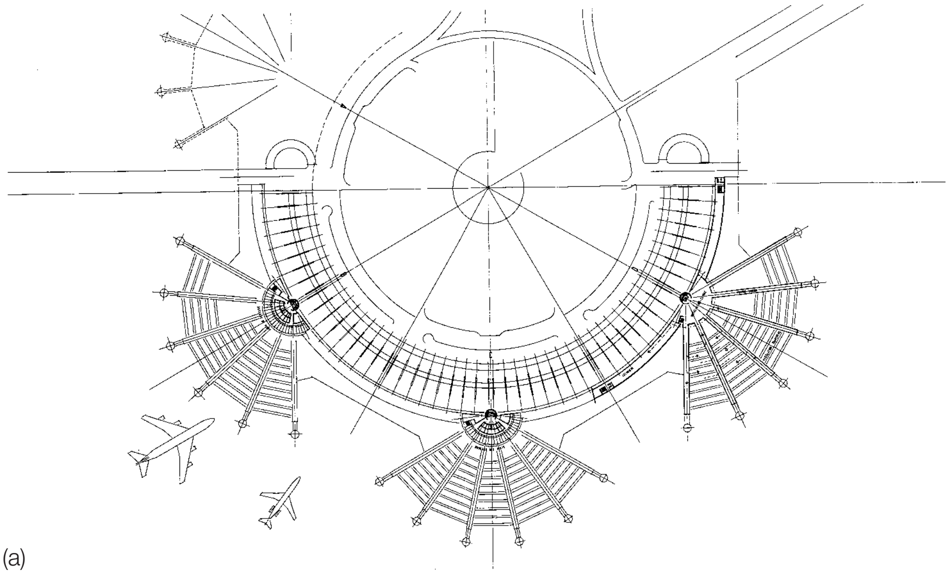
The check-in facility consists of a number of counters arranged as either frontal or island types. Frontal types are made up of a long bank of check-in positions spaced to allow passengers to pass between the counters after check-in. As such, the frontal type arrangement helps to form the barrier between the public departure concourse and the departure lounge devoted specifically for those travelling. Island-type counters consist of banks of check-in points arranged usually along the flow of the departure concourse. There is no attempt to limit access at this point to the departure lounge, where separate control points based upon boarding cards exist. Island counters are useful where centralized check-in occurs (the passenger can proceed straight to the gate lounge, as in commuting flights). Normally, island counters have about 15 check-in positions with the islands spaced 20–25m apart, and perhaps staggered in plan.

With both systems (frontal or island) it is important that the distance from kerbside or railway station to the check-in counter is as short as possible. Where lengthy journeys are encountered, assisted-movement systems should be provided such as travellators or monorail. Clearly, space is needed for passengers and for personal baggage trolleys. It is also important that passengers without baggage to check in have the facility to go directly to gate check-in.

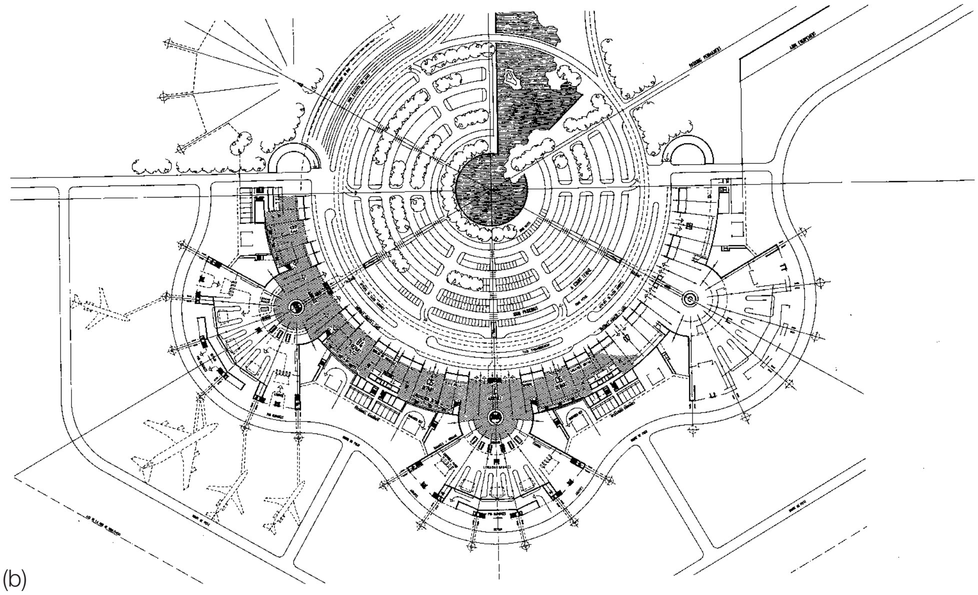
Check-in facilities under any system should be designed so that an airline company can influence the character and layout of the facility. At check-in, the customer comes into contact with the airline for the first time on the journey. It is here that perceptions of quality can be communicated.

The approach of Meinhard von Gerkan to terminal design

The German practice of von Gerkan Marg has established itself as a major player in the design of airports. Responsible for terminals at the airports in Berlin, Munich, Stuttgart and elsewhere (as well as a number of new railway stations in German cities), the practice has recently articulated its approach to transport architecture.[3] There are four main themes or aspects to the design philosophy, each separate



(a)



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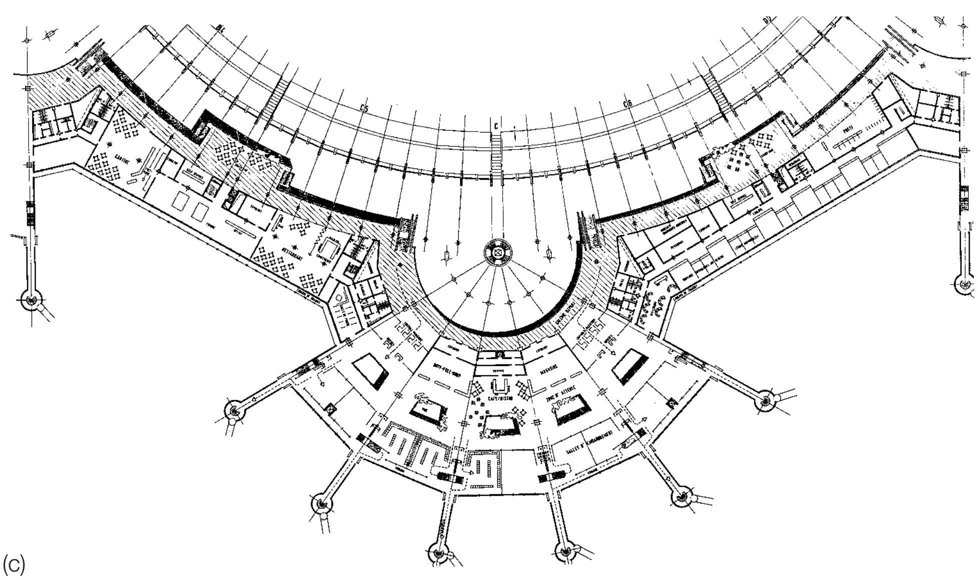
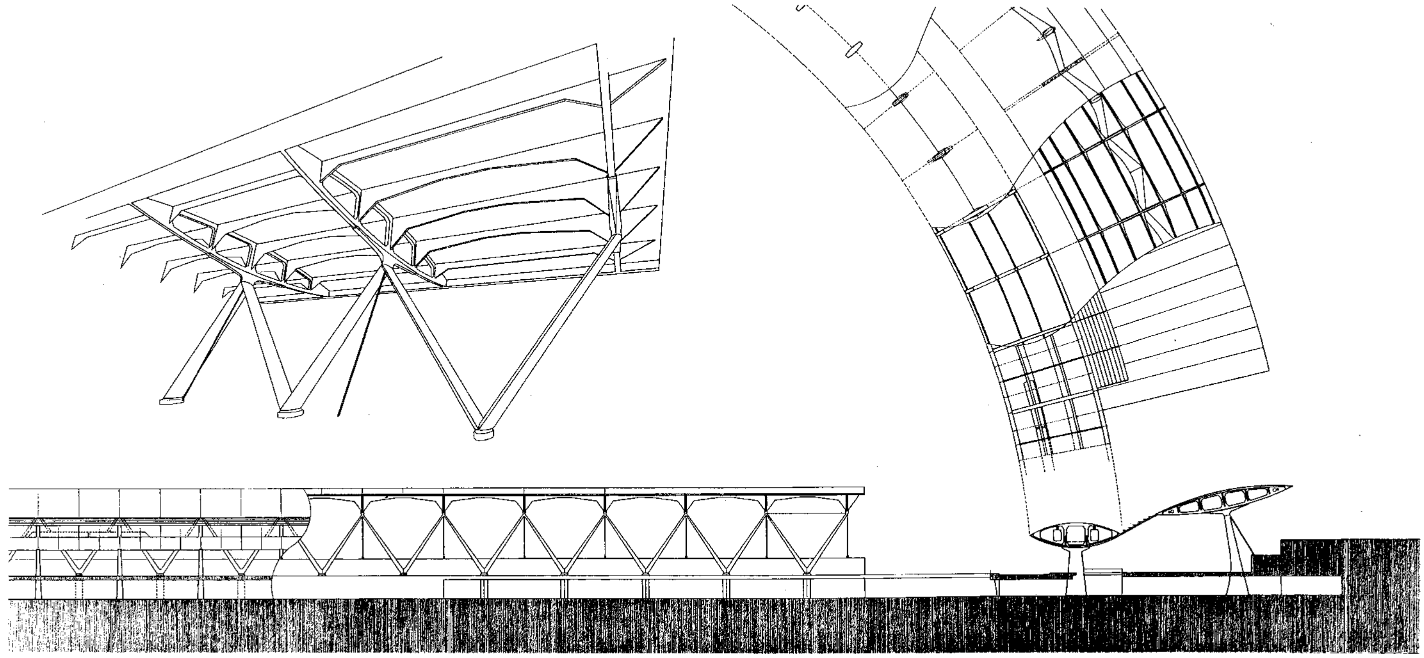


(c)

12.9 The design of Algiers Airport by von Gerkan, Marg and Partner consists of a primary geometry (a) which is translated outwards into the design of external elements (b) and internally into the layout of furniture (c). Architects: von Gerkan, Marg and Partner.



12.10 This drawing of Düsseldorf Airport shows how the structural details influence the character of interior spaces. Architects: von Gerkan, Marg and Partner.

but linked in different combinations to suit the design of a specific airport terminal.

The first concerns the need to establish a clear structure at the outset that can survive changes in the use of space or management approach which inevitably occur over time. This structure is basically a spatial order which derives from the adoption of simple geometric repetition. However, it is a structure which is not overly simple since this tends to produce simplistic (and ultimately dull) solutions. Rather, it is the employment of geometric configurations which are not only pure in shape (such as hexagons or triangles) but also interesting in themselves because of their use in combination. Geometric logic allows for outward growth and internal change since the spatial patterns are easily perceived, capable of repetition, and have a basis which is sufficiently robust to survive *ad hoc* changes. The geometry exists as a primary order that dictates the construction of the terminal and the pattern of lighting. It also, on a series of smaller scales, provides the framework for seating, floor finishes, ceiling tiles and much more. The existence of a powerful order ensures that the macro-scale of design is in sympathy with the micro-scale.

The second theme is the spatial co-ordination of the design of the airport and its hinterland as a whole. This results in the infrastructure of the airport and the design of buildings sharing a logic. As such, the runways, apron areas, roads and buildings are unified beneath an umbrella of dimensional and geometric principles. So rather than design the airport terminal as an isolated building within the airport estate, the approach of von Gerkan Marg is to co-ordinate infrastructure, landscape and architecture in a way which begins to approach urban rather than building design. Taking the first and second principles together, the result is the establishment of robust design whose shapes, dimensions and logic survive the stresses of time.

The third theme concerns the relationship between function and form. Since perceptions of function alter over time, von Gerkan Marg put great effort into creating airport terminals which are strong formally. The strong form is expressed in large, lofty, well-lit volumes, and in an architectural structure that is expressive of purpose and memorable in design. Therefore, whereas other architects create large flexible volumes which are largely neutral of meaning, von Gerkan Marg deliberately infuse their terminals with a sense of landmark. They further justify this approach, arguing that since airports are based upon the same functional system around the world, the achievement of difference has to be based upon non-functional criteria.

The argument which is employed to justify the approach is that it is hard to impose an overall vision later, and that visionary design is what distinguishes one airport from another. Von Gerkan Marg seek to establish 'place' at the outset, since the quality of place is one of the first elements to be lost as the design matures or as the building is used. And since the ground plane under the impact of retail use is largely outside the architect's control, the prime task is to design the roof or ceiling. It is how the roof is supported, what shape it follows and how light is introduced into these deep planned buildings which is the primary challenge of architectural design.

The final theme is that the details matter. Although the architect has to decide upon the large questions of structural design and geometry of space, the experience and perception of quality at the outset are also influenced by the attention to detail. The near-at-hand constructional details such as handrails, seats, and glazing assemblies are crucial to the quality of the passenger experience. These should, according to von Gerkan Marg, be in the remit of the architect. Although airport terminals are a machine of moving people, they are also experienced statically. The static expression at a detailed level matters.

Like a classical building, von Gerkan Marg argue that all transport buildings by the practice have a unified sense of order. The principles which govern the whole also dictate the detail. The approach provides a logic which is readily understood by airport managers and passengers, resulting in a combination of structural and spatial clarity. Navigation through the terminal is fashioned architecturally, and identity is provided by place-specific interventions that owe as much to cultural reference as constructional logic. It also means that later, when other designers are employed to add to the airport, the original philosophy is plain to see and easy to reinterpret.

References

1. The objectives are taken from Aviaplan AS (brochure), Oslo, 1995.
2. The list is an expansion of those quoted by Norman Ashford and Paul Wright in *Airport Engineering*, John Wiley & Sons, New York, 1991, pp. 286–287. The authors acknowledge only three functions, relegating ‘passenger services’ to a subfunction of ‘processing’. Another useful source is IATA, *Airport Terminals Reference Manual*, 8th edn, International Air Transport Association, Montreal, Canada, 1995, pp. 110–112.
3. Keynote address by Meinhard von Gerkan, conference on airport architecture, University of Lund, Sweden, 29–31 August 2001.

Passenger types, space standards and territories

CHAPTER 13

The terminal is the interface between landside and airside, between the customs-controlled and duty-free world and that of the public concourse, and between being on the ground and in the air. As a building, the terminal is a crucial and symbolic structure on every airline passenger's journey. It is both gateway to the air and, in the opposite direction, a gateway to a continent. One progresses through the terminal, moving between a series of controls and temptations from terminal entrance via the exit gate to the aircraft.

Principal terminal territories

Most terminal buildings consist of six distinct territories on departure:

- entrance concourse
- flight check-in and information
- shops, bars, restaurants, cinemas etc.
- passport control
- departure lounge and duty-free shops
- pier and gate to plane

and four territories on arrival:

- arrivals lounge
- baggage reclaim
- customs and immigration control
- exit hall.

Generally, the division between arrivals and departure is split (at least in larger airports) between different levels, with the majority adopting first floor for departures and ground floor for arrivals. Also, the entrance concourse and exit hall are usually the same space, perhaps zoned laterally to avoid conflict of movement.

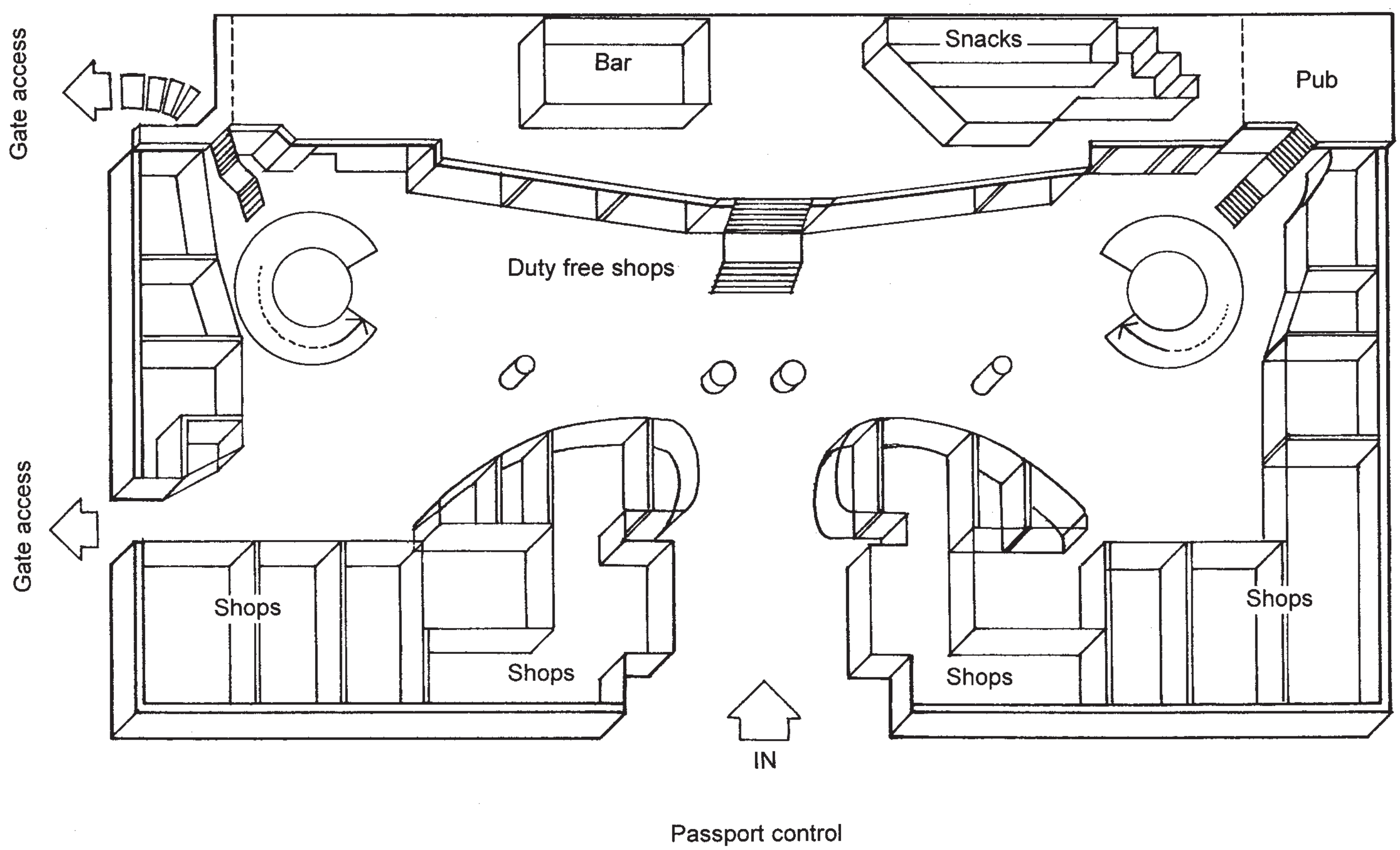
Early generations of terminal buildings (such as Heathrow Terminal 1) placed few temptations between the passengers' arrival in the building and check-in, or between the departure lounge and gate lounge. However, with greater commercial pressure and the need to achieve higher profits, the modern terminal has a sequence of

13.1 Inlaid marble art installation used to aid navigation at Terminal 2, Copenhagen Airport.

shops, cafes and bars placed conspicuously between the essential elements of the journey. Now upon entering a terminal building the passenger is more likely to be faced not by a bank of flight check-in desks but by burger bars, newspaper stalls and gift shops. These have to be negotiated before eye contact can be made with the airline company's desk. A similar pattern of interrupted movement through the terminal occurs after baggage check-in. Again, with less baggage, the traveller is vulnerable to the pull of 'dwell time', and here more commercial outlets will be found, especially close to passenger flows. This sequence continues until the passenger boards the plane and, to a lesser extent, returns when he arrives at the destination. The design of the terminal building is as much shaped by the needs of duty-free and tax-paid shopping, refreshment and leisure as by the logistical path from taxi to plane.

The revenue generated at terminals is determined partly by the nature of flights handled, and partly by the split between passengers, airport workers and visitors. Passengers are the most lucrative source of income, especially long-haul holiday and charter passengers. The latter in particular tend to spend longer in terminals than other passengers, and the special characteristics of charter holidays tend to encourage a spending spree at airports. Business travellers, though they may use conference, health club and restaurant facilities, tend to be frequent users of terminals, and pass through without loitering in shopping areas. Business trips do not attract 'meeters and greeters', so there is less income generated here as well. The design of a terminal needs to reflect the passenger mix: where charter and scheduled flights share a terminal the range of facilities (and of opportunities to spend money) is greater than in a terminal catering almost exclusively for domestic business travel. The trend towards the commercialization of terminals is fuelled by a combination of airport privatization and the growth in relatively high-spending charter passengers.

A good example of the favourable environment at terminals from the point of view of retailers is the toy store Hamleys. Besides the company's headquarters store in London's Regent Street, it has outlets at Heathrow and Schipol Airport and also a store at the Channel Tunnel terminus near Folkestone. Hamleys recognizes that modern transportation buildings provide locations as favourable to trade as traditional high streets. Similarly, Mappin & Webb's shop at Heathrow's Terminal 4 is the biggest-selling outlet for Rolex watches in the UK.[1] Besides retailing, some airports are beginning to introduce museum facilities into terminals. At Gatwick an attraction known as Skyview provides a museum on the theme of flight. There are sections on aviation history and on how the airport works on a daily basis, a chance to sit in a De Havilland Comet cockpit, a simulation ride in a Harrier jump-jet, and a



13.2 Retail plan at departure lounge. Notice that to reach the gate access passengers need to pass by shops. Gatwick North Terminal, UK. Architects: YRM.

fine panoramic viewing gallery. The shift from retail to leisure is one of the defining elements of late twentieth-century terminals.

Passenger types

Passengers at terminals come in a variety of types, and each has its own needs. There are often whole families, heavily laden and travelling at a slow pace in comparison with business passengers armed only with a briefcase and generally rather in a hurry. Long-haul passengers tend to carry the most baggage, and are usually tired from long flights, leading to frequent stops, often for refreshments. Transferring passengers are often racing through the terminal in order to catch connecting flights. Elderly travellers, perhaps in wheelchairs, also form a clear group, as do young mothers with small children. The diversity of passenger types places facilities under different pressures. The design of the terminal should therefore be such that all categories of passenger are successfully catered for: in fact, passenger loyalty depends as much upon the experience of the terminal as on that of the flight itself. One source of particular frustration is that of queuing. Queues are wasteful of space, pose a threat in the event of fires, create a poor impression of the airport, and use

13.3 Passenger movement is a key function of terminal design. Here at Terminal 2 at Charles de Gaulle Airport the routes are kept clear of seats and advertising signs. Notice the role of daylight in signalling the route.

13.4 Check-in queuing at Gatwick Airport. Trolleys double as useful seats. North Terminal, Gatwick Airport, UK. Architects: YRM.

13.5 Exiting the terminal with baggage requires large doors. Oslo Airport.

space that could be exploited for retail sales. The eradication or reduction of queuing requires attention to architectural design and airport management. For example, queues often build up near to congested exits, escalators or lifts owing to lack of provision for peak demand. Queues are also the result of ineffective management: a lack of airline staff frequently leads to long lines of people at check-in desks (this is a particular problem with charter flights). Innovations in central ticketing, which allow check-in at airport stations and car parks, offer future solutions. As a general rule passengers should be relieved of their baggage immediately upon entering the terminal, and ideally before they reach the building.

Types of terminal user other than passengers

Terminal buildings do not of course cater only for passengers. Although passengers may be numerically the largest component of terminal users there are at least six other groups of users:

- airport employees (airline staff, airport staff, shop and restaurant staff, customs officials)
- meeters and greeters (who often buy souvenirs)
- leisure visitors (who use the airport as a tourist attraction)

- local residents (who use the terminal as a convenient point to shop)
- business people (who use the airport's conference facilities)
- police and security guards.

Catering for the needs of all these groups requires careful planning of airport terminal facilities, perhaps assisted by computer queue-modelling systems. There are obvious conflicts to resolve in the allocation and distribution of terminal space. Ensuring that airline passengers receive clear guidance and information on their journey through a busy terminal is a priority that should not be jeopardized by commercial pressure. In some airports, such as Gatwick and Frankfurt, the passengers' smooth movement through the functional zones of the terminal appears at times to be impeded by shops, bars and souvenir shops. When fires occur (as at Düsseldorf Airport in 1996) it is important that passengers' perception of escape routes remain clear.

Passenger space standards

The growing commercial pressure at terminals should not be at the expense of space standards for users. IATA recommends the following average standards of space per airport passenger:[2]

- check-in queue area: 1.4m^2
- waiting and circulation: 1.9m^2
- hold area: 1m^2
- baggage reclaim area: 1.6m^2
- government inspection: 1m^2.

Taking all the space needs together, it has been calculated that the gross area of a terminal is 14m^2 per peak-hour passenger for domestic operations and 24m^2 for international.[3] Modern safety needs may increase these figures by 20 per cent where total separation of departure and arrival passengers is needed at airside, and where special security baggage-handling systems are demanded. The total floor area per passenger may then approach 29m^2.

Terminal facilities

The terminal building provides services of various kinds, including shopping, banking, hairdressing, entertainment, business facilities, car hire, and shoe cleaning. There are also services beyond that of retail or commercial sales: some, such as lost persons points and chaplaincy support, have a distinct social purpose. With 54 million passengers a year using Heathrow Airport, the throughput of people begins to approach that of the whole population of Britain. Viewed in such terms terminal buildings are more than just retail malls en route to the plane.

The non-retail services provided in terminal buildings at larger airports may include:

- banks
- foreign exchange shops
- information on land-based travel (trains, buses)
- car rental
- tourist information
- showers
- rest areas (with short-stay beds)
- laundry and dry cleaning
- beauty salon
- hairdressing
- medical services
- conference and business facilities
- spiritual support (chapel or mosque)
- cinemas and video area
- amusement arcade
- health centre
- business club
- swimming pool
- VIP lounge.

Some of the facilities and services may be provided in an adjoining building (such as a hotel) but most are contained within the terminal itself.

The Federal Aviation Administration (FAA) recommends the terminal design space standards listed in Table 13.1, which supplement the passenger space standards listed earlier. Because space standards are a reflection of levels of use on

Table 13.1 Terminal space standards

Area	Space per peak hour passenger (m^2)
Ticket lobby	0.95
Waiting areas (departure lounge etc.)	1.8
Eating and shopping areas	2.1
Visitor waiting areas (arrivals concourse etc.)	1.5
Baggage claim	1.0
Toilets	0.3
Customs	3.3
Immigration	1.0
Public health	1.5
Circulation, building plant, walls etc.	19.1
Airline operational	4.8

Source: FAA Terminal Space Design Standards

the one hand, and of efficiency of space utilization on the other, the standards are not absolute but merely recommended. Also, congestion is a measure of peak demand overcrowding, and not of the terminal under normal working conditions. Hence terms like 'typical peak hour passenger' and 'standard busy rate' are employed to distinguish between peak and normal operation.

The table confirms that terminals are buildings primarily of circulation space; areas of specific function and enclosure are of secondary importance in terms of total floor area.

Commercial versus facilities management

The design and layout of the terminal building highlight the dilemma between the concept of the terminal as a means of generating income for the airport and that of the building as a public and social facility. The relative balance between the two positions directly influences the character of the terminal. With terminals designed to generate the maximum of income, passengers are faced by banks of shops, bars, car rental offices and duty-free areas, with the travelling element such as check-in desks having a minor role. In contrast, in terminals such as Saarinen's TWA building at Kennedy Airport, New York, which have more of a public service role, the uncluttered space and uncrowded concourse areas give priority to the needs of passengers. Here check-in desks, staircases and travel information provide for those travelling rather than those visiting to purchase goods.

The trend at terminals is, however, to exploit 'dwell-time' by providing a range of facilities and entertainments to distract the traveller between arrival at the airport and departure on the plane. Commercial needs rather than social ones are normally given priority at the design briefing stage. The layout, organization and design of passenger terminals have increasingly to accept the demands of income generation. In fact, BAA earns over £700 million per year from retail-type activities at its UK airports, which exceeds by £100 million the amount of money that the company spends each year on building operations of various kinds. Viewed in this way retail revenues pay for terminals without the additional income from landing fees. Airport managers and finance directors of airline companies understand how to exploit passenger flows to generate revenue. Terminal design therefore often directly reflects the need to maximize concession revenues. This means placing as many retail activities and as much commercial space between entrance and plane as possible. It also means putting these activities (shops, bars, restaurants, duty-free concessions, car rental offices) directly in the line of passenger movement. Where concourses are split between arrivals and departure levels, it means placing commercial space on each floor level, thereby generating income from both departing and arriving passengers. Under such pressure it is easy to see modern passenger terminals as retail malls through which passengers pass – not to the supermarket check-out but to the airport check-in or departure lounge. It also explains the pressure to upgrade and expand earlier generations of terminals (such as Gatwick's North Terminal) in order to earn more from retail sales.

The location of retail space is of crucial importance to the ability of franchises to generate income. Direct contact by passengers with commercial areas (say, within 10m and on the same level) on their passage through the terminal is ideal. Locations out of the line of movement or out of eye-shot are less favoured, and tend to be used for specialist services such as hairdressing, cinemas or health clubs.

13.6 Retail and catering facilities can either obstruct or enliven concourse areas. Terminal 2, Manchester Airport, UK. Architects: Scott Brownrigg and Turner.

In 1993/94 retailing revenues at UK airports exceeded for the first time those from charging airlines for the use of the facilities. Landing fees, which provided the bulk of income hitherto, now provide less income for BAA than retail or car parking revenue generation. Such was the growth in retail and leisure activities at airports that BAA set a target of doubling the retail space at its airports by the end of the century. This put pressure on public concourses and on the openness and legibility of interior routes, and posed additional fire and security threats. It is no coincidence that the fire at Düsseldorf Airport in April 1996, which killed 16 people, began in the shopping area of the terminal. Detecting fires and organizing escape becomes more difficult as terminals become more multi-functional in nature.

Types of shop and their location

The characteristics of shops in different terminals reflect the type and destination of the passengers present. For example, Far Eastern passengers at Heathrow's Terminal 4 lead to shops such as Harrods, Selfridges and Austin Reed, which tend to sell classic fashion goods and high-quality accessories, while at Terminal 2, which is served by Air France and Alitalia, most sales are of traditional English goods. The types of shop reflect the type of people at a particular terminal. Where there are plenty of package holiday-makers using a terminal, one would expect more bars, restaurants and shops selling leisure and sporting wear. For some retailers, the objective of having shops at airports is not simply one of sales but of ensuring that foreign visitors see the company's name as soon as they arrive in the country. Terminal shopping is often profitable for the retailer: BAA's research has shown that landside concourse shops earn twice as much per square metre as do high street shops, and airside shops (where goods are tax free) nearly three times as much.[4]

Normally, with separate arrivals and departure floors retail activities are concentrated on both, but some terminals (such as at Gatwick) place an intermediate commercial floor between the two. This has the advantage of removing some of the clutter from the principal floors and allowing larger retail units to locate in the terminal. As a consequence the North Terminal at Gatwick has many household name stores within the complex. For the traveller, there is the choice of avoiding the retail areas altogether or of shopping in stores where price and quality are more competitive than with more traditional layouts.

It is normally considered a disadvantage for retailers if passengers have to move up or down a level to use shops or catering facilities. Where shopping at airports is successful with changing levels it is normally because many purchases are not undertaken by those about to travel but by casual visitors, airport staff and greeters. Where large glazed lifts and plenty

13.7 Terminals linked to hotels and surface transport greatly expand the commercial potential of airports. Munich Airport Centre, Germany. Architects: Murphy/Jahn.

of escalators are provided, some of the disincentive to change level is overcome, but evidence from Frankfurt Airport suggests that even with such measures turnover is down by 40 per cent with multilevel terminal shopping.[5]

The design and layout of terminals are driven by the need to generate as much secondary income as possible. Although in American airports the car rental business provides the biggest income (by way of rents and leasehold arrangements) for the terminal, in European and Asian airports it is that from shops, bars and particularly duty-free outlets. Because terminal income often exceeds that of airside income (such as landing fees and aircraft parking) there is much pressure to improve the performance of existing airports where space for commercial activities may be limited by out-of-date designs. As a consequence, there is currently a trend towards expanding existing terminals to create extra commercial space (for example, the enlargement of Marseille Airport by the Richard Rogers Partnership).

The distinction between the retail zones of a terminal building needs to be defined by the choice of finishes and

13.8 Materials that maintain their appearance and are easily cleaned are a feature of circulation areas. Manchester Airport Link, UK. Architects: Aukett Associates.

lighting, though it is tending to be eroded by commercial pressures. The passenger and leisure visitor are both potential customers of franchisers; the departing and arriving passenger is also targeted, as is the airport and airline employee. To some extent the distinction between airside and landside is being weakened, with many retail outlets now placed beyond the immigration control barrier. The clearly defined distinction between flow areas and commercial areas is a casualty of changing design and management philosophies. In the older generation of terminals (such as Heathrow's Terminal 1 or Paris Charles de Gaulle) large volumes of movement space were provided without the competition of retail units, flower stalls and advertising hoardings. However, today's terminal is based upon the concept of avoiding the physical separation of passenger flows from other activities. What is now sought is a kind of integration in space planning where passengers are deliberately routed through commercial areas and encouraged to linger by long check-in times.

Other sources of commercial revenue

Besides direct sales, the passengers' presence also generates income from advertising. Large, often changing signs are an increasing feature of the international terminal building. Their presence needs to be designed into the fabric of the terminal rather than (as is normally the case) added as an ill-fitting afterthought. The best locations for advertising hoardings and free-standing boards are close to passenger traffic routes within and outside the terminal. For those that let advertising space, a site at right angles to flow generates a great deal more income than one placed parallel to movement. On long routes, such as access corridors leading to gate lounges, well-designed advertising displays can enliven a dull journey, but too much advertising may annoy jaded passengers.

Another source of income at or adjacent to terminals is from hotels. It has been estimated that a throughput of 1 million passengers per annum generates the demand for a 100-bed hotel (that is, a 50-room hotel).[6] As with retail space, the hotel can be run by the airport authority itself, or more likely by a hotel franchiser who pays for the lease of land or rental of part of the terminal building. At Charles de Gaulle Airport in Paris, the hotel is placed in the centre of a combined airport station and terminal complex, providing ready access between the various facilities and modes of travel. Normally with such close integration the airport generates income both through the leasehold of land and through a levy on the hotel's turnover. Because hotels often provide conference facilities, the presence of a hotel can generate additional income in the terminal through extra passenger use and non-travelling person use.

Strategy for the selection of construction materials

There are two approaches commonly adopted for the selection of building materials and structural systems at an aesthetic or phenomenological level. The first is to layer the airport terminal from the ground to the sky, using progressively lighter forms of construction as the building rises through its various levels. Here the sub-basement and ground floor are built of massive concrete construction with structural steel employed at higher levels, and lightweight steel and aluminium cladding and even timber used in the roof construction. Such layering exploits the tectonic properties of materials and helps orientate passengers in terms of floor level. Typical of the approach is at Gardermoen Airport, Oslo, where the railway station beneath the terminal is

13.9 The structural system at Oslo Airport becomes lighter and more organic as the building rises.

13.10 The integration of natural light and architectural structure increase the sense of weightlessness. Heathrow Terminal One Airside Link.

constructed of heavy, mainly *in situ*, concrete, the arrivals hall above is of slender concrete, and the departure lounge above that caps the concrete columns with branching steel members which support gluelam timber beams which in turn provide the support for a lightweight aluminium and glass roof. The hierarchy of structural systems from ground to roof mirrors the progression from earth to sky. It is a logic which is both reassuring and aids navigation through the building.

The second approach is to place natural tactile materials where people come in contact with the building. This approach, for example, provides the terminal with hardwood handrails to stairs, timber lining to lifts, wood or cork floors, wool carpets and natural fibre seats in gate lounges. The design philosophy here is not to signal elevation through the building but to reassure passengers by providing materials of domestic or organic association in contact with hand or foot. Hence to touch an oak or beech handrail or to walk on a slate floor is to provide comfort for people in an alienating place. It is also a question of aesthetic pleasure – natural materials have a texture and touch which are rarely matched by the synthetic. Also, natural materials tend to wear longer, they look better when new and old, and they can be more readily replaced with matching items than man-made substitutes. Although they often cost more initially, the full life-cycle costing of natural material provides long-term advantages. An example is the hardwood strip floor in the departure lounge of Terminal 1 at Copenhagen Airport. Installed in 1964, it is still in use with minimum repair or replacement in 2004. In other areas of the lounge, the man-made carpets have been replaced three or four times over this period.[7] Such has been the wearability and popularity of the timber floor with passengers and retailers alike that an identical specification was employed for the departure concourse to Terminal 3 constructed in 2000.

The two strategies of layering and naturalness can be employed independently or in combination. The problem with concrete, glass and steel is that these materials are not pleasant to touch; they have no natural smell or association with forest or place. Natural materials, on the other hand, are rich in cultural memory and provide tactile pleasure. The problem with organic materials is their initial cost and their technical limits, especially with regard to structural spans. If wood, wool and cork offer contact pleasure, they necessarily need to be employed with concrete, steel and aluminium for engineering reasons. Hence, commonly both strategies are employed, providing in the process level legibility (i.e. what floor the passenger is on) and a reminder of the locality of the airport (i.e. construction materials which are drawn from the geographical area). The use of locally sourced natural materials in direct contact with the passenger provides the opportunity to build a terminal building, which though globally standardized in its structural and spatial patterns, is anchored to a specific place by the materials employed. With local materials come local crafts and patterns of building and the possibility of creating jobs in the locality. The dialogue between local and global is effectively acted out in the best recent airport terminals around the world (e.g. Kuala Lumpur). It is this cocktail of influences, expressed particularly in the use of material, which allows an airport to have, say, a Nordic character as against a Mediterranean one. Though the balance may be 90 per cent international and 10 per cent local, it is the decision to select regional construction materials which helps give the building its humanity.

The choice of finishes

The functional territories of a terminal tend to be defined by the choice of finishes, the method of lighting and the level of sound insulation. Although there is a trend towards the homogenized interior, design should help the passenger to distinguish the main sequence of spaces and their intended use. Finishes play an important role in imparting a sense of place and purpose within the terminal building. The main gathering areas, such as the departure lounge, need to have a different character from that of the check-in concourse or the mall. Similarly, customs control and baggage claim areas have their own distinctive technical standards to meet and qualities to impart.

Table 13.2 Tactile quality of materials in airport terminals

Nice to touch	Not nice to touch
wood	concrete
wool and cotton	steel
leather	plastic
cork	aluminium

The choice of finishes is therefore an aesthetic and practical one. Terminals are demanding places for materials: wall and floor finishes should continue to look good in spite of high levels of use and the wear and tear of baggage trolleys. The main thoroughfares and adjacent lower levels of walls need particularly to retain a good appearance if the image of the terminal is to be maintained. In selecting materials the architect should consider the importance of the interior space in terms of functional hierarchy, the way it is going to be used (areas where snacks or burgers are eaten pose particular problems), and the level of usage. Generally, the heaviest wear areas are given terrazzo, polished granite or ceramic tile finishes on floors, and walls are protected from trolleys, cleaning machines and wheelchairs by splayed skirtings and reinforced corners. With panel systems, the walls need to be robust, protected perhaps by stainless steel handrails and trolley guards, and capable of being readily replaced in the event of damage. With all finishes, replaceability without excessive cost and disruption of the operation of the terminal is a key consideration.

Less trafficked areas are normally carpeted. Carpets, normally specially designed for the airport, provide a quiet, soft and relatively cheap finish. Patterned carpets, though tiring on the eye, allow spills and damage to occur without spoiling the overall appearance. As with harder floor finishes, carpets can

13.11 Daylight and artificial light need to define routes and important areas such as check-in desks. Stansted Airport, UK. Architects: Foster and Partners.

be readily renewed in areas subject to greater wear simply by patching.

The different territories of modern terminals are normally expressed in the choice of materials. Shopping malls subject to great wear normally have terrazzo flooring, with refreshment areas or shops choosing their own finishes depending upon technical requirements: for example, ceramic tiles in fast food outlets, or carpeted flooring in bookshops. The customs, immigration and security check zones, too, are usually defined with different materials for desks, screens and floors.

The choice of finishes influences the acoustic performance of different areas. The selection of carpeting, for instance, helps to attenuate noise in the departure lounge, which may stem from aircraft taking off on nearby runways. The desirability of offering interesting airport views from lounges and airside concourses carries the problem of dealing with aircraft noise. Normally, a combination of double or triple glazing, carpeting and soft furnishing to seats can achieve the standards laid down in BS 2750. Aircraft sound, however, which is part of the passengers' expectation of journeying by plane, may be quite unacceptable in customs control areas or airline offices. A good rule of thumb for such areas is to achieve a dBA of 40 – a standard that may require extensive noise attenuation in offices or control areas overlooking runways.[8]

Lighting is part of the establishment of character in different parts of the terminal. Daylight should be present in the core areas of the terminal as a matter of course. Deep-plan buildings need to be subdivided by grids of skylights, or opened to the outside by folds in the roof. Light, both daylight and sunlight, is vital in guiding passengers through complex terminals. Artificial light is also vital in determining ambience, comfort and safety. Light levels need to vary according to the functional status of each part of the terminal. Main thoroughfares require higher levels of lighting than do quiet sitting areas, and immigration control needs sharp lighting for obvious reasons. Lighting, whether by ceiling or by wall-mounted fittings, or by spot or diffused sources, gives character and sparkle to different areas. Certain reflective materials, such as polished terrazzo, benefit from the radiance of artificial light, and with stainless steel, glass or marble stairs, integral strip lighting can enhance the design effect.

The check-in hall

Some airport terminals place the architectural emphasis in the check-in and arrivals concourse, others in the departure lounge. In many ways, this mirrors the distinction between the airport as the gateway to flight (hence the importance of the departure lounge) as against its role as a portal to a country (arrivals hall). Since the arrivals hall or check-in concourse is a large gathering space often shared by both departing passengers (who are checking in) and those arriving after baggage reclaim, it can claim to be the dominant enclosure. The ebb and flow of passengers in the arrivals hall is quite

13.12 The check-in concourse at Dulles International Airport designed by Eero Saarinen and refurbished in 2000 by Skidmore Owings and Merrill benefits from high levels of natural light and clear company signage.

different to the singular flow and large waiting areas in the departure lounge. While this generalization may be true of most airports, in large terminals, the arriving passengers reach the arrivals hall at a lower level than those departing via the check-in area. As a consequence, the arrivals hall is often a lofty space which accommodates a number of levels of passenger flow. This tends to reinforce the argument employed, for example, by Santiago Calatrava at Sondica Airport, Bilbao, to justify the supremacy, architecturally speaking, of the check-in hall.

Size, however, is not the only consideration. The character of the space also matters. The departure lounge is where passengers wait for the call to board their flight. It is an area for relaxation after the trying journey to the airport. Here refreshment, newspapers and usually a TV are available. There are usually soft seats, carpeted floors and lighting designed for reading. By way of contrast, the more heavily trafficked arrivals hall is usually finished in robust materials (often terrazzo or marble on the floor), seats are for resting on for short periods rather than sitting in for a long time, and lighting is designed to steer people through the building. The difference in character between the different volumes is part of the quality of Kansai Airport with its bustling canyon-like arrivals hall and the curved graceful departure concourse.

The departure lounge

Depending upon the size and complexity of the airport, the departure lounge may consist of three separate areas:

- common departure lounge
- gate lounge
- transfer lounge

or all three combined into a single envelope. The departure lounge serves three distinct types of passenger: those departing from the airport, those transferring from one flight to another, and those transiting on the same flight. In terms of airport operations the last two groups of passengers should remain on airside, and those departing directly (the first group) should not be allowed to pass back to landside.

It is preferable, both architecturally and organizationally, to combine the three lounges into a single concourse where local circumstances allow. This avoids duplication of space and manpower, and allows shops and restaurants to serve all those travelling. The gate lounge is the forward assembly point, where passengers gather before boarding the aircraft. It normally overlooks the airport apron, and passengers are held here for relatively short periods. It is usually a carpeted area with seats and a few concessionary outlets. As a rule of thumb, a square metre of space should be provided for every passenger: hence for aircraft seating 400 a space of 400m^2 is required in the gate lounge.[9]

The common departure lounge is where most travelling passengers congregate after clearing passport control, including those who are transferring between flights. Segregation may occur within the overall space to define gate lounges, but generally the departure lounge is a wide, spacious and leisurely concourse served by a mixture of shops, bars, cafes, duty-free areas, banks, business facilities, toilets and health clubs. Because some passengers may wait here for a few hours there is more space than in the gate lounge (normally 2m^2 per passenger); there are good views over the airport, plenty of natural light, and perhaps entertainment for children. Many flight information points are also required, and airline transfer desks.

The transit lounge is a space where passengers wait while flights are serviced on long-haul journeys, but normally it is simply part of the common departures lounge. The transfer lounge exists alongside the arrivals concourse for passengers who are transferring from one flight to another. Another directly connected but discrete area is the VIP lounge set aside for first class or business class passengers. With space per passenger of 3 or 4m^2, this area is normally designed to resemble an exclusive club.

The airside corridor either sits between the departure lounge and the aircraft gate positions or is a part of their overall space. It has the function of allowing linear circulation between the main departure lounge, a number of gate lounges and aircraft boarding positions. The airside corridor is in effect a walkway along the airside face of the terminal, which connects the different lounges with the aircraft boarding gate. Depending upon the nature of the terminal, the airside corridor needs to accommodate departing and arriving passengers without undue congestion. A great deal of information is needed here about flights, gate positions and exit routes. When airside corridors are over 300m long consideration should be given to travellators. Because all passengers will need to pass through the airside corridor, enough space should be provided for

13.13 Light and views across the airport apron help to give the departure lounge interest and tranquillity. Terminal 2, Manchester Airport, UK. Architects: Scott Brownrigg and Turner.

wheelchair users, passengers with baggage trolleys and those with visual impairment. Light, colour and texture should all be employed to aid passenger movement at this critical point in their journey through the terminal.

Identity and check-in design

The check-in desk is the first point of contact between the passenger and the airline company. Good design is essential to create the best impression, especially as travellers may wait here for several minutes before being served. Unless the terminal is dedicated to a single airline company, the check-in desk is likely to be shared by a number of carriers. Hence, signage is usually changed to allow a company to re-figure the desk. As a result, the check-in desk needs to be able to do the following:

- accommodate a changeable identity
- have signs which do not compete with the airport's own signage
- have signs which can be easily slipped into place and are readily stored when not in use.

The same principles are true at gate lounges that are also likely to have ticket desks that are leased for a short period.

Low-cost carriers are more likely to rent airport space on shorter time-frames than long-standing carriers. They need quickly altered check-in and gate facilities to maximize the benefits of rapid turnover. A balance has to be struck between low cost, quick turnover and the risk of low value, low service which can occur if design is overlooked. Establishing an identity is important for a start-up airline which may be using unfashionable airports or distant parts of established airports. The corporate graphics in the flight lounge and the design and colours of the check-in desk are a vital part of the image of the carrier.[10]

First class, business class and VIP passengers

With the growth in holiday package tours and casual leisure use of terminals, airport authorities have introduced fast-track routes for first and business class travellers. These extend from specially designated car parks close to the terminal to special check-in counters, fast routes through security and passport control, and preferential check-outs at duty-free shops. At airports such as Heathrow and Gatwick, first and business class travellers are given a Fast Track pass, which bypasses many of the queuing bottlenecks. The need to provide for these additional routes in a secure and discrete fashion is normally written into briefs issued to architects by airport authorities. At Gatwick the Fast Track route cuts, according to BAA, up to 30 minutes off the journey through the terminal.

13.14 Generous provision of lifts and escalators benefits both able and disabled passengers. Terminal 2, Manchester Airport, UK. Architects: Scott Brownrigg and Turner.

Fast-track routeing through the terminal is generally related to VIP facilities. First and business class passengers have their own waiting lounges normally provided by the airline with which they are flying rather than by the airport authority. Such waiting lounges consist of de luxe suites of rooms and bars, dedicated facilities such as fax machines, and occasionally direct access to secretarial services. Special rooms for VIPs (as against first or business class passengers) are provided at larger airports, with direct access by car from both landside and airside. Sometimes security, customs and passport control is provided adjacent to the VIP suite.

Provision for disabled passengers

Airports in general and passenger terminals in particular need to cater for the needs of able-bodied and disabled people alike. All stages in the journey should provide facilities for the disabled passenger in a fashion that does not hint at social discrimination. As a matter of principle disabled people should not be separated physically, but should share in the circulation provision provided for all. Hence lifts that allow ambulant passengers with baggage trolleys to move between levels should be of such a design that wheelchair users can also use them.

The routes from railway station, bus stop and car park to terminal, the routes through the terminal to the aircraft, and any rapid transit system between terminals, should all be designed with disabled people in mind. Physical impairment is relatively common (affecting 1 in about 50 passengers at UK airports), and others have varying degrees of psychological problems, which may influence their choice of routes in various ways. Good design consists of anticipating these problems and providing alternative access provision wherever possible. Lifts pose particular problems – the physical enclosure triggers panic attacks in some – and high overhanging balconies tend to destabilize others.

Most airports provide preferential treatment for disabled passengers. This commonly consists of special parking areas close to the terminal, designated zones near lifts or travellators at long-stay car parks, and concessionary fares on buses or taxis for those with proof of Mobility Allowance. Also, courtesy telephones are commonly provided for disabled passengers, with specially trained staff on hand to provide assistance through the terminal. British Airways, which carries 65 000 incapacitated passengers annually (two-thirds of whom use wheelchairs), provides a member of staff to take disabled passengers through the various controls and onto the aircraft.

Catering for physical and psychological problems is a question of design and management of terminals. Those with impaired sight or hearing provide a particular problem at airports, because flight information and route are vital passenger needs. Signs and flight information boards need to be easily read and understood, especially in airports where voice announcements are not made. Partially sighted passengers may need a combination of information provided by electronic screens close at hand and large lettered signs further afield. It is better to provide a variety of types of signs and information panels, rather than rely upon a single means of communication. Those who are deaf or hard of hearing should be provided with induction loops to assist hearing aids. At many airports a special information desk is provided to assist such travellers, and (as at Gatwick's South Terminal) this may be equipped with Minicom Supertel telephones.

The term 'disabled traveller' normally covers passengers who:[11]

13.15 Shaded walkways reduce exposure to sunlight and glare which can impair vision. Sydney International Airport.

13.16 Well-lit and spacious stairs help those with disability navigate from check-in to the departure floor.

- use wheelchairs
- are deaf or blind
- are elderly and find walking difficult
- have physical or sensory disabilities that necessitate some special assistance.

However, in designing terminals for disabled passengers, it is important that a broad definition of impairment is adopted. With an ageing population, many travellers have various degrees of restricted mobility, and most would object to being classified as 'disabled passengers'. A simple rule is to provide for the greatest quality and variety of access and information provision, because this will benefit both able and disabled passengers. Hence lifts, escalators, travellators, ramps and stairs of generous dimensions are all needed; signs of various kinds and sizes, and information available in different forms, all help those who use airports. Designers need to cater for the full spectrum of disabilities by providing, on the one hand, Braille facilities at lifts and, on the other hand, signing that takes account of colour blindness. Special seating at queuing points may be required too, because elderly people require more frequent rest.

Disabled access has both a physical and a psychological dimension. Space must be provided for wheelchair users, but – equally important – those with disability do not wish to be given special routes but to be allowed use of the normal flow areas. Segregation of disabled passengers is, except in the worst cases, an undesirable solution. Good design should ensure that corridors and concourses are free of steps, narrow doorways and bottlenecks at shops or control points. At changes in level there should be ramps (maximum rise 1 in 15), escalators and lifts. Doorways should be wide enough for wheelchairs and stretcher trolleys. Special parking bays for disabled use should be provided adjacent to the terminal door. Because many disabled passengers are accompanied by a relative or carer, space sufficient for two people to pass unimpeded should be the norm.

As a matter of course, there needs to be adequate provision of disabled toilets (preferably unisex and with space for helpers), and special low-level check-in desks for wheelchair users. Because dignity is a dimension to the disabled outlook, it is important wherever possible for the disabled passenger to be able to negotiate the journey through the airport without special assistance. Although airline staff may be on hand to provide assistance, many passengers with physical, visual, hearing or speech impairment prefer to remain independent. Where special information desks for disabled passengers are provided, some of these should be unattended and merely self-contained information booths (known as Communicaid II) as at Vancouver International Airport.[12]

Way-finding through terminals

Space at airports has an almost infinite quality with boundaries few and far between. As a consequence, spatial orientation is difficult and since the boundaries that do exist are unmemorable, the journey through a typical airport is often marked by directional confusion. Journeys through airports are essentially linear – from landside to airside – but the experience of the terminal space is rarely that of an ordered progression in a single direction. Instead the traveller is threaded through corridors and between barriers in an often bewildering fashion. The perception of both space and direction is lost: spatial dimensions become hazy under the bombardment of advertising signs, garish shop fronts and security barriers. What should be a three-dimensional cube of travel space with

13.17 External signage helps identify the location of the terminal entrance. Sturup-Malmö Airport, Sweden.

13.18 Lighting is important to the sense of arrival at night-time. Chek Lap Kok Airport, Hong Kong.

readily perceived edges and well-defined routes is usually the opposite when subjected to the four-dimensionality of the travel experience.

The ability to navigate through complex spaces is dependent upon the existence of recognizable objects and compositional wholes. The former suggests that colour and artefacts such as art have a part to play in way-finding; the latter, more difficult to achieve, is dependent upon the creation of memorable spatial compositions exploiting a combination of elements such as light, structure and materials. These should hang together to create a sense of place that cements together the various fragmentary experiences of a typical airport.

Too often airport architects think in terms of ‘space’ when in reality the traveller requires a ‘sense of place’. Turning abstract space into real airport places is dependent upon the designer thinking in terms of creating a series of linked memorable experiences.[13] Infusing the abstract and chaotic volumes of terminal buildings with elements designed to appeal to the senses – sight, sound and touch – provides a framework for the development of a language of materials and compositional effects aimed at enhancing space perception. Appealing to the senses through design requires a different approach to the rational mechanistic methods normally adopted by airport architects. Enhancing the sensory experience benefits all travellers, both those who are able and those disabled. Way-finding is a form of mental navigation which, like all forms of mapping, requires landmarks to support cognition.

To reduce the psychological stress of modern airports, architectural design could do more to aid orientation. The navigational aids include both tactile and visual means exploiting, for example, the surfaces under feet, the materials used on handrails, areas of bright colour and pools of more intensive light. The orchestration of these into a coherent whole can support the mental understanding of airport spatial hierarchies and their connecting routes. The ability to understand and select spatial information in an environment which is dense and rich in visual stimulation requires the designer to deliberately create the settings for perceptual understanding.[14] To reach one’s designation not only requires a grasp of the dimensional realities but also of the perceptual and psychological ones.

Signage

Effective signage is important if passengers are to find their way around the complex environment of an airport terminal. Way-finding is a combination of visual and verbal clues and, to be effective, the person who designs the terminal should also be responsible for the signage. Passengers form cognitive maps based upon physical and spatial information. The role of signage is to reinforce and focus understanding of the geometry of the terminal in order to direct the passenger to key routes and facilities. Good way-finding depends upon the presence of memorable physical elements and well placed, legible signs. Given that many travellers have impaired vision (perhaps as many as 10 per cent of passengers have some form of visual disability), the design, location and size of signs are crucial to the effective operation of an airport terminal.

13.19 Clarity is the key to effective signage at airports. Terminal 1, Heathrow.

13.20 At Chek Lap Kok Airport the retail signs are kept within a well co-ordinated band to prevent competition with the airport signs.

There are a number of principles which should be followed.[15] First, signs should be integral with the environment of the terminal, with provision made at the outset for additional signage during the life of the building. There is nothing more confusing or visually distracting than signs which appear as an afterthought. Sadly, this is often the case with advertising signage. Second, the position of signs is a strategic decision and should be based upon the needs of the passenger rather than other interests such as airline companies or retailers. Third, the way-finding characteristics of the terminal and the design or location of signs should share a common philosophy. Fourth, the way-finding signs should be separate from those highlighting commercial information.

In terms of the finish for signs, the letters should be in gloss with the background given a matt surface with a contrast ratio of 70 per cent between characters and background.[16] The sign should be evenly illuminated at around 200–300 lux and free of background glare. Contrast is more important than colour in the legibility of signs and, to optimize the level of visibility, black or dark blue on a yellow or white background is preferable. Electronic signs work best with white characters on a black background. Generally speaking, a combination of upper and lower case lettering helps people recognize the shape of words. For those with a visual disability, the characters should be 10mm high per metre of viewing distance and larger for passengers travelling through the terminal at speed.[17]

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Technical standards

CHAPTER 14

Fire safety and airport design

Airport terminals are hazardous buildings in terms of fire. Their deep plans and enclosed volumes mean that smoke extraction is a priority; the concessionary areas (shops, restaurants and bars) pose high fire risk; the number of people milling around mean that should a fire break out, many will inevitably be affected; and there are often long escape distances. However, terminals are also well-managed places with orderly routes and disciplined people, and because they are mainly open buildings, passengers can readily move away from the seat of a fire. Also, airports have their own on-site fire brigades and well-drilled staff, and should a fire break out the response time is quicker than in conventional situations.

Designing for fire safety consists of:

- determining the relative risk in different areas of the terminal
- establishing likely smoke patterns and spread of fire
- making assumptions about levels of occupancy
- determining the extent of fire containment by compartmentation and the fire loads involved
- using the 'islands' approach to smoke extraction and sprinkler systems
- determining the position of fire alarm and smoke detection systems
- making assumptions about fire brigade and airport staff response times
- determining the likely structural response of the building in the event of a fire.

The traditional method of rigid compartmentation has given way to the 'islands of risk approach', whereby much greater openness is permitted, and smoke extraction is encouraged by interior height. Large internal volumes divided by a combination of fire compartments and smoke extraction and sprinkler systems above the high-risk areas are replacing the earlier emphasis upon compartmentation alone.[1]

Most recent airport buildings have abandoned rigid fire compartmentation, because it tends to obstruct movement

14.1 Openness and height have replaced gloomy first generation airports. Terminal 2, Charles de Gaulle Airport. Architect: Paul Andreu.

essential for the smooth passage of people and baggage from landside to airside. Not only do fire partitions and self-closing doors physically interrupt movement, they also obscure the legibility of routes at a perceptual level. Today terminals tend to be designed on the principle of openness, with islands of greater fire risk (such as shops, bars, seating areas and check-in desks) protected by sprinklers (some using partial foam deluge systems) and smoke extraction hoods. Elsewhere interior volume and building height are encouraged, because smoke can be naturally extracted by windows in the roof, and as smoke not flame is the killer in most fires, large volumes mean that the density and hence the toxicity of smoke is reduced.

Identifying islands of potential hazard and spacing them sufficiently apart to prevent fire spread from one to another is the approach at Kansai.[2] At each high-risk island, containment of the fire by smoke extraction and sprinkler systems is preferred to an approach whereby the whole of the terminal is treated equally. Having identified the fire-risk islands, each is evaluated according to level of hazard, and the choice of materials, sprinkler system and method of smoke extraction modified accordingly. The fire at Frankfurt Airport in 1996 spread because no such island containment policy applied: at Frankfurt, as at most traditional terminals, there was an overall sprinkler and smoke extraction system, which did not discriminate in terms of level of risk.

Because smoke and heat rise in the event of a fire, it is possible to modify the ceiling profile to draw toxic chemicals out of the building. Again, the openness and interior transparency at Kansai meant that even in a building of 15 million m^3 it was possible to design for fire safety without physical subdivision of the terminal. The design approach, which encourages natural extraction, also supports passenger orientation in the event of a fire. As long as the exits, routes and stairs can be readily comprehended, large open volumes underpin, not inhibit, smoke evacuation in the event of a fire. Identifying risk islands and forming containment around them leads to a new approach to fire engineering. It means, for instance, that minimum distances need to be established between islands; that voids between floors are needed to allow smoke to rise to the roof; and that subsequent changes in the distribution and density of shops, bars and check-in desks need corresponding changes to sprinkler and smoke hood systems.

14.2 Visibility, spatial permeability and daylight are a feature of today's terminals. Cologne/Bonn Airport, Germany. Architects: Murphy/Jahn.

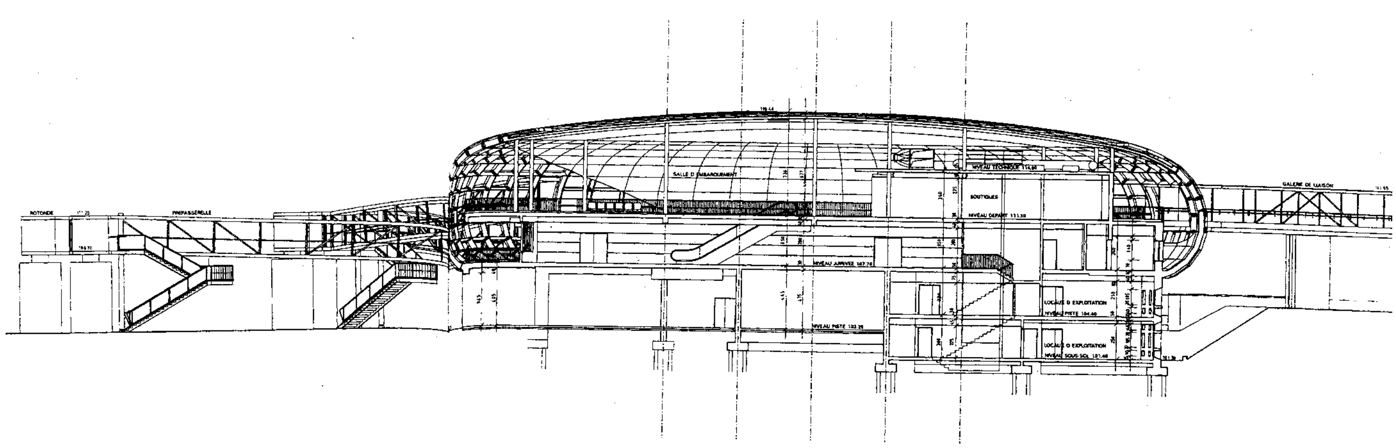
Many fires are started deliberately, and to avoid opportunities most airport authorities have introduced a policy of avoiding concealment sites. Hence modern terminals tend not to have litter bins, left luggage areas or unlocked cupboards. Preventing an arsonist from starting a fire or a terrorist from planting a bomb, by designing for openness and visibility of all public areas, tends to be the practice today. Where concealment sites are inevitable for other reasons (as in toilet cubicles) their design must seek in the choice of materials the containment of a fire or blast.

As most modern terminals are constructed of structural steelwork, this needs to be protected from fire. The usual standard is for the frame of a terminal to have a fire rating of $1\frac{1}{2}$ hours in public areas and 1 hour in offices. The steelwork needs to be encased (by, for instance, glass-reinforced cement) to a height above floor level of 4 or 5m; the remaining exposed structural steelwork must be painted with intumescent paint; and concealed structure must be lined with dry boarding. While smoke is the main killer for humans, it is flames that do the most damage to the structure of airports. Where risk of flame spread is high (as in baggage areas) there need to be masonry fire walls separating these areas from public concourses.

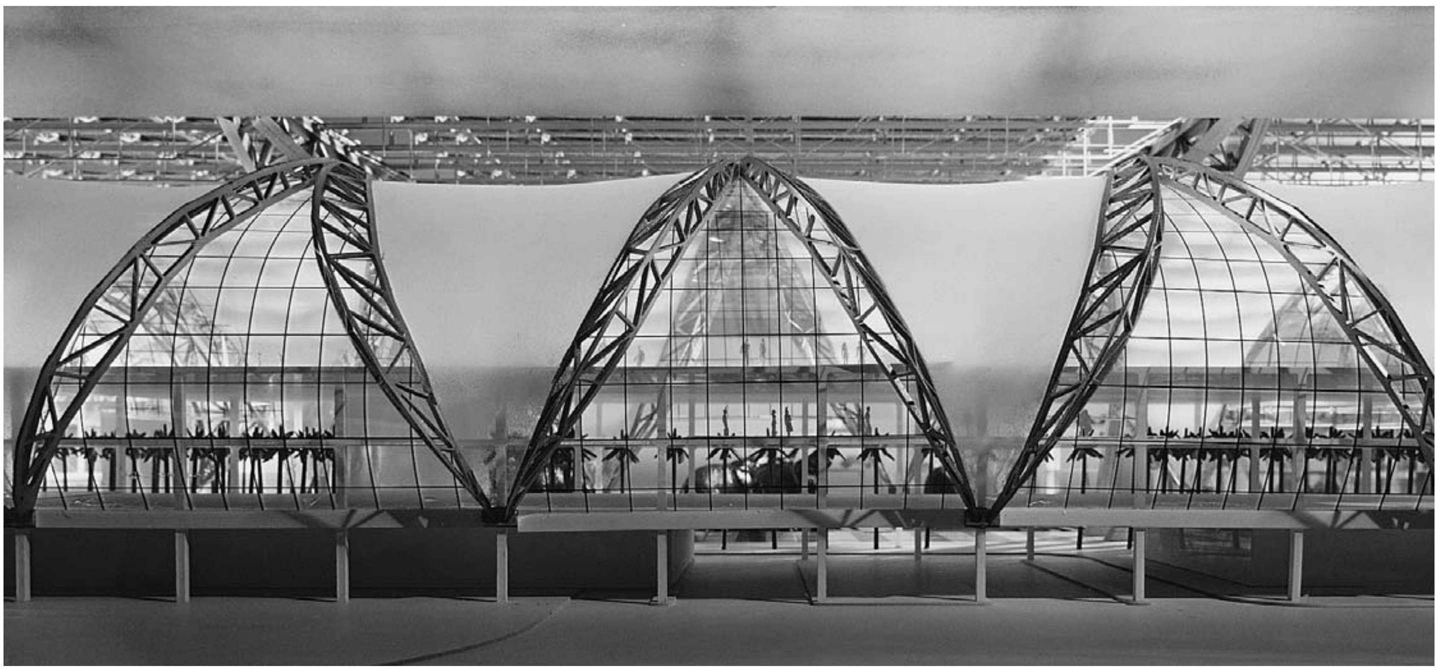
Lighting

Much has already been said about light as part of the essential architectural experience of terminals, but light is also an important technical consideration. The artificial lighting of terminals is normally the chief source of energy use (exceeding that of heating or cooling), and the means of lighting, the lamp sources used etc. have great impact upon comfort, safety and general ambience. The trend towards greater natural lighting in terminals is a means of saving energy, of reducing the build-up of heat from artificial sources, and of helping with passenger orientation. But the balance in energy use between natural and artificial lighting is complex, and much depends upon local conditions. The heat loss through windows has to be made up

14.3 Satellite Pier, Terminal 2, Charles de Gaulle Airport. Architect: Paul Andreu.



14.4 The external envelope of the terminal has to balance light penetration against solar gain, and the designer needs to alter window design according to orientation. Bangkok Airport, Thailand. Architects: Murphy/Jahn.



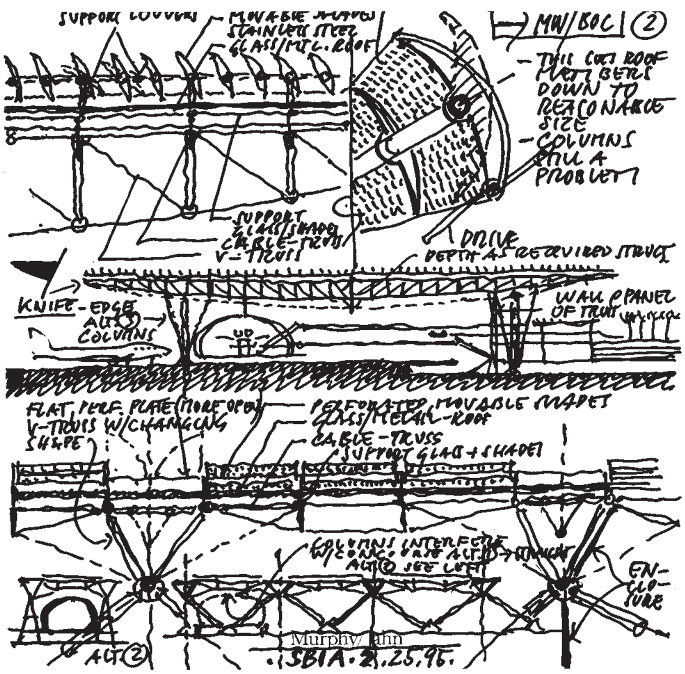
by energy released from other sources, and this generally entails fossil fuel. For any given terminal there is an 'optimum glass area which depends on the climate and orientation of glass'.[3] Given that light levels in terminals are normally similar to that in offices (especially where tickets have to be read, and where security is important), designers need to calculate carefully the relationship between window area, orientation and subsequent fabric heat loss.

The working light level in terminals is normally 200 lux, but this standard varies according to the degree of security or tranquillity of space. Such a figure suggests an upper daylight factor of about 4 per cent, which invalidates the totally glazed facade at a stroke. Where large areas of wall or roof glazing are used (as at Stansted or Kansai) it is angled, shaded, screened and treated in a fashion to reduce daylight (and particularly sunlight) penetration. At Stansted, for example, the 11m rooflights over the concourse sit above a perforated metal shade, which reduces the light transmission by 50 per cent.[4]

Few terminals are designed without natural lighting and electric lighting being considered from an architectural point of view in tandem. It is important to maintain a similar pattern of lighting by day and by night so that passenger perceptions of route and volume do not vary. This means that some electric light is used in the day even if not justified by external light levels. A common pattern is to design for a natural lighting daylight factor in concourses of 1 or 2 per cent in combination with electric lighting design of about 500 lux.[5] The result is that while electric lighting overwhelms natural lighting, there is still a sense of 'daylight'. Where daylight alone is used to light concourses, on overcast days the lack of sparkle can make for dull interiors.

The close juxtaposition of natural and artificial sources of light means that the designer can feel confident that the architectural experience remains much the same throughout 24 hours. Again, referring to Stansted, the system uses 400 watt lamps clustered at each structural tree shining upwards so that the light is reflected off the roof adjacent to the skylight.[6] The result is that both natural light through the roof and artificial light are concentrated immediately above the structural tree, giving them visual emphasis within the terminal. Light therefore draws attention to the structural concept, which – being uniformly applied – helps passengers to understand the logic

14.5 Architect's sketches for the lighting design at Bangkok Airport, Thailand. Architects: Murphy/Jahn.



and organization of the building. A similar philosophy prevails at Kansai Airport, where the rooflit canyon (or central street) has artificial light sources concentrated along its length. Because of the crucial question of passenger orientation, it is vital that architectural design and lighting design (both natural and artificial means) share the same approach.

Similar principles apply to wall lighting. A vertical window admits only about 40 per cent of the daylight of a horizontal rooflight, but with a low sun glare can be a problem through windows. Sunlight penetration through vertical windows brings the adjoining interior spaces alive, but direct sunlight can lead to discomfort, especially for people sitting or working directly in its rays. As a result, wall glazing needs to be screened (either externally or internally), or the angle of glass tilted (as at Zurich Airport) or curved (as at Kansai). As a rule, glare tends to be a problem associated with wall not roof glazing.

A combination of external screening, roof overhangs and surface treatment of the glass can deal effectively with glare while also allowing good levels of daylight penetration. Except for the deepest planned terminals, natural light from wall and roof glazing can be adequate for daylight hours. There is the need, however, to increase general light levels at key points in the building: ticket check-in, baggage areas, passport control and around shops and restaurants. Here the pattern tends to be to intensify light levels by artificial not natural means. So while general concourse areas are mainly naturally lit (and in some cases ventilated) there are pools of brighter electric light and specific task lighting (as at check-in desks). These more brightly lit areas, often located near the centre of the building, lead to high levels of energy use and consequent heat build-up. Lighting and heating design then need to be considered together, with building management systems employed that recycle the heat from lights in cold weather.

Many modern terminals are designed as passive solar buildings: the transparency helps with energy conservation, security of the building itself, and general appearance. But excessive glazing, added to lack of thermal capacity in the fabric, can lead to great heat loss in the winter and heat gain in the summer. Largely glazed terminals, though they save on artificial lighting, lead inevitably to partial or complete air-conditioning (often requiring the use of ozone-damaging CFCs).

Heating

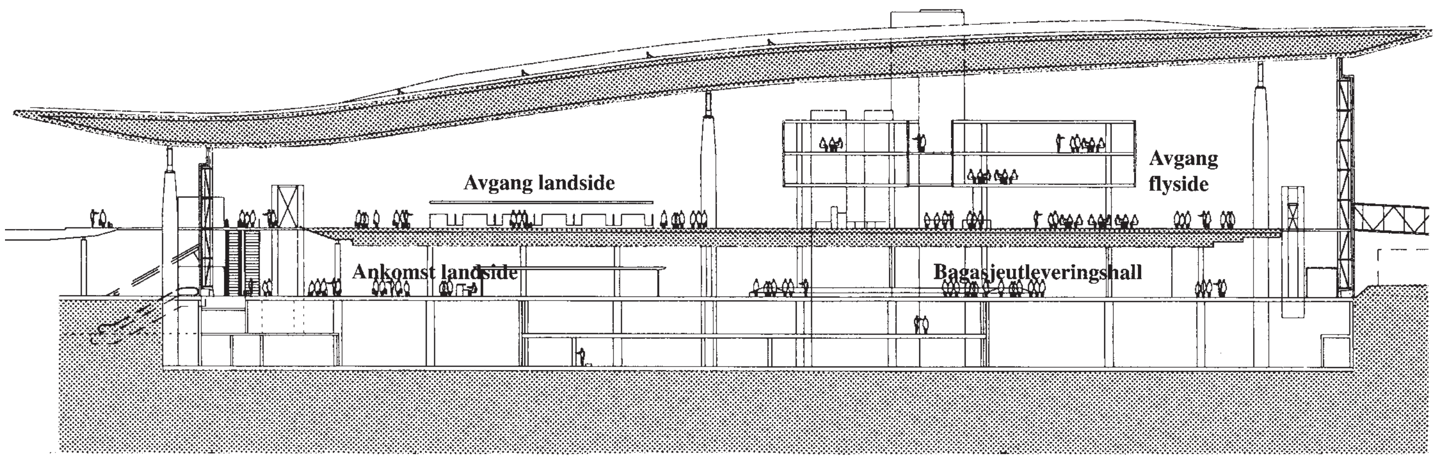
Heating, lighting, the thermal capacity of the terminal, occupancy levels and the transparency of the envelope are related factors. Most terminals of any size rely upon air-conditioning for part or all of the year, and part or all of the building. Most systems use circulating air as the means of heat or cooling distribution. The profile of the building aids the circulation of air: for instance, the undulating and curvaceous forms of Kansai, Oslo and Charles de Gaulle are a direct response to air circulation. Typically, air-conditioning circulates cooled air in the summer and warmed air in the winter. Air is normally blown into the concourse spaces horizontally and rises or falls depending upon its temperature. The shape of the space is an important factor in the degree of penetration of the blown air, and the patterns of air movement established. It is not architectural fashion but air-conditioning that determines the curved undulating roof shapes of many recent terminals. The natural curve of a jet of blown air at a set

14.6 The Futurist imagery of modern airports is based upon the expression of architectural structure, movement and walls of light. Bangkok Airport, Thailand. Architects: Murphy/Jahn.

temperature and velocity produces its own distinctive profile. Combining this with structural and spatial geometry leads inevitably to the distinctive new generation of terminals seen today.

Because air rises or falls according to temperature, the angle of discharge of air-conditioning nozzles needs to be capable of adjustment. At Kansai, nozzles positioned immediately beneath the roof distribute air at different angles according to specific need, with air drawn back in via planting boxes on the floor. The angle of nozzles can be adjusted electronically according to the season.

Most airports have macro and micro systems for heating. The former provide background heat (or cooled air) to the whole terminal, the latter to specific areas such as the arrivals walkway. In good building services design the micro installations often use recycled heat from the macro system.



14.7 The profile of roofs is often determined by the flow of air released under pressure at low level and extracted at high level. Oslo Airport, Norway. Architects: Aviaplan AS.

Fabric canopies as at Kansai and Denver, are sometimes used to deflect recirculating air or provide solar screening.[7]

Because terminals are lofty structures it is usually possible to exploit the 'stack effect' to encourage natural ventilation and to establish circulating air currents. Also, height means that the level of occupation (the lower 3m zone) can have different characteristics from those of the remainder of the interior volume. Hence it is only really necessary to heat or cool the levels that passengers use; the other spaces can have quite different temperature characteristics. With large volumes it is also possible to exploit the principle of night-time cooling whereby air at say 16°C is circulated through the building at a sufficient rate to cool the fabric, which then maintains an acceptable temperature during the day. Heating systems that rely upon circulating air allow this to happen, and if the equipment is integrated into the structure then it does so with coherence and elegance.[8]

Most terminals rely upon heat extraction systems to recover the heat from extirpated air or water in order to increase the temperature of the fresh air. At Stansted a central refrigeration plant extracts heat from the chilled water to keep it cool and then discharges the heat into a water circulating system at around 40–50°C.[9] This heat is then used for the main air-handling system. During most of the year the heating load can be met by heat extraction, but in particularly cold weather (below 5°C) boilers provide back-up.

Safety and security

The trend in terminal design towards greater transparency and openness is partly the result of increasing concern over airport security. Large glazed malls allow security staff to monitor what is happening both inside and outside the terminal, and the natural light that flows through glazed rather than solid walls improves the effectiveness of CCTV. High levels of natural light give greater definition to the images on security screens and, in particular, allow facial features to be discerned. Designing for maximum transparency is the norm, because it allows police and airport security staff to see everything that is going on. In fact, one in three of all BAA staff work in security in one form or another.

As designs for airports are being generated, the layouts are subjected to risk analysis by the airport authority and police. Overcoming security risks by good design is a growing aspect of design monitoring prior to construction. While the trend towards greater openness and transparency in terminals is driven partly by passenger wayfinding needs, the avoidance of obstruction or walls behind which terrorists can hide (or place bombs) is of equal importance. Of the six elements that form BAA's Mission Statement, the first is 'safety and security', thereby confirming the highest priority given to this aspect of airport management.

There are three distinct approaches to effective security design: surveillance, space syntax and territoriality.

Surveillance

The effective surveillance of the interior of terminals and key exterior points is crucial in the creation of a safe and secure environment. The airport lounges, shopping areas, toilets and entrance points are particularly at risk, and require surveillance directly by security staff and indirectly via CCTV cameras. Places where cars are allowed to drop off or pick up passengers adjacent to terminals pose special risks, and here management policy towards parking has to be especially vigilant.

Surveillance is most effective in terminals that are spacious and open. Well-placed cameras and patrolling police can monitor behaviour more effectively in such areas. Where physical enclosure is needed (such as around shops, bars and toilets) there needs to be extra surveillance provision, which is often provided by additional cameras placed in strategic locations. Crime prevention and airport security are mutually beneficial concerns, and cameras or security staff can detect either form of anti-social behaviour.

Surveillance is normally undertaken by uniformed security staff, police and plain-clothes detectives, and via conspicuous or hidden cameras. The range of personal and visual monitoring of terminal spaces is aimed at combating many types of crime, from pocket-picking to drug couriers, and from terrorists to baggage thieves. Airport design has a part to play in crime prevention by providing areas, routes and entrances that can be readily overlooked.

Space syntax

This is a measure of the number of people using an area of terminal space at any particular time. Safe places are those that are occupied at an optimum level: under-occupation of space poses a potential threat, as does over-occupation. At levels of over one person per square metre there are dangers, and at under one person per $20m^2$ there are also risks. High levels of human density make visual surveillance difficult, and the bumping and colliding of people and trolleys pose a danger from petty thieves as well as from risks of physical injury. Low levels of space occupation, particularly in corridors or smaller spaces, expose passengers to attack, armed robbery or mugging.

Space syntax is not an easy balance to achieve. In large spaces, such as airport lounges, low levels of occupation are restful, but the same density of occupation in more confined spaces (perhaps when there are only two people per length of corridor) can pose a threat. There are age and gender issues involved as well. Female users of terminals feel safer in buildings that are relatively heavily used, and fear unused spaces, especially late at night (perhaps after a delayed flight). Ageing passengers too fear lack of human contact, especially where their reduced mobility may place them behind other passengers.

It is by no means easy to design terminals at optimum levels of space syntax. The erratic pattern of use of airports means that terminal spaces change during the day from being heavily crowded to being sparsely populated. What architects can do,

14.8 The level of human usage helps make the airport feel safe but over-occupied spaces are inherently dangerous.

14.9 Design that gives passengers a feeling of safety and well-being in busy public areas reflects well upon the airport authorities. Chicago O'Hare Airport, USA. Architects: Group One Design/Perkins & Will.

however, is avoid short lengths and dog-legs of passageway, lifts that are rarely used, and remote airport lounges that cannot be seen from public areas. Space syntax is a measure of occupation and the relative distance between points of human density (departure concourse, check-in, etc.). Because well-used airports tend to be safer (and feel safer) than poorly used ones, there is a need for design policy and management of the terminal to be in step.

Space syntax is a useful density guide: it is to do with the characteristics of space and distance between people. Linear space (corridors) has different safety and security characteristics from those of wide space (lounges). People feel safe when there are others nearby, but cease to feel happy when strangers violate their immediate personal space. The level of background noise is also a factor: noisy places mean that cries for help cannot be heard, and hence the safety margins come down.

Territoriality

In the design of terminals, architects should seek to ensure that all the users (including passengers, airline staff and retailers) assume a territorial attitude to the space they are occupying at that moment. This is by no means easy, either psychologically or practically, in a public building. However, if users and stakeholders at terminals assumed a territorial attitude then anti-social behaviour would be challenged, thereby benefiting all. Designing terminals to generate territoriality means using physical and psychological means to define areas of space over which users would exercise certain safety or security rights. For the passenger it may mean grouping seats into small but casual enclosures where several families could exercise control over behaviour. A person here who leaves a bag unattended or drops litter will be either challenged by the group or will feel too embarrassed to undertake such behaviour in the first place. The geometry of the seating arrangement and the presence of planting tubs or tables may help to create this sense of territory.

Retailers too need to take charge of their parcel of terminal space. The design of a shop and the adjacent public area should be such that the shop assistants feel encouraged to challenge anti-social behaviour, to check quickly upon an unattended bag, and to clear rubbish before it poses a fire threat. The way in which shops, restaurants and bars form subterritories within large modern terminals helps with stimulating a sense of safety and security within units of the terminal. In fact, the more distinctive the retail unit is the more effectively it challenges the anonymity and lack of sense of territory in the terminal itself.

The same is true of the space in terminals occupied by airline companies. It is important that staff here exercise a territorial attitude over the space, and that design helps to define the limits of the space. By the use of different colours of carpet, upholstery, distinctive signage and custom-designed furniture, a piece of territorial space can be described and recognized by potential burglars, terrorists and the public at large. Airline staff will not only be able to recognize 'their' space but will feel encouraged to exercise surveillance over it. Those intent upon anti-social behaviour will recognize this and be deterred.

The three main elements of safety and security by design – surveillance, space syntax and territoriality – need to be integrated. Defining territories and subterritories within large terminals is by no means easy, but it is essential. Once territory is defined, opportunities should be provided to exercise physical and electronic surveillance over it, and this to some measure involves ensuring that the space is occupied at optimum levels – not overcrowded or deserted. It is also important through design and management to create a feeling of safety and security: good design is not just a case of preventing crime but of reducing the fear of crime.

In addition to designing for safety and security at a broad level there are a number of specific measures that can be taken according to the perceived level of risk. These include:[10]

- ensuring the physical separation of arriving and departing passengers on airside
- spot checking of security at gate lounges (in addition to centralized security combs of passengers and baggage)
- prohibition of visitors to airside, even with domestic flights
- isolation of piers by fast-acting drop grilles in the event of terrorist activity
- provision of extra space for security checks and dedicated check-in areas for high-risk flights or destinations
- ensuring that airside is security sterile by limiting (or preventing) commercial concessions on the airside
- removal of car parking or set-down adjacent to terminal at times of high terrorist activity
- prohibition of left luggage areas in the terminal
- prohibition of rubbish bins in the terminal
- avoidance of open mezzanine or gallery floors overlooking passenger areas
- closure of observation decks overlooking apron areas and runways
- construction of buildings to include materials that can absorb blast damage.

Because many existing terminals were constructed before terrorism became a problem, much attention has been focused recently upon upgrading security measures. These have led to ad hoc alterations that, although they improve the level of safety, do not usually form comprehensive and well coordinated measures. Older terminals necessarily have to accept poor security, but in new terminals design for safety and security (of people, baggage and buildings) is among the highest priorities.

Increased security after 11th September 2001

The need to pass through security checks increases the overall journey time. Currently at British airports the body and hand baggage searches add 10–15 minutes to the time taken to process from ticket check-in to departure lounge. Of this, the bulk consists of queuing with no opportunity to sit or take refreshment. Baggage is subject to X-ray examination in a semi-sealed container and the body is subject to hand-held scanners or random full body checks. As well as the delays caused by these security checks, there is also the problem of background radiation from the X-ray machines (a particular problem for staff with their longer periods of exposure). However, food and drink taken in hand baggage also become irradiated, again carrying a risk for travellers. Although there are health and safety warnings positioned at the X-ray machines, these are often obscured by staff and baggage.

The position of security checks varies according to local practice. In most of Europe and the USA, body search security checks and the X-raying of hand baggage only occur after ticket check. However, in parts of the Middle East, Asia and Africa all visitors to the airport terminal are subject to security examination on arrival. This adds to security but necessarily causes delay and frustration. The problem with the IATA,

14.10 Well designed security screening at Shenzhen Airport, China. Architect: Llewelyn Davies.

14.11 Foot patrols have greatly increased since 11th September. Typically about 12 per cent of airport staff are engaged in security.

CAA and BAA guidelines is that no real checks are made on those entering the terminal building until part-way through the building. As a consequence, the arrivals concourse is potentially a hazardous place with unchecked baggage, which could contain explosives, being in an area of high profile and public occupation. The conflict between freedom of movement and security surveillance finds expression in the armed guards who now visibly patrol the check-in and arrivals lounge of most international airports. In fact, surveillance is more intensive at arrivals than departures on the assumption that the physical examination of passengers and baggage after check-in will have eliminated risks at airside.

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8. These two words were used by Max Fordham, *op. cit.*, with regard to Stansted Airport.
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Part three

Case studies

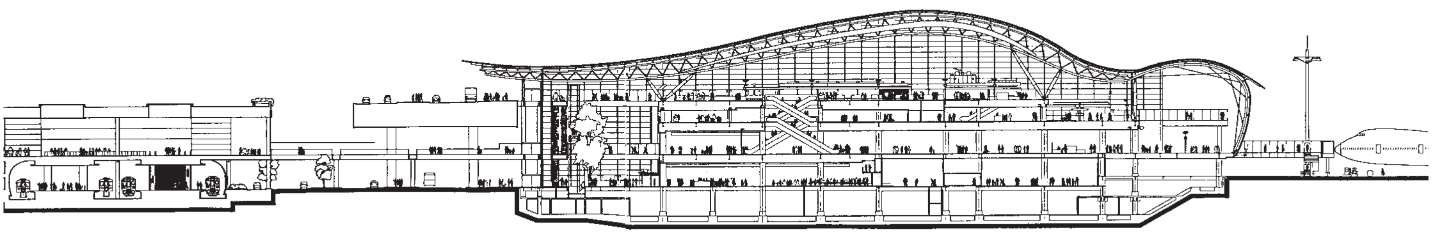
CHAPTER 15 Major international airport terminals

Kansai Airport, Osaka, Japan

The new airport at Kansai, designed by the Renzo Piano Building Workshop and opened in 1994, displays with greater authority than any other the emergence of a new generation of airport architecture. The characteristics that make it important are scale, complexity, engineering prowess and technological splendour. Kansai was the first airport of any size to be developed entirely upon a man-made island, to exploit open curvaceous forms in order to reduce ecological impacts, to manipulate light and structure to waymark the passenger routes through the terminal, to give the skin of the buildings the qualities of those of the planes, and to develop a multi-modal transportation centre rather than merely an airport. Conceived in the 1980s, and designed and constructed in the early 1990s, Kansai Airport is generally regarded as the model for the twenty-first century. The imagery is appropriate for the next century: the emphasis upon public transport access to the airport, the efforts devoted to passenger legibility and the approach to environmental design – all signal a new approach to airport development in the widest sense.

Piano's design was engineered by Ove Arup and Partners, and the approach to structure gives the terminal and the ancillary buildings a powerful order. Of all recent airport buildings, Kansai is the closest to one where the architecture of space and light, and the design of structure and constructional details, seem to push at the frontiers of the tectonic experience. Anyone who experiences the passenger terminal at Kansai will be impressed by the fusion of structural and architectural design. The sense of structure evident in the enormous curved beams and braced columns is not a hollow gesture, but is designed to give clarity and order to the terminal. Columns, beams, lattice girders and sweeping lantern lights are guiding elements that direct, deflect and assemble weary passengers. In a passenger terminal 1.6km long (it is claimed to be the longest building in the world) light and structure are the elements that punctuate interior volume and give it meaning. Piano's design rejects neutral space and minimal expression: at Kansai the approach to design is one of animating the key routes through the terminal with

15.1 The section of Kansai Airport terminal is clearly influenced by the aeroplanes themselves. Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.



a different form of structural and spatial articulation at each zone, employed to suggest hierarchies of use.

If one examines the plan and section of the airport the correspondence between form, function and meaning becomes evident. The design splits into four related parts, each subscribing to the same geometric and structural logic. The first, and most dominant, is the terminal itself; the second is the long airside boarding wing; the third is the railway station; and the fourth is the multi-storey car parks. The composition has a strict order – rationalism tempered by processional clarity, especially in the routes from car parks and station to terminal and thence to the boarding wing. The axis of movement, interrupted at various points by roads, concourses and a massive public canyon at the landside of the terminal, merely defines stages in the passengers' journey. For a building of such dimensions and level of use (25 million passengers a year) there is a remarkable sense of direction. This derives in part from the orderly nature of the plan and the way in which different spaces have been fashioned in distinctive ways. For example, the public canyon is solid and earthy – its colours and monumentality refer to traditional loadbearing architecture – while the departures lounge and airside wing are lightweight and expressive of high technology with distinct aeronautical overtones.

Part of Kansai's clarity derives from the handling of the cross-section of the airport. The terminal has an undulating roof, whose wave-like profile rises and falls to reflect the importance of the accommodation inside. This symbolism is needed because the terminal departs from the orthodox pattern of separating international from domestic movements into separate terminals. Instead, a single building handles all flights, with the organizational complexity handled not by separate buildings but by using four different floor levels in the terminal, and by lateral zoning of the long airside boarding and arrivals wing. To help resolve the confusion that the use of a single multifunctional terminal entails, the design places particular emphasis on a large lofty public concourse known at Kansai as the 'canyon'. With the proportions of a four-storey city street, the ochre-coloured canyon is a magnificent thoroughfare nearly 250m long. All passengers have to cross the canyon, and most do so at high level via first-floor bridges, which serve mainly those arriving on domestic flights, and at third-floor level for those departing. At ground-floor level the canyon is crossed by international arrivals who experience this spectacular space immediately after customs clearance. It is a worthy gateway to a nation.

The canyon is a public street within the airport, but it is not a shopping mall. It serves mainly as a means to give passengers a sense of place within a building type noted for placelessness. The canyon organizes people and airport functions; it provides information; and it is a location for 'meeters and greeters' to join up. Shopping and business suites are provided on decks partly overlooking the canyon and partly in the body of the terminal beneath the undulating roof.

At the airside, the terminal has another grand lofty space known as the 'departures lounge'. Whereas the canyon is urban, vertical and rectangular in quality, the departure lounge is wide and rounded, and has detailing that evokes that of the aircraft outside on the apron. Also, while the canyon is mainly rooflit, the lounge is lit by curved windows, which look out across the runways and downwards to the aircraft being prepared for take-off. The different characters of the canyon and lounge – the former quasi-public, the latter private and reserved for travellers – are reflected in the nature of the spaces and in their detailed treatment.

15.2 The architectonic character of the departure lounge at Kansai establishes a new standard of architectural expression for terminals. Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.

The canyon and departures lounge make up the two principal experiences at Kansai. Everything else is secondary – even the delightful and muscular top floor of the terminal. Here the curved triangular latticed beams, the fabric sails and the sets of four angled columns make the international departures hall a fine space, but one that is essentially subservient to the canyon and departures lounge. Hierarchy is expressed spatially and to a greater extent structurally where engineering scale gives importance to key spaces. Daylight too plays by the same rules: the two large lateral volumes are lit with bold or dramatically shaped windows. Elsewhere daylight filters through the floor levels or enters via largely glazed gables, which serve mainly to define the limits of the building, not functional hierarchies.

Kansai represents a fusion of architecture and engineering at a most profound level. Peter Rice, who acted as the structural engineer, has ensured that spatial sequences and functional patterns are articulated and expressed, rather than understated. The structure and detailing of the terminal may be excessively muscular for some tastes, but Kansai is symbolic of Japanese culture, where high technology and heavy engineering prevail. The development of Kansai Airport, both the construction of the large man-made island in Osaka Bay to house it and the innovative passenger terminal with its multi-modal transport connections, represents an undertaking of international significance.

The sophistication of the terminal extends to the lesser parts (some not designed by the Renzo Piano Building Workshop but by local practices). The car parks, station, control tower and access roads subscribe to the same values. Bold engineering and daring architecture complement each other, with varying treatments according to the significance of the building or the designers involved. The terminal itself is by a single design practice, and the indelible stamp of the Renzo Piano Building Workshop can be seen from the main building to the 1.7km wing of the departure lounge, and from the broad architectural concept to details such as furniture design. The same logic imposes itself upon the architectural language, whether it is in the canopy that protects passengers at the terminal's main entrance, or in the strutted supports of the lounge seats. The rigour derives from five main design principles:

- the expression of advanced building technologies, especially in the design of glazing, wall and roof cladding
- the use of muscular structural systems to animate interior volumes and provide orientation
- the use of curved profiles that respond naturally to wind pressures and aid ventilation
- the manipulation of building sections, rather than plan, to articulate routes and provide interior architectural drama
- the synchronization of building and aeronautical systems.

Taken together, these principles give Kansai its distinctive qualities, and in the emphasis upon high technologies – related at a conceptual level to ecological processes – hint at the airport architecture of the twenty-first century.

Constructional details

The curves of the terminal reflect in direct fashion the elliptical and elongated profiles of the planes. Both the main terminal building and the boarding wing share an affinity in colour, curvature and construction with the aircraft. One could imagine the boarding wing in particular being a section through an enormous aircraft of the future: the flattened curvature of the airside profile, the panels of silver grey aluminium and stainless steel, the lightweight structural framework with exposed ribs and diagonal bracing – all look like some futurist airship. Glazing and smooth steel cladding follow the same wavy lines, and share similar constructional characteristics. The section through the building remains the same – a kind of extruded shell with square cut-off ends. This adds to the economy of the terminal and, to a lesser extent, to its future flexibility. Both terminal proper and the boarding wing can be extended laterally, though major growth would have to be met by constructing another island terminal nearby.

The external smoothness of Kansai is not merely architectural fashion: it is a direct response to the typhoons that strike this part of Asia. There are no lips, eaves, skylights or parapets to catch the wind or set up eddies to disrupt the physics of the building. The disciplined geometry of the shell is complemented by vigorous detailing. Because wind and rain loading varies across the roof, the 90 000 cladding panels 1.8m by 0.6m that form it are all designed to the same high standard. There are no 'specials' to add unnecessary complexity to construction or future maintenance.

The same rigour applies to the logic of responding to earthquakes. A secondary structure is employed outside the main structure of the terminal, which absorbs the differential movement of earthquakes. The lateral forces set up by seismic activity are soaked up by the continuous secondary structure, which spans between the trusses.[1] Kansai is designed also to absorb vertical movement, which may result from the settlement of the material used to make the island, and lateral movement, which occurs in earthquakes. Rather than design a single connected structure, Ove Arup and Partners chose a double loosely tied structure where pin-joints rather than rigid connection predominate. This allows[2] for beam movements of 0.5m and landside glazing movement of 150m.

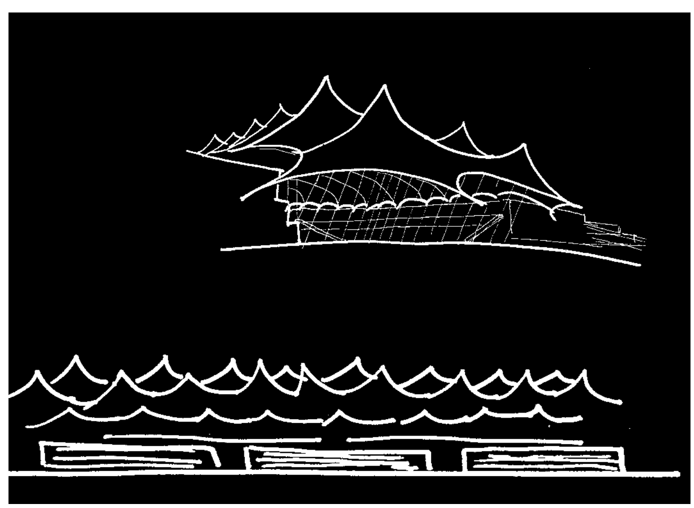
Ecology is the inspiration for the strategy behind the air-conditioning, the landscaping of the 4.37 by 1.25km man-made island, and the incorporation of planting into the terminal. The basic shape of the building derives from nature's own profiling of shapes into undulating sand-dunes at the ocean edge. The Building Workshop sought in its initial investigation of the design that of 'technology emulating, and in harmony, with nature'.[3] This is most evident in the relationship of the roof profile to the 'natural curve of a jet of air blown into the departures hall from the land side'.[4] By adjusting the building profile to the natural flow of air currents, there is no need to provide suspended ducts, which disfigure rectangular, flat-roofed terminals. The approach to air-conditioning (and to smoke venting) alludes to conditions outdoors rather than indoors, just as the masterplan seeks to create an island forest rather than merely rows of trees, and in the terminal itself a sense of a winter garden. There are limits to working with nature, though the design pushes at these frontiers to the benefit of later terminal designs such as Heathrow's Terminal 5 by Richard Rogers. At Kansai the ecologically inspired macro-system of natural ventilation is tempered locally by micro-systems that heat or cool specific locations by more conventional means.

Although Kansai was a team effort, involving principally the Renzo Piano Building Workshop, Ove Arup and Partners and the local practice of Nikken Sekkei, the airport is a considerable achievement and displays remarkable consistency. It is one of the greatest engineering feats of the modern age, yet in the principles adopted it points towards a new contract between man and nature. At a fundamental level, the airport at Kansai begins to respond, protect and add to local ecosystems: it seeks a harmonious relationship with the ocean, climate and vegetation of this part of Asia. That the airport, arguably the least sustainable of all modern urban structures, should try to emulate natural systems is perhaps Kansai's main claim to be a precursor for the design of terminals into the next century.

Denver Airport

The design of Denver Airport, Colorado, by the architectural practice of Curtis W. Fentress, breaks the mould of the sterile anonymous airport found elsewhere in the USA. The design consists of three blocks of airport accommodation beneath a lofty central volume which is roofed in fabric creating a series of tented shapes which symbolically recall the distant Rockies. Seen from afar, the white tented roofs echo the snow-capped peaks of the Rocky Mountains, and the supporting masts symbolize the trees which cover the lower slopes. Since Denver is a hub airport used by about 40 million passengers a year, many of whom do not depart but merely transfer to other flights, the brief given to the architects was to create a 'memorable symbol of the city'.[5]

The terminal building consists of a large central space three storeys high with arrivals on the ground floor, shops, etc. on a mezzanine, and departures on the upper level. The double height central spine of the terminal has the quality of a botanical garden with its extensive planting and pale diaphanous light that spills down from the fabric ceiling. Sunlight enters via triangular roof-lights in the gables and along the eaves, creating a pleasant mix of types of light which add sparkle to the interior and aid navigation. Passengers progress not across the terminal but along its main axis. This unusual arrangement allows cars to reach the building on either side of the rectangular plan, adding to the convenience (common in the USA) of car drop-off adjacent to the doors of the terminal. Beyond the roads which run parallel to the terminal are several blocks of car parks arranged axially. Thus, the main terminal at Denver is formally disposed, providing a central point with



15.3 Concept sketch by architect Curtis W. Fentress for Denver Airport with its references to the nearby Rocky Mountains.

a well-structured geometric plan of roads, car parks and runways.

The fabric roof of the terminal acts as a powerful central element within the composition. The various people movements, shops, check-in and security controls exist beneath the attractive undulations of the roof. The activities beneath are ordered by rows of elongated columns which help direct the flow of people towards the departure gates. Denver is an airport terminal where space, light and structure are not subsumed by the bustle of movement and retail activity. As a hub airport, Denver operates practically 24 hours a day. Another benefit of the unusual fabric roof is the way it glows at night, establishing a welcoming beacon in the darkness.

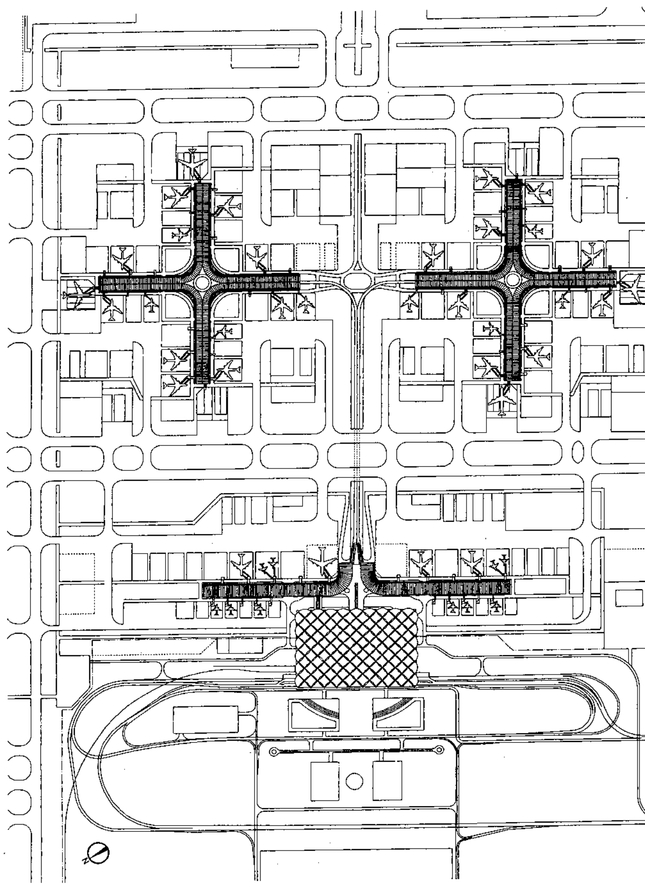
Kuala Lumpur Airport, Malaysia

The new airport at Kuala Lumpur, the hub for Air Malaysia, is positioned about 30 miles from the centre of the capital. Although hub airports play an expanding role in international aviation, they are usually an anonymous collection of terminal buildings positioned nowhere in particular. Since hub airports are the ultimate in placelessness, their architects have recently begun to address how to put identity into these anodyne fragments of global air infrastructure.

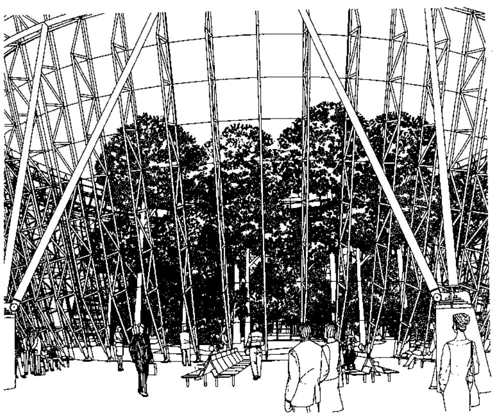
Designed by Kisho Kurokawa, the airport at Kuala Lumpur uses 'indigenous materials, forms and landscaping in an attempt to introduce diversity and complexity into a moribund typology'.[6] The creation of local distinctiveness draws upon the cultural context of Malaysia in an interesting marriage of high technology and regional references. Thus, the new airport acts as an attractive gateway to South-East Asia, drawing upon cultural references without abandoning the principles of modern design.

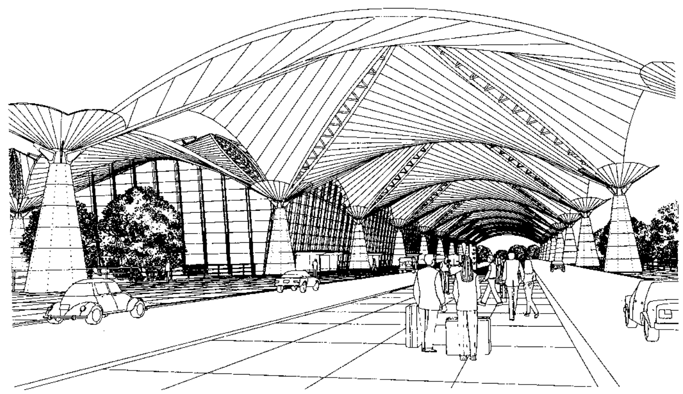
The airport is designed to be efficient, flexible and memorable. Efficiency is expressed in the rational framework of new airport buildings, both terminals and satellites, linked by a rapid transit system not unlike that at Stansted. The buildings are planned on a super-grid of infrastructure that unifies into a logical whole the terminal buildings, runways, aprons and satellites. Outward growth of the buildings has been anticipated as has internal adaptation made possible by keeping the primary structure independent of partitions. The latter provides the advantage also of maintaining the visibility of the primary structure, thereby aiding way-finding through the terminal. The internal orchestration of cone-shaped columns, banana-shaped sky-lights and inverted roofs evokes the Malaysian tradition of timber construction used in a tectonic fashion.

The main terminal building consists of two principal levels for international travellers – arrivals at first floor and departures above with two intermediate levels accommodating domestic arrivals and departures. The four-storey structure is linked to

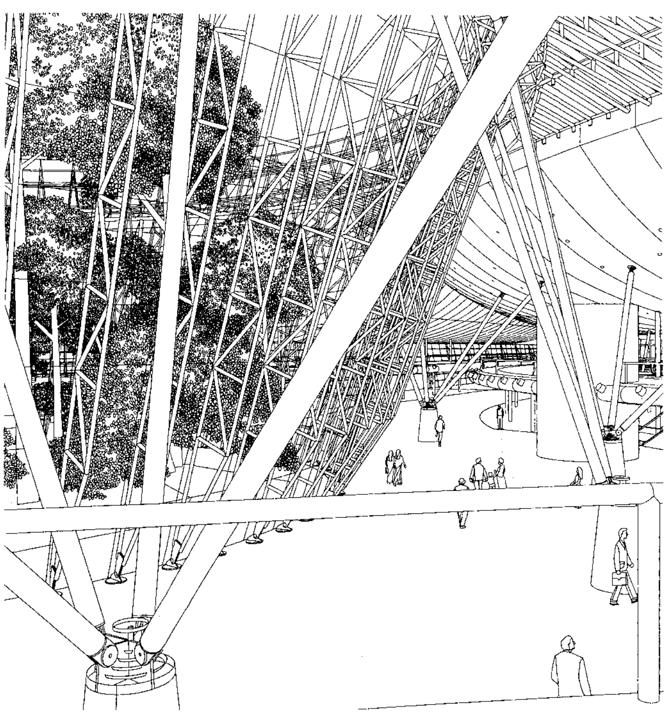


15.4 Plan of Kuala Lumpur Airport with central terminal and two cruciform-shaped satellite terminals. Architect: Kisho Kurakawa.





15.6 Sketch of exterior of main terminal at Kuala Lumpur Airport. Architect: Kisho Kurakawa.



15.5 Sketch of interior of satellite terminal at Kuala Lumpur Airport. Architect: Kisho Kurakawa.

the road system at first floor level and to the high-speed rail network via a station on the mezzanine level. Thus, it is rather more of an interchange than many modern terminals, especially as, unlike Heathrow, Detroit and Gatwick, the airport has high-speed rather than suburban rail connections. The integration of modes of movement and consequential traffic flows is well handled. The plan is ordered to give a sense of orientation with views of the aircraft from much of the terminal. The shuttle train is also highly visible to those using the departure lounge – its movements adding to the theatricality of the airport.

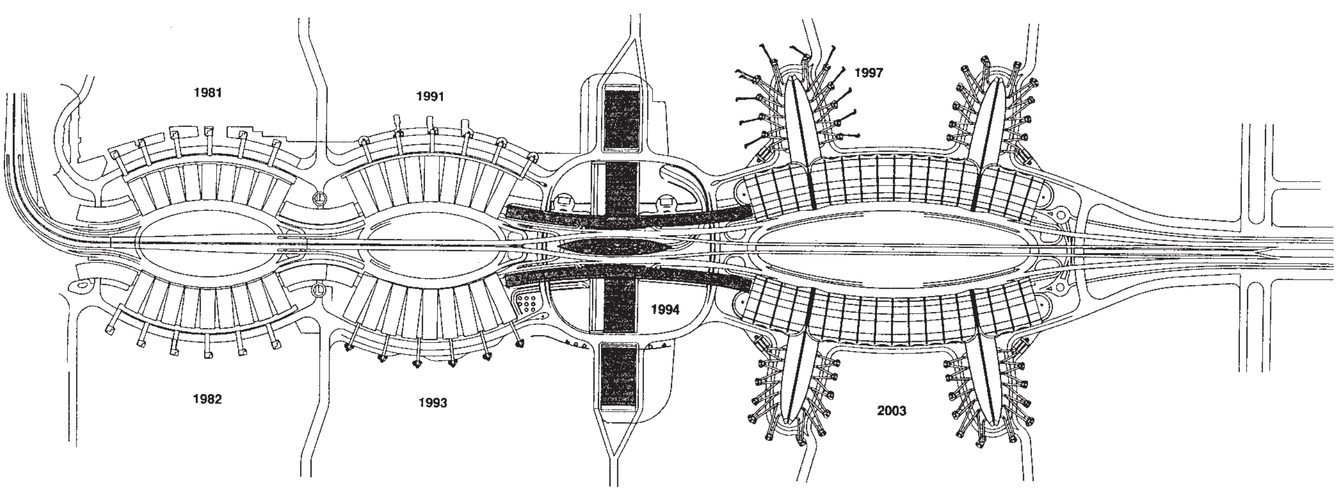
The complex roof of the main terminal building with its hyperbolic paraboloid quadrants of concrete held apart by lines of glazing provides an unusually memorable experience for those travellers with the time to look up. The undulating ceiling supported by squat columns with lighting and ventilation integrated into the column capital orders the activities below. The partitions, guidance panels, enclosed lift shafts and the automatic doors to the rapid transit system are effortlessly absorbed into the space. Softness and acoustic control are provided, not by the floor, which has a hard reflective marble finish, but by panels of timber used to clad the soffit of the roofs. The use of a local Malaysian wood as a ceiling finish adds to the regional references that abound in this airport.

The two cruciform-shaped satellites from which most travellers board their aircraft have the maximum of external area to increase the extent of passenger–plane interface. Four long arms of gate piers extend out across the apron areas, reaching almost to the taxiing areas for the runways. Each arm is narrow, affording views to either side of the boarding aircraft. Travellators run the length of each arm from a central point served by the shuttle train. Hence, for the tired or disabled traveller, there is the maximum of assisted movement. In the centre of each satellite (two are currently built, with four planned for 2008) is a cone of dense forest planting encircled by angled glass walls. These sweep around the seating areas giving passengers views into what appears to be a remnant of Malaysia's rainforest. The unexpected experiencing of so much greenery in a modern airport provides a point of punctuation on the journey to and from the plane. Thus, the central gardens provide both a soothing oasis for reflection and a landmark to aid navigation through the building.[7]

Charles de Gaulle Airport, Paris, France

Unlike London Heathrow with its four terminals and New York's John F. Kennedy with nine terminals, Charles de Gaulle Airport, north of Paris, has only two terminals. The first, constructed in 1974, is a grand circular building in the French Rationalist tradition; the second (completed in 2001) is linear in form, with flattened linked terminals placed on either side of a new railway station. Charles de Gaulle handles less than half the passengers that Heathrow handles, and yet the architecture and scale of public transport facilities are more generous in spirit. Both Terminals 1 and 2 were designed by Paul Andreu, who has become one of the world's leading architectural consultants on airport design, and who played a major part in shaping the design philosophy at Kansai Airport.[8]

Terminal 1 adopts the circle as an organizing principle (just as Nicholas Grimshaw did at the Venice Biennale exhibition design, described later in this chapter). It is a hollow-centred circle, heroic in form, with a scale and geometric clarity befitting the airport age. The movement systems revolve around the central core, which is criss-crossed by elevators and transparent passenger tubes. There are five main levels, each similar in plan, with offices or control points forming a ring outside the circular concourse areas. The arrivals lounge is on level 5, the departures lounge on level 3, shopping on level 2, and (though abandoned for security reasons) car parking on the roof. Outside these, circular roads and ramps revolve within



15.7 Elegant conception in Terminal 2 (left) and Halls E and F (right) astride Roissy Station (centre). Charles de Gaulle Airport, France. Architects: Paul Andreu, Aéroports de Paris.

a perimeter structural system of great concrete columns, which fork as they rise.

The imagery is powerful and sculptural. From the outside the circular concrete drum recalls a flying saucer (especially with its angled walls); from the inside there is a sense of space and grandeur. In its way Terminal 1 gives air travel an appropriate sense of drama and futurist imagery, but the concept is flawed from two perspectives. First, because the terminal is circular it has not proved easy to extend, and second, because each floor is much like the one above or below, it is difficult to gain a sense of relative level or direction. The attempted reconciliation of linear progression within a circular form undermines the clarity of the design. Terminals are necessarily a progression through ticket controls and security checks, and when these are placed in a centralized circular megastructure the functional organization and plan form begin to disconnect. However, the circular form does mean that passengers can gain access to aircraft more directly than in linear terminals, and close proximity to aircraft (which are parked on the apron almost immediately outside the circumference of the terminal) does give passengers interesting airport views.

Terminal 1 is based upon the dual concepts of close proximity to aircraft and dense mixed-use terminal design.[9] Andreu developed the idea from the perspective of reducing the time taken to pass through the terminal by simply reducing travel distances. Close interaction with the aircraft before boarding is said to enhance the anticipation of air travel, and the compression of activities in the terminal adds to the sense of excitement. In many fundamental ways the design is opposed to current orthodoxy with its emphasis upon clarity of route, avoidance of cross-flows, juxtaposition of lounges and retail floors, and the emphasis now placed upon security.

Entry from the terminal to the aircraft is via seven satellites, which are arranged with geometric regularity around the circular building. Again, just as the circular terminal does not give a sense of direction, so too with the satellites, which are themselves five-sided structures of identical form. Rationalist and heroic in inspiration, Terminal 1 seems to have abandoned the human dimension, favouring instead the grand scale of modern aircraft and the abstract, placeless geometries of airport masterplans.

Terminal 1 adopts a distinctive, rather French approach to airport design. The powerful circular imagery of the design, especially the use of rough brutal concrete inside and out, sets the terminal outside the framework of taste fashioned by more cautious clients (such as BAA). Yet there are lessons in the design: Terminal 1 approaches airport design from the precept of the values of the city, not those of the airport. The building is a great dense mixed-use chamber with a lofty atrium in the centre. Building structure and services are not concealed behind suspended and false walls (as in many terminals) but exposed to view. In fact, architectural structure is the main means by which scale is imparted and direction imposed.

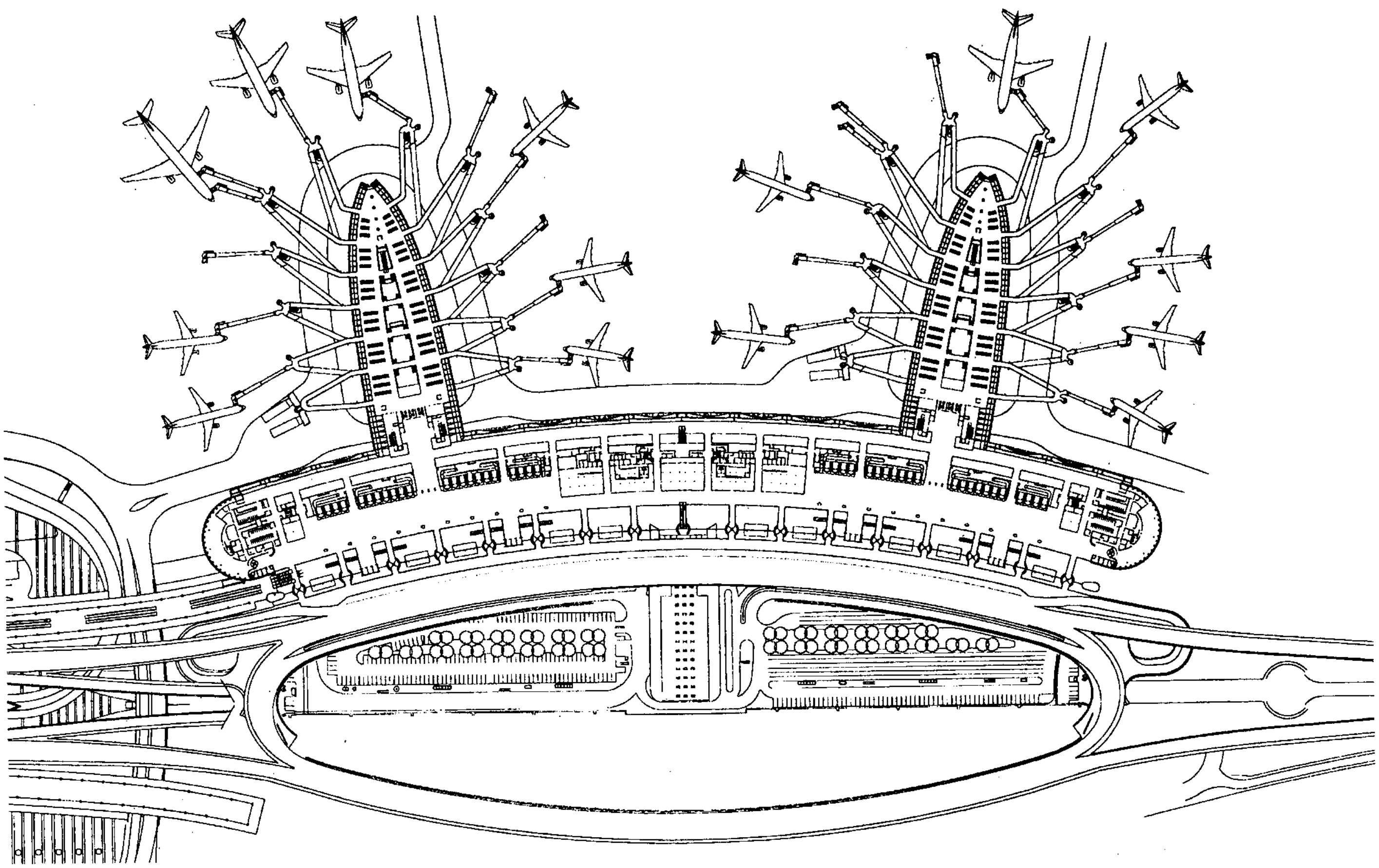
Terminal 2 can be seen as an adjustment to Terminal 1. It shares a sense of geometric order and heroic uncompromising scale, but now the circular shape is compressed into three flattened ellipses. Each is essentially a linear progression, with an axis placed at right angles to that of the underground TGV railway line. Where the two axes intersect, a great circular railway station (known as Roissy) is placed, with a hotel built as a bridge above the station roof. Hence the dense vertical integration of activities at Terminal 1 is replaced by low horizontal spread at Terminal 2. Also, while Terminal 1 is a shared facility between airline companies, Terminal 2 is dedicated almost entirely to Air France. With an expected capacity of 20 million passengers a year (as against 10 million at Terminal 1), the design has evolved on the basis of modular linear expansion. The three linked subterminals of the present design can readily be extended in either direction, and should Air France contract, the separate subterminals could each be managed by a different airline.

Terminal 2 is closer in spirit to practice elsewhere. The integration laterally of airport terminal, railway station and other land uses (e.g. hotel) recalls the pattern at, say, Kansai, and the disaggregation of the terminal into linear parts is not unlike American unit terminals. Perhaps the most important lesson of Charles de Gaulle Airport is the need to maintain clarity in the masterplan – both spatial and organizational – and then to express this in powerful architectural forms: for airport architecture is about giving the airport environment a sense of place and uplifting the spirits of those who travel by air.[10]

Terminal 2, Hall F, Charles de Gaulle Airport, Paris

Charles de Gaulle has grown with greater organizational logic than most large European airports. The French penchant for grand geometric gestures has provided Charles de Gaulle with a plan which, from the air at least, has a measure of legibility. To move from Terminal 1 through Terminal 2 to the new peninsular terminals is to pass through a sequence of circular and crescent-shaped buildings joined together by wide pedestrian walkways which split on either side of a central spine of roads. Axially positioned in the whole composition is a station served by both high-speed rail services (TGV) and suburban ones (RER). Hence, in spite of the complexity of the airport, the scale of operations is handled via a plan which unifies the whole into a legible sequence of mainly distinctive terminals and connecting spaces.

The most recent addition at Charles de Gaulle consists of two large peninsular-shaped terminals known as Terminal 2, Hall F which project from a new large hall which follows the crescent-shaped footprint of the Airports de Paris masterplan. The inadequate size of the earlier Terminal 2 building has been remedied by the construction of a much grander check-in hall.



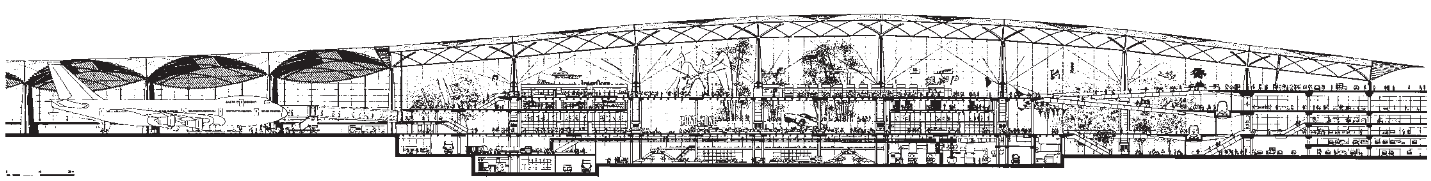
15.8 Plan of Hall F at Terminal 2, Charles de Gaulle Airport. Architect: Paul Andreu.

15.9 View of Hall E (foreground) and Hall F (background) at Terminal 2, Charles de Gaulle Airport. Architect: Paul Andreu.

Built on a shallow curve, it opens onto the airport, bringing views of the aircraft right into the ticketing areas. The large column-free space of the check-in or arrivals hall is made possible by a concrete vault spanning 74m. Arriving passengers progress through this huge, monumental volume to an airside concourse with a number of elliptical cut-out windows providing close-up views of aircraft and of the peninsular gate lounges placed at right angles to the main hall. Passengers taking the journey from ticket check-in, through security checks to the wide curving concourse are guided by bands of natural light taken across the ceiling in the direction of flow. Hence, unlike Stansted or the earlier Terminal 1, light is used to aid navigation rather than just to light the interior volumes.

The latest terminal buildings at Charles de Gaulle celebrate equally the arrivals concourse and the departures lounge. In this the architects, led by Paul Andreu, have learnt from the experience of Kansai. The new arrival concourse is reminiscent of the canyon check-in area at Kansai[11] with its triple-height volume and high-level bridges. Shaped from the outside like the wing of a 747, the finish in zinc and aluminium adds to the aeronautical character.

15.10 Section through concourse of Hong Kong's airport at Chek Lap Kok. Notice the structural distinction between elements (gate spine to left, concourse centre and car park and roads to right). Architects: Foster and Partners.



Departing passengers enter the space at high level and those arriving enter at low level where baggage reclaim is located. As a consequence, the road system is raised in a fashion familiar to most large airports with the railway station at a lower level. The cross-section provides the means of organizing the passengers and baggage with the architectural play of light, structure and volume assisting way-finding. A limited palette of materials and colours (mainly greys and buffs) provides a crisp, if arguably overly-neutral, backcloth for the drama of travel.

After security checks, passengers leave the main hall and enter large cigar-shaped terminal piers. Placed at right angles to the curving main terminal building, these are large airy volumes on two main levels bathed in natural light. In contrast to the concrete vaulted main hall, the two peninsular halls (as they are known) are constructed of steel and glass. The different language of materials provides a contrast of light and transparency which aids navigation while also giving a sense of progression from air to ground. The latter is alluded to by the tapering shape and appearance of a fuselage from the outside and the airiness from the inside. A spine of structure extends the length of the building with beams projecting on either side following the curved shape in plan. The symmetry allows seats to be positioned on either side of a wide central walkway which is punctuated by elliptical-shaped flight information stands.

The new terminal buildings and piers at Charles de Gaulle provide memorable additions to a maturing airport. Architecture is used to celebrate travel – these buildings are a huge gateway to Paris, with all the style and panache one would expect of a major European city. The contrast in construction between concrete and steel framing provides legibility by simple architectural means. The sequence of experiences from plane to station is marked by different effects of light, structure and volume. The deliberate contrasts mean that the airport is becoming a place to enjoy rather than to endure.

Chek Lap Kok Airport, Hong Kong

The airport on the man-made Chek Lap Kok island in Hong Kong Bay, opened in 1999, is the centrepiece of a large infrastructure project involving also new railways, roads, bridges and causeways. The airport, built to meet Hong Kong's economic needs into the twenty-first century, caters for 35 million passengers a year, growing to an expected 87 million in 2040.

Designed by Sir Norman Foster and Partners, the concept extends the architectural language of Stansted, but now translated into a much grander multilevel terminal. Unlike Stansted, the roof is a gentle arch, and at Chek Lap Kok the satellites are united with the main terminal by lengthy gate spines served by both pedestrian and light rail movements. In plan the design recalls the footprint of a primitive aeroplane, with angled wings, a tailpiece and fuselage. Here however the analogy ends, for in section and detail the design speaks the language of transport architecture, not flight.

The main terminal concourse consists of three main levels – baggage handling on ground, arrivals on first, and departures on second floor – and extends beneath a wide gentle arch from a five-storey car park on landside to satellite piers and waiting aircraft on airside. Structural design (by Ove Arup and Partners) inevitably plays a large part in determining the character and quality of the terminal. Such are the dimensions of the terminal (it is the size of Terminals 1 and 2 at Gatwick and Terminal 4 at Heathrow put together) that the spacing of columns and the grid of roof beams have a primary role in articulating interior space and making it understandable to travellers. Over 4 million ft^2 (40 000m^2) of terminal is enclosed by the delicate curvaceous roof, and according to Foster's office the baggage hall beneath is the size of Wembley Stadium. With interior volumes on this scale, structure is more than an exercise in supporting floors and roofs: it is the main

15.11 View of arrivals concourse, Chek Lap Kok Airport. Architects: Foster and Partners.

15.12 Detail of terminal ceiling at Chek Lap Kok Airport. Architects: Foster and Partners.

means by which directional legibility and internal order are provided.

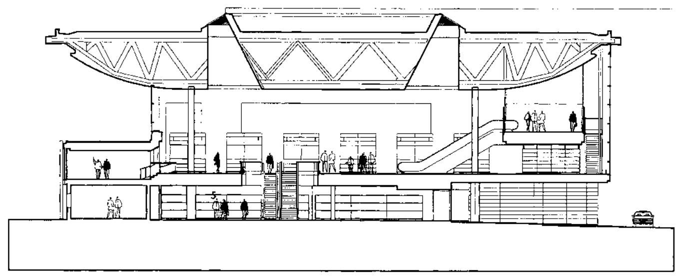
The design and brief have been developed with BAA International (also the client body at Shenzhen Airport in China), who have had a long-standing relationship with both architect and engineer. BAA, having successfully undertaken airport expansion in the UK, has recently taken its expertise in project management, site feasibility and cost control to other parts of the world, often employing UK designers and engineers in the process. The new terminal at Hong Kong also reflects the changing function of airports. Besides handing passengers, the airport is also expected to transport over 1.3 million tonnes of cargo a year. Within the terminal itself about 10 per cent of the floor area is given over to business and conference facilities. No longer can terminals be viewed as a singular activity: they inevitably engage in the social and business life of the city they serve.

Foster's Hong Kong office, established to produce the 30 000 contract drawings needed to bring the terminal to fruition, paid considerable attention to the standardization of parts. Elements of construction were designed to avoid variation, and (in tune with BAA ethos) the design matured in collaboration with component manufacturers and suppliers. This inevitably has given Chek Lap Kok an air of repetitive order, especially in the design of roof elements and principal facades. A major 36m square structural grid breaks progressively down into 12m and 9m planning grids, which lead in turn to component and partition grids of 1500mm. The hierarchy of grids from structural frames to constructional units allows components, assemblies and panels to be produced relatively economically. The sense of a rectangular order in plan and refined curved forms in section provide a robust discipline throughout both terminal and satellite areas. In this sense the design is a logical development of the precedent of Stansted, confirming that terminal's continuing relevance to airport architecture.

Copenhagen Airport, Denmark

Copenhagen Airport has seen major expansion over the past decade. The construction of Oresund Bridge linking Denmark and Sweden led to Kastrup (or Copenhagen Airport) becoming the major airport not only for much of Denmark but also for southern Sweden. The building of a new rail link as part of Oresund Bridge led to the construction of a station at Kastrup directly beneath the new Terminal 3. Thus, the 18 million passengers a year at Kastrup now have direct high-speed trains running west to the centre of Copenhagen (10 minutes) and east to Malmö (20 minutes) and to Lund (35 minutes). Kastrup Airport has grown over a decade into a major transport interchange serving a thriving region of Europe via a combination of plane, train, bus and car.

Designed by KHR Architects of Copenhagen, Terminal 3 was completed in 1999 and has a floor area of 40 000m^2 with a station of a further 12 000m^2. The latter has four tracks and two main platforms capable of accommodating trains of 14 carriages in length. Access to the station is via a series of ramps and travellators placed at right angles to the main axis of Terminal 3. Passengers arriving or departing are drawn to the spine of daylight that runs through the centre of Terminal 3 in the direction of passenger flow. This shaft of light (and often sunlight) draws passengers to check-in and to the various galleries that provide refreshment or shopping at higher levels along the route. Since the station is also open to the sky above the tracks, there is a similar avenue of light into which the trains arrive. Thus, both axes, skilfully placed at right angles

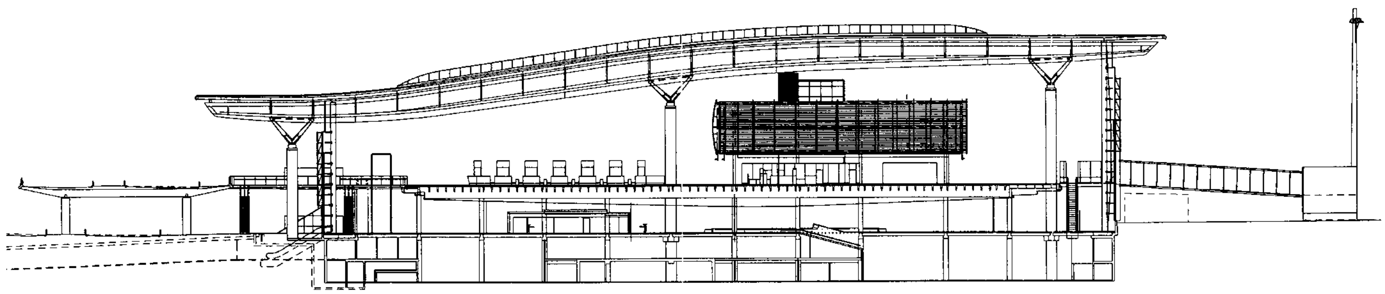


15.13 Passport Hall, Copenhagen Airport. Architects: Holm and Grut.

to each other, provide the main means whereby passengers navigate their way through the new terminal. Also, since the terminal is on three main levels, diagonal views are kept open as a further aid to orientation.[12]

Passengers arriving at Terminal 3 are not only encouraged to follow the band of light but to walk between pairs of giant columns that further define the route. It is like walking through the nave of a cathedral with the shops, information points and ticket check-ins placed like aisles to the sides. The columns are extremely tall, drawing the eye upward to the roof-light above. The presence of the columns placed to express the route through the terminal also helps to prevent encroachment by retail or other activities into the path of passengers. Hence, compared to other airports with a more neutral structure (Manchester, Stansted, Schipol), the major circulation areas are kept open both physically and perceptually.

Between Terminals 2 and 3 the Schengen Hall (a new customs area) was built in 2002 to provide a more legible link between finger piers C and D and the bus terminal. The ground floor of the hall contains bus lounges with direct access to five covered bus platforms as well as police and asylum rooms. Above, there are passport control points with escalators and lifts providing access to tax-free shops and ticketing areas. The design of the hall is a double-height rectangle with a large elliptical ceiling set with a band of curved roof-lights. The effect of the elliptical ceiling is to signal the point of intersection between routes and to help locate the position in the passenger's mind of the major stairs and escalators.



15.14 Section, Gardermoen Airport, Oslo. Architects: Aviaplan As.

Development at Kastrup Airport over the past decade has not only provided air travellers at Copenhagen with extra space, but it has also added to the ease with which passengers can move between bus, rail and air services. However, in addition, a deliberate attempt has been made to exploit the potential of architectural design to signpost the routes and functional hierarchies at the airport. This is further reinforced by the judicious placing of public art at points where orientation is required on the routes through the terminal buildings.

Gardermoen Airport, Oslo

Oslo Airport was designed in 1995 by Aviaplan AS, a consortium of architects, engineers and contractors. It exploits a redundant military airfield nearly 50km from the centre of Oslo. The former military runway has been converted to domestic flights with a new longer runway constructed to serve international flights. The new airport terminal sits between the two runways which are 2km apart and is served by a railway station and bus terminus. The airport covers an area of $12km^2$ and cost around £1.2bn to build in 1998. The two runways at Oslo Airport (one international, the other domestic) allow for more than 80 take-offs and landings per hour. Assuming each flight holds 100 passengers, this means a throughput of 8000 passengers per hour. The aim is for 50 per cent of passengers to use the new train service (which runs at 10-minute intervals) with a further 15 per cent arriving by bus.

Since Norway has a national architecture policy, the new airport adopts many principles which are the result of governmental ambition. For example, the emphasis upon public transport supports Norway's strategy for sustainable development, as does the use of timber in construction and the maximizing of natural light. From the airport authority's standpoint, the new terminal was designed as an efficient gateway to aviation services. The brief required a flexible building, economic to build and run, simple to operate and robustly detailed.[13] The initial design featured a wide span steel roof but this was modified later after political pressure to include a large element of timber construction in order to help market the Norwegian timber industry. The latter change reinforced the building's design philosophy which was to use heavy construction at the ground and progressively lighter construction as one moves vertically through the terminal.

The new terminal consists of a large simple building supported by 30 free-standing concrete columns. These support massive glulam timber beams whose presence is rarely denied within the terminal building. The timber beams sweep above the departure hall, rising to airside to create a wall of glass adjacent to the aircraft aprons. The terminal is on three main levels with a generous departure hall above the arrivals area which sits over the baggage sorting area. A long airside pier extends at right angles to the axis of the terminal providing access via gate lounges and telescopic bridges to the planes.

The construction of the airport exploits the tactile and cultural quality of materials. Concrete and timber are mixed with aluminium, slate and glass to provide an attractive play of colours and textures. The timber and slate make reference to

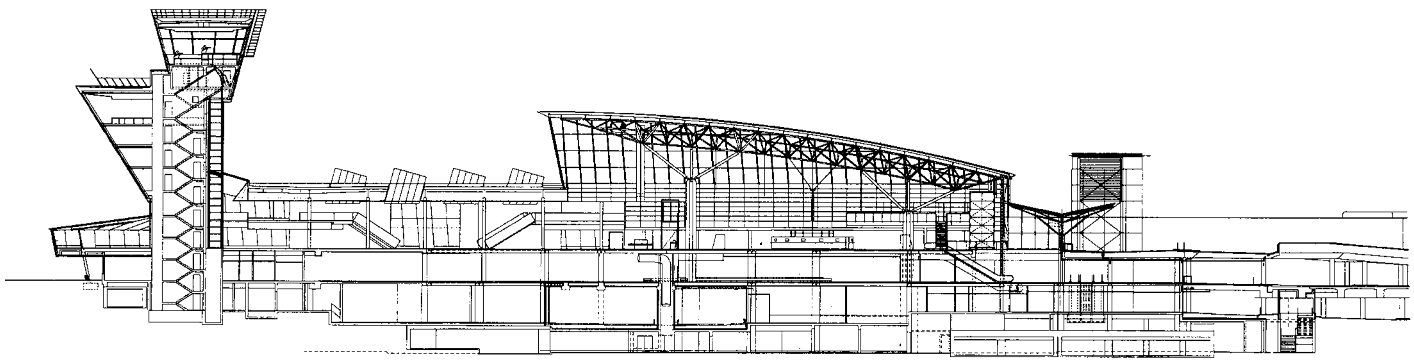
15.15 View of departure concourse at Gardermoen Airport, Oslo. One of the office 'pods' is to the left.

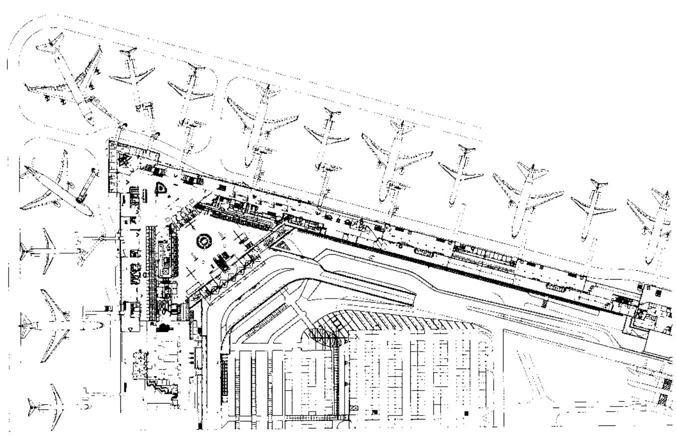
the Norwegian countryside, whilst the sophisticated glazing technologies employed refer to the internationalism of air transportation. A major feature of the departure hall is the three office pods which stand at high level in the volume. These, enclosed in a hall of louvered glass, provide points of reference which aid orientation in the space. From the outside the curved roof helps the terminal shed the weight of its winter snow. Another climatic design feature is the way the terminal entrances are set well back behind generous over-sailing roofs to prevent snow being walked into the building.

Terminal 2, Helsinki Airport, Finland

The unusual triangular shape of Helsinki's Terminal 2 was the result partly of the alignment of runways but also the need to integrate the new terminal with a control tower positioned to overlook the runways. The new Terminal 2 is entirely for international travellers with Terminal 1 converted to domestic travel. Both are linked by a generous glazed walkway nearly 200m long, which affords views over the car park and airport landscaping.

15.16 Section, Terminal 2 at Helsinki Airport. Architect: Pekka Salminen.





15.17 Plan, Terminal 2 at Helsinki Airport. Architect: Pekka Salminen.

Terminal 2 consists of a wide arrivals hall where check-in is conducted linked to a lower arrivals area served by escalators. Passengers pass through the apex of the triangular-shaped hall through passport and security checks to two wings of gate lounges. A long transit hall placed within the acute angle provides views of the nearby aircraft standing on adjacent aprons.

Designed by Pekka Salminen Architects, Terminal 2 is not large by European standards. Built in 2000 to accommodate anticipated growth following Finland's transitional absorption into the European Union, the new building has an understated elegance. This is the result of a simple plan which angles passengers towards the point of departure, moving them upwards and outwards in a logical fashion. The space frame ceiling structure above tilts to further express the direction of movement with the shallow curve expressive of an aircraft wing.

In order to unify Terminals 1 and 2, the palette of materials in the new building follows those employed in the older neighbour. Steel, glass and terrazzo are the major construction materials on the inside, all used with Scandinavian finesse. On the exterior, stainless steel, aluminium and tinted glass are employed, creating a high tech image for the airport.

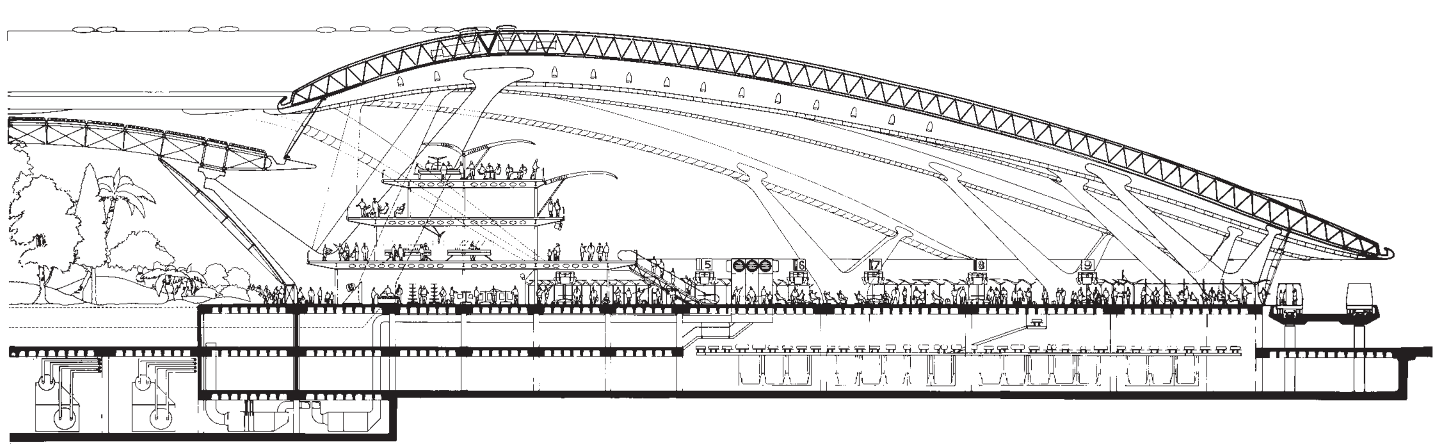
Airport design: Fifth International Biennale of Architecture, Venice 1991

As a generic design proposal, that by Nicholas Grimshaw & Partners for an international airport at the Venice Biennale of 1991 has had influence on the development of ideas surrounding terminal design. Grimshaw's design consisted of an integrated airport and railway station based upon an oval plan. The relative simplicity of the spatial geometry, which involved only two radii, and the clarity of the routes through the proposed terminal made the building memorable as an architectural concept when exhibited at the Biennale. Its influence is perhaps to be seen as far apart as Richard Rogers' competition entry for Heathrow's Terminal 5 and Aviaplan's design for Oslo Airport. Both extend the language of huge-scale muscular-framed pylons with extensive internal landscaping between elements of the building, and plenty of daylight flooding through breaks or folds in the roof.

Grimshaw's terminal design was also one of the first to be conceived deliberately as a landmark structure within the openness of a typical international airport. The oval footprint and the elegantly curved roof created a sense that the terminal was the focal point architecturally within the vast collection of buildings that constitute the modern airport. From the outside the terminal consisted of an elliptical bubble of translucent roofs traversed by great deep lattices supported by angled columns. The building was nearly all roof, which swept down like the petals of an enormous flower, each fold or segment separately expressed. From the inside of the terminal, the experience would have been akin to walking through a giant doughnut with a great elliptical glazed atrium in the centre. This space, filled with forest-sized trees, marked the barrier between arrivals and departures, celebrating the transition with rare aplomb.

The exaggerated attention given in the design to questions of light, planting, directional understanding and architectural space signalled a new direction in 1991 for airport design. Hitherto (Stansted is a good example) terminals were conceived as elegant but rational structures: large flexible boxes able to accommodate changes in airport planning without being compromised by excessive architectural ambition. Grimshaw's design turned such concepts on their head; the role of design was now to exert a presence, to give legibility to users confused by the changes of level and direction of a typical airport, to uplift the spirit, and to provide a celebratory gateway to the country that the airport served. Instead of a flat-roofed, Cartesian conception, Grimshaw provided at the Venice Biennale a modern cathedral of flight.

The section is a simple one: all the services and facilities needed are placed in a great market hall, mainly at one level. Trains deliver passengers to this deck, who process through check-in, restaurants, shops etc., all at the same level (with obvious advantage for disabled passengers). The central atrium is a giant green space to overlook from cafes and galleries around its edge, rather in the way that houses face onto a leafy square in central London. The trees, earth banks and shrubs located here are not designed to be entered but to be looked upon. Hence landscape and nature are used to relieve the stress of modern airline travel, not to screen an offensive object. Baggage is handled beneath the main deck, where air-conditioning equipment is also housed. Fresh air, admitted at low level, is drawn through the terminal by the thermal currents generated by people and equipment. It is



15.18 Proposal by Nicholas Grimshaw & Partners for Terminal 5 at Heathrow based upon the design for an international airport exhibited at the Venice Biennale in 1991.

extracted at roof level through vents that also provide smoke extraction in the event of a fire. With similar economy, the air intake points at lower level double up as fire escapes in an emergency.

The physics of air movement supports the oval-shaped terminal plan and the curved section. It combines also to create an architectural space that gives presence and dignity to mass modern air travel. The concept design is based upon an anticipated aircraft movement every two minutes (or up to 14 000 passengers per hour), with 68 parking stands for aircraft ranging from 120 to 800 seats in size. This approximates to 30 million passenger movements a year, roughly the capacity of Heathrow's Terminal 5.

The terminal and piers are physically separated: passengers travel between the two on underground railways in the fashion of Stansted. The piers (or airbridges as the design calls them) are detached structures laid out as two parallel arms crossing the airport apron. Trains running every two or three minutes would each carry 150 passengers to the different aircraft gates along each pier.

Inevitably, Grimshaw's concept design at the Venice Biennale and his competition entry for the design of Heathrow's Terminal 5 have much in common. Although the arrangement of piers changed, there is little difference in fundamental thinking. Both designs feature a large central glazed space – essential for orientation and the creation of interior scale. In both too the expression of massive structural members is the primary aesthetic element, and in each design curvaceous volumes and daylight suppress the tendency of commercial activity to reduce internal spaces to second-rate shopping malls. Although the practice has yet to construct a major new airport, the ideas put about in exhibition and competition entry have helped shape the thinking of others.

Terminal 5, Heathrow, London: initial design

Terminal 5 at Heathrow promises to take one step further the new approach to airport design witnessed already at Stansted and Kansai. If the proposals by the Richard Rogers Partnership emerge relatively unaltered, the new terminal will on completion in 2006 confirm the arrival of a fresh generation of airport architecture. Whereas the first wave of airport terminals were largely characterless, orthogonal, poorly lit and often labyrinthine structures, more recent terminals – of which the embryonic design for Terminal 5 is a prime example – exploit natural light, spaciousness and curvaceous forms to reduce the stress of air travel, and to provide greater clarity of route. The design commission, awarded to Rogers in a limited competition in 1991, which included Renzo Piano and Michael Manser as assessors, also represents a move towards combating the trend whereby terminals look the same the world over.

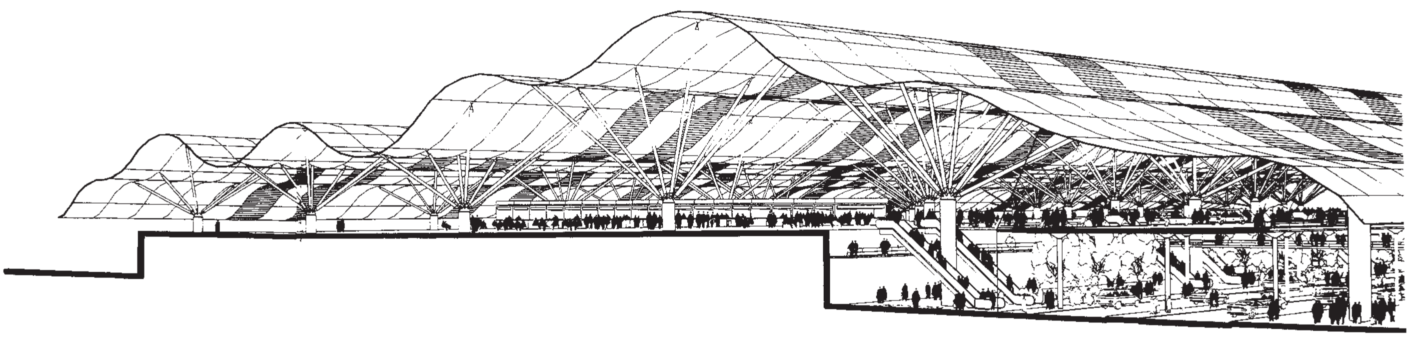
Terminal 5 combines two principal technical elements – new rapid baggage handling and assisted people-movement systems – with the design of space and structure, which draws upon a combination of ecological and urban metaphors. The rationality of movement is tempered by great tranquil spaces, where the variegations of light, shade, solid and void are meant to recall the pattern of streets and parks in a city. The juxtaposition of invisible mechanical systems, which move baggage with unprecedented speed and efficiency, with sensuous tent-like shelters and almost floating ceilings supported by branching columns gives Terminal 5 an altogether different character from Heathrow's earlier buildings. The patterns of light, structure and diaphanous material are intended by the architects to give passengers a 'positive memorable experience'.[14]

15.19 Elevation of Grimshaw's design for Terminal 5. The concept owes something to Andreu's circular forms employed at Charles de Gaulle Airport, though here modified by the need for natural ventilation.

15.20 The Richard Rogers Partnership's original design for Terminal 5 at Heathrow uses technology as a metaphor for contemporary culture. In its absorption of ecological principles the design strikes a new balance between the airport and nature.

In some regards Terminal 5 represents a new appreciation of the commercial value of good design on behalf of BAA. The brief instructed Richard Rogers' office to develop a design that was unmistakably of the UK, and which would act as a prestigious front door to the country. Coordinated by Raymond Turner, BAA's design director, the building will fail, he claims, if it is not an exceptional experience for the passenger and fails to promote the customer-oriented ethos of BAA.[15] In order to help integrate the different buildings and structures into a coherent whole, the brief required that all the principal buildings (T5 is more than a single terminal) should share a common architectural style, with the Rogers' office being 'the guardian of design principles'.[16] According to the BAA, the quality of the environment is the main means by which customer perceptions are shaped. Large spaces beneath an undulating and unfolding roof, plenty of natural light, and a structural system that is reminiscent of trees in a park achieve a distinctiveness that may help to set Terminal 5 apart from other major world airport terminals.

15.21 Sectional perspective of original Richard Rogers Partnership's design for Heathrow Terminal 5. Architects: Richard Rogers Partnership.



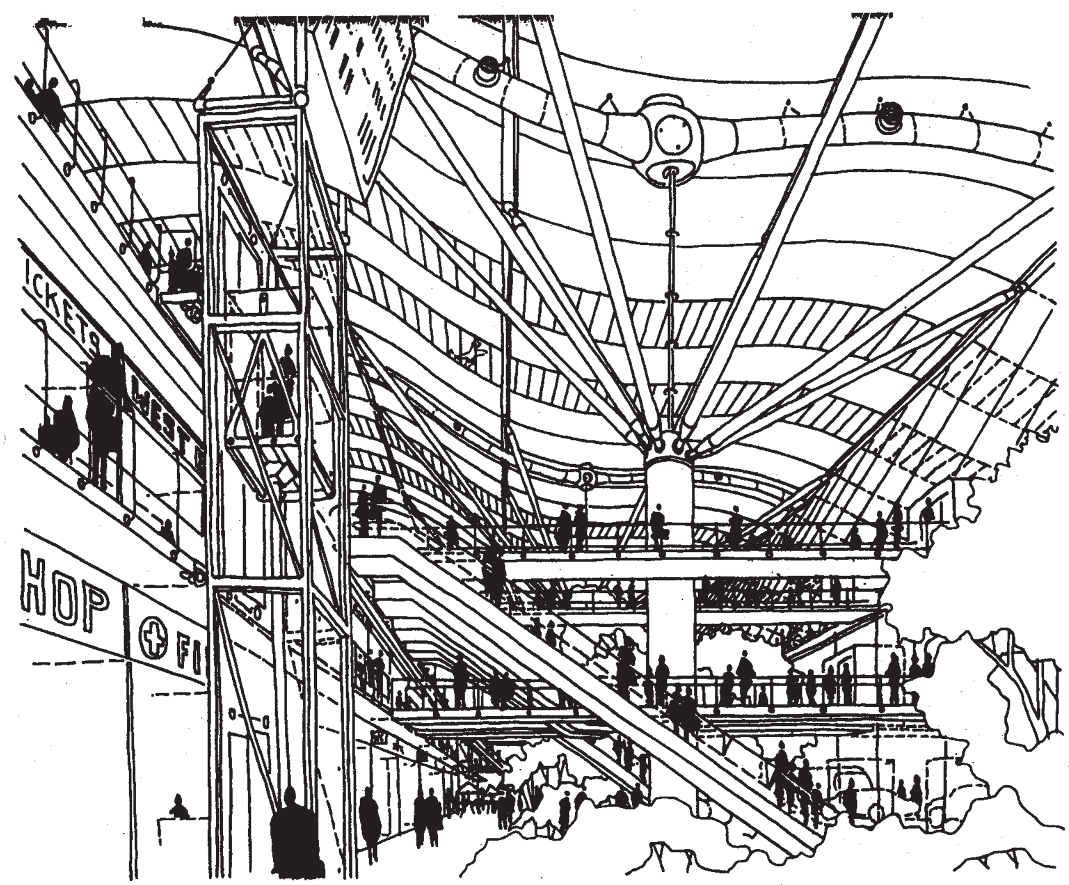
The building is rectangular in plan and, like Stansted, extends a bay of roof outwards to protect the landside approach road and the airside access jetties. Hence passengers are sheltered at the car and bus drop-off point on one side of the terminal and at the point where planes are boarded on the other. The sheltering roofs are not canopies attached to the side of the building but part of a single undulating roof, which rises and falls to mirror the activities inside the terminal. At its highest point the roof glides over six-storey interior spaces created by three linear ridges of retail and office accommodation. The sequence of atria and accommodation islands helps to define the functional progression through the terminal. The principal public areas, marked by lofty atria, contain the four main concourses: assembly and check-in; shopping; customs and departures; and airside aisle.

The progression through the building is steered by natural light: successive bands of daylight signal the next stage in the journey through the terminal. Immediately beneath each line of rooflights stand the branched columns that support the roof. Consequently, the columns and their radiating arms are picked out in light, adding a further element to passenger orientation. Two types of natural light are employed: direct light, which enters the centre of the building, and a softer, diffused light, which filters through the complex roof structure.[17] Because artificial light is the principal element of bought-in energy (accounting for about 40 per cent of building running costs), the design seeks to optimise natural sources. Roof glazing allows daylight penetration into the core of the building, where major offices (for airline, customs and immigration staff) and concourses (duty-free shopping etc.) are located. The undulating roof is also intended to reduce (by deflection) light spillage into the night sky: a potential hazard for pilots and a source of community annoyance.

Terminal 5 owes its geometric simplicity and structural elegance to the precedent set by Stansted, yet it takes Stansted's tree-like columns and islands of rooflights a step further forward. The undulating roof gives interest and direction, whereas Stansted's flat ceilings are without a sense of hierarchy or progression. While Terminal 5 and Stansted may share similarities in plan and structural arrangement, the cross-sections of the two buildings are quite different. Terminal 5 is a multilevel terminal with departures above arrivals in the traditional arrangement, but split to allow diagonal daylight penetration. A central bank of elevated shops and bars allows the baggage reclaim hall to flow beneath, and gives justification for the roof to rise in the middle. The irregular elevation given to the roof not only enlivens the building from the outside (particularly, one anticipates, with views from the air); it also gives meaning to the interior progression inside. In this respect it is a hybrid between the exuberant, structurally muscular Kansai Airport and the neutral yet refined flat-roofed Englishness of Foster's design at Stansted.

The roof is a major defining element in the design. Its wave-like form extends the precedent of Kansai in two important ways. Whereas Renzo Piano's roof has a double asymmetrical shallow and abrupt curve, the design of Terminal 5 consists of five symmetrical waves of varying height. The effect is not one of a single wave but of a series of ripples peaked in the centre. The other significant departure from Kansai concerns the

15.22 Direction of progress indicated by light and roof undulation in the original design for Heathrow Terminal 5. Architects: Richard Rogers Partnership.



construction of the roof. Kansai is beefy and vigorous in its structure and detail, with several layers of roof construction each individually expressed. Rogers' roof design is 'a single-layer skin', which passengers perceive as a delicate cover that is supple and that shapes the space.[18] It is free of services, so that the elegance of the structure is not compromised. Again, following the example of Stansted, the height of the roof allows smoke venting by natural means. In some ways the architecture of Terminal 5 is softer than in many recent airports, and its engineering is understated and poetic rather than posturing. This is to achieve what John Young (a partner in Rogers' office) describes as an 'ambience of calm and visual clarity'.[19]

Some principles of the construction had already been fixed before the design was changed. To speed site operations it has been decided to use steel for the superstructure, concrete on pad (not pile) foundations for the substructure, and lightweight cladding. With little space for the storage of materials on site, and complex beneath-ground conditions (because of airport services, underground railways etc.), the need to reduce weight and maximize prefabrication has emerged as an important discipline. The building will not be air-conditioned throughout its area or throughout the day. The intention is to use mixed-mode ventilation maximizing the thermal currents inside, which flow from the interesting roof shape. Natural light, and ventilation are all part of the environmental strategy, aimed not just at energy conservation but at the health and psychological welfare of workers and passengers.

The design combines the detached satellite terminal arrangement with the idea of a core terminal served directly by aircraft parked on the apron. It dispenses with long elevated piers, preferring to use instead relatively short lengths of underground passageways with travellators and rapid transit systems. These serve the two independent satellite terminals (a third one is planned for the future) but access from the extended Piccadilly Line and Heathrow Express stations is possible only via the main terminal. The arrangement allows aircraft to park close to the buildings in a 'toastrack' plan, thereby maximizing apron and taxiing areas. The compact layout also reduces travel distances for passengers, and provides ease of transportation interchange. The satellite buildings (or mini-terminals) are designed as smaller versions of the core terminal. They share its folded curved roofs, which allow light to penetrate to the centre. The simple repetitive plan form repeats the arrangement elsewhere, though there is less need to orientate the passenger where proximity to views outwards across the airport runways suffices.

It is evident that in the design of Terminal 5 effort has been made to learn from earlier airport designs – mainly Kansai, Stansted and Stuttgart. The BAA's policy of prototype development, evaluation and subsequent refinement allows the sources and influences at Terminal 5 to be identified. However, the design promises to have that sense of occasion that Rogers rightly identifies as a feature of great nineteenth century railway stations[20]. Both architect and client share an ambition to create a 'light, airy, stress-free environment' in what is rather more a massive passenger transport interchange than merely a terminal building in the traditional sense. As with Victorian railway termini, the engineer has played a large part in shaping the architecture as well as the structural design of the building. Inevitably, Ove Arup and Partners have been the engineering collaborators working with Rogers' office since their commission in 1991, just as they did earlier with Foster at Stansted and Piano at Kansai.

When Terminal 5 is completed in 2006 it will handle 30 million passengers a year, nearly half of Heathrow's predicted total at that time. This compares with 30–40 million at Seoul Airport (whose land-side interchange was designed by Terry Farrell and Partners), 25 million at Kansai, and 10 million at Stansted. With such numbers, architecture is the main vehicle available to uplift the spirits and provide a spectacle in the tradition of the great stations of the past. Light appears, from the published plans, to be the key to the architectural experience and the means of navigating such a complex, multi-level building. Light and hierarchies of space are also used to define the major processional routes through the terminal. Because natural light is exploited to the full, problems of glare and solar gain have had to be overcome using louvres, angled walls and eaves overhangs. The expressed environmental controls provide a measure of complexity and detailed richness to the design, especially theprovision of fabric canopies so conspicuous in the published interior views. Angled walls, required to reduce solar gain, have the advantage also of reducing radar reflectivity.

The passenger needs of comfort, stress-free travel, legibility and excitement, which were BAA's prime concerns, have been translated into an elegant design. As Turner notes, Terminal 5 represents an 'inside out' approach to design.[21] It is not a classical modernist pavilion in a verdant park (the model of Stansted), but a building shaped by environmental factors, site planning factors, the need for passenger orientation, and current thought on the relationship between architectural quality and corporate mission. That BAA should value design as a marketing tool and a means of promoting company loyalty represents a departure from earlier practice in the 1960s and 1970s. Though the design of Terminal 5 has had to adjust to planning conditions that flowed from an earlier public inquiry, there is an elegant robustness to what Rogers' office calls a 'seamless unity of space, structure and natural light'.[22]

Revised design for Terminal 5: Heathrow

The design of Heathrow's Terminal 5 by the Richard Rogers Partnership has developed a great deal since planning permission was granted in 2001 following an extensive public inquiry. The design of the terminal now includes a parallel block of car parking six storeys high, separated from the terminal entrances by a quasi-public park. The arrangement

15.23 Aerial view of revised design for Terminal 5 at Heathrow. Architects: Richard Rogers Partnership.

15.24 View of exterior street between new terminal and car park. Revised design for Terminal 5, Heathrow.

15.25 Interior of check-in concourse. Revised design for Terminal 5, Heathrow.

of buildings, landscape, roads and runways confirms the suggestion made by Rogers on his appointment in 1998 that airport design is as much an exercise in urban design as in building design. High-level bridges connect the car parks to the wide and expansive check-in lounge which, as the computer images show, are animated by a play of shadows cast across the lines of structure.

The park sandwiched to the south of the terminal means that views outwards on the landside are over a double line of trees while those airside are over the aprons to the runways. Thus, directional legibility is provided by 'green' landside views and 'aircraft' airside ones. There is greater economy of structure and simplicity of volumes in the latest design for T5. The wave roof of the earlier scheme has been transformed into a single bow-shaped structure which is interspersed by bands of roof-lights which signal the direction of movement. Wide branching columns act as arrival portals from roadside with a matching colonnade framing the view over the runways. As in the earlier design, the single terminal provides only a dozen or so directly accessed aircraft stands: the majority of flights are boarded from satellite piers reached (as at Stansted) by underground trains.

In 2004 the project cost was £3.75 billion or about £5.5 billion Euros. Rogers' office is the lead designer supported by a number of other practices including YRM (responsible for Terminals 1 and 2 at Gatwick) and HOK. Planned to open in 2008, Rogers sees the terminal as 'a genuine civic space (and) a worthy successor to the great railway stations of the nineteenth century'.[23]

New procurement guidelines for Terminal 5

Besides the new design approaches outlined, Terminal 5 is the first major UK airport to be evolved within BAA's construction, procurement and project management guidelines of 1995 (see Chapter 7). The architects and engineers have generated

15.26 The proposed new airport at Bangkok is evidence that tectonic architecture and regional traditions can be reconciled. Architects: Murphy/Jahn.

the design within a kit of parts that, once developed and tested, will be manufactured with life-cycle quality, ease of assembly and replaceability in mind. Prefabrication and standardization are key concepts: both are considered essential in cost control, in speed of construction and in terms of reliability. Added to this, many products (because of site access and storage constraints) will be flown in, thereby exposing UK suppliers to international competition – another BAA tenet.

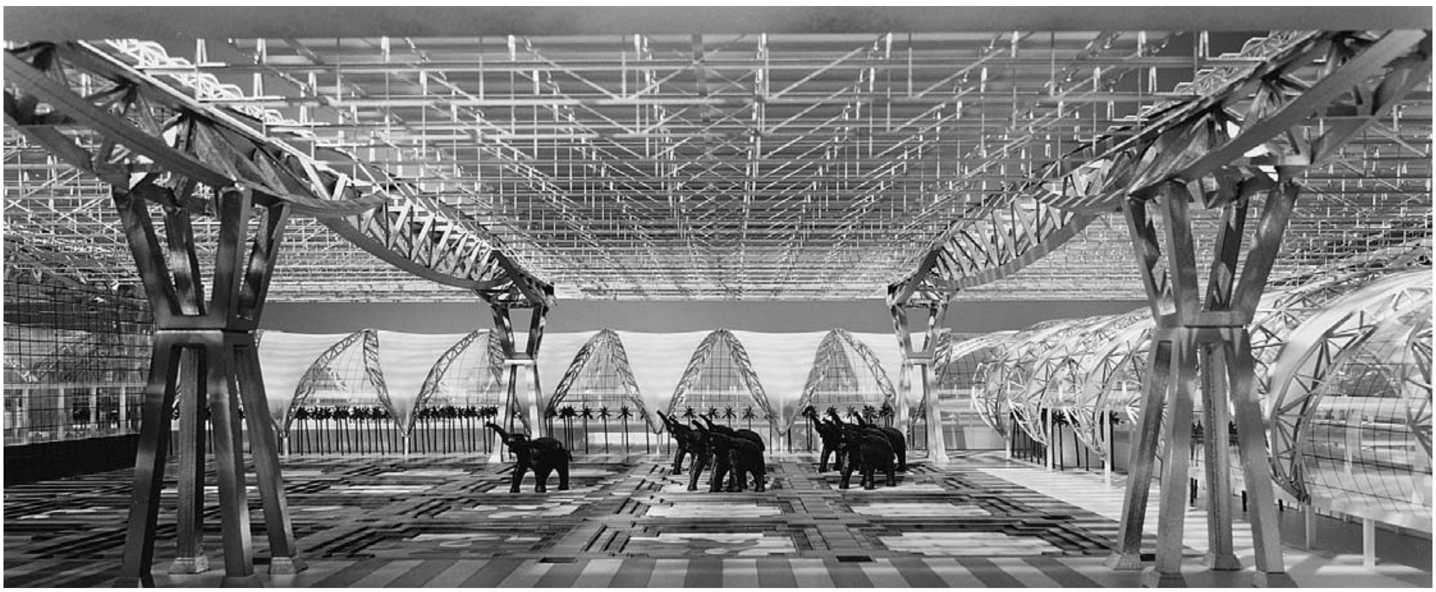
Prefabrication limits the freedom of design but, as Rogers notes, 'good architecture is about rhythm and continuity',[24] both of which stem from a limited palette of components. At an estimated cost of £1.25 billion, the role of the architect is seen by BAA as primarily that of ensuring 'value for money', with the philosophy of value engineering providing the discipline to judge design decisions against measurable benefits. In fact the airport authority intends to construct Terminal 5 at a cost of £1000 per m^2 as against the usual £1600 per m^2. Davies (of Rogers' office) had some trepidation initially, and still thinks the design team should at times have taken a firmer line, but he concedes that defending the integrity of the scheme is not undermined by questions of value for money. The aim was to have 50 per cent of the detailed design completed before work started with framework, with 'framework agreements' providing the basis for fine tuning on site.[25]

Bangkok International Airport, Suvarnabhumi, Thailand

The new Bangkok International Airport is being built on a large vacant site outside Bangkok, and is due to open in 2005. Designed by Murphy/Jahn to cater for 30 million passengers a year, the concept places emphasis upon passenger rather than aircraft movement. With an expected flow per hour of 5000 international and 2000 domestic passengers, there are to be 50 gates arranged alongside a lengthy U-shaped terminal with two main landside entrances (domestic and international).

The terminal will have an area of 0.5 million m^2, and is broken down into separate parts in order to provide relief and legibility. The concept is simple: a series of large modular terminals, each served by wings of airside corridor with aircraft gates on either side. The main terminal sits beneath a giant roof trellis, which unifies the various elements and provides shelter from solar radiation. The trellis is constructed of steel and concrete, and arches over the access road on landside and a courtyard of palm groves on airside.

The terminal itself is curved with full-height windows, providing views across the apron area. These enormous triangular openings also provide the spatial framework for aircraft gates and the adjoining gate lounges.



15.27 The central concourse at Bangkok Airport is intended as a great gathering place, not unlike the booking halls of nineteenth-century railway stations. Architects: Murphy/Jahn.

Murphy/Jahn have developed a particular tectonic language for their terminals. Here, they suspend the ticketing area from the structural trellis, and exploit the visual dynamics of the interpenetration of the tubular concourses with rectangular and cylindrical rotundas. The result is a design of great structural daring and interesting arrangements for the introduction of natural lighting into the core of the building.

The internal arrangement in the terminal, with its curved lattice beams and stretched rounded roof, is complemented by the approach to the design of the outdoor spaces. These are seen as landscaped courtyards with trees, sculpture and pavement patterns. Because they are the first areas of Thailand seen by arriving passengers, there are cultural artefacts such as sculpted elephants placed amongst the planting. Hence the high-tech architectural language of the terminal itself is counter-balanced by traditional features in the spaces between the buildings, just as in the design for Seoul, Inchon International Airport, the tempering of modernity by tradition is seen as important in giving the new generation of airports a sense of place.

Beijing Airport, China

Beijing Airport's Terminal 3, designed by a collaboration between Foster and Partners, Arup and the Dutch transportation planners NACO, has a planned capacity of 27 million passengers a year. Unlike other recent airports with separate terminal buildings and satellites (e.g. Kuala Lumpur), the new £1.2 billion terminal in Beijing is designed to absorb both elements in a sweeping, almost bird-like composition. Like Chek Lap Kok, the design employs the geometry of large-scale movement patterns to produce a combination of curved and linear elements. The approach from landside takes all road-based traffic (buses, taxis and cars) into a crescent which sweeps around a circular lake sprinkled with fountains. The lake reflects the arrivals façade of the new terminal which is itself curved on a shallow arc. The effect is to unify landscape and building design in a fashion which responds to Beijing's urban, rather than architectural, scale.

Inside the terminal a line of roof-lights takes perception towards the aircraft sitting beyond at their stands adjacent to

15.28 Aerial view at night of Beijing Airport. Architects: Foster and Partners.

15.29 Aerial view during day of Beijing Airport. Architects: Foster and Partners.

the building. The proximity of the aircraft to the terminal provides an immediacy lacking in many modern airports. The sweeping curves of the terminal lead to a long gate pier which gives access to the bulk of flights. The gate pier extends for over a kilometre and contains along its spine a light rail system. A number of stations are planned along the pier, each bathed in natural light. The way-marking role of natural light is a feature of the design and marks a departure for Lord Foster from the more neutral and diaphanous light of Stansted and Chek Lap Kok.

The new terminal sits centrally between two runways – one existing and the other planned. It is expected that one will be predominantly for international flights and the other for domestic, an arrangement adopted in the new Oslo Airport. Also, like Oslo, a railway station sits at the entrance to the terminal on its central axis. Planned to open in 2008 when Beijing hosts the Olympic Games, the terminal is designed specifically to be a landmark and gateway to China. Thus, the aim of the consortium is to create ‘a new icon’ which will in Foster’s words be a ‘symbol of place and togetherness’.[26]

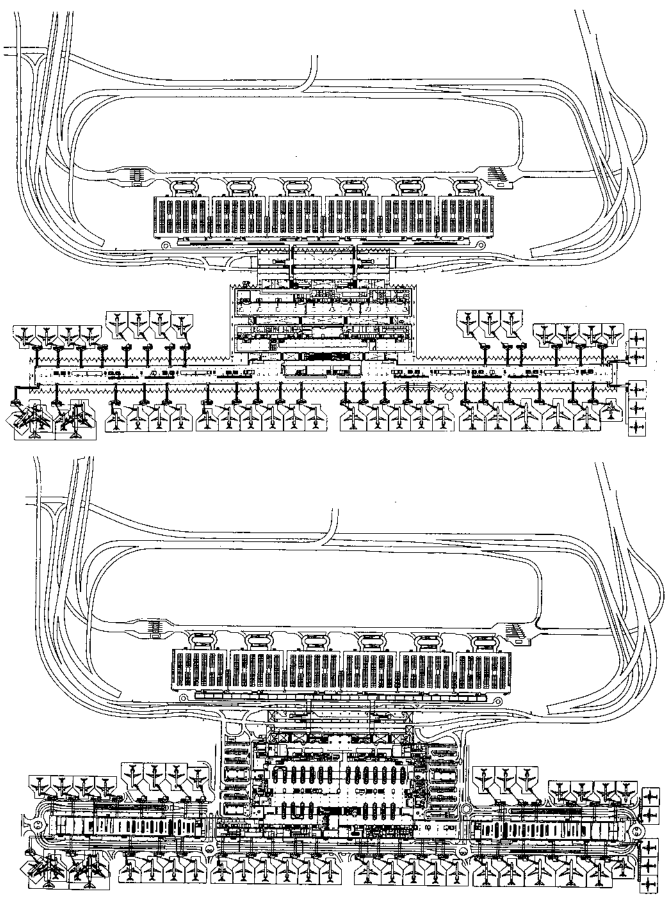
Barajas Airport, Madrid, Spain

The new terminal at Madrid’s Barajas Airport, designed by the Richard Rogers Partnership (RRP), is planned to handle 30 million passengers a year. Like many recent airports, the design consists of a large terminal of 500 000m^2 and a separate satellite of 200 000m^2 reached by underground railway. Besides the new terminal and satellite there is also a mainline railway station, new roads, car parks and light rail system within the airport. Thus, Barajas Airport marks a kind of airport-based interchange on the edge of Madrid.

The design undertaken by RRP in collaboration with the Spanish architectural practice of Estudio Lamela and engineers INITEC, is a marriage of architecture and structural engineering.[27] Like Terminal 5 at Heathrow (also designed by RRP), Barajas is an international hub providing the principal gateway between Europe and Latin America. A key principle of the design of the terminal is that of ‘clarity and legibility’ with passengers’ walking distances kept to a minimum.[28] The building has a straightforward linear plan with the line of movement passing through parallel banks of accommodation – check-in, customs, retail, security, gate lounges. Placed at right angles to the flow are facilities such as train stations, car parks, roads and satellite piers. Consequently, the plan is like a street with shops on either side and cross-streets giving access to bus stops and stations. Where the busy junctions occur, as at check-in, the path forward is clearly understood, thereby reducing stress.

Part of the design philosophy is the exploitation of the terminal roof as a means of providing way-marking through the building. With the lower areas given over to retailing, bars and security barriers, the ceiling assumes particular importance. The terminal is covered with an undulating roof which provides

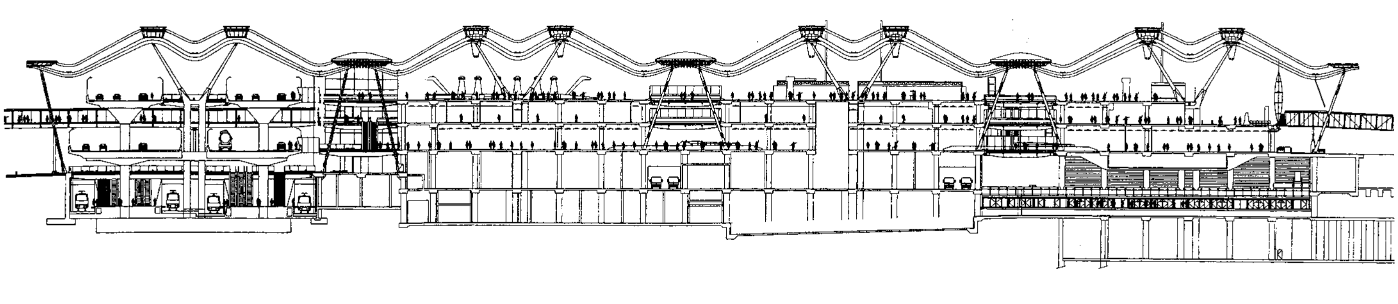
15.30 Plan of Barajas Airport, Madrid. Above, departures floor; below, arrivals. Architects: Richard Rogers Partnership.



daylight to the upper levels, and with a series of canyons cut through the floors, light is taken to lower levels. The wave-form roof, louvers for solar control and the enormous 'V'-shaped structural columns provide an architectural order which is sufficiently robust to withstand the visual pollution which is the inevitable consequence of retail outlets. The roof is in effect the architecture.[29]

The three main canyons which cross the movement flow are each lit by their own bands of roof lights. As a result, the canyons are well lit, providing a point of attraction for the eye. Most passengers cross the canyons on high-level bridges which add to the pleasure of passing through the terminal. Vertical circulation is concentrated in the canyons which are in effect the cross-streets in the terminal. Rather than passengers having to walk around the shops (as at Stansted and Heathrow's T3), they are arranged as attractions in streets (or canyons) to the left or right of movement. The effect is to make the destination (i.e. the plane) either visible or at least readily perceived.

The façade is designed to be largely free of the roof supports. This allows the edge of the building to adapt or expand without jeopardising the operation of the terminal. The columns are elliptical-shaped supports in concrete which then fork in to support a splayed pair of steel struts. The glazing line – a bow spring double section in stainless steel – is independent of the main supports and of the perimeter props required for wind stability. The angled fenestration is, in fact, hung from the roof and merely held in place at the floor. It is an arrangement which provides acoustic benefits and lessens the chance of glazing fracture. The result is a sleek, largely



15.31 Section through main terminal at Barajas Airport, Madrid. Architects: Richard Rogers Partnership.

15.32 Barajas Airport under construction in 2003.

seamless wall of glazing without diagonal struts and ties. By setting the glazing line about 3m back from the roof edge the problem of solar gain is overcome without resort to external louvers or fritted glass.

The finishes are more organic than in many of Rogers' buildings. The roof is lined on the inside with Chinese bamboo which follows the undulations of the ceiling. The floor is surfaced in natural stone – limestone generally with granite in the heavily used areas. The effect is to produce a terminal which has a natural appearance in the public areas with sunlight playing on the surfaces in a lively fashion.

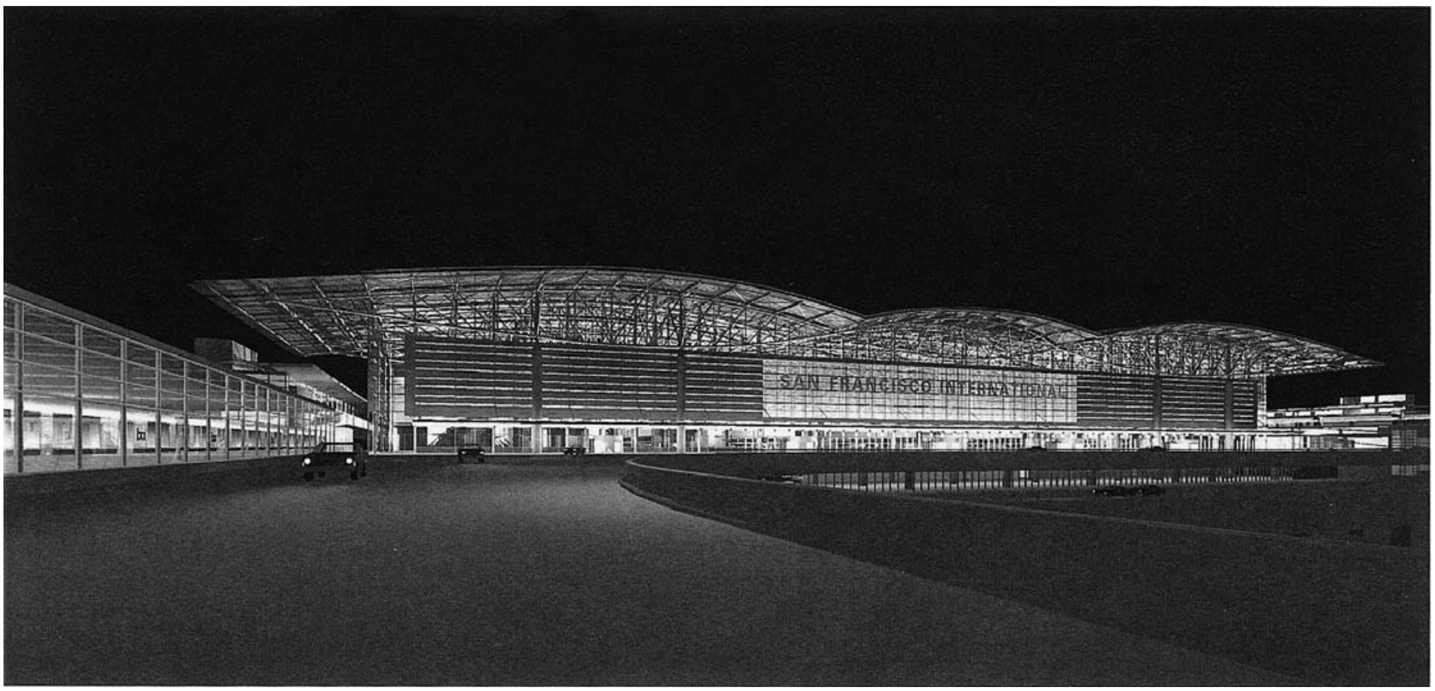
San Francisco Airport: International Terminal

The new International Terminal at San Francisco Airport designed by Skidmore Owings and Merrill (SOM) (in association with Del Comp & Maru and Michael Willis Architects) was constructed at a cost of $400 million. Sandwiched between existing terminal buildings, the new terminal is a majestic three-storey structure with extensive internal mezzanines. With a planned capacity of 18 million passengers a year, the terminal adopts the normal arrangement of raised arrivals lobby, beneath which sits an extensive floor of baggage handling and building services. As a consequence of placing the main ventilation and heating plant on the lowest floor, the ceiling is free to exploit the penetration of natural light which floods into the terminal via an undulating roof of steel and glass.

Passengers enter the terminal mainly through a large centrally placed concourse. They immediately encounter the check-in desks which form banks at right angles to the long axis through the building. The check-in hall is a grand space, not unlike a nineteenth-century railway station with its wide promenades and dramatic overhead structure. Beyond the check-in desks are the usual security and passport checks, beyond which stretch shops and restaurants. These are placed in order to help define the route through to the north and south terminals where most flights are boarded.

The new terminal acts architecturally as a gateway to the remainder of the airport. According to the design director at SOM, the aim was to create a building symbolic of flight and of arrivals.[30] The majestic steel and concrete structure is intended to give a memorable experience of the journey through the airport. Natural light taken into the terminal in the form of crescents of sunshine help to define the direction of

15.33 Model, San Francisco Airport. The new International Terminal is in the upper centre. Architects: Skidmore Owings and Merrill.



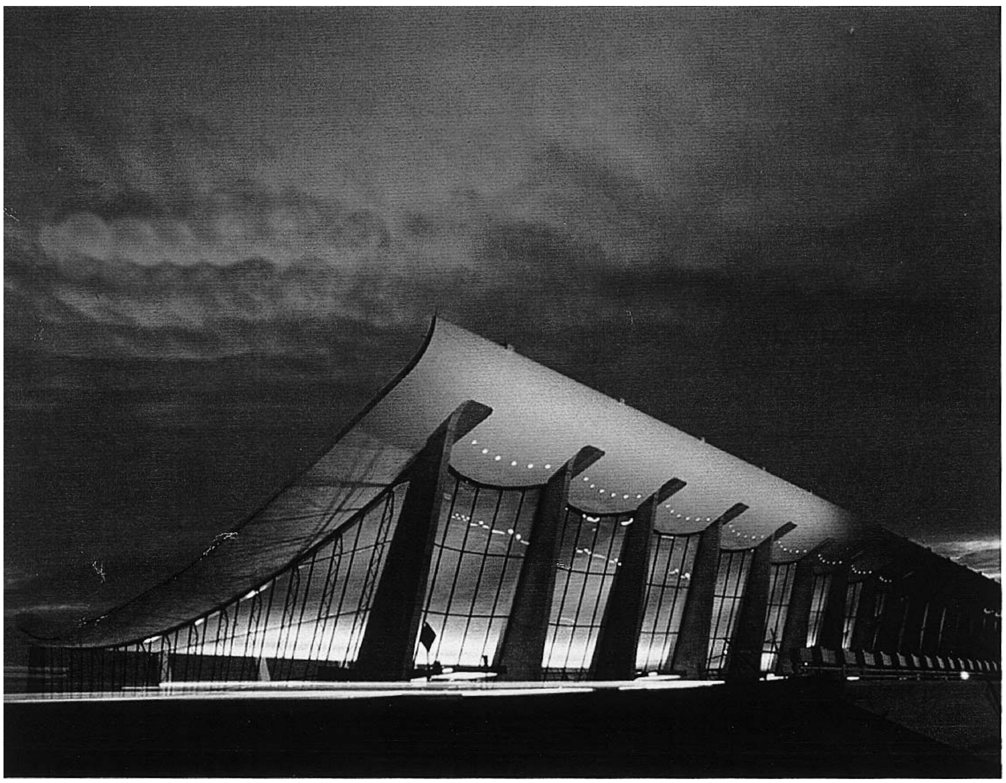
15.34 Impression of International Terminal, San Francisco Airport. Architects: Skidmore Owings and Merrill.

flow. The main structure consists of three lengths of exposed steel trusses spanning over 250m and supported by two lines of columns. At their edges the trusses cantilever to produce dramatic overhangs. Between the roof trusses some 20–25m metres above the floor run large curved glazed quadrants bringing sunlight and shadows to the interior. Mechanical ventilation is provided via secondary structures in the main hall such as the shops and ticket stands. Over-heating is prevented by exploiting the section to provide shade and by fritting the glass on the exposed south and west elevations.

The new International Terminal at San Francisco has learnt from the example of Chek Lap Kok, Kansai, Seoul and Charles de Gaulle. The airport now has a landmark to welcome arriving passengers and a distinguished gateway through which to depart. The emphasis upon space, light and structure is a departure from the norm in many US airports where there is a tendency to see airport terminals as synonymous with bus stations. What is particularly remarkable about the design is the delicacy of the structural engineering in an area noted for seismic activity. In spite of the considerable technical and functional complexity of inserting a large new terminal into an existing airport, the result sets a new standard in airport architecture for the west coast of America. Besides the terminal itself, there are new linking concourses, a BART railway station, multi-storey car parks and an inter-terminal light railway system.

Refurbishment and extension of Eero Saarinen's design of Dulles International Airport, Washington

Designed in 1958, Dulles International Airport, Washington, is regarded by many as the world's first terminal designed specifically for jet travel. The architect Eero Saarinen sought a terminal which would minimize walking distances and maximize views of the aircraft on adjacent runways. As a result there are no columns inside the terminal and to avoid reflections



15.35 Dulles International Airport, Washington, designed in 1957 by Eero Saarinen and extended in 1999 by Skidmore Owings and Merrill.

on the glass walls, the perimeter glazing is angled at about 70°. The original design was a large two-storey terminal with check-in counters and shops in the centre. Passengers moved through the building at an elevated level with baggage handling below.

The original terminal was designed for 12 million passenger movements a year. Recent extensions to the Saarinen design plus the construction of new terminal buildings have increased the passenger capacity to 40 million. The expansion of facilities at Dulles International, designed by SOM, adds about 86000m^2 of accommodation, mainly in the form of extensions to existing terminal buildings. These form a linear pattern on either side of the Saarinen design with new and existing facilities connected to a high-speed people-mover system.

The position and size of the new terminals were determined by the need to maintain visual supremacy of the Saarinen building (which is listed as a State Monument) and the need to preserve sight lines from the air-traffic control tower. The expansion of the Saarinen building by seven bays relieved stress on the internal accommodation of the building, allowing it to meet modern-day security and retail demand more effectively. An extra internal floor was also added, creating a three-level building better suited to modern aviation needs.

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National airport terminals

CHAPTER

16

Stansted Airport, UK

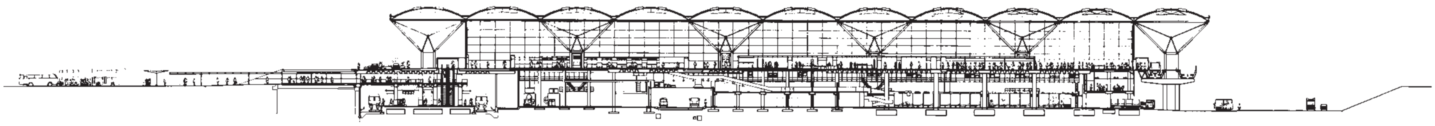
Stansted Airport has two particular interests for the terminal designer: it is essentially a single-level building (contrary to the orthodoxy outlined in Chapter 11), and the evenly spaced grid of columns does not gesture to the direction of passenger flow. Sir Norman Foster's concept design, evolved between 1982 and 1984, was based upon the idea of an elegant and directionally neutral terminal with detached satellites set in a spacious English landscape. There is a classical simplicity and an aesthetic calm in the work, as a result not only of the graceful cube-like buildings placed within flat green fields, but of the ordered discipline of the buildings themselves. Each is primarily a felicitous composition of expressed columns and roof structure, which order shops, booths and ticket points in pools of natural light, with walls and floors in various shades of grey.

The approach at Stansted is a far cry from other recent terminals, where colour, the interconnection of interior levels and dramatic directional structure (such as at Kansai and Terminal 2 at Charles de Gaulle) lead passengers from landside to airside. The detailed brief at Stansted issued to Foster's office instructed the architect to create:

- a convenient, safe terminal
- an adaptable terminal capable of phased construction
- a modern terminal able to accommodate the largest aircraft of the foreseeable future (up to 800 seats)
- an economical terminal, at least 10 per cent cheaper than other recent BAA buildings.

It was a brief that tended to encourage a single-storey solution, in terms of cost, flexibility, passenger convenience and incremental development. The brief also gave Foster's office a central role. His practice was to design a total terminal, from building services to ticket counters, telephone booths and signage. A single concept was to permeate the whole design in the heroic modernist manner, but the integrity of this totality proved difficult to defend even in the first five years of operation.

The choice of a single-storey building sets the terminal at Stansted apart from other larger airports. Whereas



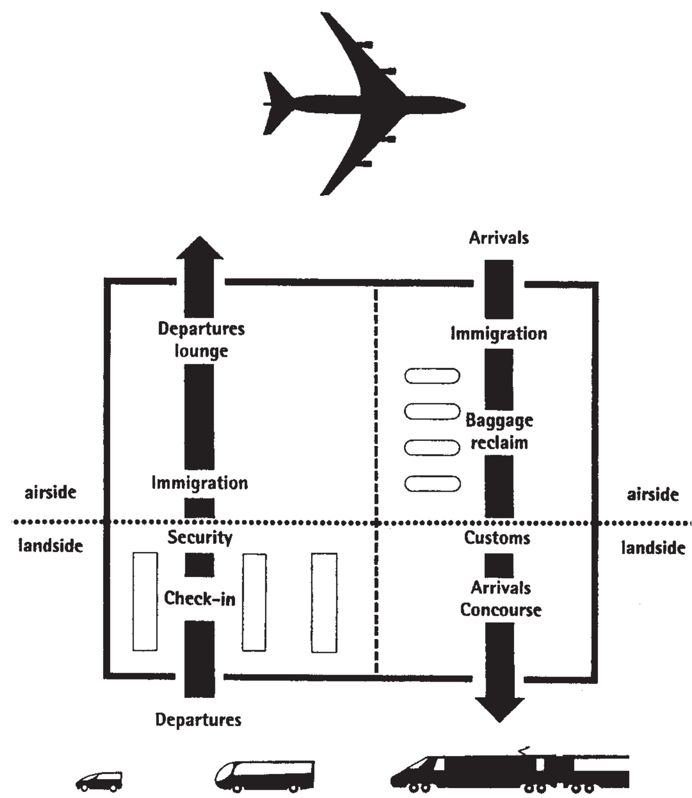
16.1 Section of Stansted Airport, UK. Notice how the main structure extends beyond the limits of the terminal, creating shelter at the edge. Architects: Foster and Partners.

16.2 Light rail trams are used to transport passengers from the terminal to the satellites at Stansted Airport, UK. Each AEG Westinghouse tram cost £1 million. Architects: Foster and Partners.

single-level buildings are often the preferred choice for smaller regional airports (such as Southampton), the complexity of international airports leads invariably to two- or three-level passenger terminals. At Stansted, both Sir Norman Payne, the chairman of BAA at the time, and Foster favoured a one-level terminal. Payne said that BAA had 'known for years that the ideal airport terminal was a large open space on one level – like the Olympia Exhibition Hall'.[1] This provided the economy of construction, flexibility and maximizing of retail revenue that BAA required, and for Foster provided the justification for a calm, elegant and transparent pavilion set in an uncluttered landscape. Moreover, the openness of Stansted (nearly 1000ha of developable space) provided the means to spread laterally rather than build vertically, which tends to be dictated elsewhere by site restrictions (as at Gatwick, Manchester and Heathrow).

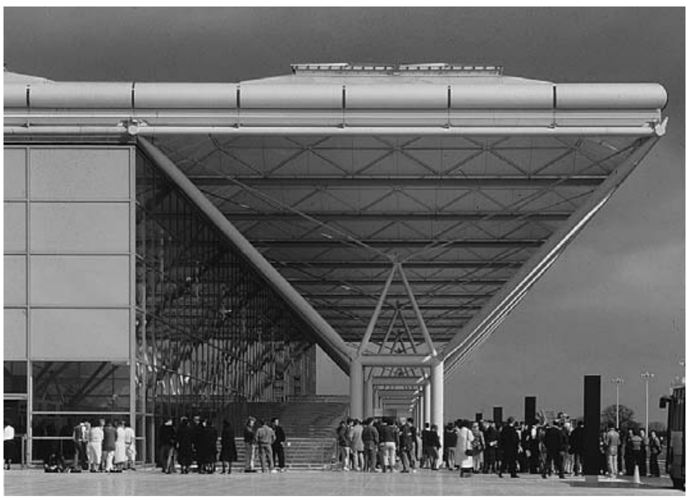
Stansted is a pavilion-like terminal six bays by six, with each column (or cluster of four) on an orthogonal grid of 36m. In its single-storey, rather rectangular simplicity, the design owes something to the terminal at O'Hare Airport, Chicago designed by Naess and Murphy (later to become Murphy/Jahn) in 1962. Both Stansted and O'Hare share the Miesian architectural model of crisp cubes of accommodation within large sheets of glazing set behind a disciplined structural framework. It is perhaps no coincidence that both Payne and Foster share a respect for the undemonstrative example of O'Hare's early terminals.

The decision at Stansted to separate the main passenger terminal from the satellites used for boarding the planes was a departure from previous UK practice. Hitherto it was more common to have radiating finger piers, which took passengers, often along lengthy high-level walkways, to the aircraft gate. Similarly, the practice common in the USA of using unit terminals serving major airline companies was rejected. Instead, BAA opted for a hybrid system whereby passengers travel by electrically powered trams (a form of light rapid transit) from within the terminal building to two (later to become four) satellites built out on the apron. Following Gatwick's example, Stansted employed rapid transit people-movers (each of the five Westinghouse shuttle trams cost £1 million), thereby adding to the sense of innovation that is a recurring feature of the design.



16.3 Concept plan for Stansted Airport, UK. The rational basis for the plan has an undeniable logic. Architects: Foster and Partners.

BAA was anxious to build adaptability into the design at the outset. While the brief called for operational flexibility, Payne and his colleagues were conscious particularly of the retail opportunities that modern airports provide. Though Foster voiced disdain for this aspect of terminals, describing them as 'discount shopping centres on a grand scale, with an emphasis on emptying your pockets, rather than charging you with the thrill of travel',[2] the brief gave little direct instruction about the need to accommodate the retail revolution then under way. Design evolution at Stansted unfolded against a background where the large internal volumes required by BAA and elegantly provided by Foster's office gradually became seen as potential floorspace for highly profitable retailers. Inevitably, soon after

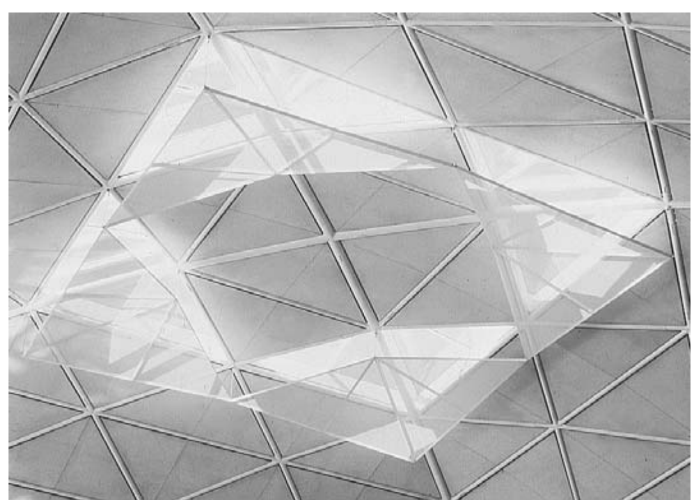


16.4 The sophistication of the constructional detailing at Stansted gives the building appeal at many levels. Stansted Airport, UK. Architects: Foster and Partners.

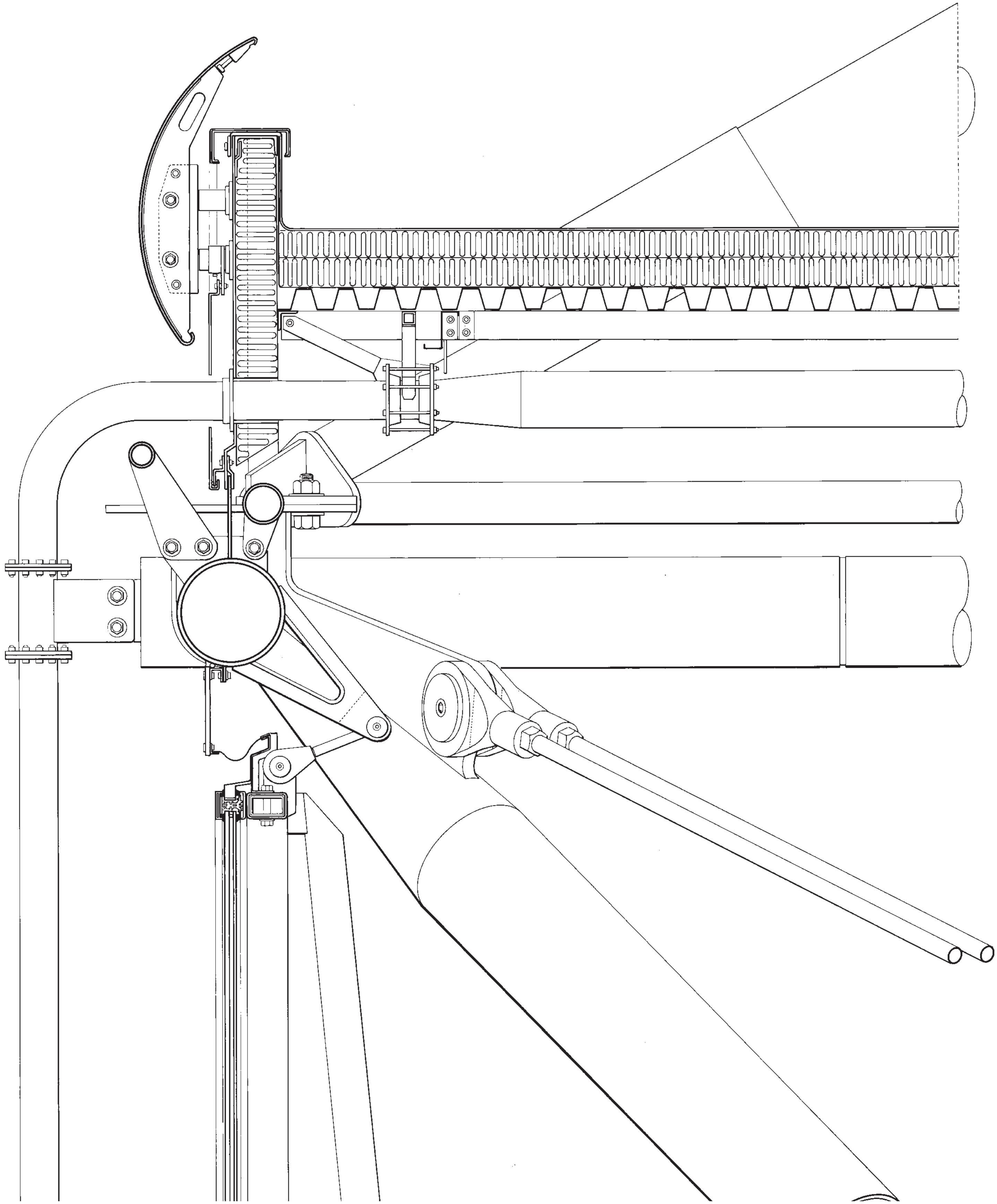
the building had opened, the purity of the original concept was compromised. Rather than place shops, bars and duty-free on a separate floor (as at the North Terminal at Gatwick) or split the terminal into a departures level complete with shops and a less cluttered arrivals level (as at Manchester Terminal 2 or in Rogers' original design for Heathrow's Terminal 5), the single-storey solution at Stansted proved vulnerable to the very success of airports as a popular building type in which to loiter and shop for fashion and leisure goods. It has also suffered from growing concern over international terrorism, resulting in the installation of additional opaque security screens and barriers, which undermine the building's essential transparency.

The large internal spaces at Stansted exist mainly as a base course of bars, shops and customs control areas, which form the day-to-day life of the passenger terminal. The architect's original sketches showed the possibility of seeing directly through the terminal from landside to waiting aircraft on the apron. The visual link between landside and airside was a central goal of design philosophy, which served to justify the lofty internal volumes, the elaborate tree-like columns, and the pools of sunlight that were intended to articulate the interior routes. In fact, the choice of a single-storey building was largely fashioned by the idea of a unifying airport ground plan zoned between landside and airside, with the terminal straddling the two.

If the simplicity and elegance of Stansted have proved vulnerable to changes in the management and use of interior space, this should not detract from the airport's considerable aesthetic and practical qualities. Much survives of Foster's original concept: the linear progression through the building without changes in level or direction; the openness, which allows views to be had across the runways and, internally, along the major public concourses; the use of light (especially sunlight) to animate interior spaces and define routes; and finally the exploitation of architectural structure to give scale and presence to the building. Notwithstanding the encroachment by fast-food shops, free-standing market stalls, and the glitter of bars, the building's underlying order and simplicity shine through. At the edges of the building, particularly, the Miesian logic of the glazing and framing details, the use of an enormous porte-cochère of free-standing columns at the road edge, and the corresponding arrangement through which the shuttle passes, all testify to thoughtful design.



16.5 Diffused dappled light is a major part of the aesthetic experience at Stansted Airport, UK. Architects: Foster and Partners.



16.6 Eaves detail at Stansted. The airfoil deals effectively with wind loading. Notice how space between the components allows access to the various elements and ready replacement of parts. Stansted Airport, UK. Architects: Foster and Partners.

Adaptability and phased construction, required of the BAA brief, have been met largely in two ways. The terminal, though square in plan, can be extended sideways. The lateral expansion does not require any modification to the roadside or rail approach, nor to the airside shuttle system. Additional bays allow for the construction of extra baggage-handling facilities, and increased space for departures and arrivals lounges, but without upsetting the operation of the airport. Both sides of the terminal can be expanded by two bays, thereby nearly doubling the building's capacity. The other way in which expansion can be met is by constructing additional satellites. Two of the four originally planned have been built, but by increasing the number of shuttle trams from five to eight, they can readily serve the four independent satellites designed for the full 15 million passenger projection.

The architecture of Stansted is noteworthy because of Foster's skilful manipulation of architectural volumes, structure and daylight. The volumes are not complex and interconnected but regular and serene in the manner of the Sainsbury Centre at the University of East Anglia. By adopting an unusually high ceiling level (justified partly as a means of smoke control) the sense of interior space is heightened. Whereas BAA terminals elsewhere have ceiling heights of 6–10m, at Stansted the height is 12m. Cleverly, the design exploits the perception of the high ceiling by creating square pools of natural light within a roof structure not unlike interconnected umbrellas. The grids of squares of light in both directions set against the angular steelwork of the columns, and the general luminescence of the space, give Stansted a quality quite unlike modern terminals elsewhere. It is an architecture of frame, panel and light – not of walls, weight and heavy engineering. Only in the baggage undercroft and in the station does heaviness rather than a sense of lightness prevail.

Terminals have to accommodate a great deal of clutter, and adapt during their life in unexpected ways. The approach at Stansted seeks to use the space within the four separate supports that make up each major column as a services and information zone. Pipes, ducts, kiosks and booths are provided within these regular bays (each 3m square) and hence are evenly distributed throughout the terminal. By using the space within each cluster of four columns for air handling and light fittings, both light and fresh air are manipulated to enhance the passenger experience. Uplighters placed within the column zone highlight the branches of the roof space, helping to create legibility and a sense of linear direction in public spaces – increasingly encroached upon by retail activities of various kinds. While the bases of the tree columns are often lost in the whirl of lower-level activities, the diagonal branches of the trees remain visible and picked out in light. Similarly, fresh clean air is dissipated through the trunks of the columns, metaphorically referring to the trees as health-giving elements in the design of the terminal.

The attempt at Stansted to create 'clarity and transparency' was specifically in order to help travellers to orientate themselves. Foster exploits views of aircraft, runways and landscape to help explain visually where 'you are actually going'.[3] This is evident in the three key parts of the journey – through the terminal itself, the shuttle trams, and at the satellites. Each is mainly a glazed structure where views out are largely unobstructed, and where the passenger moves logically in the direction of perceived flow from landside to airside. Only in the terminal itself, where the even spacing of columns suggests a more neutral directional bias, do the architectural cues have an element of ambiguity. Here, as *Progressive Architecture* notes, the breadth and depth of the space have become excessively obstructed by encroaching shops, bars, kiosks, check-in, security, customs and baggage claim facilities, which undermine the passengers' sense of direction.[4]

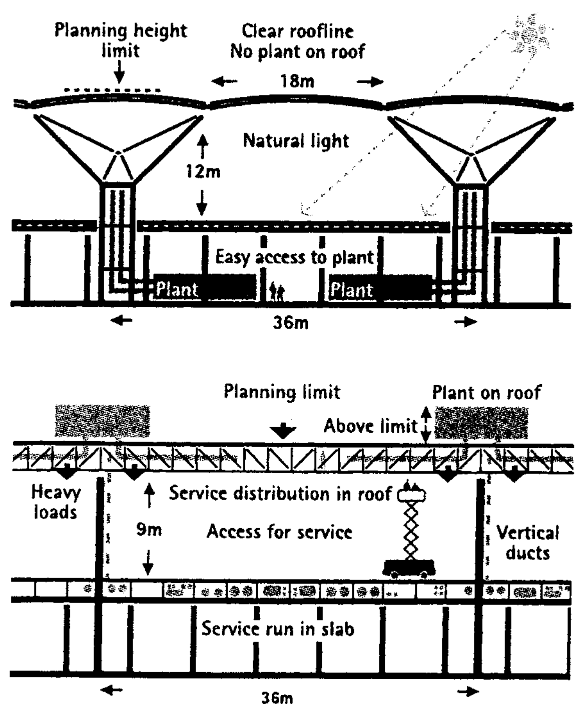
Being single storey, highly glazed and rooflit, Stansted can claim to be a relatively low-energy terminal. There is balance struck between lighting and heating energy demands, with much of the heat provided by solar and casual gains (that is, from heat provided by artificial lighting and equipment). Because the building is largely naturally lit, daylight and sunlight become part of the aesthetic experience. By avoiding the levels of artificial lighting common to other terminals, Stansted not only saves energy (about half a million kilowatts of electricity a year),[5] but is relatively economical to run, because lighting at terminals is responsible for about 40 per cent of total bought-in energy. Also, with lower levels of artificial lighting, the problem of excessive heat build-up in the summer months is reduced, thereby minimizing the size of mechanical ventilation plant. The main problem at Stansted is one of glare: direct sunlight, especially through wall glazing, can be uncomfortable at times in spite of the fritting of the glass.

In terms of UK airport design, Stansted, as *The Architectural Review* notes, sets a 'standard in being logical, customer-orientated and elegant':[6]

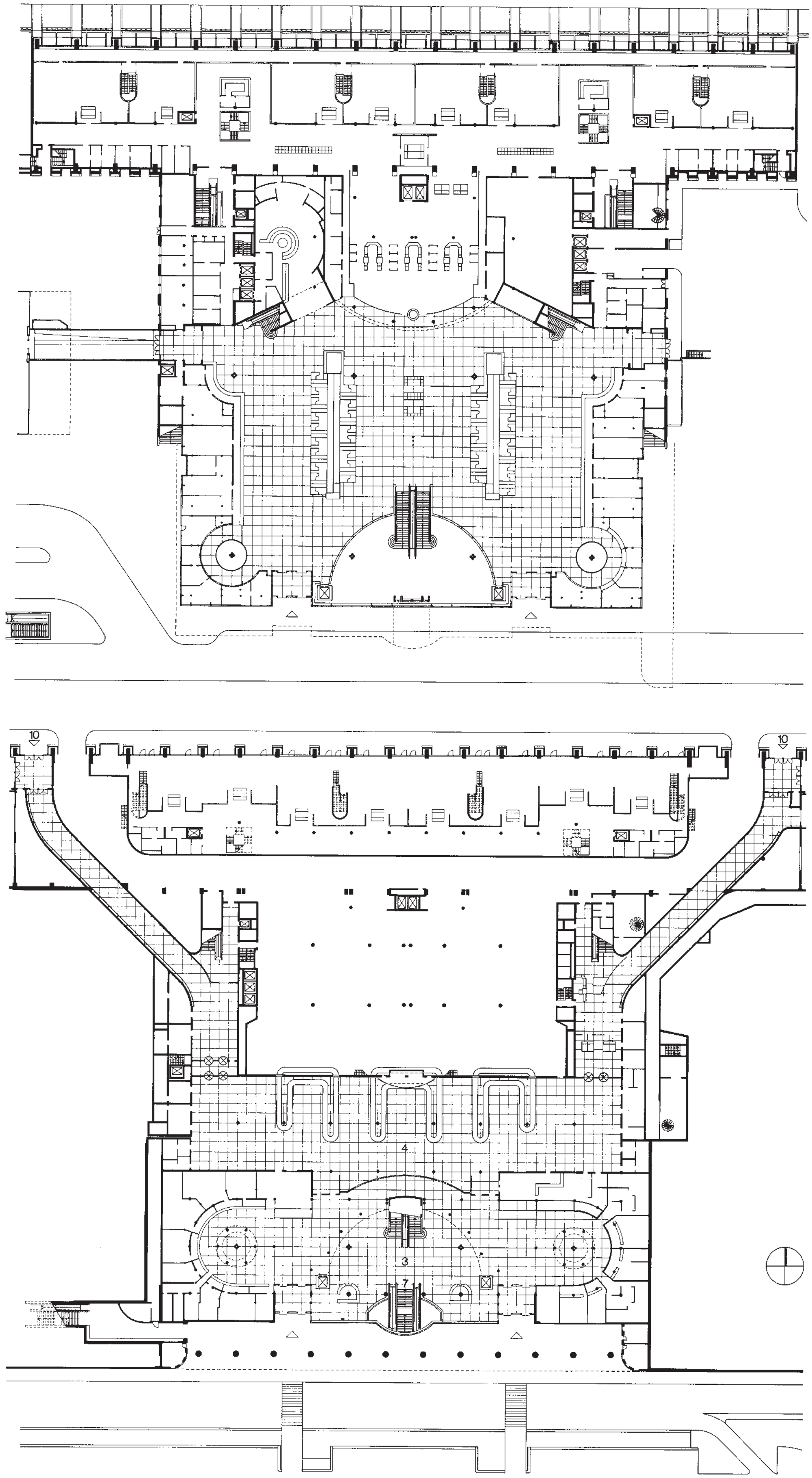
- logical in the sense of a clearly articulated linear progression from landside to airside, in the structural clarity, and in the adept handling of light
- customer-orientated in the lack of stairs, changes in direction and disorientating internal corridors, the scale of internal spaces, and the integration of rail and air
- elegant in the graceful well-proportioned lines, the sense of calm and repose.

16.7 The reality of Stansted Airport under the impact of advertising. Notice how the advertising competes with the flight information.

Notwithstanding the seemingly inevitable compromises forced upon the building by changes in management ideology (especially with regard to retail expansion and advertising), the terminal represents an interesting new direction in airport design. With hindsight, perhaps the controlling hand of one designer cannot determine every detail, and should not attempt to do so within an industry noted for its flux. Perhaps all the terminal architect can expect to shape are the essentials of good architecture – space, structure and light – leaving many details to be determined by others and freely altered on short timescales. If there is a single lesson to be learned from Stansted, it is the need to split the signature spaces and architectural elements from the lesser details, allowing the former to have lasting qualities and the latter to adapt more readily to market needs. As *Progressive Architecture* warns, the design at Stansted 'imposes an elegant but possibly vulnerable order on the chaotic activities of airports'.[7]



16.8 Comparison of environmental design of Stansted (above) and orthodox airport (below).



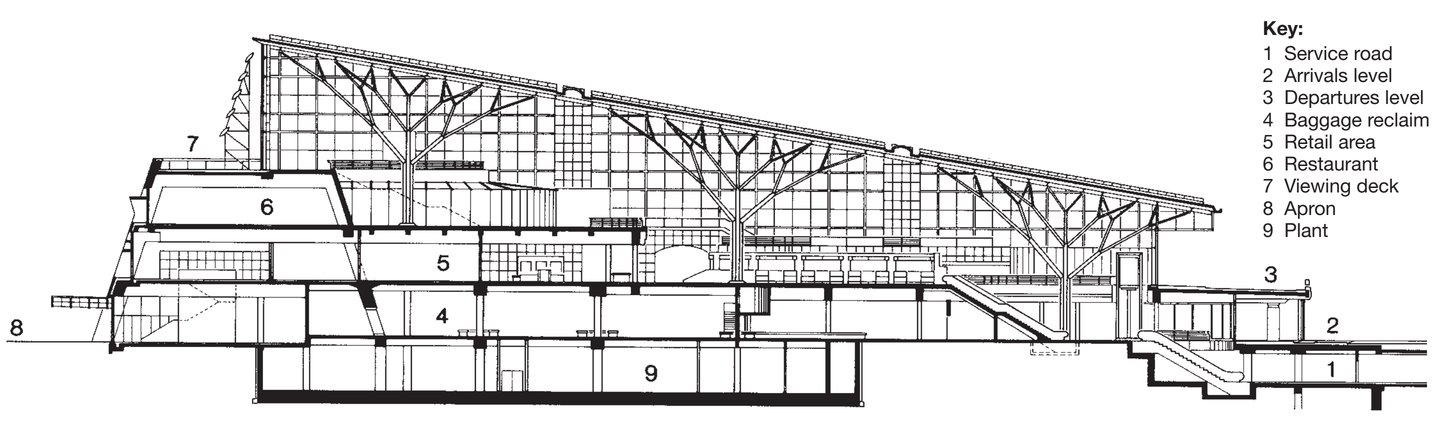
16.9 Arrivals and departures levels at Stuttgart Airport, Germany. Architects: Von Gerkan, Marg & Partner.

Stuttgart Airport, Germany

Designed in 1991 by the German practice Von Gerkan, Marg & Partner (GMP), the terminal at Stuttgart Airport serves a metropolitan area of 4 million. It is one of six busy regional airports providing, in an integrated fashion, the needs of the unified Germany. The form of the terminal consists of two separately expressed rectangles: the first houses the check-in, arrivals and departures concourses; the second a three-storey airside concourse facing across the runways. In plan the two rectangles, both expressed boldly in elemental shapes, slide into and through each other. Whereas the block housing the main public concourses is mainly glazed and transparent, the other – providing direct access to the aircraft – is more solid, with apertures cut crisply from panelled impervious walls. Architecturally, too, the two elements of accommodation are given distinction in the cross-section shapes adopted: a triangle for the transparent block and a trapezoidal form for the airside block.

Von Gerkan, the partner responsible for the design, chose a language that, in its play of shapes and transparencies, helped to give passengers a sense of arrival and thence a feeling of direction en route to or from the plane. The section of the terminal rises upwards as one moves from landside to airside, hinting metaphorically at the transition from ground to flight (see also Munich Airport, Chapter 18). The rising ceiling, expressed also in the growing height of tree-like branching columns, allows passengers after check-in to move towards greater light and interior volume. However, the airside concourse cuts across the space, providing terraces and viewing ledges to look both backwards into the public concourses and outwards to the aircraft waiting on apron areas. The relative solidity of the airside concourse seems at odds with the spirit of the whole, though it is justified by the balances of solidity and transparency sought by the architect. The argument draws in part upon the need to reduce noise from aircraft within the terminal, and to provide an architectural framework for the airline offices, bars and duty-free shops found in such areas. Where the triangular-sectioned concourse block faces the runways, noise attenuation devices in the form of expressed louvres provide further animation to the airside facade.

Inside the main concourse block, architectural structure and rooflighting help to articulate the complex patterns of movement within the public areas. As at Stansted, columns and beams create such a powerful visual order that different activities within the spaces below are contained fairly happily. The bands of rooflights on a two-way grid help to express the structural bays of the columns, also helping to reinforce the fundamental spatial order of the interior. The progression of different concourses within this space and the linking staircases and escalators all obey the structural logic and



16.10 Section through Stuttgart Airport, Germany: the terminal rises towards airside. Architects: Von Gerkan, Marg & Partner.

16.11 Departures concourse at Stuttgart Airport, Germany. Architects: Von Gerkan, Marg & Partner.

gesturing of the columns. Because the movement through the terminal from landside to airside is both linear and upward, diagonal views are important. Here again the design seeks to exploit these, with projections into the space for restaurants, bars and viewing areas providing dramatic angled views through the branching columns. Such is the complexity of the structural arrangement that a single column splits into 48 branches before it reaches the ceiling.

Stuttgart Airport shares affinities with Stansted (it was designed after Foster's proposals had been published), and helps to point towards the growing subtlety of terminals such as Heathrow's Terminal 5. Stuttgart can be seen as a tilted version of Stansted, and one that exploits the traditional arrangement of the departure lounge above the arrivals lounge (Stansted is a single-level terminal). However, in the orchestration of progression, architectural space and structure, Stuttgart has a refinement lacking in Stansted and which the design by the same architects for Munich Airport effectively extends.

Hamburg Airport, Germany

The rebuilding of the terminal at Hamburg Airport has resulted in a building that is a useful model for larger regional airports. Designed by Von Gerkan, Marg & Partner (GMP) and constructed in 1994, the terminal handles about 8 million passengers a year, many on charter holiday flights. Roughly comparable in capacity to London's Stansted, the building is on two main levels, with departures above arrivals in orthodox fashion. The section of the building splits the incoming and departing passengers, subjecting those arriving from flights to a lower level largely devoid of natural light or spatial drama. As a compensation, however, the departures hall is a grand expansive space. Here elegant curved trusses, lines of lantern lights and branching columns not only articulate the space but, in the incline of the ceiling, hint at the direction of flow and allude to the transition from ground to air.

The new Hamburg Airport is a model of integrated facilities with the terminal at its centre. Two blocks of offices sit as book-ends on either side of the main terminal, and a circular car park to the south-east completes the composition. Taken together these building elements and others planned (such as a circular atriumed hotel) form an urban whole, and help to shield the terminal from external noise and unwanted solar gains. The two rationally composed office blocks placed against the gables of the terminal contrast pleasantly with the structurally expressive and transparent terminal and, being so close, allow office workers to take advantage of the facilities provided for passengers. At Hamburg, the terminal is not an isolated building but the focus of a fairly dense composition of different land uses and architectural forms grafted onto an existing airport. In this regard it represents different thinking from that in the UK, where at Southampton and Manchester Airports the terminal is largely for passengers, not a centre for integrated regional development.

The design of the new terminal at Hamburg represents a refinement of the precedent at Stuttgart, designed in 1991 by the same architects. Like Stuttgart, Hamburg is a split-level terminal with a grand double-height departure hall sitting above a ground floor used for arrivals, baggage handling and mechanical plant. Emphasis is placed spatially and architecturally upon the departure hall: it is more a public gathering space than a mere concourse. Sensibly, the shops and restaurants that disfigure other terminals are at Hamburg kept mainly to elevated galleries overlooking the hall. Twin scissor-shaped staircases and escalators lead to these

16.12 Acoustic and solar shading at Stuttgart Airport, Germany. The walls are angled to deflect sound. Architects: Von Gerkan, Marg & Partner.

16.13 Hamburg Airport, Germany. Architects: Von Gerkan, Marg & Partner.

galleries, which in their openness and position help to animate the space with activity. Beyond this double-height bank of commerce stands the airside corridor (here called the departure pier), which serves not only the new terminal but older terminals that survive from earlier periods.

The departure pier is an important element of the design, and provides commendable open views both into the departure hall and outwards to aircraft standing on the apron. The pier is almost entirely glazed, each structural bay being divided by three large sheets of fritted glass set in minimal frames. To reduce glare and solar gains, there is a large skirt of expressed aluminium panels held on diagonal struts, which follow the gentle curve of the pier. The view from airside is inviting; the transparency of the pier and the constructional finesse of the air jetties make the journey from the plane as welcoming as that in the opposite direction from car, bus or train.

GMP bring a structural and organizational sophistication to their airports. The practice combines rational planning with bold cross-sections and strong formal geometries. As a result their terminals are clear to use, with routes marked by the direction of structural members and expressed in the flow of light, both counterbalanced by pure architectural forms. At Hamburg seven large triangular trusses describe a gentle inclined curve across the ceiling, with each truss also defining the dimensions of lines of skylights. Hence the passenger can follow the pull of these aesthetic forces towards the departure gate, and by implication upwards to the departure pier. Even passengers using the almost subterranean arrivals hall are welcomed by a pool of light and crescent of shops at the end of their journey from the baggage reclaim area. Here, too, cafes and bars are provided en route to the car park and bus stops. It is a pattern that allows those waiting for arriving passengers to enjoy a cup of coffee while enduring the frustration of delayed flights. Again, sectional geometries are well used, with the arrivals concourse placed beneath the raised road.

It has been suggested that both Hamburg and Stuttgart airports represent important steps towards the emergence of a clear typology for the smaller regional terminal. The assertion is based upon the clarity, simplicity and directness of circulation patterns, and the grandeur and drama of the main spaces.[8] Certainly, compared with many larger terminals, the architects

16.14 Hamburg Airport, Germany. Architects: Von Gerkan, Marg & Partner.

for Hamburg have established a pattern of uses inside the terminal and land uses outside that supports passenger needs in a clear and attractive fashion. The design also expresses the excitement and sheer thrill of air travel – an exhilaration found mainly in the curved wing-like section and the seven crescents of lantern lights over the departures hall. Because the terminal is highly glazed (but protected by oversailing roofs and *brise soleil*), it glows at night in a welcoming fashion, and provides few dark corners to worry security staff. The very transparency of the building contrasts pleasantly with the relative solidity of treatment of the related buildings in the complex – the two office blocks, circular hotel and car parks. As an urban grouping, therefore, the play of architectural transparency and volume helps to define the function of each part and reinforce functional hierarchies. As the airport is developed to its full capacity (three such terminals are proposed placed side by side) this sense of a civic dimension will increase. Just as Terminal 5 at Heathrow is seeking to give that airport more the qualities of a city, so too but on a smaller scale at Hamburg.

Cologne/Bonn Airport, Germany

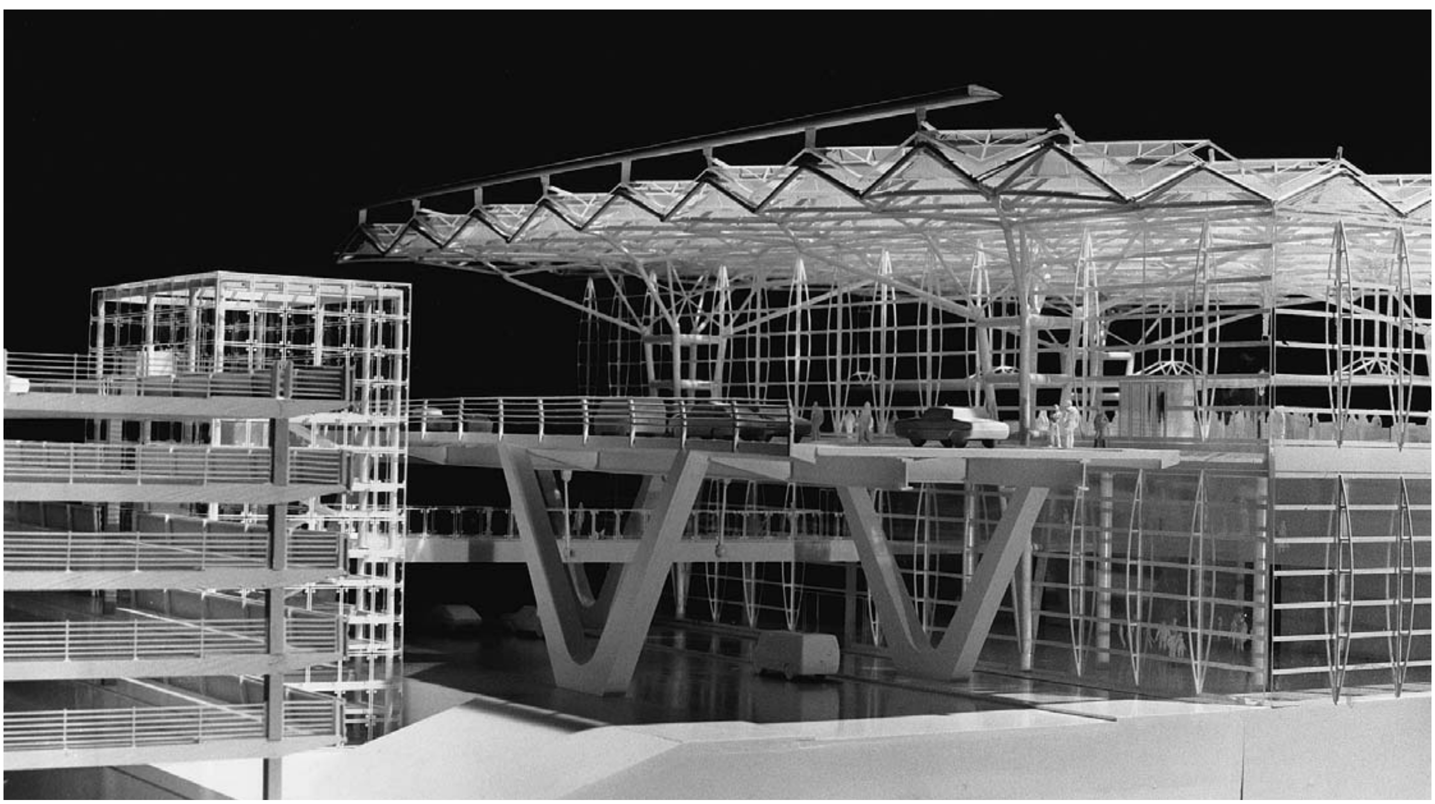
The extension to Cologne/Bonn Airport demonstrates how existing terminals can be enlarged without destroying the original design concept. Designed by Murphy/Jahn, the extensions consist of two wings that extend the present terminal with, in addition, a new terminal built alongside one of the wings. Whereas the original terminal was built of powerful concrete forms, which stepped to create a distinctive profile, the new buildings are mainly glazed, with steel frames and lightweight roofs.

Structural elegance and rational planning, features of Murphy/Jahn's airport architecture elsewhere, find particular expression at Cologne/Bonn. The functional problem of creating a large extension (it roughly doubles existing provision) without destroying the coherence of the original has been solved by reinforcing the existing footprint of splayed wings. These are constructed about the wedge-shaped road system, creating an extended 'wall' of terminals with set-down points evenly spaced. The height of the new buildings is deliberately kept lower than that of the original terminal in order to maintain the functional hierarchy.

Within the new terminal a double-height roadside concourse distributes passengers into departures at high level with arrivals underneath. As is usual in terminals of this size, the road is bi-level, and sheltered for nearly its full width by the oversailing terminal roof. With structural bays measuring 30m by 30m, the four column supports provide (as at Stansted) a framework for the integration of building mechanical systems. The repetition and rational arrangement of structure and cladding reduce cost by providing standardized components and allowing for overlapping erection sequences, thereby shortening construction time.

The design strives to avoid overheating while also providing a high level of natural light. The skylights are oriented towards the north, and the clear glass facade is protected from direct sunlight by a 15m-deep roof overhang. Elsewhere solar screen glass is employed, fritted to avoid colour distortion. Only the lower levels of the concourse areas are heated or cooled; above 3m the air is allowed to exceed comfort conditions. The stratification of temperature and humidity creates relatively economical air conditioning while providing also an effective thermal buffer zone between inside and outside temperatures at the upper levels.

16.15 Cologne/Bonn Airport, Germany: model. Architects: Murphy/Jahn.



16.16 Cologne/Bonn Airport, Germany: model roadside access. Architects: Murphy/Jahn.

Seville Airport, Spain

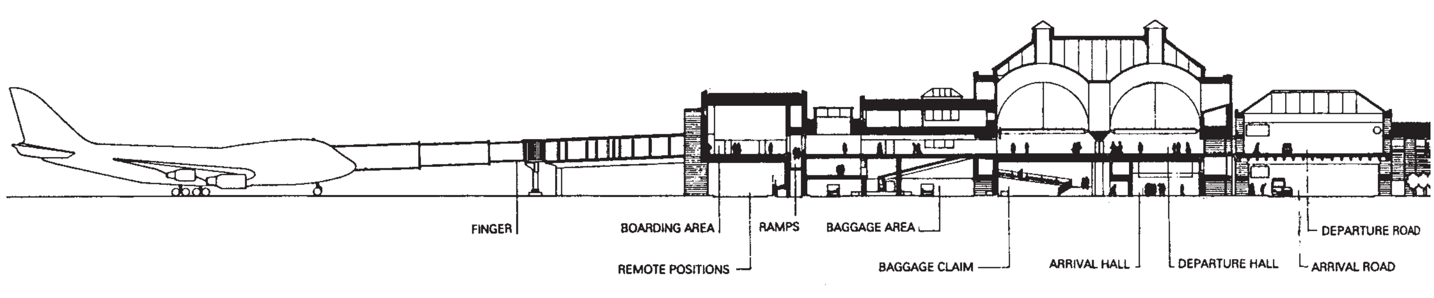
Two aspects of Seville Airport (opened in 1992 to coincide with the city's Olympic Games, to designs by Rafael Moneo) depart from current orthodoxy: first, the incorporation of car parks into a unified rectangular whole, which is thoroughly integrated with the terminal; second, the adoption of a masonry rather than technological aesthetic, and one that alludes to an earth-bound pre-aviation age. These two factors result in an airport quite unlike other recent productions and more akin in its architectural gestures to a large civic or educational complex.

Whereas other contemporary airports treat car parks as – at best – loosely related structures, here they are embraced in a large, walled enclosure and roofed over with pitched roofs. The masonry enclosure of the car parks extends towards airside, where it forms the outer limits of the main terminal concourse. The grouping into an orthogonal enclosure of these parts (and others such as an office building) is more suggestive of an urban or monastic composition than a modern airport. Added to this Moneo uses gravity, not lightweight suspended structures, to define the principal spaces. Progression from car park to plane is articulated through a play of plump columns, great semicircular concrete arches and tight pools of light. The interior is almost Romanesque, especially in the departure lounge, which makes reference not to flight but to the historic traditions of this part of Spain.

Moneo's design stands on its head the precedents set by architects from Saarinen to Foster and Piano. There is no visible association with the iconography of the aircraft, and inside the terminal there is little attempt at relating interior experience to external spectacle. One cannot readily see the aircraft through the check-in hall windows; instead the passenger enjoys a dramatic interior play of top-lit lofty semicircular arches and round columns. The interior experience is decidedly inward, with pockets of light defining routes or animating the ceiling. Even retailing plays a relatively minor part in these cavernous, cathedral-like spaces.

By way of contrast the long departure lounge (nearly 300m in length), which provides access to the boarding gates, is more orthodox in treatment. Here large rectangular windows overlook the apron areas giving passengers their first real experience of the mode of transportation that they are about to take. Designed in a rational fashion, this area is reached by passengers from the check-in hall by passing through a transition space of airline offices, security controls, etc. The choice of architectural language helps to define in the passengers' mind the sequence of spaces: big Romanesque arches for the check-in hall, brick enclosing courtyards with sun-shading roofs and clipped orange trees for the car parks, flat-roof low ceilings for the control spaces, and finally lofty large windowed concourses for the long boarding area. Each stage in the sequence has its own architectural expression, yet the parts are well grouped geometrically and communicate the logic of movement in terms of the use of building materials.

Throughout the airport a relatively small repertoire of construction materials is employed: yellow concrete block,



16.17 Seville Airport, Spain: section. Architect: Rafael Moneo.

blue glazed roof tiles, white plaster and solar tinted glass. These elements – especially the golden yellow blockwork and blue tiled roofs – unify the parts, creating from afar a sense of an urban community rather than an airport. The effect is further enhanced by the square glazed rooflights (at the top of each bay of the check-in hall), which suggest chimneys on apartment blocks.

Moneo integrates the different parts into a considered whole, but the design allows each to be separately expressed, by creating a small sphere of independent space about each element of the terminal. The *porte-cochère* on the upper floor (for the departures-level roadway) is held back from the wall of the departure hall by a metre of free space. Similarly, the twist in plan of the main restaurant and office block gives identity to this part, though here angle and steps are used as defining gestures. Again, with the boarding area a slot of space and light defines this zone from the customs and control region. Within a language of unifying elements, Moneo ensures a degree of structural independence for the principal parts in order to guide passenger perceptions.[9] Within these tight and contrived independent spaces, the architect skilfully inserts stairs, ramps and lifts, thereby adding to their significance.

Seville is remarkable for the reversal in thinking behind the design. The exterior is solid and mainly impervious (not transparent and lightweight); the interior spaces are inward and contemplative (not airy spacious shopping malls); the car parks are walled – almost medieval – gardens (not random expanses of asphalt). Gravity rather than weightlessness determines the architectural gestures of the main terminal spaces. Colour too is used with purpose: strong blues, yellows and white replace the neutral silver greys of other airports. Even with a relatively orthodox two-level terminal (departures above arrivals with a two-level entrance roadway) Moneo has shown that the modern terminal can absorb local architectural traditions to enhance the dialectic between international and regional cultural traditions.

Palma Airport, Majorca

Serving the holiday island of Majorca, Palma Airport, designed by Pere Nicolau Bover, has grown more rapidly than most. The decision to create an 'airport city' rather than merely a collection of terminal buildings was based upon the assumption that passenger flows would increase from 18 million a year in 1998 to around 30 million by 2020. The masterplan for the new airport sought an orderly framework for growth which would provide Majorca with a memorable gateway while also catering for the unpredictability of international tourism.

The idea of an 'airport city' led inevitably to questions of urban and landscape design. Palma Airport is one of the few recent transport facilities which sought an architectural language to tie together the different buildings from terminals to hangars, car parks to hotels. As a consequence, all buildings are white, glass acts as a mirror to the wider landscape of hills and water, and pitched roofs are employed wherever possible to break up the skyline and improve the view from the air. Palma Airport has the consistency of a large business park with tree planting, fountains, sculpture and earth mounds mediating between big buildings and the expansive landscape (Figure 1.25).

Unusually too, the airport authorities decided in the construction of the new terminals in 1998 to cater for the anticipated growth of passengers to the year 2020. Thus, the check-in area is unusually spacious, allowing passengers to check in their baggage and continue in the same direction without being impeded by queuing passengers.

16.18 Palma Airport, Majorca. Departures floor. Architect: Pere Nicolau Bover.

16.19 Sun-bathing terrace on roof of Palma Airport.

Since many travellers transfer directly to coaches and taxis at the airport, the ease of interchange is a major factor in the design of the airport. Direct baggage check-in is available before passengers reach the terminal, reducing stress and time delays in the building. The additional space created by pre-travel baggage transfer has been used to provide more extensive shops, restaurants and bars than is the case with similar-sized airports. These facilities are mainly located on an upper floor as part of an extensive departure lounge. Unusually, some of these are located around a glazed roof terrace (called a solarium) which, besides having deck chairs, pergolas and palm trees, opens onto an outside terrace for sun-bathing. Palma Airport is, in this regard, part of the holiday experience. But rather than hide this area away from the public gaze, it is adjacent to the main thoroughfare between check-in and departure control.

The detailed design of the airport and its pedestrian routes has sought to exploit the play of sunlight and shadows. These are brought into the terminal via a structural frame of angled and curved steel members set either against the open sky or placed beneath extensive glass roofs. The rhythm of shadows, the sparkle of sunlight, blue skies and white finishes creates a stimulating environment for often tired passengers.

Sondica Airport, Bilbao, Spain

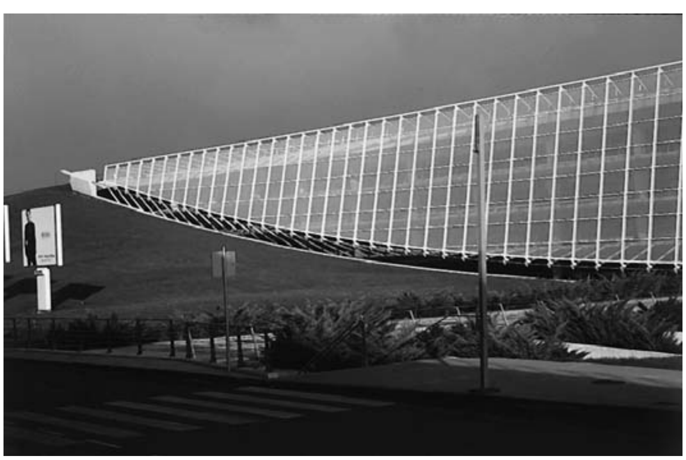
Designed in 1990 by Santiago Calatrava's office in Zurich, the new terminal building is part of the comprehensive redevelopment of Bilbao's principal airport. Rather than construct a new airport on a fresh site, the authorities chose the logistically more difficult task of rebuilding and restructuring the airport around the existing infrastructure of runways and hangars. Bilbao, like many regional airports in Europe, has had to adapt over the past decade to an unexpected rise in passenger movements. The city of Bilbao has proved particularly successful at attracting new investment, and this in turn has placed pressure on its airport.

Calatrava's design provides the powerful architectural vision and consistent structural language necessary to accommodate future growth. The brief required of the architect a framework whereby future extensions and increases in traffic could be housed without destroying the clarity of the concept. The airport at Bilbao has also had to cater for a big increase in international flights, with the new terminal accommodating regional, national and also international movements.

The concept places great emphasis upon a spacious departure concourse. This lofty and expansive central volume,

16.20 Landside view of Sondica Airport, Bilbao.

16.21 Approach to check-in hall at Sondica Airport, Bilbao.



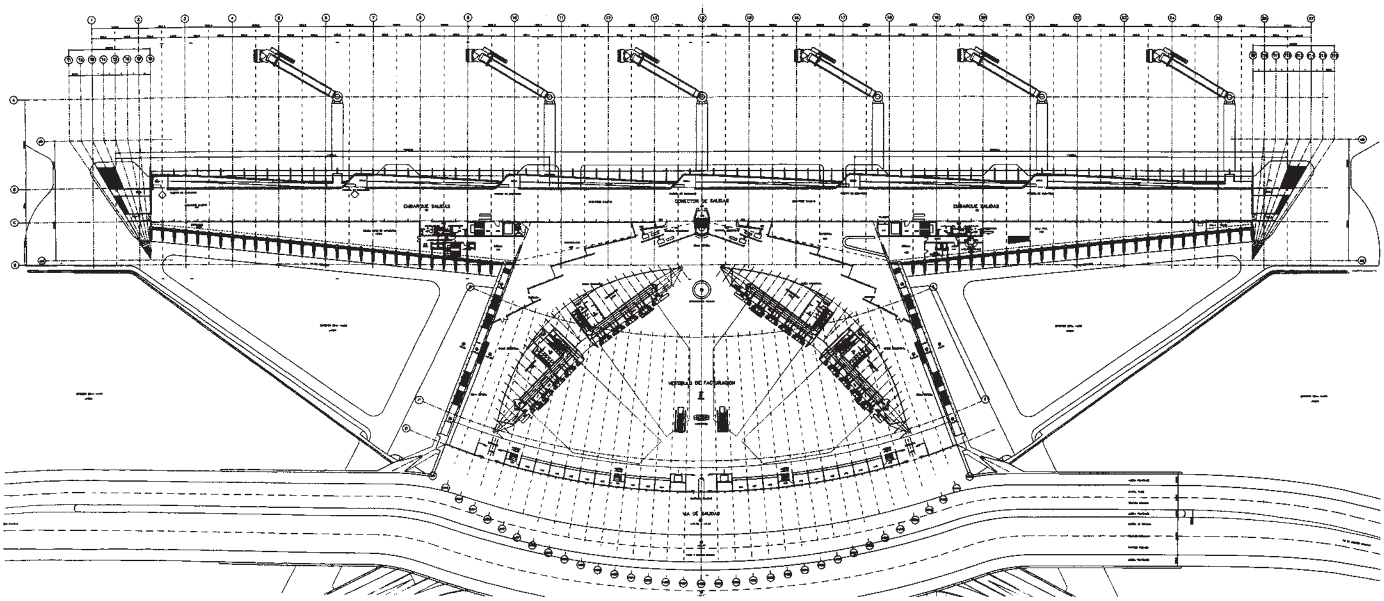
16.22 Car park, Sondica Airport, Bilbao.

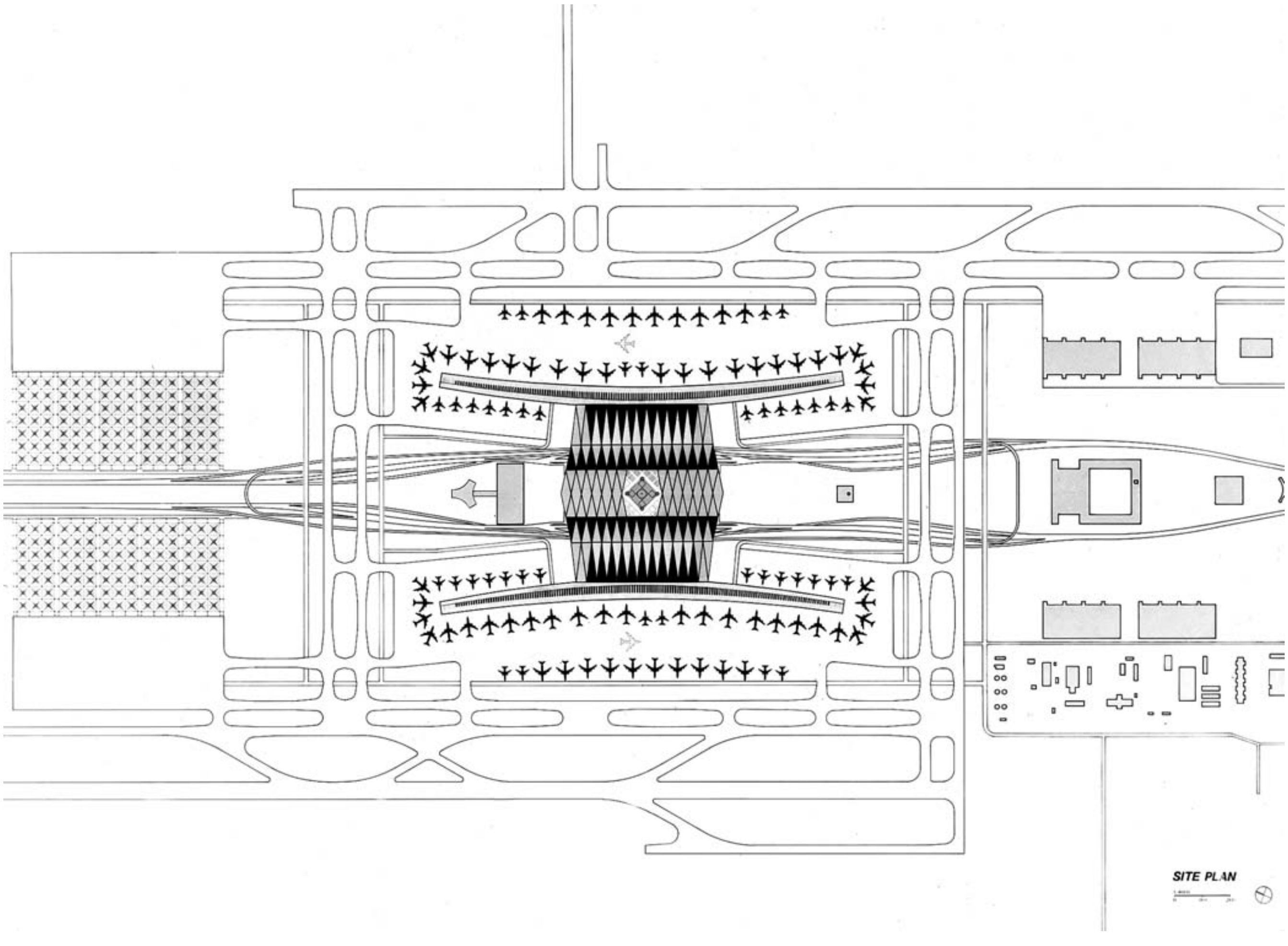
clad predominantly in glass, orders all other functions about itself. It rises from an almost triangular plan to a prow high above the airside corridor. The beak-like prow hangs above the aircraft standing at their gates, reminiscent of a giant bird of prey. From the ridged spine of the departure lounge roof runs a fan of beams and angled columns that buttress the glass walls. It is a design of characteristic Calatrava bravado, which derives its authority from the way in which the departure lounge gestures towards the act of flying, with the airside concourse hinting at the aircraft wings. Irrespective of the appropriateness of the bird metaphor there is no denying the way in which the design clearly articulates the principal public areas, and distinguishes them formally from the aisles or gate spine that give access to the aircraft. Unlike many airports, the car park too is closely related, and shares in the architectural language. It is axially located on the central route through the terminal, with a hanging canopy suspended over four floors marking the car park entrance.

Rather than separate the arrivals and departures lounges laterally, Calatrava places them both in a great central space. They are merely at different levels one above the other, not diagonally staggered as at Stuttgart, Kansai and in the design for Terminal 5. All ancillary accommodation (customs, airline offices and airport administration) is housed in the arms (or wings) overlooking the aircraft parking areas.

Sondica Airport terminal owes a great deal in its spatial and structural concepts to Lyon-Satolas Station, also by Calatrava. Both feature a large, sculptural – rather zoomorphic – central form with wings that give access to trains or planes. Where one uses a departures aisle the other uses platforms, but the concept remains much the same. As at Satolas also, the structural materials move from concrete at or below the ground to steel in the air. Both structural materials at Sondica are

16.23 Sondica Airport, Bilbao, Spain. Notice how in Calatrava's design the passenger is directed by the angle of walls and position of structure. Architects: Calatrava Valls.





16.24 Plan of new Jeddah Airport in Saudi Arabia. The distinction between terminal and gate is particularly clear, as is that between the central concourse and check-in areas. A mosque lies in the centre. King Abdul Aziz Airport, Jeddah. Architects: Murphy/Jahn.

covered in metal panels rather than left exposed in the polluted airport atmosphere.

Sondica Airport is remarkable for the application of a consistent – yet sculpturally expressive – architectural syntax. Calatrava's uses of structure and internal volume are not empty gestures but the main means by which functional meaning and organizational hierarchies are communicated to the airport traveller. The terminal opened in 1998 at a cost of £130 million.

King Abdul Aziz International Airport, Jeddah, Saudi Arabia

Designed by Murphy/Jahn of Chicago, the new airport for Jeddah consists of a central rooflit terminal and two curving arms of airside corridor giving direct access to gate lounges. The layout is based upon a square of runways and taxiing areas in which the terminal is centrally located. Access roads pass beneath the aircraft-taxiing ways, and reach the terminal at basement level. As a consequence, vertical movement through the building is as important as horizontal movement, and to make this as enjoyable as possible natural light is taken through a series of internal courtyards to the lowest level.

The concept has an elegant simplicity. The central terminal is lozenge shaped, with a central glazed street that accommodates vertical movement and distributes functions laterally about the spine. In the centre there is a small temple for worship.

The curved lightweight roof gives the terminal a tented character, which befits a terminal designed mainly for pilgrims. However, between each facet of roof a line of glazing brings light into the building, creating a diamond-shaped grid of daylight. Angled columns on the lower level and tree-shaped columns and beams on the upper level reinforce the lightweight, almost nomadic, quality of the terminal.

Functionally, the split between a central terminal where ticket check-in, passport control and shopping occurs, and the slender angled wings of the airside concourses, gives the building a form that is easily grasped. The layout adopted can also be readily extended by constructing satellites along each pier.

The Haj Terminal at King Abdul Aziz Airport, Jeddah, Saudi Arabia

Designed in 1985 by Skidmore Owings and Merrill (SOM), the Haj Terminal at Jeddah Airport is remarkable for the short period of its annual occupation and the use of a naturally lit and ventilated structure. The terminal is used for only six weeks of the year when Muslim pilgrims converge on Mecca for their annual pilgrimage. Thus, the Haj Terminal serves as the international gateway for pilgrims drawn from around the world. Rather than disrupt the workings of King Abdul Aziz Airport by the seasonal influx of visitors, the decision was made to locate the new terminal at the edge of the airport. This has allowed it to adopt an unusual form and internal arrangement.

The terminal makes reference to the tented structures employed by the nomadic peoples of the region. The metaphor, acted out in teflon-coated fibreglass membrane suspended from slender concrete supports, provides an enclosure where the pilgrims can gather, pray and (if need be) sleep overnight. The terminal does not have walls other than as noise baffles which act at airside. There are, however,

16.25 Haj Terminal, King Abdul Aziz Airport, Jeddah. Architects: Skidmore Owings and Merrill.

internal partitions required for privacy or security at a lower level. The terminal is essentially a canopy which shelters passengers and allows them to be processed before or after their flight. The canopy forms a collection of cone-shaped shelters which are open to the sky and divided periodically by openings for cross-ventilation. Internal tubular structures provide for the support of loudspeakers and mechanical ventilation for when temperatures become intolerable.

The Haj Terminal is a special kind of airport building. Tailored to the specific needs of pilgrims, it provides shelter for up to 80 000 pilgrims at any one time beneath a canopy covering 190 000m^2. Pilgrims are allowed to cook within the terminal, thereby reinforcing the traditional Muslim lifestyle. The building won an Aga Khan Award for Architecture in 1990 for the way it reconciled the needs of global air travel with the spiritual needs of the community.

Shenzhen Airport, China

The design for the second terminal at Shenzhen Airport in China (only some 30km north of Hong Kong) was won in competition by the UK practice Llewelyn Davies in collaboration

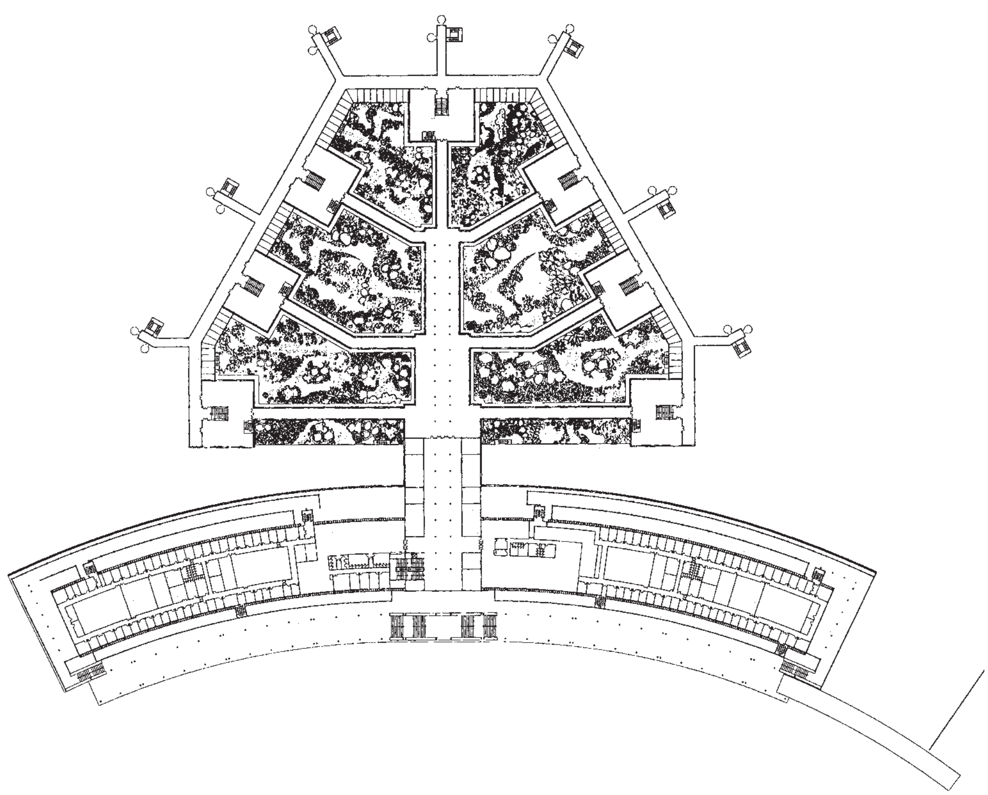
16.26 Check-in hall, Xian Airport, China. Architect: Llewelyn Davies.

with BAA International in 1995. It is planned to handle 12 million passengers a year, and opened in 2000. Shenzhen Airport is one of ten regional airports designated as centres for economic development by the Chinese government in 1990. It has become the country's fifth busiest airport, with the first terminal handling over 5 million passengers a year.

The concept behind the design for the second terminal is one of logical and legible routes through the building, an emphasis upon customer quality in the concourse areas, and elegance in the handling of space and structure. While the design had to adopt the building footprint imposed by the airport masterplan, the use of architectural means such as transparency, large column-free spans, an undulating roof, and clear spatial progression of interior volumes, gives the building lightness of touch. The philosophy behind the design suggests a terminal not unlike Stansted, with its prominently single-storey section and distinctive roof just above head level. The curved roof, similar to the one employed at Xian airport (Figure 16.26), lifts at the landside access road to provide a lofty welcoming shelter. The need to bring daylight without heat gain into the core of the terminal has resulted in narrow bands of roof glazing integral with external solar screening. The roof canopy extends on all sides over the line of walls in order to provide further solar protection.

Jakarta Airport, Indonesia

Designed by Paul Andreu, this medium-sized airport is notable for the adoption of a language of design drawn from the vernacular building tradition of Indonesia. The integration of the airport with the surrounding landscape led to the building receiving an Aga Khan Award for Architecture in 1995. The



16.27 Plan of one of three satellite piers at Jakarta Airport. Architect: Paul Andreu.

airport consists of a large arc of terminal facilities with three satellite piers extending outwards over the apron. Each satellite is joined to the main terminal building by a pitched roof pier lined by gardens in which sit a number of pavilions where passengers wait to board their planes.

The references to the local method of building are intended to evoke cultural and climatic memories. Rather than air-condition the airport, the decision was made to use traditional materials, techniques of construction and methods of ventilation in order to create a new airport which was distinctive to place and relatively inexpensive to build. By employing the colours, perfumes (in flower scents) and construction details of Indonesia, the airport has become a true gateway to the country.

The aim, according to Andreu, was to create a sense of a township of traditional houses buried in the landscape rather than an anonymous airport.[10] Construction materials such as bamboo screens, clay tiles and red bricks combined with a domestic aesthetic of pitched roofs, which are hipped at their gables with central chimney-like ventilation towers, create the appearance of a holiday village rather than an airport. Unusually, views from the terminal windows are invariably over the palm trees of surrounding gardens as against aircraft on the runways.

The arc of the arrivals hall, ticket check-in and baggage reclaim area screens the extensive car parking from the bulk of the airport. The arc can be extended making the design both flexible and traditional at the same time. Rather like Moneo's design for Seville Airport, this is one of the few modern terminals which has largely abandoned the language of high tech in favour of local cultural references.

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Regional airport terminals

CHAPTER

17

Southampton Airport, UK

Designed in 1990 by the London architects Manser Associates, the new terminal at Southampton Airport was one of the first to fold and undulate the roof to bring daylight into the core of the building. Southampton is a small regional airport, all on one level in terms of passenger concourses, with a three-storey spine of offices for airport, airline and immigration staff through the centre. Between the central offices and the arrivals and departures concourses – arranged as aisles on either side – are two wide bands of rooflights, which bring light into the public areas. Functionally, the generous rooflights lead to a relatively energy-efficient building by saving on the cost of artificial lighting, but perceptually the juxtaposition of the roof glazing, diagonal roof structure and the elevated wall of offices creates a sense of place and direction within the terminal.

There is a simple articulation of the main architectural elements in both plan and section. The simplicity, coupled with relatively uncluttered interior spaces and a bird-like form externally, gives Southampton Airport a rare elegance for the genre. The projection of the central spine of office accommodation towards the runway in order to house flight control offices adds to the avian outline. Externally, it is relatively easy to read the major elements of accommodation: the transparency of the building envelope and the logic of the arrangement together add up to a building with functional clarity. Inside, too, the progression of spaces and routes for the passenger is clearly marked in terms of volume, spatial sequences and light. Architecture seems deliberately to overcome the sense of disorientation and alienation found in other airports. Admittedly, this is in part a product of size; Southampton handles less than a million passenger movements a year. But Manser has used openness, transparency (both upwards and outwards) and structural refinement to calm and guide the airline traveller.

The plan is commendably rational, and owes something to Stansted's geometric simplicity. Like Stansted, this is a single-level terminal, nearly square in plan, with oversailing roofs that protect the external walls from solar gain and

17.1 Southampton Airport, UK. The exterior marks the skilful resolution of a complex programme. Architects: Manser Associates.

interior spaces from glare. The two main concourses – arrivals and departures – are actually more like two atria. The first on landside receives passengers, then processes them through ticket check and passport control. Here a few cafes, shops and bars are located, but the rising curve of the roof and the expansive angled rooflight put commerce in its place. The second, on airside, is a similarly proportioned space, with duty-free shops and bars having views out at the gable over aircraft waiting on the apron. Because all aircraft are boarded on foot or by apron bus, the usual arrangement of jetty and gate piers is absent. This not only adds to the elegance of the terminal but means that passengers can engage more directly in the experience of air travel.

Structurally, the terminal has marked simplicity of form and detail. By using the walls of the central spine of offices as part of the building's main supporting structure, there is no need for secondary columns. Southampton is column free, with wide span loads taken on a series of diagonal struts. The central spine orders the terminal perceptually and also in terms of constructional logic. Without columns the spaces have a greater sense of size, and for retailers and facilities managers the lack of columns provides operational flexibility. Under these conditions walls and daylight take on extra significance, and here the design exploits the walls' ability to define territory and restrict access. The route through the central spine is clearly expressed, with big square openings cut into the off-white panelled walls.

The middle floor of the three-storey spine contains the building services, including air-conditioning. However, its location right in the centre of the terminal means that no secondary ducts are needed: air can be taken directly into the public concourses on either side and above the airline offices and below to the customs and baggage areas. Without roof-mounted ducting the public concourses retain their structural simplicity.

Part of the philosophy behind the design is an ambition to express the workings and construction of the building. Manser has sought to make explicit the means by which the building is supported, how it performs as a working terminal, and how the parts are assembled. It is an approach to design with a certain spartanness, yet at Southampton (as at Stansted) there is not the utilitarian feeling experienced in some other regional airports. This is due to the use of beams bent into concave curves with assemblies held apart to allow space and light to bounce off the surfaces. There is a sense of order that pervades the whole and the parts: a rigour that may prove vulnerable in time as the airport is used and adapted.

Being simple in concept, the terminal can readily be extended. It is designed to allow for linear growth in either direction. The structural bays are not ended with solid walls, but merely stop where current passenger demand requires. The brief required extendibility, and the external finishes – mainly silver polyester-coated aluminium panels and clear glazing – can readily be demounted.

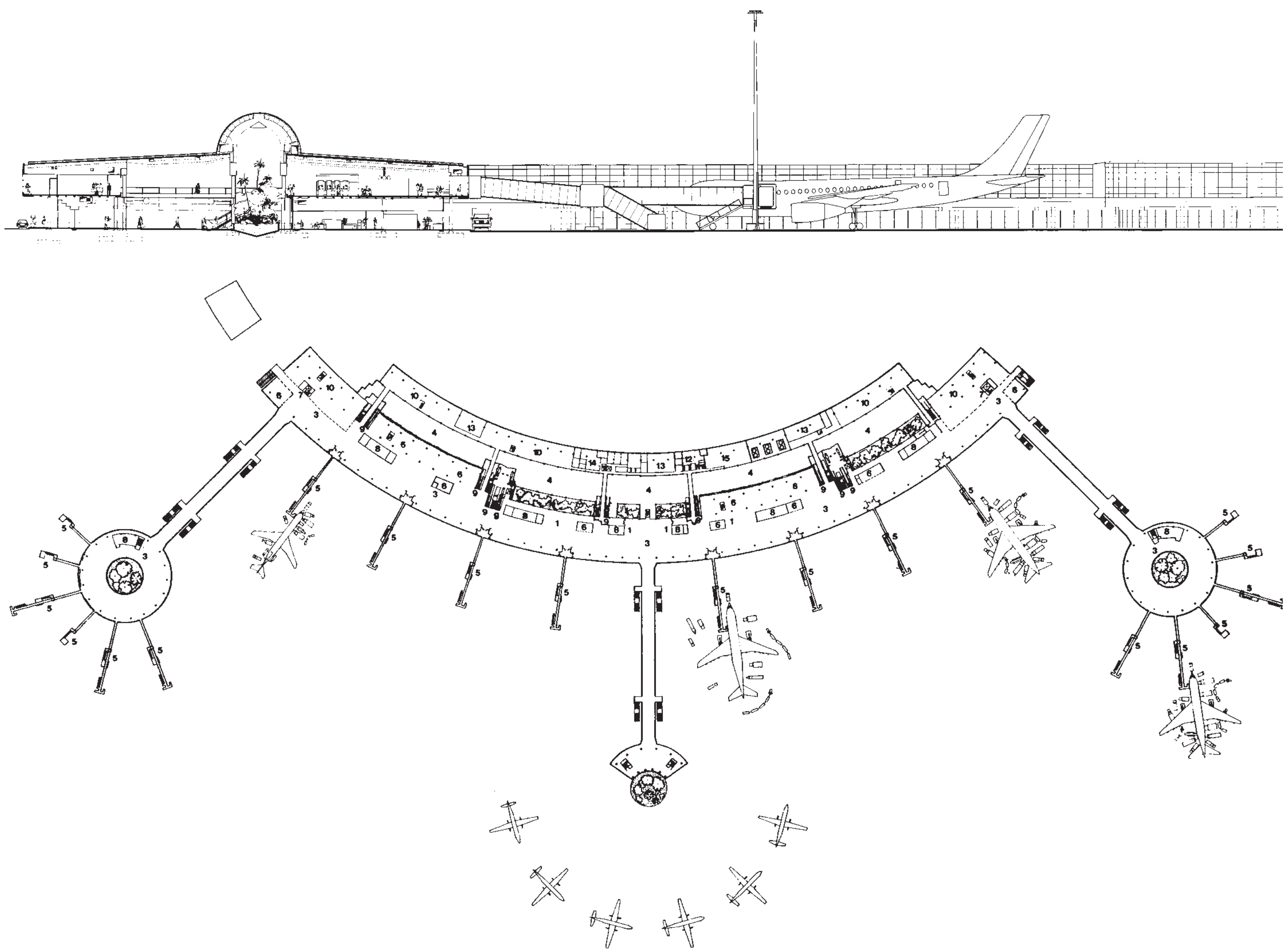
Southampton has met BAA's demands for a relatively cheap (it cost £23 million in 1994), elegant but adaptable regional terminal. It has become a model for other countries, with interest in the building being expressed from as far apart as Australia, Russia and Malaysia.[1] Part of the value of the terminal lies in the relative economy of the design and the way in which the money used has been directed at achieving greatest benefit for the passenger. Southampton Airport cost £800/m^2 as against £1250/m^2 at Stansted and half the amount for a typical multi-storey terminal.[2]

Two Australian airports: Brisbane and Rockhampton

Regional airports have the opportunity to provide clarity of route that is often denied to larger airports. Two good examples are the airports at Brisbane and Rockhampton, both in Queensland, Australia. The first is by far the larger, catering for nearly 1 million passengers a year; the second is much smaller, with traffic flows only about a tenth of that figure. In scale Brisbane is roughly analogous with Edinburgh and Rockhampton with Southampton.

Unlike bigger airports, which are really mini cities, regional airports have to mediate between the human scale and that of aircraft within the limited dimensions of fairly small termini. The typical regional airport is a long, shallow building with a road on landside and aircraft parked alongside the terminal (without lengthy piers) at airside. This is certainly the form at Rockhampton, where all aircraft are boarded directly from the apron, and in modified form at Brisbane, where in addition there are three satellites. However, the typology is relatively simple: a two-storey terminal with departures on upper level and arrivals below, and a roof-glazed concourse parallel to the road.

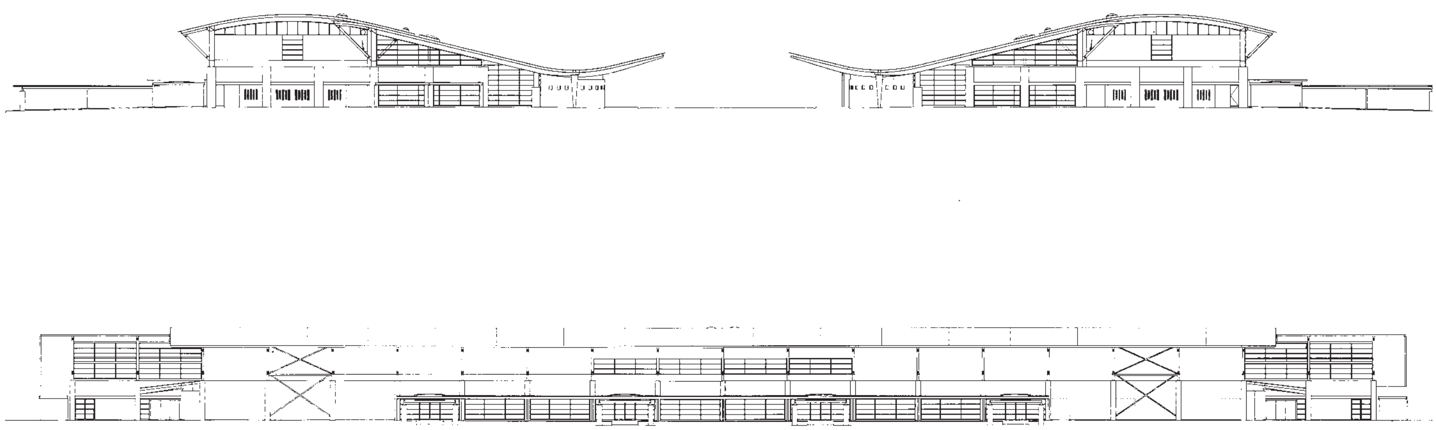
This basic form lends itself to local variation, and is readily capable of being expanded should demand increase. At Brisbane it is bent into a huge crescent, which forms an embrace for the car park and points the three satellite piers in different directions towards the runway. The terminal itself has a central vaulted rooflit spine, which elegantly divides the public concourse (where check-in is located) from the departure lounge. The spine is lofty, filled with interior planting and expressed in concrete barrel vaults. Being on a shallow curve it provides a point of orientation for those entering from either landside or airside – the sunlit double-height space contrasts



17.2 Brisbane Airport, Australia. The form of the terminal, with a sweeping curve and three satellites, articulates the function with particular clarity. Architects: Bligh Voller Architect.

pleasantly with the more utilitarian spaces on either side. The slender concrete columns and palms evoke the mood of a tropical garden right in the centre of the terminus, and provide a moment of tranquillity for the traveller.

One advantage of slender curved terminals is that they can readily be extended. Expansion at regional airports tends to be by linear extension of existing buildings, while at international airports expansion is normally via the construction of whole new termini (as at Heathrow and JFK, New York). The shallow curve at Brisbane is ended with temporary gables, and all internal routes are designed so that they can be extended later without operational disruption.



17.3 Rockhampton Airport, Australia: elevation and section of terminal. Architects: Bligh Voller Architect.

Designed by Bligh Voller Architect, the Brisbane terminal has remarkable clarity of organization, which results, at least in part, from a 'calmly understated minimalist grid'.[3] The grid, like that at Stansted, is a lightweight steel frame developed to support an aluminium and glass cladding system. From both the inside and the outside the rectilinear lines of the silicone and neoprene extruded joints contrast pleasantly with the expressed concrete portals of the entrance canopies and the internal mall.

A similar well-organized approach is found at Rockhampton Airport by the same architects. Again its basic form and architectural language derive from articulating the interior routes and bringing daylight into the centre of the terminal. At Rockhampton, however, an undulating roof is adopted, partly as a reference to the profile of the modern aircraft fuselage but also to help protect the building from wind pressure. As in many recent terminals, the ends of the roof project to protect the landside drop-off point and the airside access routes.

The roof at Rockhampton rises towards the aircraft, gesturing at the enhanced scale on airside. At its highest point the roof is glazed, allowing the presence of the sky to penet rate to the interior lounges. Although designed for vertical segregation (of departing and arriving passengers), it currently operates as a single-level terminal. As with Southampton Airport, the undulating roof is both an internal means of articulating route and an external gesture towards flight.[4]

Guadeloupe Airport

The new terminal at Guadeloupe Airport designed by Paul Andreu (assisted by Pierre-Michel Dalbench and Dominique Chavanne) is relatively small but maintains the level split between departures on the upper floor and arrivals with baggage facilities below. A similar symmetry occurs in plan with one large hall for check-in and arrivals facing the landside and a space which mirrors it for departures on the airside. Both are relatively large volumes with areas of accommodation designed as self-contained rooms within the space. Passengers are encouraged to navigate their way through the two large volumes by the use of daylight which enters the terminal via a perforated façade of glass and metal panels.[5]

Between the two large passenger volumes sits a bridging element constructed of more heavyweight concrete construction. The bridge contains the main control functions in the terminal. Here customs and passport offices are located, plus the back-up spaces for airport authority staff. To pass across the bridge of controls is to move metaphorically into a different kind of environment where the journey really begins. Since the security areas demand an increasing amount of space, at Guadeloupe Airport they project through the gables of the building, providing architectural punctuation. Their position here also gives direct access to the airport apron and

17.4 View of Guadeloupe Airport. Architect: Paul Andreu.

runway areas, and should extra accommodation for security be required in the future, these cross-wings can be extended without interfering with the arrivals or departures flow.

Guadeloupe has a demanding solar climate for much of the year. The response in the new terminal has been to reduce the area of glazing, to tilt the main façades to limit exposure to the sunshine and to over-sail the roof to provide shade. The perforated metal sheet glazing system incorporates natural ventilation through the façade. Added to this, the concrete of the central bridge uses the thermal capacity of construction to further moderate temperatures.

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1. Martin Spring, 'Air waves', *Building,* 9 December 1994, p. 32.
2. *Ibid.,* p. 34.
3. Michael Keniger, 'Queensland drama', *The Architectural Review,* December 1989, p. 7.
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5. Paul Andreu, *The Discovery of Universal Space*, l'Arcaedizioni, 1997, p. 122.

Other airport structures

CHAPTER 18

Transportation Centre at the International Airport at Inchon, Seoul, South Korea

The new Inchon International Airport at Seoul in South Korea confirms the important place that the Asia Pacific region is currently playing in the development of a new approach to airport design. Designed by the UK practice of Terry Farrell and Partners, Seoul, Inchon International Airport continues the new and largely invigorated approach already seen at Kansai and evident too in the design of Hong Kong's new airport at Chek Lap Kok and the second Bangkok International Airport in Thailand. These are all essentially large-scale infrastructure projects, which act as intermodal transportation centres and urban development nodes, rather than simply as airports. As international, national and regional transportation centres they perform many functions, besides providing access to the air. Linked to high-speed train and local train and bus services, they will see many travellers pass through the airport en route to other destinations. As a result these new Asian airports (of which Seoul is perhaps the best example to date) require a fresh approach to form, organization and function. The role of design is primarily that of providing clarity and orientation while also meeting the needs of flexibility and operational flexibility.

According to Terry Farrell and Partners, the main factors that determined the design of the new airport at Seoul were the requirements to:

- provide a gateway to South Korea, and signify in symbolic fashion a reunified nation
- provide a focal point for international and inter-Asia trade activities (that is, more than just air movement)
- provide a transportation centre embracing a wide range of intermodal systems
- exploit design possibilities to provide user legibility through the airport.

The masterplan at Seoul is capable of being implemented in phased units over a 20-year timescale. The project is, however, more than just the construction of an airport: it includes the development of reclaimed land between

18.1 The Transportation Centre combines Western technology with a respect for Korean traditions. Seoul Airport, Korea. Architects: Terry Farrell and Partners.

Yong Jong and Yong Yu islands just east of the airport site, the construction of an eight-lane expressway, double track railroad, double-deck suspension bridge, underwater road tunnel, high-speed ferry service and helicopter routes. Not all parts are designed by Farrell's office, but the masterplan provides the spatial and investment framework whereby over time the various elements can be provided in a well-organized fashion.

The airport consists of a Transportation Centre sitting between a crescent-shaped Terminal 1 and a rectangular Terminal 2. The Centre is the visually dominant part: it towers over the two terminals and establishes axes through them. Both terminals are key aesthetic parts (hence the use of crescent and rectangular forms), visually recognizable in plan and section but subservient to the Centre. The latter sits astride the parallel tracks of the railway, which – like the runways – are the main parameters in determining the site layout.

The Centre is a complex and expressive structure: it signals in dramatic fashion the presence of the airport, and hints towards the passengers' contact with Korean culture. The decision to locate the control tower within the Centre (as against an isolated structure as in most airports) gives the means to project a great prow above the Centre's roof. The angled control tower, sitting on double legs and counterbalanced both structurally and visually by the curved steel walls of the Centre, provides a memorable bird-like image for weary passengers. There is an undeniable hint of Calatrava in the concept design, but Farrell's office has been developing along similar lines in other infrastructure projects for some time (for example, the CrossRail bridge over the River Thames of 1993).

A central axis unites the Centre in direct fashion with Terminals 1 and 2. The axis is defined by various means: the huge curving triangular roof, elevated banks of escalators, the spreading from a central point of secondary routes, and double-height volumes. The Centre is a separate structure between the terminals and between multi-storey car parks, which flank either wing. Light, gardens and space are taken between each part, thereby providing identity for the major elements. The effect of the deliberate differences in expression between the key parts of the airport, the parcels of garden space between them, and the exuberant triangular form of the Centre are all intended to allude to the flamboyant and colourful Korean architectural tradition. The roof of the Great Hall of the Centre is, according to the architect, a direct reference to 'a bird in flight' and a symbolic gesture towards Korean culture expressed in local Buddhist temples.

18.2 Inchon Transportation Centre, Seoul Airport. Architects: Terry Farrell and Partners.

18.3 Arrivals concourse, Inchon Transportation Centre, Seoul Airport. Architects: Terry Farrell and Partners.

Normally, the passenger terminal building dominates an airport, and is the main architectural experience for travellers. At Seoul, however, the Transportation Centre is the primary element: it is the largest structure, and the one through which all passengers pass en route to or from either terminal. The justification for the Centre's prominence is the scale and extent of intermodal transport facilities at Seoul. Farrell's design celebrates in an unprecedented fashion the mainly public means of reaching the airport (rail, metro, bus) at the expense of the private car. Inside the Centre the four-platform railway station exists as an identifiable element with its own glazed roof sitting within the curved atrium space of the Great Hall of the main building. At the station, passengers can check in their baggage before proceeding at a more leisurely pace to Terminals 1 and 2.

Natural light is admitted via the enormous glazed atrium to all six levels of the Centre. At high level (on level 4) a people-mover system takes passengers via an elevated light railway to either terminal. Placed high up within the Great Hall, the light railway has its own station served by lifts and escalators. The plan with its radiating connections to Terminal 1 are, according to Farrell, symbolic of the Korean fan, yet the metaphor is steeped also in Western futurist imagery.

The grand glazed roof of the Centre's Great Hall is a spectacle from the air, especially with the neck of the air traffic control tower angled dramatically above the roof. The tower shares the structural logic of the remainder of the Centre from which it grows, and has a deliberate totem-like quality in its detailed treatment. The way in which the Centre nestles into the curve of Terminal 1 and extends arms to Terminal 2 suggests a controlled composition rather than incremental growth, which is the pattern at most international airports. There are no Cartesian grids at Seoul, and little evident opportunity for subsequent linear expansion. Farrell's design is a grand statement in the tradition of a fine nineteenth-century railway terminal. This is evident too in the treatment of spaces between the principal buildings. The Transportation Centre is constructed (for safety reasons) partly below ground, and only the curved roof of the Great Hall breaks the skyline. On either side of the glazed roof, however, gardens are provided, which gives the Great Hall the ambience of a temple surrounded by quasi-public space. This helps to reinforce in passengers' minds the role of the Centre as a symbolic pavilion and gateway – to the airport and to Korean culture.

Geometry, openness and light are the main characteristics of the design. Triangular geometry is the driving force that orders the principal spaces in plan, and it is used again to structure the interior volumes. The symbolic roof is both a metaphor and the means by which legibility and landmarking are provided. In what is thought to be the largest intermodal transportation centre in the world, Farrell's design exploits with particular potency the idea of bold expressive structural form to provide functional clarity. Yet it is boldness that combines the Western rationalist approach to airport design with respect for Korean cultural traditions in their widest sense. The combination of rationalism and romanticism at Seoul represents a valuable search for place-specific airports in an increasingly standardized world culture.

Airside Centre, Zurich Airport

Airport centres are a new way of unifying the disjointed development of terminal buildings that has occurred over previous decades. Few of the larger airports in the world have either adopted a masterplan or adhered to one when such has existed. Growth has often been haphazard and opportunistic, with the architectural experience suffering as a consequence. At Zurich Airport the decision was made to build a new airside centre to act as a hub, both visually and functionally for the collection of existing facilities. The plan, realized to designs by the UK architect Sir Nicholas Grimshaw, with structural engineers Ove Arup & Partners, creates a hub and transport centre linked directly to the existing terminal buildings.

The airside centre seeks to unify the airport experience at Zurich by creating a new building through which all passengers must pass. The competition brief called for a landmark building which Grimshaw's team has realized by a combination of tilting glazed façades, enormous projecting curved roof, and triple-height volumes. The centre is served by a combination of modes of transportation which converge either at the building or nearby. The underground metro station, landside rail terminal and centre share a common language of construction materials and a common network of spaces. They represent the new public realm of Zurich Airport and are designed specifically to refashion the image of the airport. All the new spaces share a sense that the movement volumes are to be celebrated, using structure and elegant materials to create memorable travel experiences.

The design has sought clarity of space and function, and restraint in the use of materials and colours. As Andreu has found at Charles de Gaulle, the neutral greyness of aluminium, marble and steel can be enlivened by people, shops and signs which bring a sense of theatre to the airport estate. The architects' task at Zurich was to create volumes which are legible, spacious and well-lit, trusting that human use will add the necessary sparkle (see Figure 1.28).

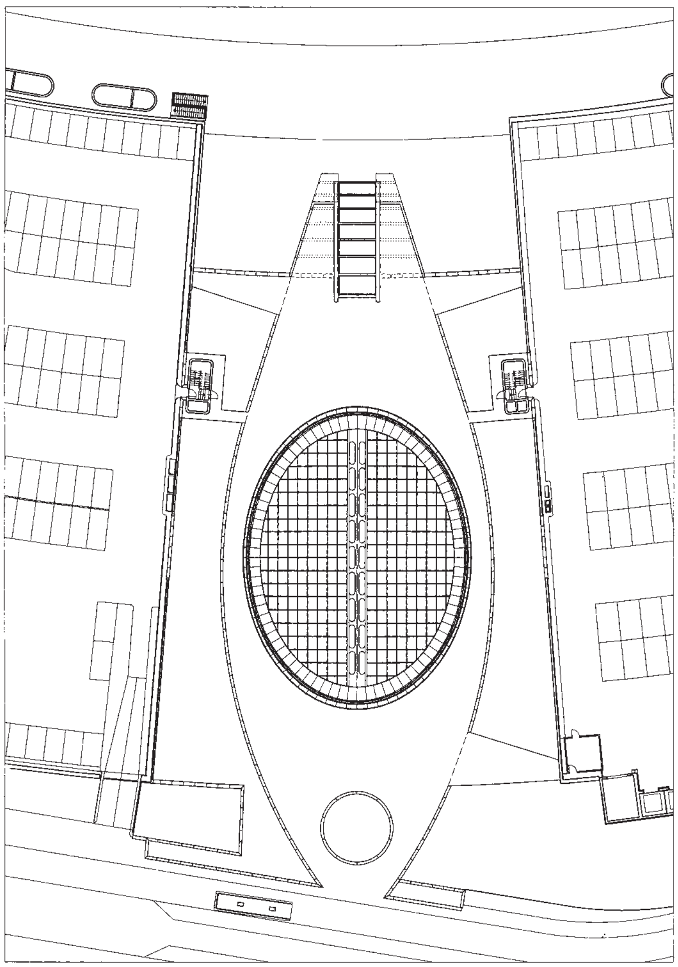
In spite of the complexity of the interchange and the scale of movement (40m passengers a year), the airside centre has calmness without over-simplification. The connections between air, car and rail are self-explanatory with architectural structure being employed to reinforce the perception of routes and the hierarchy of spaces. This is particularly important as the centre has 1600m^2 of catering facilities and 5000m^2 of shops. These activities are housed mostly on a mezzanine level above the main concourse. Here passengers can look across the bustle of movement below and out onto the runways.

The new airside centre is an example of how the scale of an airport building can be humanized by dividing large volumes into smaller parts. The apparent size of the building is reduced by employing set-backs in section and by encouraging the

Table 18.1 Design priorities at Zurich Airport

Feature	Effect
clarity	of space
restraint	use of materials and colours
calmness	atmosphere within the spaces
transparency	views in and out
freshness	a special element and material tuning the atmosphere of the main spaces

Source: Kai Flender/Maria Roberts, *Pan European Airports*, 25 July 2003



18.4 Plan, Airside Interchange, Zurich Airport. Architects: Nicholas Grimshaw and Partners.

action inside the building to impact upon the façade creating visual richness. The layering of the façade, the large curved roof overhang and the angled walls all help to undermine the sense of a single monolithic building. The airside centre is a building which wraps gently around activities rather than enclosing them rigidly in an orthogonal architectural frame. The dialogue between the macro-scale of the outside and the micro-scale of human activity inside makes this a building which, although large, is also perceived as welcoming.

Air traffic control towers

Air traffic control towers are one of the most distinctive and architecturally prominent structures at airports. Within the wide open landscapes of a typical airport, the control tower represents a vertical point of reference, which can do much to enhance the image and aesthetic profile of an airport. Being shaped by demanding functional programmes, such towers are also often highly sculpted three-dimensional structures. Their main function is that of controlling the movement of

18.5 Air traffic control towers give airports an essential vertical dimension. They need to be designed as landmarks. Schipol Airport, Amsterdam, the Netherlands. Architects: Bentham Crouwel.

18.6 Air traffic control tower at Oslo International Airport, Norway. Architects: Aviaplan AS.

18.7 Control tower at Sydney Airport, Australia. Architects: Ancher/Mortlock/Wooley.

aircraft in the air and the movement of service vehicles and planes on the ground. The need to have visual surveillance over both results in buildings that are often isolated structures some way apart from the remainder of the airport buildings. However, because the operation of the passenger terminal and that of the aircraft are necessarily related, control towers are sometimes constructed as rooftop extensions to the main terminal or more frequently loosely affiliated structures.

Control towers direct and coordinate aircraft movements in the vicinity of the airport. Air traffic control staff monitor aircraft movement on apron areas, taxiways, runways and in the air. Clear visibility is crucial, and sightlines dictate the positioning of the tower relative to other structures such as hangars, terminals and piers. From the tower itself it is vital that views are unobstructed by columns, that glare does not occur or interfere with display screens, and that visibility angles are maintained. The angle and configuration of the glazing need to provide safe and comfortable working conditions under both sunny and cloudy skies, during the day and night. Ergonomics is one of the main design constraints in control towers.

Because control towers are physically divorced from the ground and are placed in high fire-risk locations, the means of escape in emergency is an important factor. The escape stairs add to the formal composition and complement the lifts normally used in gaining access. In some control towers, such as at Sydney Airport, the escape stair plots a different geometry from that of the main shaft of the tower, thereby enhancing the design as a three-dimensional composition.

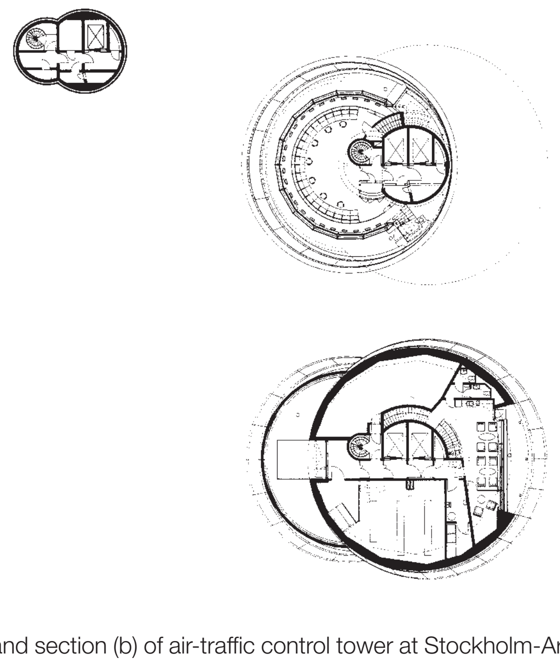
Another novel control tower is at O'Hare International Airport, Chicago, designed by Murphy/Jahn Architects in 1990. It is grander than the example at Sydney but shares its sculptural complexity. The core of the tower is a hollow concrete column, which contains elevator, cables and technical equipment, with the escape staircase wrapping around it.[1] The concrete core supports a steel-framed faceted glass curtain of ancillary and office accommodation. The swelling and contracting of the glass wall reflects the internal planning, with its control room at the upper level. During the day the three-dimensional tower provides a welcome point of orientation at the airport: at night it glows, giving the tower depth and luminosity and adding to its symbolic significance.

Control towers normally consist of mainly large, open, column-free working space overlooking runway and sky. Air traffic control staff monitor aircraft movements visually and on electronic screens. The navigational installations require periodic upgrading of the electronic and mechanical equipment, creating a need to design such towers with replaceability in mind. The life of air traffic control systems is generally under 10 years, requiring three or four complete refits in the life of a typical control tower. As with the design of passenger terminals, the life of the outer structure and of the internal arrangement are on two quite different timescales.

Control tower, Arlanda Airport, Stockholm

The new control tower at Sweden's major airport at Arlanda exploits twisted geometry and plays of light and shade to produce a landmark. Growth in passenger flights in the

(a)



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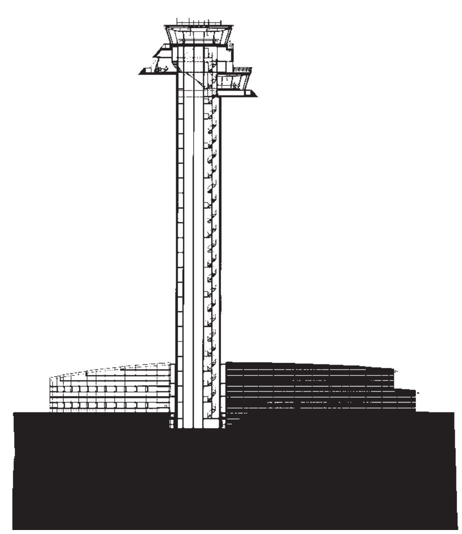
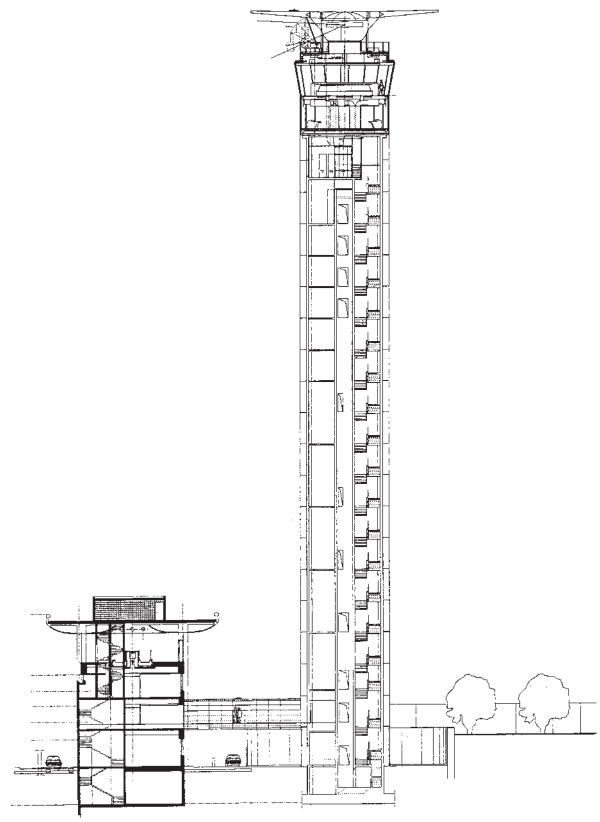


18.8 Plan (a) and section (b) of air-traffic control tower at Stockholm-Arlanda Airport. Architect: Wingårdh.

18.9 View of air-traffic control tower at Stockholm-Arlanda Airport.

18.10 Air-traffic control tower at Charles de Gaulle Airport. Architect: Paul Andreu.



1990s led to the need for a new traffic control tower located more centrally than its predecessor. Designed by Wingardh Arkitektkontor AB, the design is based upon the theme of two contrasting structures unified into a single whole. There are two control 'cabs', two shafts of lifts and stairs, and two wings of offices at the ground. The duality has been expressed in a contrasting play of black and white bands of cladding, producing an effective eye-catching composition from afar. Added to this, the bands of construction have been used to relay fragments of text from Saint-Exupèry as part of an installation by the Swedish artist, Silja Rautanen.

The new control tower is designed to be seen from the airfield. It gives scale to Stockholm-Arlanda Airport, providing a point of punctuation in a landscape of mainly horizontal planes. The banding helps to exaggerate the geometric shapes providing a hint of shadows even on grey days. Being distinctive in design, the control tower acts as a point of navigation, and a reference in space as well as on the ground. The design consists of extensive staff offices on the lower floors from which rises an interlocking tower capped by an elegant control point. It is the play of the architectural elements which makes this particular air traffic control tower worthy of note.

Munich Airport Centre, Germany

The Munich Airport Centre reflects the growing role of airports in providing conference, business, office and hotel facilities.

18.11 Strikingly planted roof of car park at Munich Airport Centre, Germany. Architects: Murphy/Jahn.

The Centre, designed by Murphy/Jahn, serves both the airport and the Munich region. With direct access on the one hand to the airport and on the other to the S-Bahn railway system, the Munich Airport Centre is able to attract custom from both directions.

The concept is relatively simple: a grid of hotels, offices, shops, restaurants, conference centre and clubs, located parallel to the main terminal building. Between the two, the existing road system provides ready access to the airport terminal on one side and the new Centre on the other. With gridded layouts of buildings the streets and malls take on particular significance. Here they alternate between access roads and glazed walkways, which in turn lead off giant sheltering glazed canopies.

The presence of a new railway station within the complex opens the development to non-airport uses. There are leisure and conference facilities spread between leafy courtyards constructed on the roofs of subterranean car parks. The new

Centre has also been designed to provide direct check-in and baggage claim facilities in the hotels and conference centre, thereby allowing the new facility to relieve pressure within the existing terminal.

The architectural concept developed by Murphy/Jahn breaks down the rigid division between the inside and the outside of the terminal building. Canopy-sheltered courtyards and streets allow the various buildings to merge with each other, creating a sense of urban village. Exterior planting plays a key part: it softens the interiors of buildings and their facades, tempering the harsh lines of the tectonic airport architecture. The combination of building and landscape design, and airport and conference centre buildings, has allowed Munich Airport to become a good example of the airport as a self-contained, economically diverse urban entity.

Reference

1. Werner Blaser (ed.), *Helmut Jahn Airports,* Birkhäuser Verlag, Berlin 1991, p. 94.

Part four

The airport of the future

CHAPTER 19

Characteristics of twenty-first-century airports

The question is sometimes asked: What is likely to distinguish twenty-first-century airports from those of the twentieth century? The airport is one of the very few thoroughly modern building types. There are no precedents for the airport or its principal building – the passenger terminal. The airport evolved just before the Second World War from largely temporary structural beginnings: tents, marquees and Nissen huts in the case of Heathrow. By the 1960s the airport had matured into a distinctive and immediately recognizable group of buildings and engineering works. The passenger terminal was a large usually rectangular building, sometimes with a two-level road system on landside and long glazed piers giving direct access to aircraft on airside. The control tower was a separate structure overlooking the runways and apron areas. Hangars, aircraft service areas, car parks, hotels and office buildings for airlines or airport authority made up the supporting entourage.

By the close of the century, however, the airport began one of those shifts of form that mark the maturing of a building type. Just as species evolve and settle into recognizable forms in response to changing conditions, so too the airport (and particularly the passenger terminal) started to develop new characteristics. Whereas the first generation of airports were relatively simple entities serving the fairly straightforward function of supporting air transportation for a wealthy minority, the later terminals became part of mass transportation, partly in response to the unexpected growth in global tourism. Inevitably, the airport has had to respond to these changing conditions, and in the process has evolved into a mature species. No longer is the airport a rather grand railway station served by cars on one side and planes on the other: today the airport is a complex, dynamic, multifunctional entity mirroring the cultural richness and diversity of modern life. As a consequence, the modern airport is a regional growth centre having no respect for green belts or the traditional values of the small communities nearby.

Not all airports have evolved yet to this level of typological sophistication, but it is possible to identify the key elements that distinguish the twenty-first-century airport from that of the twentieth century. Three determining factors are involved:

- land-use diversity
- intermodal transport integration
- environmental sensitivity

which together help to define second-generation airports and give them their distinctive architectural form.

Land-use diversity

As airports have matured they have become major economic centres. Modern airports are now business centres that operate quite independently of air travel; they are locations for conferences; they contain hotels used by local people, and shopping malls that serve regional retail needs; and they are important warehousing centres. As Gatwick has matured, the number of people using the various facilities from air museum to retail mall has risen. At Heathrow, the chapels, gym, business centres and hairdressers cater for the 58 000 airport staff as well as the 63 million who pass through the terminals each year. At the smaller scale, some regional airports are less airports in the traditional sense and more industrial estates with a runway through the centre.

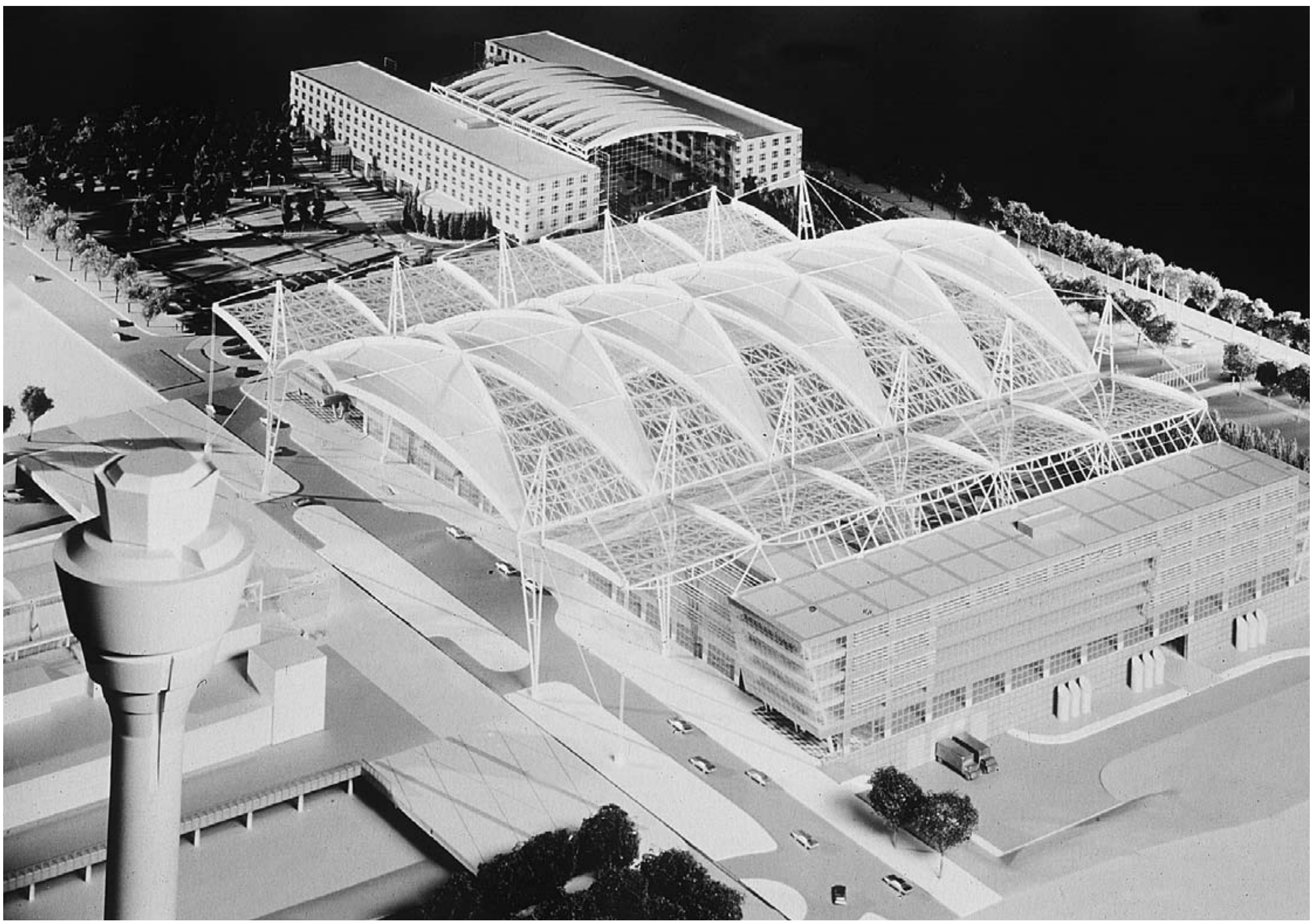
The loss of functional simplicity is expressed in the diversity of buildings and land uses encountered at a modern airport. Early photographs of airports show simply a runway, terminal and large open car park – the public elements connected by single-level two-way roads. By the 1960s car parks had become multistorey, and roads two-level and one-way; terminals had complex split sections; and two or three runways were commonplace. A similar shift in complexity and intensity began to occur in the 1990s: airports had become regional or even national centres for economic growth with conference, business, leisure and retail pressures within the airport proper and in the hinterland. Rather than seek to control these pressures, most governments have accepted the economic and social advantages of airport-led growth, and had by the 1990s begun to plan for the changes to the regional infrastructure. What started as an airport had (again Gatwick is a good example) become a major magnet for development, influencing the pattern of land uses, transportation systems and employment distribution within a 20km radius.

Looking at London's airports – Heathrow, Gatwick and Stansted – it is clear that all have become new towns, attracting people and jobs from other areas. Without official recognition Gatwick has become the Milton Keynes of the south side of London, and Stansted looks set to be the same for the north-east quadrant. Orthodox town planning cannot control the pressures brought about by airport expansion: what steps are taken are mainly token, and in preserving one parcel of land from development government controls merely transfer the pressure elsewhere. Just as new towns evolved from relatively simple beginnings (especially the plantation towns of Ireland, France or America) so the airport new town started life with a straightforward brief. With time and success the typical twentieth-century airport has grown into a sizeable town with the airport runway and passenger terminal at its centre. Looking further ahead into the mid-twenty-first century one can imagine airports such as Heathrow having their own university, hospital, and maybe even professional soccer team – all characteristics of mature cities. Even today one does not talk of Heathrow Airport but merely Heathrow; the place has clearly outgrown its original justification.

Given the apparent inevitability of growth, one needs to question airports constructed on man-made islands (such as Kansai and Chek Lap Kok in Hong Kong). Islands in the ocean can accommodate airport functions, but they cannot provide the space needed for the expansion of the regional economy. The choice of physical separation (such as Kansai Airport) or integration into the regional infrastructure of development (such as Chicago Midway) is one that airport authorities and governments need to consider jointly.

Airports change into complex beings over time. Piecemeal development or wholesale redevelopment (the two means by which growth and complexity are accommodated) lead remorselessly towards functional multiplicity. The result is a collection of buildings approaching an urban whole, with the same formal intricacy and hierarchical relationships as are encountered in a mature town. Heathrow, Charles de

19.1 Airports are developing into two types: those that are integrated into the urban structure (such as Munich) and those that are separate entities, often built on man-made islands (such as Kansai). Munich Airport Centre, Germany. Architects: Murphy/Jahn.

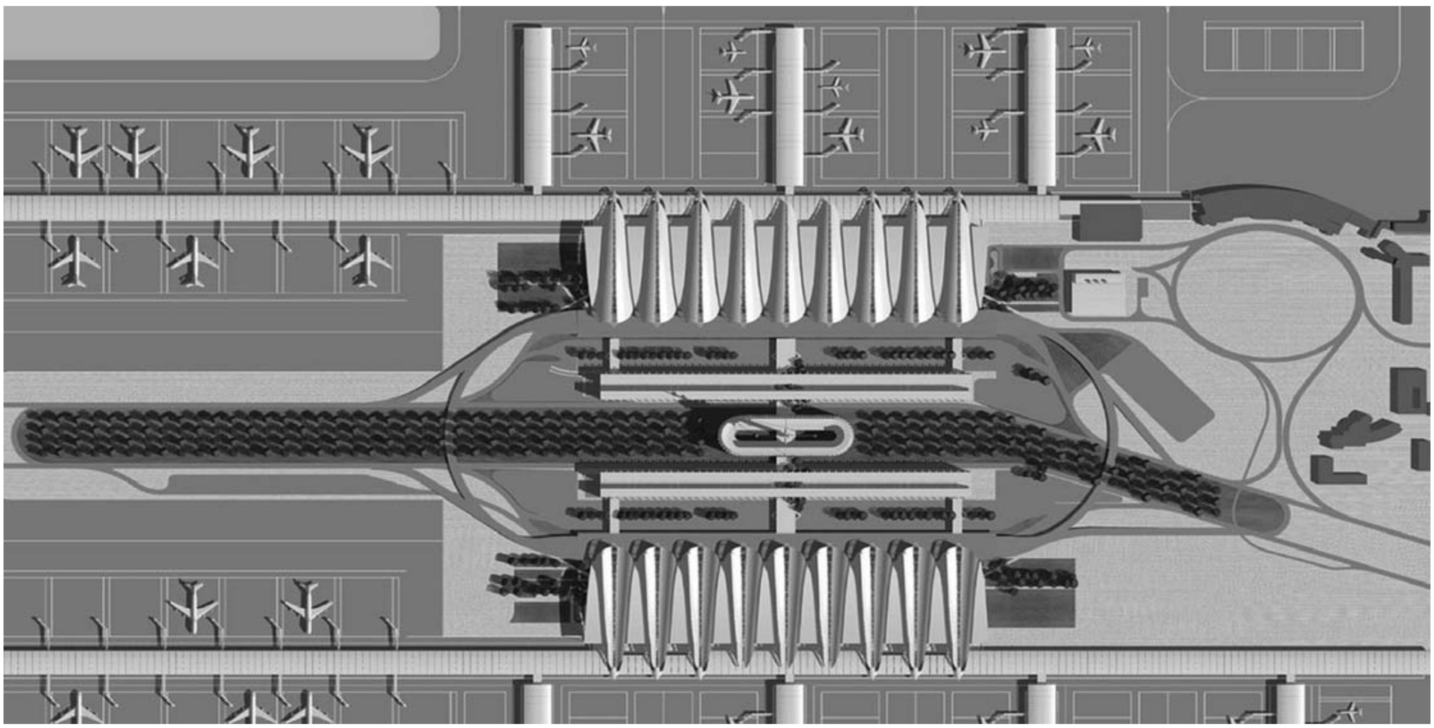


Gaulle and Kennedy airports all display these characteristics. The twenty-first-century airport, however, if built from scratch (as in Madrid's Barajas Airport) can house the land-use diversity within a structure that accepts the changing nature of airports. Foster's design for Beijing Airport provides an urban concept from the outset: the majestic plan with great wings and terraces is mildly suggestive of an ambitious eighteenth-century new town such as Bath. Accommodating growth and diversity within a plan of robustness and clarity is a characteristic of the twenty-first-century airport.

Intermodal transport integration

Modern airports are becoming large and complex transportation interchanges, where you can move freely between car, bus, rail, metro and aircraft. It is the integration, often within a single building, of transportation modes that distinguishes twenty-first-century airports from those of the twentieth century. In fact, such are the level and variety of transport systems at some modern airports that many passengers pass through them or change at them without the intention of using

19.2 Masterplan for Xian Airport prepared by Llewelyn Davies shows the integration of bus, rail and airport services into a coherent whole.



the airport at all. Berlin (ICE), Charles de Gaulle and Schipol airports are as much interchanges for all kinds of transportation services as they are airports. Here some passengers transfer from metro to regional or high-speed railway services, or from car to rail, and do not venture into the airport departure lounge at any part of the journey.

In many ways the changes in the distribution and complexity of land uses at airports and the growing integration at them of other forms of transportation are related factors. For an airport to serve effectively as a conference venue it needs local as well as regional and international transport links. Similarly, if an airport is to become a leisure or transit venue in its own right, it requires efficient bus, underground or mainline rail services. One trend in airport development noticeably evident at present is the extension of rail services to airport terminals (Manchester and Lyon Satolas are good examples). A better mix of transport facilities allows different types of people with different needs and diverse income levels to use the full range of facilities present at modern airports. If an airport is to serve its regional population effectively then intermodal transportation is essential.

It is true to say that the effective integration at airports of various types of rail, bus and private transport distinguishes the contemporary airport. This helps airline passengers to reach the airport with reduced frustration, it avoids travel delays for airport or airline staff, and it encourages the airport to grow as a business or leisure centre. Many large airports such as Heathrow cannot legitimately claim that they are airports of the twenty-first century (as BAA does) until a better balance is struck between public and private means of getting there.

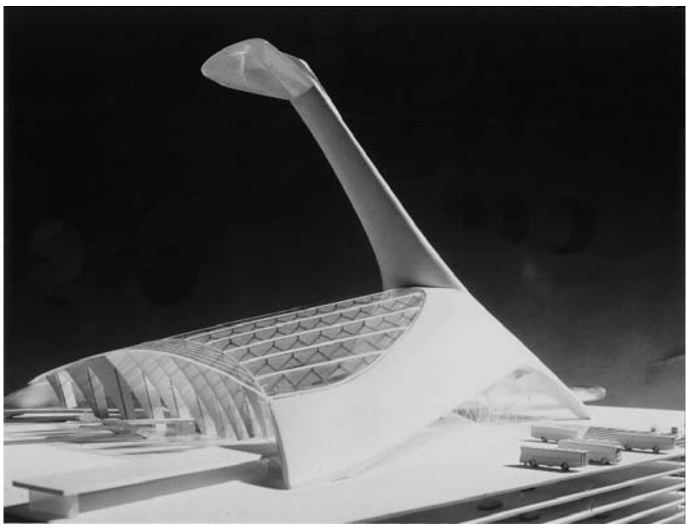
The integration of the full repertoire of public transport facilities into airport buildings adds greatly to the complexity and difficulty of designing terminals. At some airports the terminal and other forms of transportation are physically embraced within an enormous interchange (those at Zurich

19.3 The new Oslo Airport is well connected to the road and rail network (notice station at bottom). Architects: Aviaplan AS.

and Seoul airports are good examples); in others (such as Oslo or Manchester airports) the bus and rail terminals are separate structures within the estate of airport buildings. At Charles de Gaulle, itself a model of effective transportation integration, the five levels of the terminal allow road, rail and plane connection to be achieved with remarkable clarity. If the physical integration within a large terminal interchange of various kinds of public transport represents the high point of modern airport engineering, then the architect has the task of maintaining legibility through the maze of levels and structures involved. Intermodal transportation not only helps us to define the twenty-first-century airport, it establishes a modified typology for the building type.

Environmental sensitivity

To call modern airports 'environmentally' benign is to engage in relative, not absolute terms. Transportation by plane



19.4 The design for Seoul, Inchon International Airport transport interchange by Terry Farrell and Partners draws its imagery from a combination of natural and cultural references. Credit: Nigel Young.

and all the supporting infrastructure of the contemporary airport is one of the most ecologically damaging human endeavours. However, the twenty-first-century airport recognizes the environmental problem while the twentieth-century airport ignored it or fought to disclaim damage with the help of lawyers. What characterizes recent airport development and contemporary airport management is the open recognition of the scale and complexity of adverse environmental impacts. This has led to airport designers having to address environmental and ecological issues at the outset, and to airport managers responding more effectively to airlines that break noise, pollution or public safety standards.

The new environmental consciousness that has emerged as a feature of the twenty-first-century airport finds expression in five distinct ways:

- Airports are designed to respond to, rather than resist, climate, ecology and nature.
- Terminals are designed to reduce the use of energy.
- Terminals employ materials of low toxicity, and maximize natural sources of light and ventilation.
- Planting forms an important air purification and spiritual function in and around terminals.
- The airport authorities and local communities cooperate on environmental action.

These five points are not separate but related expressions of the new environmental awareness. The neighbourhood of an airport is seen not as a battleground between community groups and those who manage the airport but as a hinterland of common interest. Macro-level environmental action involving partnership between airport authorities, local councils, schools and wildlife groups is becoming more commonplace. As BAA recognizes, airports can grow only if the whole community, not just the airport managers, share a common goal, and in this the reduction of environmental impacts is a key element.

The airport of the future looks set to exploit the forces of nature to make travel less fatiguing and buildings less energy consuming. Designs such as that for Heathrow's Terminal 5 and the new international terminal at Oslo point in new ecological directions. At Terminal 5 the sectional profile of the building exploits air currents to promote natural ventilation and the extraction of smoke in the event of a fire. Here too interior planting purifies the air and provides an air of tranquillity,

19.5 Detail of timber roof at Oslo Airport. Architects: Aviaplan AS.

and exterior planting helps to baffle aircraft noise, sifts out pollutants, and modifies surface drainage by ecological means. At Oslo the terminal – designed by Aviaplan AS architects – uses local timber and stone in the structure and finishes in order to reduce the toxicity of the building and limit the importation of materials from across the world. As in many recent airport designs natural light is maximized to reduce the need to consume energy generated by non-renewable means. Solar gain and interior glare are combated by external grilles, with daylight shelves used to increase the penetration of natural light into the depths of the terminal.

Unlike an earlier generation of airports, many recent masterplans provide a necklace of tree belts, pockets of wildlife habitat and earth banks to both screen terminal buildings and encourage the absorption of the airport into the wider landscape. At both Gatwick and Heathrow recent landscape plans attempt to bring the agricultural or woodland countryside up to the terminal buildings, car parks and hotels. Through the selection of plant species, and in the choice of colours for the buildings, airport and environment seek a happier compromise than in the past.

These characteristics are increasingly features of world airports. The ecology movement finds sharper expression today than in the past. Kansai Airport is one of the more environmentally benign of major recent airports. The design of the terminal and the choice of planting mitigate to a degree the intrusion of a man-made island and the removal of a mountain on the Japanese coast to construct it. Similarly, in the USA the new hub airport at Denver borrows the tented metaphor of the local indigenous people as a sop to environmental concerns. At Seoul, Inchon International Airport, the design by Terry Farrell and Partners creates oriental gardens inside the terminal, and dense planted squares between it and adjacent buildings.

The twenty-first-century airport is a microcosm of the twenty-first-century city where work, leisure, travel and ecological systems melt into one. The challenge for architects and engineers is to match more equitably the industrial and organizational system of the airport with the natural systems and cultural priorities of the region that it serves. This means a better balance between airport design and nature in its widest sense: a correspondence between building engineering, human values and ecological principles. The idea of a flexible environmentally friendly terminal, where few parts are fixed and much is evolved on the principle of renewable modules, begins to give the modern airport the underlying order of an ecosystem. The twenty-first-century airport and its region will take on the features of a mature ecosystem where resources are used locally, where the minimum of materials are used to create the maximum social and environmental benefit, and where the airport is at the centre of a sustainable pattern of development.

19.6 When Glasgow Airport was extended (right) a generous area of roof glazing was provided to create natural light in the centre of the terminal. The original terminal (left) was designed by Basil Spence in 1960.

Sustainable development and the airport: the example of BAA

Sustainable development as a concept has begun to influence even the sterile and artificial world of the airport. BAA, for instance, adopted in 2001 a strategy for ensuring that its business is 'operated and grows according to the principles of sustainable development'.[1] As a paradigm, 'sustainable development' offers the advantage of providing a framework which seeks to integrate and balance three key dimensions – environmental, social and economic sustainability. It is all three of these which impact upon the welfare and development of a typical airport. Since airports, and their terminals in particular, have a considerable impact upon the physical and economic environment, airport authorities are naturally keen to ensure that the 'future of the aviation industry is a sustainable one'.[2]

BAA's strategy is modelled closely on the UK government's four objectives for sustainable development, namely, 'the effective protection of the environment, prudent use of natural resources, social progress which recognizes the needs of everyone, and the maintenance of high and stable levels of economic growth and employment'.[3] Inherent in the objectives are certain conflicts for airport developers, especially the balance to be struck between environmental protection and job creation. In 2001 BAA introduced the following 10 initiatives aimed at achieving sustainable development:[4]

- promoting a vision for cleaner, smarter growth
- pursuing stakeholder partnerships with local communities
- integrating strategies which bed sustainable development in day-to-day decisions
- improving performance and reducing waste
- influencing solutions in areas such as climate change
- proactively engaging in governmental consultations on achieving a sustainable aviation industry
- acting responsibly as an employer
- thinking long term and using the best advice
- communicating and monitoring performance on sustainable development
- exploring the role of new technology to reduce impacts.

These initiatives, supported by externally audited monitoring, provide a basis for the culture changes necessary at BAA to move towards sustainable development. However, as a company answerable to shareholders and where performance is measured by stock market ratings, there are limits to the scale of action which can be taken. Thus, BAA warns that its commitment to sustainable development should not expose the company to unnecessary risk. Also, since many of the adverse impacts at an airport are the result of the operations of airline and other companies, there is a limit to the influence the airport authority can have on its own. Here, however, BAA has taken action to penalize noisy aircraft, those who use old-fashioned heavily polluting aircraft engines, operators who flout the noise restriction corridors, companies which generate excessive waste and operators who do not follow good employment law. Thus, in adopting a clear statement on sustainable development, BAA is hoping to influence the action of the many operators and companies which use its UK airports.

Since the ten initiatives listed earlier are general in nature, BAA also introduced in 2001 five key environmental objectives as a result of discussion with local and national stakeholders. These, which will be monitored annually till 2010, are:

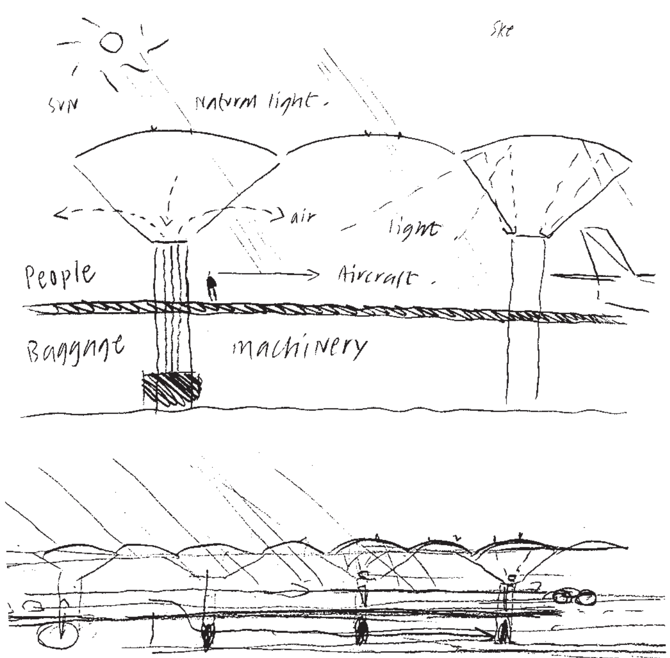
- impact of operations on climate change
- local air quality
- noise
- effectiveness of surface transport
- waste generated.

All five are designed to mitigate the impact of airport business activities on the environment and are supported by annual targets. The targets are not only externally audited and verified, but the performance of BAA is published annually. Typical of performance targets is the aim to achieve 50 per cent of surface transport to Heathrow by public means (rail and bus) by the year 2005, a 2 per cent reduction in energy use per year, and a 4 per cent reduction in noise disturbance to local residents.

By establishing these benchmarks, BAA can communicate its policies to other companies, measure its own and their performance, and make adjustments where necessary in contract or franchising agreements. Whether BAA is the most innovative airport authority in the area of sustainable development is unclear; certainly, government with its regulations and investment policies for public transport also has a key role to play. But in setting standards and targets BAA has at least opened the airport estate in the UK to the currents of environmentalism flowing more generally. To its credit, BAA, in spite of years of under-investment in modern infrastructure and buildings at UK airports, is setting the global pace in the area of balancing airport business needs with sustainable development. In 1999/2000 BAA achieved the highest score in the top 50 companies worldwide for its sustainability reporting.[5] In time this will affect not only the layout of the airport and the design of its buildings, but also the management ethos of the various companies which lease space from BAA or provide the airport with services.

Green thinking at Stansted

By turning the traditional airport terminal upside-down, Lord Foster was able to place the mechanical services in a basement where they had the benefit of ground cooling, as against in the roof where air-conditioning is more typically located. This simple inversion freed the ceiling of cumbersome plant, allowing natural light to permeate into the building. Without a uniform suspended ceiling there was the possibility of exploiting daylight and structure to provide the terminal with architectural character. Foster identified three main problems with roof-mounted services – the first was the weight and the



19.7 Lord Foster's sketches of environmental strategy at Stansted Airport.

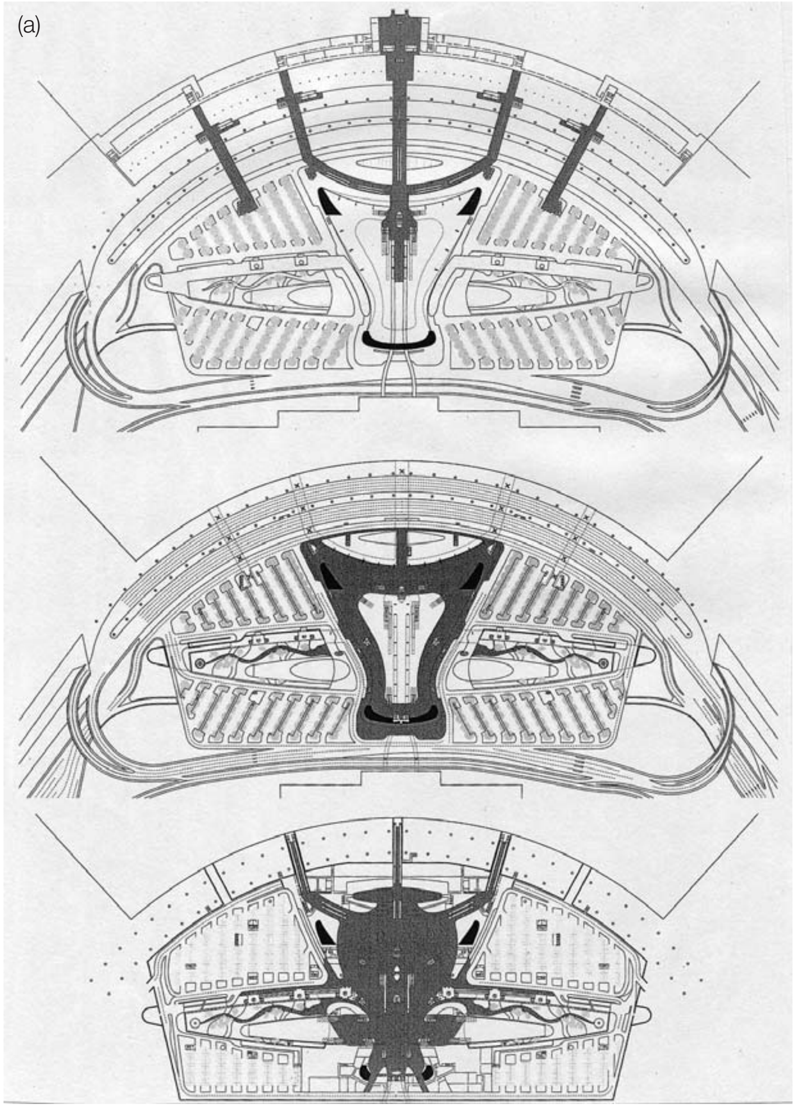
structural consequences, the second was the disturbance to passenger movement when the ceiling had to be accessed, and third was the grim and anonymous environment which stemmed from the suspended ceiling response.[7]

Stansted turns the previous assumptions on their head, saving on energy and disruption to the workings of the terminal, while also questioning the corporate standardisation of airport architecture. In this sense Stansted, though modest in terms of size, marks the beginning of a fresh generation of airport terminals. Energy is saved by exploiting daylight, rather than artificial light (about 32 per cent of the typical energy needs of an airport terminal stem from lighting). Reduced artificial lighting results in less cooling and ventilation, and by introducing daylight through the structural trusses, passengers have a chance to orientate themselves by the geometry of light and column. By liberating the roof of Stansted from the encumbrance of building services, the terminal becomes more graceful and joyful to use. This is partly the result of sunlight which is allowed to enter in a controlled fashion through the roof-lights, creating highlights on the floors below. It is also the sense, subtly perceived, that the buoyancy of the air is influenced by outdoor conditions – creating a space not separate but in contact with nature.

Green thinking at the International Airport at Inchon, Seoul, South Korea

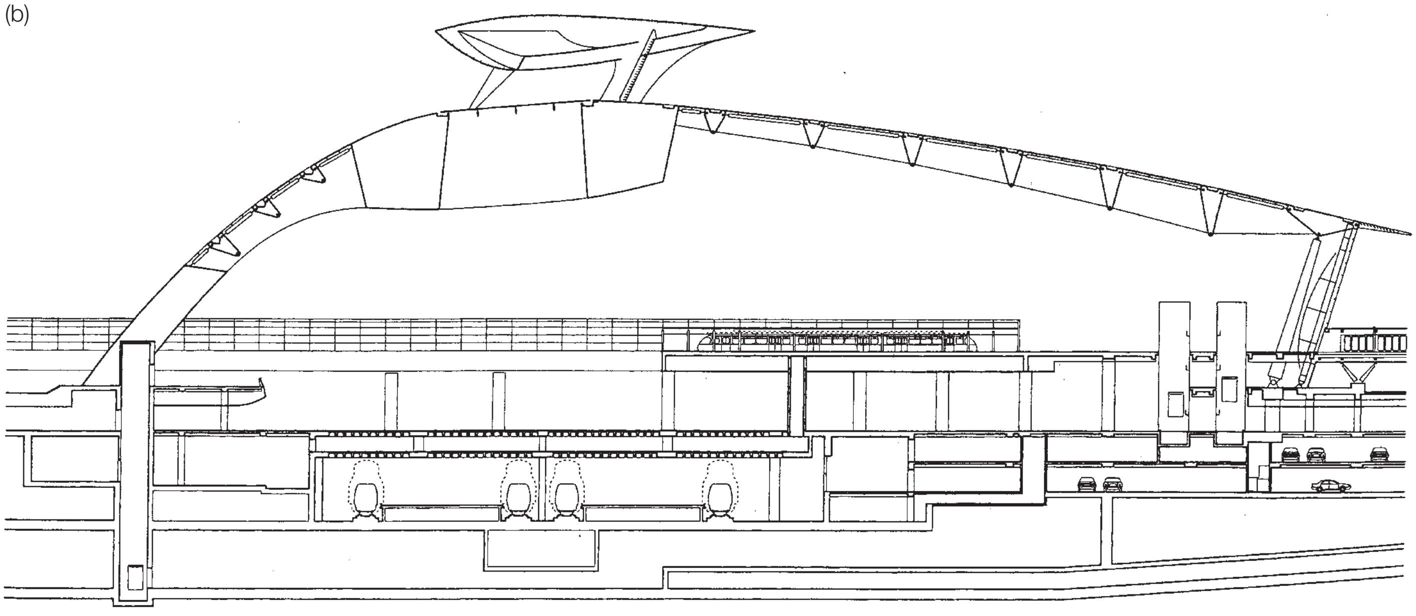
The new Transportation Centre at Inchon Airport features many innovative green technologies which spring from the problem of designing airport facilities in a hot climate. The design by Terry Farrell & Partners reduces energy use by manipulating the shape and orientation of the building according to the sun's path.[8] The internal environmental needs of heating in the winter, cooling in the summer, and ventilation throughout the year are achieved by designing a building which exploits natural energy flows. Solar gain and good daylight penetration are utilized by extensive glazing in walls and roof with solar protection provided by movable louvers. Unlike most other similar transport buildings, this example has a degree of natural ventilation provided by opening lights in the roof and at the eaves. Natural ventilation cannot, however, provide comfort throughout the seasons and to augment the opening windows,

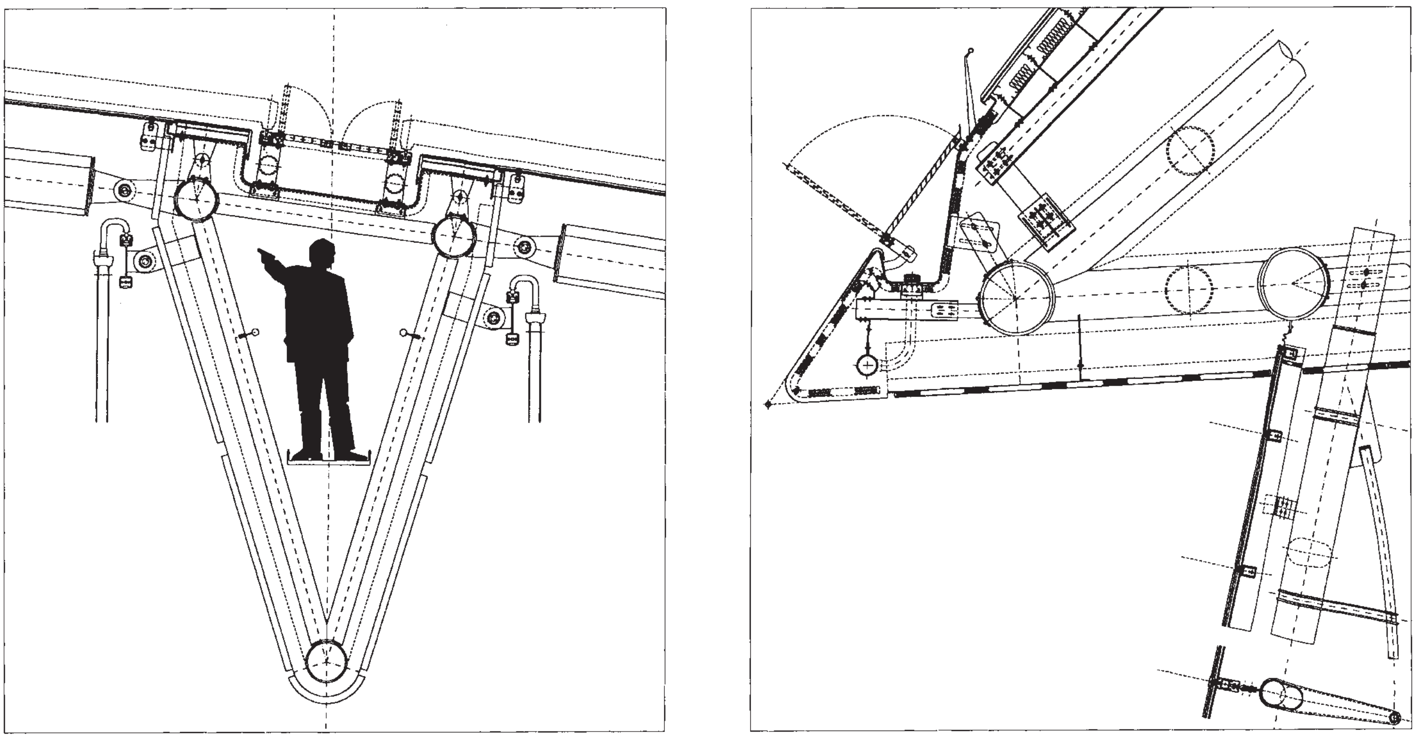
(a)



19.8 Plans (a) and section (b) of Transportation Centre, Inchon Airport, Seoul. The shape of the roof is largely determined by environmental criteria. Architects: Terry Farrell and Partners.

(b)





19.9 Details of roof and eaves ventilation at Transportation Centre, Inchon Airport, Seoul.

low-level cooled air is introduced in the areas occupied by the public. The emphasis is upon treating the occupied areas of the transportation centre rather than the whole space. To overcome excessive heat build-up alongside the glazing areas, a system of nozzles blows cooled air towards the glass which is then exhausted at the eaves. The same nozzles and low-level vents are used to introduce warmed air during the winter.

The façade adopts an intelligent environmental system of double-glazing with integral ducts built into the glazing frame. It provides (with the solar shading) a flexible and responsible perimeter skin to the large spaces of the building able to balance seasonal variations in heat loss, solar gain, condensation and daylight need. The construction keeps the various elements separate, allowing maintenance staff to monitor performance and to make adjustments without jeopardising the integrity of the whole (Figure 19.9).

The aim at Inchon of reducing the airport's impact on the environment stemmed from a government initiative. As the gateway to Korea, the new airport is seen as providing an example of how energy and technology can be integrated. The use of largely natural means of ventilation in the main hall of the Transportation Centre results in a building without disfiguring ventilation cowls on the roof. Thus, the view from the air is of an elegant shell which curves in response to the environmental demands. A further refinement is the way rainwater from the roof is used for irrigation, utilizing the adjoining landscaped areas for treating the waste water in an ecological fashion.[9]

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3. DETR report, *A Better Quality of Life*, 1999, preamble.
4. The list is a paraphrase from *BAA Corporate Sustainability*, *op. cit*.
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7. Malcolm Quantrill, *The Norman Foster Studio,* E & FN Spon, 1999, p. 227.
8. *Architecture Today,* Profile, 2002, no. 1, p. 15.
9. *Ibid.*

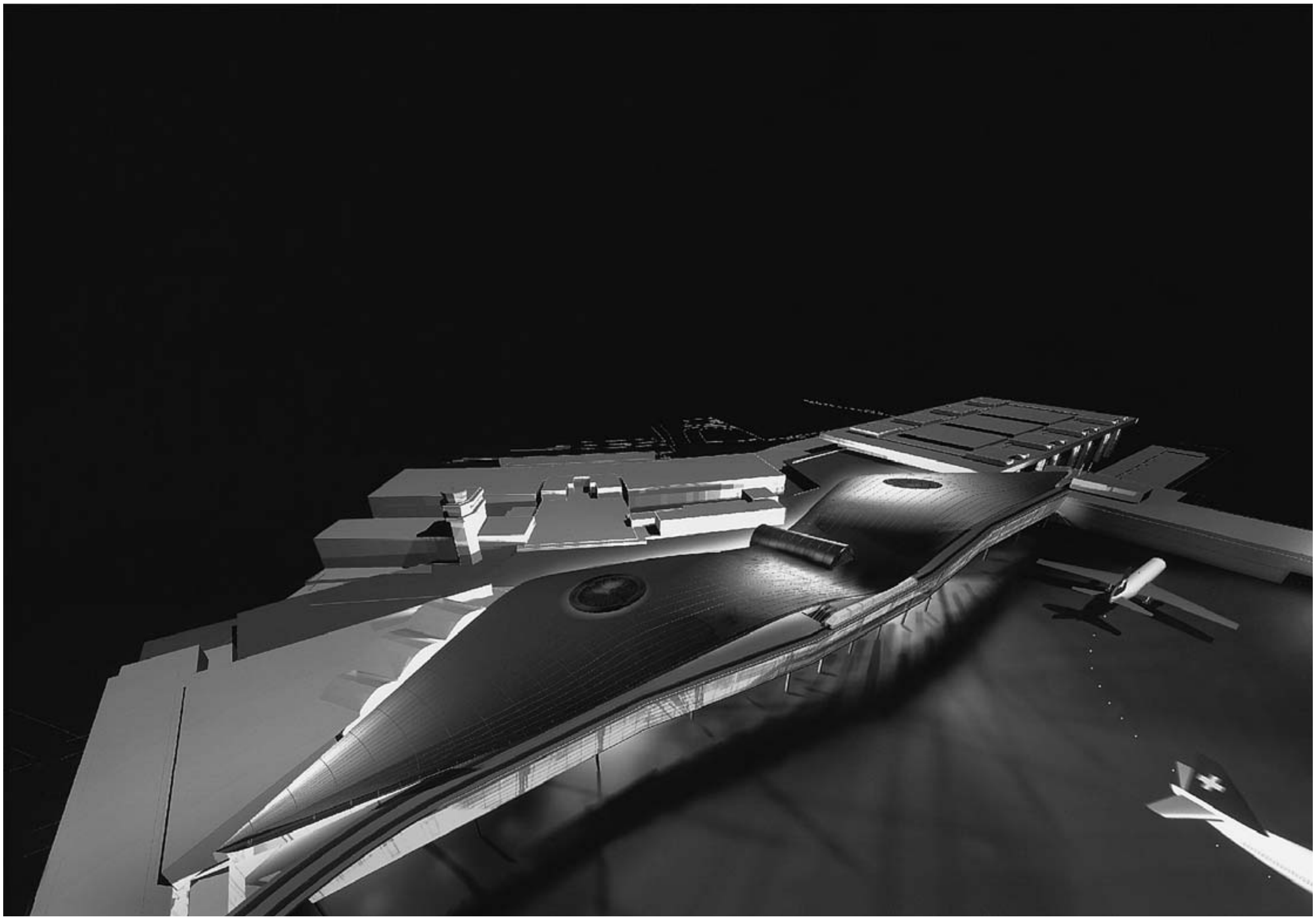
CHAPTER 20 The terminal of the future

As the airport takes on a distinctively different form at the close of the twentieth century from that in the middle, so too the passenger terminal is evolving in distinctive ways. The future terminal will be quite different from that experienced at most airports today – differences that reflect social and technological trends in the world at large, and specific changes in the management of airports. The modern airport, and certainly the airport of the twenty-first century, is a huge, complex and noisy theatre. It is a focus for a wide diversity of human activity – from travel to leisure, from shopping to health clubs, from plane-spotting to conferences, and from family reunions to church outings. Airports have become travel theme parks, where up to half the people present are not about to fly at all. Such functional ambiguity has undermined the simplicity of the airport and given it characteristics similar to those of cities. The 'vast, diversified and noisy theatre' of the typical modern airport reflects directly the chaotic, complex, multicultural and fragmented contemporary urban condition.

The airport as a new type of city

Arguably, big airports such as London Heathrow are a vision of the city of the twenty-first century – urban areas made up primarily of information systems, of complicated multi-levelled movement, of individuals who with their mobile phones and fax machines are self-contained workstations travelling around the world without offices or even homes. Airports are increasingly places where time is as important as money, where business people meet and strike deals, and where buying and eating become the prime leisure activities for weary travellers. Heathrow is a worrying but challenging vision, which architects have to address if their designs for terminals are to have any contemporary relevance in the widest sense.

Modern terminals such as Kansai – claimed to be the biggest building in the world – are so large that they have invalidated the Modern Movement's fixation with the singular architectural object. Size and internal complexity have made the terminal of the future (the design for Heathrow Terminal 5 is a good example) into megastruc-



20.1 Airports are becoming urban assemblies offering architectural quality and civic values. Zurich Airport redevelopment. Architects: Nicholas Grimshaw & Partners.

tures, where activities inside are housed as self-contained villages surrounded by open space. The large international terminal of the twenty-first century looks set to take on the characteristics of traditional urban areas, not just in their functional and human multiplicity, but in the formal language employed. Big modern terminals are arranged in plan with streets and squares, gardens and towers, districts and neighbourhoods. When a building becomes as large and diversified as a small town (Heathrow alone employs 68 000 people) then it is inevitable that the prime buildings take on civic characteristics.

The repertoire of streets, malls, squares, villages and landmarks that characterizes the design of some of the more ambitious airports (such as Charles de Gaulle and Kuala Lumpur) reflect the changing life of airports. When 63 million or more passengers pass through an airport in a single year (in Heathrow's case more than the population of the country it serves), there are ramifications for design. Terminals cannot be conceived as solitary, singular, high-technology enclosures any more; they need to form urban assemblies, with neighbouring buildings such as hotels and car parks playing subsidiary roles in an architectural sense. Internally there is the need to create route legibility and a sense of place in public areas. Psychologically the modern terminal needs to provide stimulation for some and tranquillity for others.

The vast complexity of passenger terminals, with their great intermodal transport connections and electronic communication webs, provides a possible model for life in the twenty-first century. Some argue that the single sublime object, represented for example by Sondica Airport, mirrors the model for the cultural, human and commercial richness of contemporary life. Others contend that a more functional terminal, which is able to accept the messy, noisy, competitive world and still provide a building that is pleasant to use, serves management and passenger needs more effectively. The obvious precedents for the former are the medieval cloth walls of Northern Europe and of the latter, the railway terminals of the nineteenth century. Both functioned as heroic places of financial or transport exchange, but they were also centres for social interchange, for gossip and meeting unrelated to trade or movement. The halls, exchanges and stations were

20.2 Kansai Airport is the personification of tectonic perfection. It is an architecture that defies gravity, just like the aircraft that the terminal serves. The swaying angled lines of the structure and the rhythms of light provide a memorable experience. It is a gateway both to the sky and to Japanese culture. Kansai Airport, Osaka, Japan. Architects: Renzo Piano Building Workshop.

magnificent urban landmarks – some based upon circular or elliptical shapes – with internal malls for trade or refreshment set apart from public gathering spaces. Interior galleries and lofty rooflit halls provided a dramatic and imposing backcloth for both commerce and town life.

The search for place in terminal design

Modern airport terminals are so large that they cannot be readily comprehended. The use of streets, malls and gardens inside the terminal allows the passenger to grasp the sense of direction or location. But formal and spatial geometries are not enough: the volumes created need to be expressed and articulated. Here structure plays a part. Columns, beams, arches and lintels bring the space alive, and allow the traveller to grasp the sense of direction, the speed of movement through the terminal, and the functional hierarchies present. Again Kansai is a good example: the departure lounge with its oversailing curved steel lattices and the flowing textile canopies signals significance beyond that of constructional need. The modern terminal uses structure and construction to communicate meaning and function in the messy, noisy theatre of airport life.

Space and structure together form important components in the design of terminals, but light – especially the white light of sunlight and the dappled play of daylight – provides a further element in the designer's repertoire. The terminal of the future will use light as a tactile material, moulded and shafted to guide passengers and to help define sitting areas or shopping malls. The single feature that distinguishes first-generation from second-generation terminals is the introduction of natural light into the centre of the buildings. As terminals have become larger light has assumed greater importance. Light is now used to draw passengers in the direction of flow from landside to airside, to define in the opposite direction baggage reclaim or exit routes. Light is also used to distinguish public from private routes, noisy from quiet areas, and festive from tranquil spaces. Sunlight is employed to provide sparkle, to animate structure, and to bring alive the exhilarating and lofty volumes of modern airport terminals.

20.3 For the terminal designer light is a tactile material, which can be moulded and manipulated like any other. Light mixed with structure and interior space is the essence of the architectural experience. Hong Kong's airport at Chek Lap Kok. Architects: Foster and Partners.

In conjunction with light, roofs have changed their shape or form. The important role of interior volume in accommodating the functional diversity of modern terminals is complemented by great wavy roofs, which open and fold to bring in daylight. Light, both sunlight and diffused daylight, is used to penetrate to dark cores of the terminal building, allowing interior planted gardens to become the norm and giving justification to the construction of shopping malls and retail villages within the huge megastructures of modern terminals. Taken to its logical conclusion the terminal of the future becomes a great doughnut-shaped building with an enormous atrium above a tree-planted winter garden at the heart of the building. In Nicholas Grimshaw's prototype design for the terminal of the twenty-first century, exhibited at the Venice Biennale in 1991, the vision extended to a naturally ventilated elliptical botanical garden around which passengers circulate left or right. Instead of arrivals and departures being differentiated by moving up or down a level, Grimshaw rotates them around a huge green garden in the centre. The roof is curved and depressed in the middle – not flat as in earlier terminals – with the space between the terminal and garden roof used to promote ventilation and smoke extraction on solar principles.

Modern terminals are increasingly engaging with the twentieth century's fascination with the vertical dimension. Early terminals were single- or double-storey buildings, but today's terminals are four storeys high (Kansai, for example), and future terminals are set to become nearly twice that height (such as Heathrow Terminal 5 and Seoul). Airports have always exploited the vertical dimension – flight itself is its ultimate manifestation – but the passenger terminal has only recently explored height and the spatial dynamics of multilevel. Technical and safety criteria limit the height of terminals, but that has not prevented designers from setting their buildings some way below ground in order to balance the vertical dimension with the horizontal. Superimposed levels expressed as daring bridges, flying escalators and interpenetrating lifts now connect the main floor levels of the modern terminal with secondary galleries. As retail floors are slotted between the

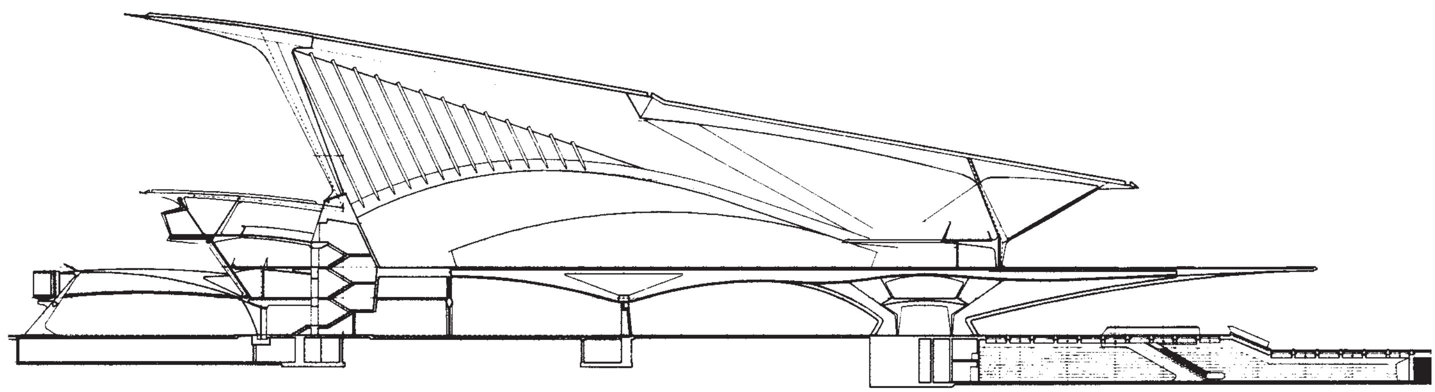
20.4 The search for 'place' in a global world. Haj Terminal, King Abdul Aziz Airport, Jeddah. Architects: Skidmore Owings and Merrill.

20.5 The vertical dimension exploited at Stuttgart Airport, Germany. Architects: Von Gerkan, Marg & Partner.

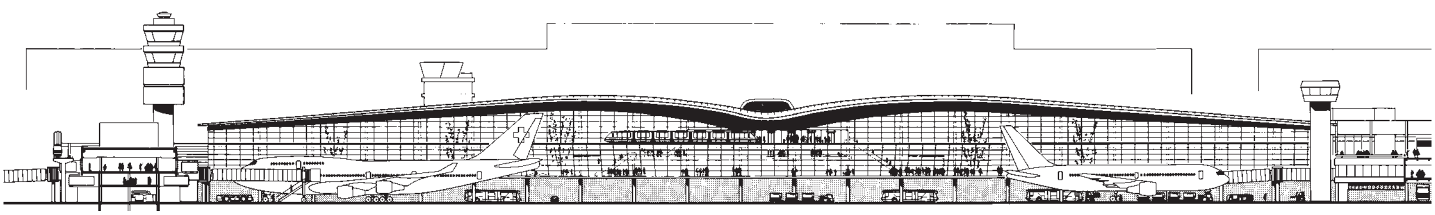
principal departures and arrivals levels (as at Gatwick North Terminal) or form dramatic cliffside galleries overlooking the departure lounge (as at Stuttgart), the more the sense of vertical movement and interpenetrability of upward space is exploited. Multistorey terminals now replace the single- or double-deck terminals of old, adding to the complexity and drama of the modern terminal. This in turn has led architects to approach the design of terminals as exercises in cross-sectional manipulation as much as in plan. The sheer scale of the modern terminal demands the use of the vertical dimension in order to prevent terminals from becoming endless ground-capturing structures.

Culture and meaning through design

The architectural potential of the modern terminal is developing in all directions. The possibilities in space and height are being exploited: the dynamics of the horizontal and vertical plane, and the juxtaposition of the flat and undulating line. The serpentine curve of many recent terminals is a reflection of the sense of adventure and liberation from modernist design orthodoxy. Where once Cartesian two-way grids predominated (as at Bahrain International or Montreal Mirabel),



20.6 Curved expressive lines based upon zoomorphic shapes are replacing the Cartesian boxes of earlier terminals. Sondica Airport, Bilbao, Spain. Architect: Santiago Calatrava.



20.7 Glider wing profile proposed at Zurich Airport, Switzerland. Architects: Nicholas Grimshaw & Partners.

the modern terminal is angular, directional, curved, exuberant and expressive. Rationality is in retreat; the romanticism and expressionism of the very earliest airports are in the ascendancy. Part of this is spurred on by the fear that the modern airport is becoming standardized, with little to distinguish one terminal from another. The serpentine line, the oval, the crescent, the angular and the fan-shaped terminal allow their designers to explore the dialectic between the international and the regional – to balance the tried and tested layouts dictated by IATA design manuals with the distinctive cultural traditions of different parts of the world. The terminal of the twenty-first century will be a building of diversity and cultural richness whereas the terminal of the twentieth century was mainly a building of orthodoxy, repetition and standardization.

Another manifestation of the terminal of the future is the formal distinction made between key parts of the building. Early terminals made little architectural differentiation between the main check-in concourse, the departure lounge and the gate lounge. Neither did earlier terminals distinguish between the terminal and the transportation interchange that served it. However, as intermodal links become more extensive, and as the functional clarity between passengers actually flying and visitors to the airport becomes less clear, the terminal itself has tended to split into three recognizable elements: the transportation centre, the public concourse of the airport, and the gate lounge. The first now contains trains, buses and trams; the second retail malls, cinemas and business facilities; and the third bars and duty-free shops for those actually flying. The more the functions diversify, the greater is the need to accommodate each within its own building or sub-building rather than in a formless, confusing megastructure.

20.8 French liking for the 'grand projects' expressed at Nice Airport. Architect: Paul Andreu.

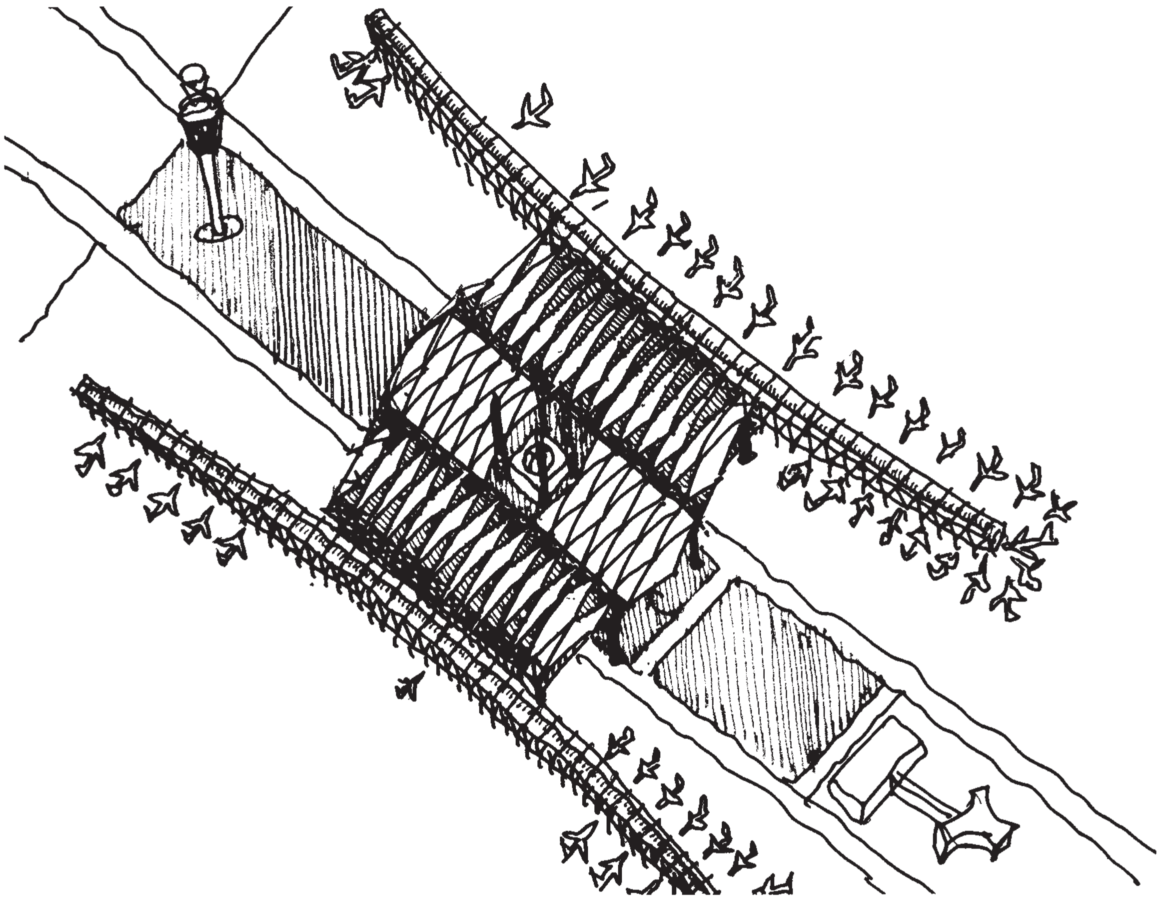
Reconciling technology with ecology

The final expression of the terminal of the future is in the balances struck between nature and technology. The terminal of the twenty-first century will work with ecology not against it: environmental systems and building systems operating largely in tune. This means, for instance, that the terminal will not be entirely sealed against the forces of climate, but will flex and respond to wind, rain and sun. The laws of nature and physics will determine in direct fashion the shape and operation of the building. The undulating roofs and angled walls of many recent airport terminals are a reflection of heightened ecological awareness, not a mere fashion. The folded wavy roof allows the natural air currents to ventilate the building without the use of climate-destroying air-conditioning; it facilitates smoke venting in the event of a fire; and it allows the terminal building to slip through the turbulent air currents of a typhoon. Interior planting too provides important air purification and humidity control. Both interior and exterior tree planting help to filter out sunlight, and provide the necessary tranquillity to overcome stress. The terminal of the future will live, move and breathe like a giant living organism, stretching out tentacles of life and recycled impacts into the wider environment.

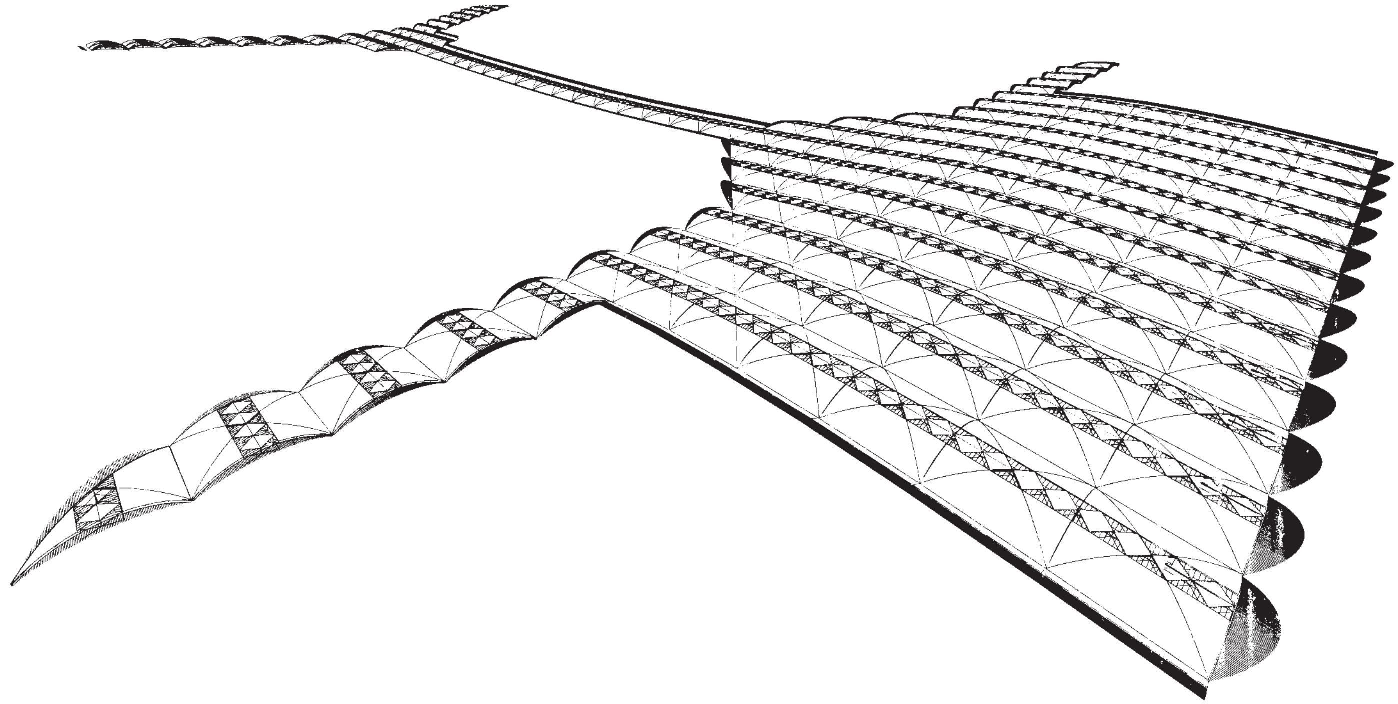
Terminals and tectonic expression

Because airport terminals engage more directly than most other building types in questions of structure and the poetics of construction, they approach tectonic perfection. A tectonic architecture is one of weightless effects, where the 'eurythmy

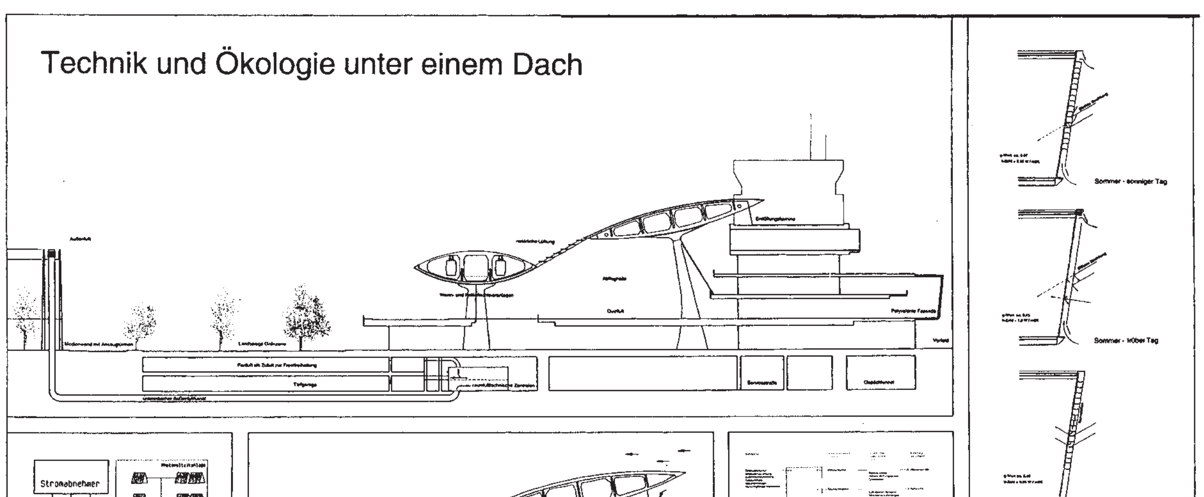
20.9 Spatial separation of the parts gives the terminal greater formal strength. King Abdul Aziz Airport, Jeddah, Saudi Arabia. Architects: Murphy/Jahn.



20.10 The laws of nature and physics are coming together in fresh ways in modern terminals. Bangkok Airport, Thailand. Architects: Murphy/Jahn.

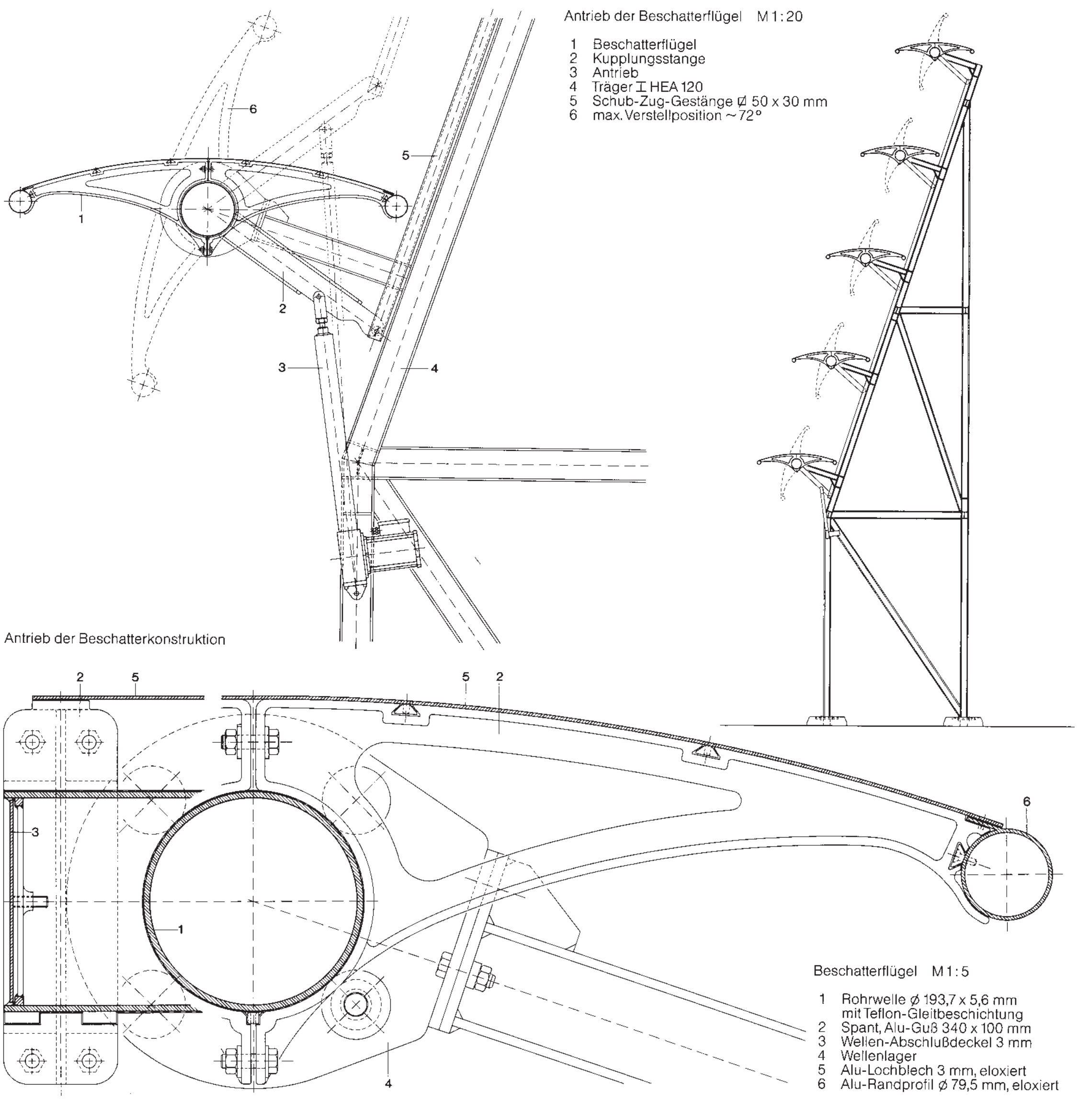


20.11 The roof at Hong Kong's airport at Chek Lap Kok, has a sense of weightlessness that allows it almost to take off. Architects: Foster and Partners.



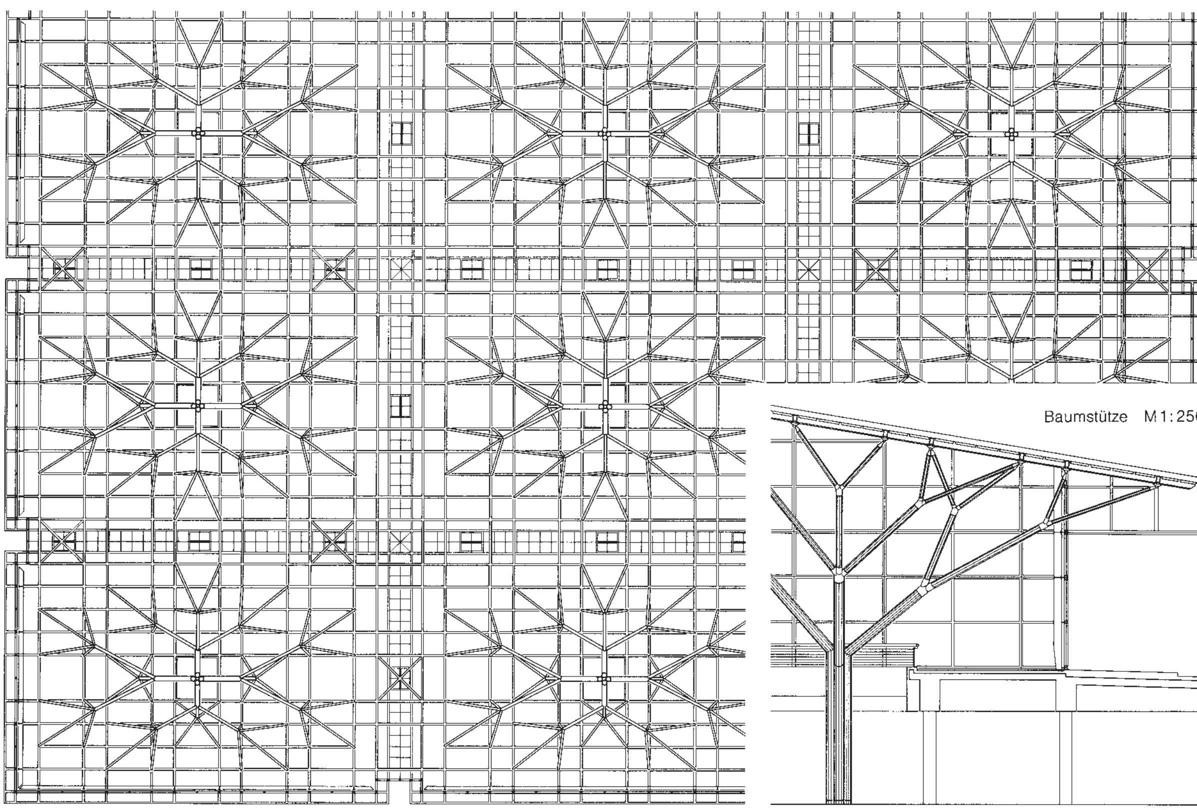
20.12 Wind and solar study at Düsseldorf Airport. Architects: von Gerkan, Marg and Partner.

20.13 Chongping Airport, China, uses technology as a symbol of new cultural expression. Architect: Llewelyn Davies.

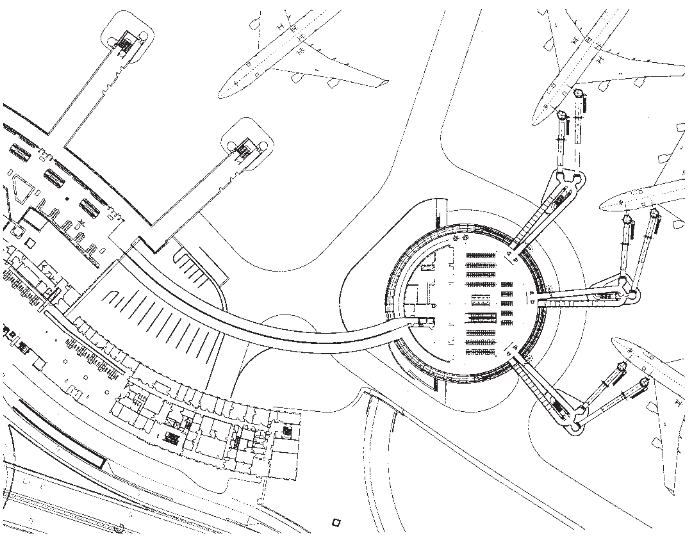


20.14 The articulation of the joints and panels gives the terminal its tectonic interest at a detailed level. These drawings were prepared for Stuttgart Airport by Von Gerkan, Marg & Partner.

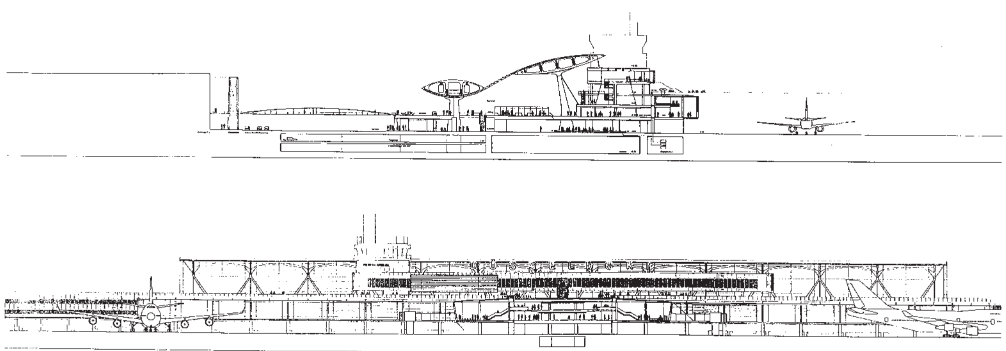
20.15 Stuttgart Airport showing the visual effect of environmental technologies. Architects: Von Gerkan, Marg & Partner.



20.16 Stuttgart Airport, Germany, roof plan and section; the roof engages in tectonic discourse from the ground up. Architects: Von Gerkan, Marg & Partner.



20.17 Elegance in plan. Satellite at Terminal 2 at Charles de Gaulle Airport. Architect: Paul Andreu.



20.18 Elegance in section and elevation at Düsseldorf Airport. Architects: von Gerkan, Marg and Partner.

of its parts and the articulation of its joints'[1] become the main means of expression. The best terminals combine in rare and splendid form the tectonic ideal: it is this symbiosis of spatial and technological expression that helps us to define the airport terminal.

Certain terminals, such as the design of Chongping Airport in China, put greater weight upon tectonic than other forms of expression. Terminal 1 at Charles de Gaulle is muscular in its construction but hardly tectonic. A tectonic architecture is one in which structure and construction aspire to undermine the apparent weight of the building, reducing gravity to an almost floating unearthly state. Joints, lines, ties and slender members replace the heavyweight wall and column; corners are understated or eroded; ceilings float; floors are thin horizontal planes.[2] The tectonic is becoming a quasi-autonomous force stamped upon modern terminals throughout the world. The reason is obvious: terminals are like the aircraft they serve – part of the topographical technology of modern life. For many architects the tectonic is the Gestalt of the age, and the terminal is the perfect vehicle for its expression.

Through technology, terminals are transformed into buildings of beauty and tranquillity. It is evident in the case studies of real and projected terminals that a particular approach to a tectonic architecture is unfolding. There are four identifiable elements in the terminal of the future:

- the search for weightlessness
- the poetic expression of the separate parts in space
- the articulation of the process of movement
- a preference for thinness over thickness.

Integrated with other design dictates, such as space management and ecology, there emerges a formal technological language for the creation of the modern terminal. In this the tectonic plays a greater or lesser part: it can shape the whole architectural concept (as in the design of Terminal 2 at Charles de Gaulle) or merely the expression of elements (as in the roof at Kansai). Many architects see the question of technology and its expression as a spiritual mission; here the airport environment is a perfect testbed for their ideals. Where the constructional process as well as the overall concept is embraced within the tectonic discourse, there emerges an elegance befitting the airport age.

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1. Kenneth Frampton, *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, MIT Press, Cambridge, MA, 1995, p. 20.
2. *Ibid.,* p. 22.

Glossary

aircraft gate position
An aircraft stand close to a terminal and identified by a specific gate.

aircraft movement
An aircraft take-off or landing.

aircraft stand
Area on apron where aircraft is parked for servicing, loading etc.

airport
An area of land (including buildings, runways and control towers) for the arrival or departure of aircraft.

airport roads
Network of public and private roads providing access to airport buildings and areas.

airside
Area under government or airport control providing access to aircraft, and prohibited to non-travelling public.

apron
Paved area on airside where aircraft are parked for loading.

arriving passenger
A passenger arriving at terminal by air.

automated people-mover (travellator)
A transportation system for moving large numbers of people travelling distances too great on foot.

baggage
The personal property of a passenger.

carousel
Rotating baggage-claim device.

channel
Route for passengers through terminal.

CIP lounge
Special airport lounge for commercially important passengers.

closed-circuit television (CCTV)
Television primarily for security surveillance.

concessions
Passenger amenities provided by retail, food services etc.

concourse
Open space or hall in passenger terminal, used for circulation or waiting.

customs area
Part of terminal building under control of customs authorities.

departing passenger
A passenger departing from a terminal by air.

domestic flight
Flight within a single country not involving government controls.

dwell time
Time that a passenger spends in a terminal.

flight information board
Electronic signage board showing flight details.

gate
Point of passenger access to aircraft.

gate lounge
Waiting area adjacent to gate.

government controls
Checkpoints for government, health and immigration control.

hub airport
Airport designed primarily as a transfer facility, normally under the control of a single airline.

international flight
A flight between two or more countries, and subject to government controls.

landside
Area of airport or terminal to which non-travelling public has access.

loading bridge
Adjustable corridor bridging terminal and aircraft door.

meeting point
Defined area for rendezvous, normally in arrival concourse.

pier
A protruding extension to a terminal building giving access to aircraft gate.

satellite
Building surrounded by aircraft gate positions, normally separate from terminal building.

screening
Security checking by personal or electronic means of passengers and airport staff.

sterile area
Area of terminal building to which only security-cleared passengers and staff have access.

terminal building
A building between landside and airside where passenger and baggage processing takes place.

transit lounge
Area set aside for passenger who has arrived by plane but is not terminating at airport.

visitor
Non-passenger and non-employee using terminal building.

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Note: The bibliography refers to principal sources employed: further references can be found at the end of each chapter.

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