# DESIGNING AIRPORT PASSENGER BUILDINGS FOR THE 21st CENTURY

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Synopsis: Experience in North America since its economic deregulation in 1978 indicates that the design of airport passenger buildings is a key to the economic performance and competitive viability of both an airport and its airlines. As the air transport industry becomes increasingly liberalised, future world-class airports will have passenger buildings quite different from those prevailing today. As now, good designs will feature hybrid configurations tailored to meet the different types of traffic at the airport. The better facilities of tomorrow will not, however, be narrowly defined as terminals, but broadly as buildings that also serve as facilities for a large and volatile transfer traffic. They will thus be highly flexible for expansion, and for changes in the percent of transfer passengers and the industrial organisation of the airlines. Most obviously, they will include a range of automated devices for moving passengers rapidly around the landside areas, and be remarkable for the size of the midfield passenger buildings.

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## Introduction

Passenger buildings for the latest generation of designs for world class airports are quite unlike those created before. The major airports planned from the 1980's onward each feature midfield terminals. These are complexes of passenger buildings set away from the landside access to the airport, typically located somewhere in the middle of the airfield between the runways.

The prototype, and possibly best known, example of midfield terminals is at Atlanta/Hartsfield. The main passenger facilities there consist of parallel buildings, each surrounded on all sides by airfield apron and aircraft. These buildings are connected to the landside of the airport by a small underground train, known as a "people mover", similar to those installed at London/Gatwick, London/Stansted and Singapore airports.

The latest designs for major airports all involve midfield passenger terminals. These include the new Denver International Airport to be inaugurated in 1994; the Pittsburgh airport completely renovated around a midfield terminal in the shape of an X; the new Hong Kong/Chek Lap Kok airport under construction; and the proposed new airports at Bangkok, Kuala Lumpur/Sepang, and Seoul. The new facilities at London/Stansted also feature midfield passenger buildings.

[Figure 1: Midfield Terminals at the New Denver International Airport (artist's rendering) -- about here]

Many newly constructed, major airports do not have midfield terminals. However, these facilities were planned many years ago, before the latest developments in airport planning. The terminal at Munich II, for example, is a long linear building with aircraft on one side: this design was established in the early 1970s. The same can be said for the new terminals in Japan at Osaka/Shin Kansai and Tokyo/Haneda. The new passenger buildings at Paris/de Gaulle are likewise extensions of terminals conceived and started in the 1970s.

Does the concept of midfield passenger buildings represent an important, fundamental addition to airport design? Or is it a fad, much like the concept of "gate arrival" terminals that was implemented in the early 1970's at Dallas/Fort Worth, Kansas City and, in 1992 after a generational lag between planning and construction, in Japan at Sapporo/Shin Chitose? Connoisseurs of airport planning will remember that these gate arrival terminals have been a major source of difficulties for their owners, tenants and users. Thus at Dallas/Fort Worth, American Airlines has plans to demolish its buildings and replace them with a midfield terminal, and Delta has already built a midfield addition to its facilities. As regards Kansas City, TWA relocated its operations to St. Louis, essentially deserting Kansas City because its gate arrival buildings precluded efficient hub operations. Will midfield passenger buildings similarly seem to be a mistake in retrospect?

Recent analyses indicate that midfield passenger buildings do represent an important basis for designing airport terminals in the 21st. century.[1,2] This is because air transport is being transformed as airlines and airport operators evolve from slowly changing, governmentally controlled bureaucracies to privatised companies responding rapidly to consumers. The functions of passenger buildings are concurrently changing dramatically. Their airline clientele increasingly recognises the need for flexibility and efficiency, and demands passenger buildings that meet these new needs. As a result, previous concepts of design for airport terminals must be revised.

## Background

**Standard concept of terminals:** To appreciate the necessary changes, we must understand the usual premise of design for airport buildings. The traditional idea, in a word, is that passenger buildings are terminals, that is, that they are simply points of arrival for travelers going to a city or, conversely, gateways for departure. As a recent review of London/Stansted put it:

> "[Sir Norman's] proposal [for Stansted] was based on two key propositions. First, the path from land to air should be clearly delineated..."[3]

This view has important consequences.

This notion that the passenger building is a terminal implies that the loads on the building are independent of its design. If passengers want to see Paris, they are unlikely to let the design of a building influence their travel plans, and the number of passengers to Paris would progress according to the overall growth of the region.

The notion that the passenger building is a terminal also excludes the idea of transfers. It is increasingly the case, however, that passengers use airports as a transfer hubs, as places to change aircraft. Moreover, this type of traffic not only has special requirements, different from those of terminating passengers, but is sensitive to the design of the airport buildings. If the airport buildings are not suitable, the traffic may go elsewhere (as happened at Kansas City).

The notion of a terminal building thus lets designers think in terms of stable loads and requirements. It leads them therefore think that passenger buildings can be designed to architectural standards on the basis of simple rules of thumb for sizing the requisite spaces and services.[4],[5],[6],[7].

The design of airport buildings has thus primarily been construed as a question of form rather than function. Emphasis has been placed on artistic qualities[8],[9],[10],[11] as reflected in another description of London/Stansted:

> "...every airport has to house a mass of low level accommodation, ranging from check-in desks to customs and passport control booths...these are bound to conflict with and clutter the simplicity of the main idea. The architect's response has been to impose a very strong order on the lower structures which is completely independent of the larger order of the building itself"[12]

Architects have thus been encouraged to choose designs from catalogues of configurations[13],[14] as a matter of taste, not of efficiency or performance. Quite routinely, an architect with limited or no prior experience with airports will design a passenger building according to a programme focusing on loads simply described in terms of passengers per year or peak hour.[15] Thus for Sir Norman Foster at London/Stansted, Helmut Jahn at Chicago/O'Hare, and Renzo Piano at Osaka/Shin Kansai.

The notion of a terminal building also lulls airport owners into thinking that the design of the passenger facilities is inconsequential for either the economic performance of the airport or the prosperity of the region. Recent developments demonstrate that this conclusion is quite false.

**Airports may now be transfer points:** The fastest growing and often the largest airports now do not function merely as terminals. They are transfer points, airports at which a large percent, often a majority, of the passengers use the airport to change from one aircraft to another. Table 1 illustrates how this has been happening in the United States. This shows first that most of the largest airports are indeed transfer hubs. Moreover, the traffic at the major transfer airports (bold face) has, since economic deregulation in 1978, grown on average around 200% (that is, tripled), about 3 times as much as at otherwise comparable airports.

[Table 1 about here]

The fraction of airport passengers transiting through the transfer airports is frequently more than half. At some airports as many as 3 out of 4 passengers continue their trip on another flight within one or two hours. This is the case at Atlanta, Chicago/O'Hare, and Dallas/Fort Worth in North America. Elsewhere, high rates of transfers are seen, for example, at Amsterdam, Hong Kong, and the Northwest Airlines operations at Tokyo/Narita.

**New Concept of Airport Passenger Buildings:** The increasing importance of transfer traffic in airport operations redefines the needs of the passengers and the functions that should be provided to serve them.

Passengers do not simply proceed between the airport and the city, they also move between aircraft. Passengers and airlines not only desire rapid movement of the travelers and their baggage, they critically need it because of the high cost of missed connections. (Researchers have estimated that it costs KLM about US$ 125 per suitcase that misses a departure.[16]) Restaurants are not just a convenience, but may be a necessity for passengers connecting between short flights that do not feature meals.

**TABLE 1. TRANSFER AIRPORTS IN THE UNITED STATES HAVE BEEN AMONG THE LARGEST AND FASTEST GROWING, SINCE THE ECONOMIC DEREGULATION IN THE US AIRLINE INDUSTRY IN 1978.**

| **CITY, AIRPORT** | **EMPLANEMENTS, MILLIONS** 1978 | 1992 | **GROWTH %** 1978-1992 | **TRANSFER AIRPORT?** |
|---|---|---|---|---|
| CHICAGO / O'HARE | 20.3 | 28.7 | 41 | YES, BUT |
| **DALLAS/FORT WORTH** | 8.9 | 24.4 | **174** | **YES** |
| LOS ANGELES INTL. | 11.8 | 23.2 | 97 | |
| ATLANTA | 16.4 | 19.7 | 14 | YES, BUT |
| SAN FRANCISCO INT. | 7.5 | 17.2 | 129 | |
| DENVER/STAPLETON | 8.0 | 13.4 | 67 | YES, BUT |
| **PHOENIX** | 2.8 | 10.7 | **282** | **YES** |
| **NEW YORK/NEWARK** | 3.9 | 10.4 | **167** | **YES** |
| **ST. LOUIS** | 4.3 | 10.3 | **140** | **YES** |
| **DETROIT / METRO** | 4.6 | 10.1 | **120** | **YES** |
| **MINNEAPOLIS/ST.P.** | 4.0 | 9.6 | **140** | **YES** |
| NEW YORK/LAGUARDIA | 8.0 | 9.2 | 15 | |
| BOSTON | 5.9 | 9.1 | 54 | |
| MIAMI / INTERNTL | 5.7 | 9.0 | 58 | YES, BUT |
| HONOLULU | 5.5 | 8.7 | 58 | |
| **PITTSBURGH** | 4.4 | 8.6 | **96** | **YES** |
| NEW YORK / JFK | 8.1 | 8.3 | 2 | |
| HOUSTON/INTERCONT. | 4.2 | 8.3 | 98 | YES, BUT |
| **CHARLOTTE** | 1.4 | 8.2 | **486** | **YES** |

Sources: U.S. Federal Aviation Administration[17],[18]

Notes: The "yes, but" airports each had major changes that disrupted their role as transfer airports:

* Chicago/O'Hare lost most of the hubbing operations of American Airlines, transferred to Dallas/Fort Worth;

* Atlanta, Denver, Miami/International and Houston/Intercontinental each lost major hubbing services as Continental went bankrupt (twice) and Eastern disappeared.

The notion that airport buildings are just terminals is obsolete. Instead of thinking of terminals, and being burdened with the limited concept this implies, designers need to think more generally of airport passenger buildings.

**Airports now compete for transfer traffic:** Passengers traveling from their origin to their final destination by way of an intermediate airport may choose their transfer points. The transfer traffic is interested in convenience and ease of transfer. Beyond fares (and discounts through frequent flyer programmes), passengers care more about the smoothness and reliability of the connection than the name of the nearby city. For example, in traveling between Boston and Milan, I can transfer at Amsterdam, Frankfurt, London/Heathrow, New York/Kennedy, Paris/de Gaulle, or Zurich. Since I am normally offered competitive fares on all these routes, as a practical matter I choose to use the airport -- and in fact the passenger buildings -- which provide the smoothest, most reliable connection. My trade, and that of many others, is highly sensitive to the functional design of the passenger buildings.

Airports and their home airlines compete for transfer traffic. Those that cannot provide quick, reliable connections between flights -- for passengers, baggage and aircraft -- will not be competitive and will lose passengers, revenues, and the jobs that go with them. If people choose to fly between Boston and Milan via Zurich, for example, because they can make connections by walking across a corridor rather than by changing buildings and fighting their way through inspection queues at London/Heathrow, London and British Airways have lost their business.

Airport passenger buildings are part of the competition. Well designed facilities will accommodate transfer traffic easily. They will thus enhance the attractiveness of an airport and the competitiveness of its airlines. Thus Washington/Dulles and Raleigh/Durham attracted hub operations from United and American Airlines in no small part because of the way these airports organized their passenger buildings.

**Airport traffic is thus volatile:** The inherently great uncertainty about future loads on the airport passenger buildings has enormously increased, along with the greatly increased competition between airports associated with the development of transfer points. Under the best circumstances airport traffic is virtually unpredictable: the total number of passengers can only be estimated within +/- 50% over a normal 20 year life of a building.[19],[20]

Airport traffic has also become quite volatile with deregulation and competition, as passengers shift their travel patterns according to the ever changing relative competitiveness of the airlines.[21] Table 1 and its notes both illustrate the wide disparities in traffic growth at individual airports, compared to the average of the group, and gives examples of the jumps in traffic as airlines shift their hubs or go through major changes.

The nature and requirements of the airline clientele can also change substantially, as airlines vary types and number of services offered at individual airports. At New York/Laguardia over the last 15 years for example, the new passenger building now occupied by US Air was successively controlled by Eastern and Trump Airlines, and planned for shuttle and regular services, as these and other competing airlines (including Pan American, New York Air, Peoples Express, Delta and American Airlines) started various types of operations, merged and went bankrupt.

**Failure of traditional design:** In this context, many airport buildings originally hailed as architectural successes now appear to be operational failures.[22] Because the design of the passenger buildings affects the attractiveness of an airport for transfer traffic, buildings that could not adapt to serve this traffic have caused significant hardship for their owners and users. Economic deregulation lets airlines compete aggressively and, as they do so, avoid airports with dysfunctional passenger buildings.

Many airports have lost significant traffic or market share, because their passenger buildings have hindered transfer traffic and made the airport uncompetitive. Kansas City is a prime example of this phenomenon. Once the world headquarters for Trans World Airlines, it lost a third of its traffic when TWA moved its hub to St. Louis on the grounds that the three distinct linear terminals at Kansas City made it extremely difficult for passengers to connect between flights. Similarly, both New York/Kennedy and Copenhagen lost traffic when SAS moved its transfer point for transatlantic passengers to a compact new building at New York/Newark.

These effects of competition are increasingly apparent worldwide as the airlines become freer to compete with each other. This is happening through the increased liberalisation of the rights of airlines to operate in foreign countries; the privatisation and greater commercial policy of formerly national airlines (such as British Airways, Lufthansa, etc.); and the establishment of ever larger areas of free trade (such as the European Common Market and the North American Free Trade Area).

The instability of traffic and effects of unsuitable design of airport buildings have been most evident in North America, where the airline industry has been deregulated the longest. It is thus to this area that we must look for indications of what could happen elsewhere.

**Lessons from North America**

**Prevalence of transfer airports:** The airlines' ability to route traffic in various ways between its starting point and destination, and to set prices freely, leads them inevitably to establish transfer operations at convenient airports. This is a key lesson for the owners and designers of airport passenger buildings.

Airlines establish transfer hubs because these facilities reduce costs and, odd though this may seem, increase passenger convenience through increased frequency of service between city-pairs. All else being equal,[23] the combination of lower costs and delays gives an airline an unbeatable advantage, compared to airlines that do not establish transfer hubs.

By bundling traffic bound for different destinations onto a common route through a transfer point, airlines reduce costs in two significant ways. They can obviously use relatively larger aircraft than would be sensible on a route with fewer passengers, and thus achieve economies of scale. More subtly, by using a central hub the airlines can reduce the number of extra aircraft and crews they have to maintain. These two advantages more than offset the cost of indirect routing of passengers through transfer airports.

By routing traffic through transfer airports, the airlines are able to offer more frequent service between cities that would otherwise only have infrequent connections. More frequent service gives passengers both more convenient and -- because of the possibility of backup flights -- more reliable travel. Also, more frequent flights reduce the time a traveler may have to wait for the next flight. On the whole, these factors outweigh the extra travel time associated with passing through well organized transfer airports.

These advantages have impelled airlines in North America to establish transfer hubs all across the continent. Each airline serving the transcontinental market, for example, has its own hub for this service: Dallas/Fort Worth (American); Houston/Intercontinental (Continental); Atlanta or Salt Lake City (Delta); Minneapolis/St.Paul (Northwest);St.Louis (TWA); Chicago/O'Hare (United); and US Air (Pittsburgh).

The airlines selected these mid continental airports as transfer hubs because they offer relatively easy, convenient transfer service. Airlines specifically evaluated various options, and decided to focus their operations -- and the passengers, and the jobs -- at those airports.

Airport managers now recognise the real possibility of attracting airline business by offering transfer services. Trade publications routinely report news such as:

> [Stockholm/Arlanda is] "starting to market itself as a hub and ... is targeting Far East airlines and Aeroflot to use the airport as a northern European hub."[24]
>
> [Manchester's] "aim is to have 10% transfer passengers within three-four years, compared with 2-3% of our scheduled passengers now....We have seen what happens in the U.S., and our view is that you are either a hub or your become a second-rate airport."[25]

Airports interested in these kinds of opportunities need to make sure that their passenger buildings facilitate transfer traffic.

**Midfield passenger buildings as a Consequence:** To facilitate connections between flights, both travelers and aircraft must be able to move easily. Airport passenger buildings should simultaneously minimise the distance passengers have to travel between aircraft, and provide easy access for the many aircraft making connections.

The obvious way to minimise the distance between connections is to place aircraft all around the passenger building rather than just on one side.  Roughly speaking, a passenger building serving aircraft on all four sides will be half the length, half the distance between gates, of an equivalent traditional linear building, such as those recently opened at Manchester and Munich II,  with aircraft only on one side.

To facilitate access by aircraft, any passenger building should be placed relatively far from other buildings, so that aircraft can arrive and depart without having to wait for each other, as they typically have to do around terminals with closely spaced finger piers, as at New York/Laguardia for example.  Access is better when passenger buildings are centrally located between the runways, so as to minimize the delays (and great costs) of lengthy trips along taxiways. Access is best when aircraft can turn straight into their gate positions off of high-speed taxiways, as they can when the passenger buildings are parallel, as at Atlanta and New Denver.

[Figure 2: Plan of New Denver International Airport, first phase development -- around here]

The economic need to insure that an airport can provide easy connections, coupled with the consequent need to minimize delays to passengers and aircraft, thus lead to the design of midfield passenger buildings.  These are now being planned both for all the major new airports (Denver,  Hong Kong/Chek Lap Kok, Kuala Lumpur/Sepang, new Seoul as mentioned before), and at existing airports to replace traditional terminal buildings.  Thus United Airlines replaced its finger pier terminal at Chicago/O'Hare with a midfield building. American Airlines proposes to tear down its linear terminal buildings at Dallas/Fort Worth, and replace them with a big rectangular midfield passenger building. The plan for Washington/Dulles is to centre future activities around renovated and extended midfield facilities.

**Designing for the 21st. Century**

**Maintaining flexibility:** As experienced airport planners know, "the forecast is always wrong". Inevitably, the number and type of passengers turn out differently than anticipated. This is because of new aircraft technology and airline routes, the relative progress of national economies, changes in tastes, not to mention wars, oil crises and the like.[19]

Designers of airport passenger buildings should thus plan for flexible development of the facilities. They should both leave room for expansion, and allow for major shifts in patterns of the traffic. A clear lesson from the North American experience is that the percent of transfer passengers may fluctuate enormously, because airlines either decide to coordinate their activities and establish a new hub (as SAS and Continental Airlines did at New York/Newark), or to relocate their transfer activities (as American Airlines recently did at Columbus).

Frankfurt's unfortunate experience with its new Terminal 2 vividly illustrates the need for flexibility. As a news item about the construction of this project put it:

> "...already [during construction] the facility's dedicated use as an international terminal is in jeopardy ... there is now the possibility that it may handle domestic/EC [European Community] traffic ...

> Lufthansa did not want to separate its domestic and international traffic .. [it is] determined to maintain and build on Frankfurt's hub status ..." [26]

In short, because Frankfurt failed to anticipate changes, it is having to rework its original design substantially, at great expense -- even before opening the new facility!

The need for flexibility in design is of course reinforced by the possibility that aircraft manufacturers will produce a new generation of super jumbo aircraft, with 90m. wing spans, and able to carry about 800 passengers.

Airport planners need to design strategically. They need to build in the flexibility both to respond effectively to new opportunities, and to reduce the size of their operations if anticipated traffic fails to materialize.[27] Since the development of transfer traffic is a major possibility, airport planners should specifically allow for this type of traffic.

The new International Passenger Building at Brisbane is a good example of flexible, strategic planning. The planners recognised the enormous uncertainly in the nature of their future traffic: the Australian international airline, Qantas, has acquired the domestic airline, Australian, and might eventually need to conduct hub operations; so might Air New Zealand, Ansett and Singapore Airlines. The planners have consequently designed a building that can respond, through expansion and the shift of internal walls, to a wide range of future types and levels of traffic.

**Hybrid Designs:** As experienced airport designers also know, different types of buildings are best for different types of traffic. No single simple configuration of airport passenger buildings is best for all circumstances.[28]

In general, "gate arrival" buildings are best for "commuter" traffic consisting of short business or pleasure trips between major cities. These passengers need to get to their aircraft as soon as possible, do not make connections, have little need for services and typically carry their bags on board. A simple narrow shelter between the road and the aircraft suffices for this traffic. The Shuttle terminal operated by Delta Airlines at New York/Laguardia is a good example of this design.

The use of "transporters", that is of apron passenger vehicles that ferry passengers between passenger buildings and their aircraft, is an economical way to serve traffic that fluctuates widely between seasons. In contrast to built facilities, transporters are relatively inexpensive and can furthermore be parked -- and their costs minimised -- in the off season. "Transporters" have thus been a standard element at large airports at which the traffic varies substantially between the high and the low seasons, as at Zurich and London/Gatwick for example.

Since the traffic at major airports usually consists of a variety of flows, the most effective designs for airport passenger buildings similarly feature a mix of functional elements. The best designs blend "gate arrival" facilities for commuter or shuttle traffic, "transporters" to handle seasonal peaks of traffic, and midfield buildings to facilitate transfer traffic. The complex of Air France terminals at Paris/de Gaulle, that combine transporters, gate arrival and finger piers, illustrates the principle. In short, the best configuration for an airport passenger building is a hybrid design.

**Accommodating transfer traffic:** Midfield passenger terminals appear to be the most effective way of catering to transfer traffic. They provide the maximum of convenience to both the passengers and their aircraft. They simultaneously minimise the distance passengers have to move between aircraft, by clustering aircraft around all sides of a building; and minimise aircraft delays, by eliminating the dead-end aircraft aprons that force aircraft to wait while others enter or exit the area.

Midfield passenger buildings must, of course, connect with ground transport. This requirement has impelled the design and construction of a wide range of people movers, automated devices for moving passengers rapidly around the landside areas. This concept, pioneered at Tampa in 1971, has been widely implemented for midfield passenger buildings, first at Seattle/Tacoma and then at Atlanta, Dallas/Fort Worth, Houston/Intercontinental, Pittsburgh, London/Gatwick and London/Stansted. It is now being implemented at the New Denver International and is planned for Hong Kong/Chek Lap Kok, the New Seoul and the New Kuala Lumpur/Sepang.

People movers to midfield passenger buildings are generally best placed underground. This configuration avoids dead-end aircraft aprons, which force aircraft both to taxi on roundabout paths and to wait for each other as they enter and exit these cul-de-sacs. The new Japan Air Lines terminal at Tokyo/Narita illustrates these difficulties with above ground people movers. Underground people movers are thus a standard feature of midfield passenger buildings, as at the new facilities at Pittsburgh and London/Stansted.

**Size of midfield passenger buildings:** Midfield passenger buildings will normally be remarkably large. As a rule of thumb, they will appear to be about twice as large as normal for any given level of annual traffic.

Midfield passenger buildings appear large because they must simultaneously handle the peaks of both arriving and departing passengers. They must in particular allow for the concurrent parking of a peak number of aircraft, arriving nearly simultaneously in 'banks' of flights scheduled to minimise transfer times. This requirement means that midfield passenger buildings must have considerable airside frontage.

The inside of midfield passenger buildings can be relatively small, however. Passengers connecting rapidly between flights do not need to check bags or get tickets. Nor do they need much lounge space. With the 45 to 60 minutes scheduled for transfers at US airports, for example, a typical passenger might only have 15 minutes or so to sit down. Passengers spend most of their time moving between flights and in the queues for getting on and off the aircraft. Midfield passenger buildings can thus be quite narrow, on the order of 30 or 40 meters, as compared to the 100 to 150 meter depth common for standard airport terminals.

Most obviously to the observer, midfield passenger buildings may appear to dominate the landside area. When midfield facilities are an integral part of the airport design, the terminal element connecting the local passengers with the city can be quite small. Most of the travelers to and from the city will actually use flights served by midfield buildings. The landside building that connects with ground transport, the terminal building properly speaking, will mostly contain connections to transport, baggage claim areas, ticketing and office facilities. It may also serve special kinds of flights, such as shuttle or international services. As airports become larger and mass transport becomes a more necessary part of airport access, the landside terminal building can be expected to be centralised around a mass transport or rail station.

The airport passenger buildings at Atlanta, New Denver International, Hong Kong/Chek Lap Kok and London/Stansted each illustrate these features: the midfield passenger buildings are two to three times the size of the landside passenger terminals next to the rail stations or parking garages. The functional characteristics of these airport passenger buildings may be considered models for future designs.

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