The Evolution of Airport Design: Philosophy, Function and Form

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The Evolution of Airport Design

Philosophy, Function and Form

Robert Stewart PhD 2020

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Philosophy, Function and Form

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Cover - The de Havilland DH 91 Albatross Fortuna in front of the control tower at Croydon Airport in 1939 – Source: Aeroplane Monthly Nov 1984 (Colin Ambrose).

Abstract

The Evolution of Airport Design - Philosophy, Function and Form

The aim of this research is to understand the line of development of airport design and consider whether airport architecture is inherently transient and doomed to obsolescence.

Little has been written about the multidisciplinary nature of airport design and why, when, where and how new airport concepts have evolved so this is the contribution of this thesis. Airport design is different from other forms of architecture and engineering by virtue of the sheer scale of the development which is more akin to city planning. Because it is on a city scale it requires the input of many disciplines with different philosophies.

This thesis analyses the role of architectural philosophies such as Futurism in capturing the spirit of flight and facilitating growth and change, the engineering approach to safety and operational robustness, the planning focus on connectivity and the environmentalist's concern with sustainability.

The primary influences on the evolution of airport design, such as airline growth, aircraft characteristics, safety and security and commercial viability are considered, together with how technological advances in communication, mechanisation, automation and digitisation have helped airports avoid obsolescence.

The evolution of design response has been looked at through several lenses: the architect concerned with the layout and form of the terminal, the engineer focusing on the design of the airfield, the planner developing the airport as an interchange, and the environmentalist making airport development sustainable.

There are case studies to show which concepts have been flexible enough to accommodate growth and change. It concludes that the evolution of airport design can best be categorised in a series of stages each of some two decades.

Pioneering Era	1920 to 1940
Evolutionary Phase	1940 to 1960
Jet Age	1960 to 1980
Transfer Interchange	1980 to 2000
Mega Hub	2000 to 2020

This research considers which airports have been adaptable, survived best and avoided obsolescence. The thesis concludes that airport master plan and terminal concepts have largely evolved in response to increasing traffic volumes, and that those that have proved most durable and avoided obsolescence are those that have planned for growth and change from the outset.

Declaration

I declare that all the material in this thesis is my own work.

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Finally, thanks to my wife, Olwen Edwards, for putting up with my obsession with this research over four years and then meticulously proof reading the draft of the thesis.

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6.194	*'Flight', Mural by James Brooks, La Guardia–*	*Murals of New York City: The Best of New York's Public Paintings from Bemelmans to Parrish*	*1939*	W
6.195	*Santos Dumont Plan, Rio de Janeiro*	*World Airports*	*1939*	B
6.196	*Santos Dumont, Rio de Janeiro, Aerial Photograph*	*Pinterest*	*c1955*	W
6.197	*Gatwick central pier*	*British Caledonian*	*1958*	A_1
6.198	*Gatwick South Elevation*	*YRM*	*1958*	A_3
6.199	*Gatwick Apron*	*Gatwick Airport Consultative Committee*	*1958*	A_2
6.200	*Gatwick, External View*	*British Caledonian*	*1958*	A_1
6.201	*Gatwick Check-In Concourse*	*RIBA Library*	*1958*	L
6.202	*Paris, Orly*	*LeZebre*	*1961*	W
6.203	*New York, Idlewild (JFK), International Arrivals Building*	*Jon Procter*	*1958*	W
6.204	*New York, JFK – National Airlines Terminal,*	*Photo by Gill Armitage, Amiaga*	*1969*	W
6.205	*Berlin Brandenburg*	*Seele.com*	*2020*	W
6.206	*Frankfurt Terminal 3 Visualisation*	*frankfurt-airport.com*	*c2025*	A_2
6.207	*Amsterdam, Schiphol Competition Winner KAAN Architecten*	*static.dezeen.com*	*c2023*	J
6.208	*Marseilles, Norman Foster Competition Winner*	*Source Foster + Partners*	*c2023*	A_3
6.209	*Stansted*	*weirdnews*	*1991*	W
6.210	*Hamburg*	*Panoramio com*	*1993*	W
6.211	*Kansai*	*Wikimedia - https://ja.wikipedia.org/wiki/user:663highland*	*1994*	W
6.212	*Hong Kong*	*Source: Foster + Partners*	*1998*	A_3
6.213	*Madrid T4*	*Airports of the World*	*2006*	B

Figure	Description	Source	Date	Type
6.214	*Madrid T4*	*RSHP*	*2006*	A_3
6.215	*Heathrow T5*	*BAA*	*2008*	A_2
6.216	*Beijing Capital*	*Arup*	*2008*	A_3
6.217	*Grand Central, California*	*Airfields-freeman.com*	*1928*	W
6.218	*Figure - Denver with Rocky Mountains in the background*	*Architonic.com*	*1995*	W
6.219	*Soekarna Hatta, Jakarta*	*Tripadvisor*	*1985*	W
6.220	*Siem Reap, Cambodia*	*Anton Ivanov/shutterstock*	*2006*	W
6.221	*TWA Terminal, JFK, New York*	*Conde Nast Traveler*	*1962*	W
6.222	*Washington Dulles*	*flydulles.com*	*1962*	W
6.223	*Lyon Satolas Airport (Gare de Lyon Saint-Exupéry), TGV train Station*	*Matt Feldman, inthedistance.net*	*1994*	W
6.224	*Calatrava's Sketches for Lyon Satolas Airport station*	*slidesharecdn.com*	*1994*	W
6.225	*Sondica, Bilbao*	*EpidemicFun.com*	*2000*	W
6.226	*Seoul Incheon, Interchange*	*Farrell's, & Pinterest*	*2001*	A_3 + W
6.227	*Mexico City, Winning Competition Design*	*Archinect & fr-ee.org*	-	W
6.228	*Beijing Daxing, Visualisation and Interior*	*Business Traveller & china-underground.com*	*2019*	W
6.229	*Shenzhen Boan*	*Skyscraper City & Shenzhen-Bao'an International Airport*	*2013*	W
6.230	*'Aerodrome', Hangar and Workshops for Airships and Airplanes*	*Building for Air Travel*	*1930*	B
6.231	*Comparison of Le Bourget and Farman Goliath plans*	*Art Deco Airports*	*1937+ 1919*	B
6.232	*Farman Goliath Aircraft – Source:*	*vehiclepad.com*	*1919*	W
6.233	*Ramsgate*	*Aviation Postcard Club*	*1935*	P
6.234	*Panama City, Tocumen*	*Foster & Partners*	*2019*	A_3
6.235	*Leipzig – Halle*	*Postales Inventadas*	*1929*	P
6.236	*Berlin Tempelhof*	*Arkhitecton*	*1939*	W
6.237	*Birmingham Elmdon*	*Pinterest*	*1938*	W
6.238	*Pan American, JFK*	*Life*	*1962*	M
6.239	*St Louis Lambert*	*Landmarks Association of St. Louis*	*1956*	W
6.240	*TWA Terminal, JFK – Source*	*Ezra Stoller photographer*	*1962*	B
6.241	*Washington Dulles Model*	*The Atlantic.com*	*1958*	W
6.242	*Los Angeles, Theme Restaurant*	*VCA Engineers.com*	*1962*	A_3
6.243	*Stansted*	*Foster + Partners – Photo: Ken Kirkwood*	*1991*	A_3
6.244	*King Abdulaziz, Jeddah*	*SOM*	*1981*	A_3
6.245	*Hamburg*	*GMP Architekten*	*1993*	A_3
7.01	*An aerial view of Camp Leaside's facilities, near Toronto, Ontario, taken from a Curtiss JN-4 "Canuck"*	*Royal Canadian Air Force*	*1918*	W
7.02	*Plans for Many landing Fields*	*Aircraft Journal No 4*	*1919*	J
7.03	*Windsock*	*Municipal Landing Fields and Air Ports*	*1920*	B

Figure	Description	Source	Date	Type
7.04	*How to layout and build an Airplane landing Field*	*National Advisory Committee for Aeronautics, Technical Memorandum 164*	*1922*	B
7.05	*An AAA Airport, U.S. Department of Commerce*	*The American City 37 (November 1927, p642)*	*1927*	J
7.06	*Oakland, California*	*Board of Port Commissioners, Port of Oakland, California*	*1930*	A_2
7.07	*Pontiac Municipal Airport, (officially Oakland County International Airport)*	*emotionreports.com*	*1930*	W
7.08	*Boston Logan (originally Boston Commonwealth)*	*Flickr – photographer US Army Air Service*	*1923*	W
7.09	*The Army's RS-1 blimp, Ford Airport*	*Abandoned and little known airfields*	*1926*	W
7.10	*Ford Airport airfield with concrete runways*	*Abandoned and little known airfields*	*1931*	W
7.11	*Ford Airport - MI Airport Directory*	*http://www.airfields-freeman.com*	*1946*	W
7.12	*Nansen, Odd & Squire, Latham C., Third Prize, Lehigh Airports Competition*	*American Airport Designs*	*1930*	B
7.13	*Chicago Municipal Development Plan*	*Chicago Midway*	*1941*	A_2
7.14	*Chicago Municipal, Aerial photograph during construction and prior to rail line diversion*	*Chicago Tribune*	*c1940*	N
7.15	*American Airport masterplans*	*Airports: Their Location, Administration and Legal Basis*	*1930*	B
7.16	*European Airport Master Plans*	*Aviation and the Aerodrome, H. Angley Lewis-Dale*	*1932*	B
7.17	*Stockholm Bromma*	*Wikipedia*	*1936*	W
7.18	*Berlin Tempelhof*	*Bezirksamt Tempelhof, 1998 p.81*	*1939*	W
7.19	*New Orleans – Sushan, New York - La Guardia and Washington DC - National*	*Airports, Some Elements of Design and Future Development, John Walter Wood*	*1940*	B
7.20	*Comparative American Airport Master Plans*	*Airports, Some Elements of Design and Future Development*	*1940*	B
7.21	*Comparative European Airport Master Plans*	*Airports, Some Elements of design and Future Development*	*1940*	B
7.22	*London, Isle of Grain*	*Flight*	*1943*	J
7.23	*London Heathrow Wartime Master*	*House of Commons Briefing Paper 1136, 12th June 2017*	*1944*	L
7.24	*Post WW2 Airport Master Plans*	*Airport Planning, Charles Froesch & Walter Prokosch, British Airways (LHR)*	*1946*	B & A_1
7.25	*Gatwick, Continental Master Plan, Norman and Dawbarn*	*Flight 25th November 1943, p 578 - 580*	*1943*	J
7.26	*Airport Master Plans*	*Famous Airports of the World, John Stroud*	*1954 – 56*	B
7.27	*Airport Runway Lengths in descending order*	*Famous Airports of the World, John Stroud*	*1954-56*	B
7.28	*Airport Master Plans*	*The World's Airports, John Stroud*	*1973*	B
7.29	*Airport Master Plans 1*	*The Airport Passenger Terminal, Walter Hart*	*1980*	B

Figure	Description	Source	Date	Type
7.30	*Airport Master Plans 2 – Source*	*The Airport Passenger Terminal, Walter Hart*	*1980*	B
7.31	*Dallas - Fort Worth Master Plan*	*Architectural Design*	*1973*	J
7.32	*Dallas - Fort Worth Aerial View*	*USDA Farm Service Agency*	*c2015*	W
7.33	*London, Maplin Artists Impression of proposals for a 3rd London Airport*	*airporthistory.org*	*c1973*	W
7.34	*Paris Charles de Gaulle, Section*	*Architectural Design*	*1974*	J
7.35	*Paris Charles de Gaulle*	*Architectural Design &* *Google Earth*	*1974* *C2015*	J & W
7.36	*Airport Runway Lengths in descending order*	*Airports of the World, John Stroud*	*1980*	B
7.37	*Atlanta Hartsfield Master Plan Evolution*	*Airports of the World, John Stroud*	*1980*	B
7.38	*Atlanta Hartsfield terminal layout,*	*Sunshine Skies*	*1970s*	W
7.39	*Atlanta Hartsfield aerial view*	*Google Earth*	*c2010*	W
7.40	*Atlanta Hartsfield, End-Around Taxiway GOMACO World 36.1 - January 2008*	gomaco.com	*2008*	W
7.41	*Dallas Fort Worth, End–Around Taxiways (in orange)*	*DFW Vision for the Future 2030* *www.dfwairport.co*	*2018*	W
7.42	*Hong Kong International Airport, Two Runway Master Plan 2015*	*HKIA Master Plan 2030*	*2015*	A_2
7.43	*Hong Kong International Airport, Three Runway Master Plan 2030*	*HKIA Information Pack 20.06.2014*	*2014*	A_2
7.44	*Singapore Changi Terminal 5 2036 Concept Plan*	*Ministry of Transport, Singapore*	*2019*	A_2
7.45	*Kuala Lumpur International Aerotropolis*	*klia.com.my*	*2018*	A_2
7.46	*Heathrow Expansion Programme*	*LHR Planning Process & Environmental Assessment 07.03.2017*	*2017*	A_2
7.47	*Heathrow 3rd Runway Image*	*Heathrow Airport Ltd*	*c2018*	A_2
7.48	*Istanbul Grand Master Plan*	*http://igairport.com*	*2019*	A_2
7.49	*New Airport for London, Isle of Grain*	*Atkins*	*2013*	A_3
7.50	*Dubai World Central Model*	*Emirates Magazine*	*2019*	A_1
7.51	*Dubai World Central Master Plan*	*Dubai Airports*	*2019*	A_2
7.52	*Runway layouts of the top 30 busiest airports in the USA*	*NOMO Design, runway series*	*c2015*	P
7.53	*Runway layouts of the Top 30 busiest airports in Europe*	*NOMO Design, runway series*	*C2015*	P

7.54	*Top Fifty Busiest International Airports*	*mapsoftheworld.com*	*2016*	W
7.55	*Top Twenty Busiest Airports Master Plans*	*Atkins Ltd*	*2016*	A_3
7.56	*Future Airport Master Plans*	*Atkins Ltd*	*2016*	A_3
8.01	*ILA Exhibition Poster*	*Smithsonian Institute*	*1909*	L
8.02	*Parseval Airship at ILA Exhibition*	*ILA Official Postcards – German Postal History*	*1909*	P
8.03	*Official postcard ILA (Internationale Luftschiffahrt Austellung)*	*German postal History*	*1909*	P
8.04	*ILA Air Race Poster*	thefirstairraces.net/meetings/fr0910/events.php	*1909*	P
8.05	*City of Canberra, Master Plan showing the location of the proposed airport*	*National Archives of Australia*	*1912*	L
8.06	*Futurist Interchange Sant'Elia*	*Author's collection*	*1912*	C
8.07	*Ville Contemporaine – Le Corbusier*	*Author's collection*	*1922*	C
8.08	*Lehigh Airport Competition Honourable Mention Design*	*American Airport Designs*	*1930*	B
8.09	*Rush City entry from Richard Neutra to the Lehigh Airport competition*	*: Architectural Record August 1930*	*1930*	J
8.10	*Metropolis, Science Fiction Film, Fritz Lang*	*The-Philosophy.com*	*1927*	W
8.11	*Proposed Landing Platform over Pennsylvania Station, New York*	*Popular Mechanics*	*1929*	M
8.12	*Proposed Landing Platform, London, Westminster*	*: Popular Mechanics*	*c1930*	M
8.13	*Aeroparis, André Lurçat:*	*André Lurçat: CNAM SIAF ADAGP*	*1931*	L
8.14	*Aeroparis, André Lurçat*	*100 Years of Architectural Drawing*	*c1932*	B
8.15	*New York, Manhattan, Rotary Airport, Norman Bel Geddes*	*Harry Ransom Center, The University of Texas at Austin*	*1932*	L
8.16	*New York, Manhattan, Rotary Airport*	*Tumblr*	*1932*	W
8.17	*Berlin Tempelhof*	*wordpress.com*	*1928*	W
8.18	*Frankfurt Rhein-Main site plan*	*: Die Deutschel Luftfart*	*1938*	B
8.19	*Frankfurt Rein Main, opening day*	*Fraport AG*	*1936*	A_2
8.20	*Postcard of Frankfurt Airport with the autobahn in the foreground, airship hangar in the background and photomontage of the Zeppelin LZ 27*	*motorbloeckchen.com*	*c1936*	P
8.21	*Frankfurt Interchange*	*antik-falkensee.de*	*1936*	P
8.22	*Frankfurt Rhein-Main site plan – Interchange top right*	*Fraport AG*	*2018*	A_2

Figure	Description	Source	Date	Type
8.23	*La Guardia, New York showing the integrated planning concept with interchange between road, airplanes, large seaplanes, light seaplanes and yachts*	*Macaulay Honors College*	*1939*	L
8.24	*New York, La Guardia showing the two level forecourt segregating arriving and departing traffic. Departures vehicles set down at the upper level and arrivals vehicles picked up at the lower level*	*Bettmann Archive*	*1939*	L
8.25	*Aerial view of La Guardia with forecourt and Grand Central parkway in the foreground*	*Courtesy American Airlines, from the e-book "The Golden Days of Airline Travel" published by higgebooks.com*	*1939*	A_1
8.26	*Washington Dulles Airport Access Road (DAAR)*	*FAA Handbook of Information, Dulles International Airport*	*1962*	C
8.27	*Washington Dulles Airport, Landside Zone and Forecourt*	*FAA Handbook of Information, Dulles International Airport*	*1962*	C
8.28	*Washington Dulles showing two level forecourt and pedestrian underpass in section*	*Saarinen*	*1962*	A_3
8.29	*Washington Dulles model of terminal & forecourts seen from the car park*	*Balthazar – Korba Architectural Models*	*c1960*	W
8.30	*Konigsberg Airport Tram Service, in foreground on the left and in the background on the right*	*Pinterest*	*1931*	W
8.31	*Konigsberg Tram Network showing extension to the Airport*	*Pinterest*	*1935*	W
8.32	*Frankfurt, Rebstock Site Plan*	*Die Deutschel Luftfart*	*1924*	B
8.33	*Frankfurt, Rebstock Terminal*	*Die Deutschel Luftfart*	*1924*	B
8.34	*Flughafen the underground station serving Berlin Tempelhof*	*A multifaceted monument, the complex heritage of Tempelhof Central Airport*	*1928*	T
8.35	*Section though 40-metre overhang of the canopy by A. Schleusner showing the roof canopy over the passenger boarding area and spectator terrace*	*Hecker 2000, p. 96*	*1939*	B
8.36	*Section through terminal with rail track highlighted in yellow*	*Die Deutsche Luftfarht, Geschichte der Deutschen Verkehrsflughafen*	*1939*	B
8.37	*Germania Master Plan Architect: Albert Speer*	*Landesarchiv, Berlin*	*1937*	L
8.38	*Volkshalle/Große Halle, Berlin Model 1937 - Architect: Albert Speer*	*Britlink*	*1937*	W
8.39	*Tempelhof Airport New Terminal model showing original concept for a circus at the entrance Architect: Ernst Sagebiel*	*Alibaba.com*	*1937*	W
8.40	*Aerial view of Gatwick, with the railway and station in the foreground*	*YRM Library (reproduced with permission from RMJM)*	*1936*	A_3
8.41	*Gatwick terminal with underground link to station highlighted in red*	*RIBA Library*	*1936*	L

Figure	Description	Source	Date	Type
8.42	*Heathrow master plan*	*Illustrated London News, Saturday 25 May 1946*	*1946*	M
8.43	*London, Gatwick*	*British Caledonian*	*1958*	W
8.44	*Gatwick with Rail Station, Interchange and Transit Link to the North Terminal in the foreground*	*BAA*	*c2000*	A_2
8.45	*Amsterdam, Schiphol Interchange*	*Schiphol Airport*	*c2000*	A_2
8.46	*Paris, Charles de Gaulle, TGV Station*	*Aeroport de Paris*		A_2
8.47	*Seoul Incheon to Seoul Gimpo AREX rail link*	*The Global AirRail Alliance*		W
8.48	*Seoul Incheon rail network*	*The Nation*		N
8.49	*High speed rail link from Seoul Incheon to Pyeongchang*	*Winter Olympic Games*	*2018*	W
8.50	*Seoul Incheon Airport Terminal 1 Interchange*	*Thousand Wonders*		W
8.51	*Miami, Dinner Key – Pan American Airways Seaplane Base and Terminal*	*Wikimedia.org*		W
8.52	*Singapore Kallang 'Land/Sea' Airport*	*Flight Global 26.08.1937*	*1937*	J
8.53	*Singapore, Kallang, terminal landside in the early 1950s and airside after closure and restoration*	*Courtesy of Mr Koh Kim Chay & Singapore National Library Board*	*c1955 & c2015*	W & L
8.54	*Singapore, Kallang Aerial Photographs - Combined Landplane & Seaplane Airport, showing airfield and sea plane approach - Sources:*	*Pinterest & Collection Database, Australian War Memorial, ID 119757 Photographer: Lieutenant R.J. Buchanan*	*1945*	W & L
8.55	*New York, La Guardia, Seaplane Terminal*	*Smithsonian Institution Photo Hans Groenhoff*	*1940*	L
8.56	*New York, La Guardia, summer 1940 A Pan Am B314 at anchor in Bowery Bay. At upper right is Rikers Island Channel, take-off and landing area for the Boeing Clippers*	*www.flightwisdom.com*	*1940*	W
8.57	*Sydney Seaplanes*	*Photo- Parker Blain Broadsheet Sydney*		W
8.58	*Sydney Seaplanes*	*Alquemie.com.au*		W
8.59	*Vancouver Seaplane Terminal*	*Vancouver Harbour Flight Centre*		W
8.60	*Vancouver Seaplane and Cruise Terminal*	*Vancouver Harbour Flight Centre*		W
8.61	*- Male, Maldives – Transfer between long haul land based airplanes and island hopper seaplanes*	*transmaldivian.com/services & blog.holidaysplease.co.uk*		W
8.62	*Terminal for ocean liners, trains, airplanes and seaplanes – The Austin Company*	*The Airport Book, Martin Greif*		B
8.63	*Proposed Third London Airport, Foulness, Thames Estuary*	*UK Progressive*	*1973*	W
8.64	*River boat to London City*	*London City Airport*	*1988*	A_2
8.65	*Marco Polo, Venice, Master Plan*	*One Works*	*2030*	W
8.66	*Marco Polo, Venice, Vaporettos and water taxi dock*	*Bob and Sue Williams*		W
8.67	*Osaka Kansai to Kobe Sea Transfer*	*Wikimedia http://earthobservatory. nasa.gov/Newsroom/NewImages*		W

Figure	Description	Source	Date	Type
8.68	*Figure - Ferry Routes to HKIA from the PRD*	*HKIA Masterplan*	*2030*	A_2
8.69	*HKIA Land, Sea Air Transfer*	*Airport Authority Hong Kong*		A_2
8.70	*HKIA SkyPier Passenger Flow Layout*	*Airport Authority Hong Kong*		A_2
8.71	*HKIA Marine Cargo Terminal*	*HKIA Masterplan*	*2030*	A_2
8.72	Gaza Airport and Seaport	ET Magazine (Engineering and Technology)	*2017*	M
8.73	*DWC Location plan*	*AEC Online*		W
8.74	*DWC Sea-Air logistics*	*Pinterest*		W
8.75	*Extract from HKIA 2030 masterplan 2030 – Air Freight as a ratio to world trade – 1996 -2009*	*IATA*		A_2
8.76	*Empire State Building, New York with Hindenburg passing in 1936, with inset details of the mooring mast*	*wordpress.com*	*1936*	W
8.77	*Bell Textron – Concept for Inner City Airport*	*Bell Helicopter Textron*	*1994*	W
8.78	*London City STOLport*	*London City Airport*	*c2000*	A_2
8.79	*Tampa automated people mover linking the terminal with remote satellites*	*Westinghouse (later Bombardier and now Adtrans)*	*1971*	B
8.80	*Dallas Fort Worth – Network APM system*	*Journal of Advanced Transportation, Vol. 33, No.1, p.35-50*	*1974*	J
8.81	*Dallas Fort Worth – Vought Airtrans Automated People and Goods Mover System –*	*Wikipedia https://creativecommons.org/licenses/by-sa/2.0*	*1974*	W
8.82	*Atlanta Hartsfield underground APM system*	*Atlanta Hartsfield and Westinghouse*	*1980*	A_2
8.83	*Section and site plan showing the tracked transit system (TTS) or APM*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.84	*Heathrow Terminal 5 - Passenger flow logic showing the complexity associated with centralising transfer security*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.85	*Heathrow Terminal 5 cross-section showing passenger flow through terminal and satellite*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.86	*Heathrow Terminal 5 cross-section showing baggage flow through terminal and satellite*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.87	*Heathrow Terminal 5 exploded axonometric of the Hub Infrastructure*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.88	*Heathrow Aerial Perspective of Terminal 5 Complex – Source:*	*YRM (reproduced with permission from RMJM)*	*2008*	A_3
8.89	*Heathrow Ultra Personal rapid Transit (POD)*	*Heathrow Airport*	*2009*	A_2
8.90	*Ultra, Personal Rapid Transit*	*Ultra*	*2009*	W
8.91	*Hong Kong International Airport – Air, Road, Rail and Sea Interchange*	*HKIA*	*c2010*	A_2

Figure	Description	Source	Date	Type
8.92	*Hong Kong International Airport 2008 – Asian Megahub*	*HKIA*		A_2
8.93	*Imperial Airways and Air France coaches arriving at Croydon Airport*	*Historic Croydon Airport Trust*	*1928*	L
8.94	*Imperial Airways head office with town check-In, direct platform access and covered forecourt*	*RIBA Architecture Image Library Nos: 72869, 72872 and 72871- Photographer: Charles Borup*	*1939*	L
8.95	*Airlines Terminal 42nd Street New York, Postcard*	*www.6sqft.com*	*1941*	P
8.96	*Airlines Terminal, New York 42nd Street, Interior*	*LaGuardia Airport*	*1941*	A_2
8.97	*Airlines Terminal, New York 42nd Street Sectional Perspective*	*LaGuardia Airport*	*1941*	A_2
8.98	*Airport Limousine Service*	*La Guardia Airport*	*1941*	A_2
8.99	*BEA West London Air Terminal*	*The Library Time Machine*	*1957& 1963*	W
8.100	*Airport Express Check-in Hong Kong*	*Hong Kong Extras.com*	*c2000*	W
8.101	*Hong Kong Airport transfer*	*hongkong-airport-transfer.com*	*c2010*	A_2
8.102	*Heathrow Central Bus Station*	*Heathrow Airport Ltd*	*c2010*	A_2
8.103	*Frankfurt Airport Bus Station*	*Frankfurt Airport*	*c2018*	A_2
8.104	*Hong Kong, Coach Interchange*	*Wikizie.co*	*c2018*	A_2
8.105	*TAT Day-Night Rail-Air Service*	*oldtrailsmuseum.org*	*1929*	W
8.106	*TAT Advertisement -*	*oldtrailsmuseum.org*	*1929*	W
8.107	*Paperweight marking the start of TAT rail-air service*	*Wikipedia*	*1929*	W
8.108	*British Airways Advertisement*	*Flight 12.11.1936*	*1929*	J
8.109	*ICE integrated rail/air service at Frankfurt airport*	*Lufthansa*	*c2018*	A_1
8.110	*A New Airport for London, Proposed Rail Network*	*Atkins*	*2013*	A_3
8.111	*Lufthansa Timetable 1939*	*Historic Airports (courtesy of John King)*	*1939*	A_1
8.112	*Atlanta, Georgia, 'Midnight Merry-Go-Round' – 'Hubbing' at Atlanta*	*A Dream Takes Flight (courtesy of Jack Gray and H.W. Tofflemire)*	*1939*	B
8.113	*The Hub Concept: The most efficient way of connecting many points*	*Heathrow Airport Ltd*	*2014*	A_2
8.114	*Best Connected Long Haul Airports*	*Heathrow- Taking Britain further (p49)*	*2014*	A_2
8.115	*Atlanta Hartsfield 'toast rack' planning concept*	*Google Earth*	*2018*	W
8.116	*Waterloo Air Terminal*	*Tim Dunn on Twitter*	*1955*	W
8.117	*Waterloo Air Terminal and Heliport*	*Pinterest*	*1955*	W
8.118	*Airlink helicopter over Gatwick*	*ashpole.org.uk*	*c1980*	W
8.119	*'Metroport'*	*The Guardian*	*1965*	N
8.120	*Walter Gropius (centre) with a model of the Pan Am Building, showing its juxtaposition with Grand Central Station*	*OTRO*	*1965*	W
8.121	*Aerial view of the Pan Am building with a NY Airways helicopter in the foreground*	*Pan Am Historical Foundation*	*1965*	A_1

Figure	Description	Source	Date	Type
8.122	*Grand Central Terminal*	*rarehistoricalphotos.com*	*1954*	W
8.123	*Pan Am heliport*	*6sqft.com*	*1965*	W
8.124	*'Broadacre City'*	*Wikimedia*	*1957*	W
8.125	*'Broadacre City' and helicopter concept*	*Frank Lloyd Wright*	*1958*	A_3
8.126	*Spruce Creek, Datona Beach, Florida*	*livingwithyourplane.com*	*c2018*	W
8.127	*Spruce Creek Fly-in*	*sprucecreekproperties.com*		W
8.128	*John Travolta's House,*	*community.infiniteflight.com*		W
8.129	*UberAir - Air Taxi*	*Uber.com*	*2020*	W
8.130	*Illustration of a floating barge Vertiport at San Francisco Bay*	*Uber Elevate*	*2016*	W
8.131	*Airport de Paris Vertiport Model*	*Groupe ADP*	*2020*	A_2
8.132	*Vertiport for the Paris Olympics 2024*	*Airbus / Artist Impression: MVRDV*	*2020*	W
9.01	*Aerotropolis*	*Popular Science November 1939*	*1939*	M
9.02	*Terminal Concept*	*Airport Planning*	*1946*	B
9.03	*New York, Idlewild Original Concept and Airport City Revision*	*Architectural Record*	1948-1962	J
9.04	*Schiphol Airport City*	*kcap.eu*		W
9.05	*Schiphol Airport master plan*	*ggau.net*		W
9.06	*The Squaire, Frankfurt*	*Amoma.com*	2011	W
9.07	*Munich Airport City*	*Skytrax*	1992	W
9.08	*Aerotropolis*	*John D. Kasarda and Taoyuan Aerotropolis*	2000	B
9.09	*Hong Kong International Airport Aerial View of SkyCity and SkyPier Ferry Terminal*	*720 Collaborative Strategic Master Planning Consultancy*	1998	A_3
9.10	*Hong Kong Tung Chung - Source:*	*Wikipedia*	1998	W
9.11	*Hong Kong Chek Lap Kok and Tung Chung and Lantau Island*	*Wikipedia*	-	W
9.12	*Seoul, Incheon*	*Wikipedia*	-	W
9.13	*Seoul Incheon, Yeongjong, Cheongna and Songdo*	*Seoul Incheon*	2015	W
9.14.	*Seoul Incheon master plan, with five runways and two terminals*	*Seoul Incheon*	2015	W
9.15	*Seoul Incheon connectivity*	*About Airport Planning*	-	W
9.16	*Songdo Landmark City Master Plan*	*John Portman and Associates*	-	W
9.17	*Songdo City showing link to Incheon airport*	*mooyoung.com*	-	W
9.18	*Beijing Daxing Location Plan*	*Australian Business Traveller*	-	W
9.19	*Beijing Daxing Master Plan*	bjbna.com	-	W
9.20	*Beijing Daxing – Original Masterplan*	*NACO*	-	A_3
9.21	*Beijing Daxing Terminal Area*	*ADPI*		A_3
9.22	*Istanbul Grand*	*Daily Mail*		N
9.23-	*Istanbul Grand Aerial Image*	*Airport Technology*		P
9.24	*Istanbul Grand, Aerial view –*	*Nordic-Office of Architecture, Grimshaw Architects, Haptic Architects*		A_3
9.27	*Dubai World Central Aerotropolis*	*emirates247.com*		A_1

Figure	Description	Source	Date	Type
9.28	*Dubai World Central Master Plan*	*Dubai South*		W
9.29	*Dubai Metro*	*Wikipedia*	*2030*	W
9.30	*Dubai Jebel Ali Port*	*Megaconstrucciones.net*		W
10.01	*Osaka Kansai*	*Pinterest*		W
10.02	*Chubu Centrair*	*Pinterest*		W
10.03	*Kobe*	*Pinterest*		W
10.04	*Kyushu*	*Pinterest*		W
10.05	*Hong Kong International*	*AECOM*		A_3
10.06	*Seoul Incheon*	*Incheon Master Plan*		A_2
10.07	*London, Isle of Grain – showing comparative size with contemporary airports*	*Flight*	*1943*	J
10.08	*London 3rd Airport Proposal on reclaimed land at Maplin Sands*	*British Airports Authority*	*1973*	A_2
10.09	*A new airport for London, Isle of Grain, master plan*	*Atkins*	*2013*	A_3
10.10	*New York, JFK showing its proximity to Jamaica Bay and Metropolitan New York*	*Jamaica Bay and JFK Environmental Assessment*	*1971*	R
10.11	*Aircraft Noise*	*Eurocontrol*		W
10.12	*Logo of the Anti-Noise League, The pressure group behind the 1935 exhibition*	*Science Museum*	*1935*	L
10.13	*Kings Cross Airport, Charles Glover*	*Illustrated London News*	*1931*	M
10.14	*Comparison of conventional 'step-down' and continuous descent approach*	*silentaircraft.org/approaches (Cambridge MIT)*		W
10.15	*Noise impact of steeper approach angles*	*yourheathrow.com*		A_2
10.16	*Impact of displaced thresholds*	*Smart Aircraft Training*		W
10. 17	*Illustration of the fixed ground service equipment at Washington National Airport*	*Airport Planning, Charles Froesch*	*1942*	
10.18	*Amsterdam Schiphol -The Buitenschot Land Art Park*	*land8.com - Photograph Captain Luchtfotografie*		W
10.19	*Hong Kong International, 3rd runway predicted noise contours*	*HKIA Masterplan 2030*	*2030*	A_2
10.20	*A New Airport for London, Isle of Grain - Noise contours*	*Atkins*	*2013*	A_3
10.21	*Heathrow Air Quality Comparison Map and "Blueprint for Reducing Emissions"*	*Heathrow Airport website*		W
10.22	*Carbon Footprint*	*TO 70 Consultancy*		A_3
10.23	*Stockholm-Arlanda's Aquifer*	*LFV*		A_3
10.24	*Improvements to Heathrow Airport Water Discharges 2014-2018*	*Heathrow*		A_2
10.25	*Air and Water pollution in Jamaica Bay*	*Jamaica Bay and JFK Environmental Assessment*	*1971*	R

Figure	Description	Source	Date	Type
10.26	*Annual waste generated at airports*	*Benchmarking airports based on a sustainability-ranking index S. Kılkıs and Atkins research*	*2018*	A_3
10.27	*Local residents protest at Frankfurt-Main Airport*	*Airport Watch*		W
10.28	*Local residents protest at Heathrow Airport*	*Airport Watch*		W
10.29	*Amaala, Saudi Arabia*	*Foster + Partners*	*2020*	A_3
11.1.1	*Dayton, Wright Field:*	*Airports by John Walter Wood*	*1904*	B
11.1.2	*Start of the first flight of Flyer III, June 23, 1905, Orville at the controls. The hangar is just left of centre and the catapult tower is on the right*	*US library of Congress*	*1905*	L
11.2.1	*Flugplatz Johannisthal Plan*	*Wikimedia*	*1916*	W
11.2.2	*Map of Berlin Johannisthal*	*Grin.com*	*1927*	W
11,2.3	*Flugplatz Johannisthal Hangars*	*Alamy*	*1920*	W
11.2.4	*Berlin Johannisthal – First scheduled Flight to Weimar 05.02.1919*	*Wikipedia*	*1919*	W
11.3.1	*Croydon Control Tower + annotation*	*Fine Art America - Poster by Sheila Terry*	*1928*	P
11.4.1	*Königsberg site plan and location plan*	*Die Deutschel Luftfart* (Treibel, 1992)	*1922*	B
11.4.12	*Königsberg seen from the airfield*	*bildarchiv-ostpreussen.de*	*1922*	L
11.5.1	*Berlin Tempelhof site plan showing the 1st and 2nd terminals*	*Airports, John Walter Wood 1940*	*1928/ 1939*	B
11.5.2	*Berlin Tempelhof 1*	*Deutsch Lufthansa AG*	*1928*	A_1
11.5.3	*Berlin Tempelhof 2 1955, view under cantilever canopy*	*peterpapke.de*	*1939*	W
11.6.1	*Gatwick 'Beehive' Terminal*	*UK Airfields and Airports*	*1936*	W
11.6.2	*Gatwick 1958*	*ukairfieldguide.net*	*1958*	W
11.6.3	*Gatwick 1983*	*Gatwick*	*1983*	A_2
11.6.4	*Evolution of Gatwick from 1958 to1988*	*: YRM (reproduced with permission from RMJM)*	*1958-1988*	A_3
11.7.1	*Le Bourget, Site Plan 1939*	*Airports – John Walter Wood 1940*	*1939*	B
11.7.2	*Le Bourget, Landside view*	*picclick.fr*	*1937*	W
11.7.3	*Le Bourget, Airside view of control tower*	*del campe*	*1937*	W
11.8.1	*La Guardia Masterplan*	*Airports, John Walter Wood 1940*	*1939*	B
11.8.2	*La Guardia, aerial landside view*	*stuckattheairport.com*	*1939*	W
11.8.3	*La Guardia, airside view of landplane terminal and 'skywalk'*	*Pinterest*	*1939*	W
11.9.1	*Chicago O'Hare, Master Plan*	*Chicago Tribune Graphics*	*1948*	N
11.10.1	*St. Louis, Lambert, initial and ultimate site plans*	*St Louis Municipal Airport, Economic Studies*	*c.1951*	R
11.10.2	*St Louis, Lambert, aerial view showing extended 4th terminal module & finger pier*	*CMJ*	*c.2000*	W

Figure	Description	Source	Date	Type
11.11.1	*Idlewild, the terminal city concept with multiple airline terminals*	*Architecture USA*	*1959*	B
11.11.2	Figure New York, JFK, Aerial view	Architecture Daily Photo: Jeffrey Millstein	*c2010*	J
11.11.3	New York, JFK Terminal area plan	JFK Airport	*c2015*	A_2
11.12.1	Washington Dulles, Masterplan	FAA	*c2018*	A_2
11.12.2	*Washington Dulles interim update with remote satellites still served by mobile lounges*	*Library of Congress*	*c2010*	L
11.13. 1	*Los Angeles International aerial view*	*airporthistory.org*	*1963*	W
11.13.2	*Los Angeles (LAX) Theme Building*	*California Historical Society Collection, USC Libraries*	*1962*	L
11.14.1	*Dallas Fort Worth Terminal Zone-International terminal at the centre bottom is a later centralised addition*	*fromabove.altavista.org*	*c2015*	W
11.14.2	*Dallas Fort Worth International Terminal, Skylink Transit in the foreground*	*Wikipedia*	*c2015*	W
11.15.1	*Paris, Charles de Gaulle 1965*	*Sideshare.net Jeanmarie-Chevallier ADP*	*1965*	A_2
11.15.2	*Paris, Charles de Gaulle 2015*	*Wikipedia- By CellarDoor85 – 52031981*	*2015*	W
11.15.3	*Paris, Charles de Gaulle Future Terminal 4, with T2 in the foreground & circular T1 top left*	*cdg.parisaeroport.fr*	*2020*	A_2
11.16.1	*Atlanta Hartsfield Long Term Master Plan with 5th parallel runway to the south and new mid-field terminal area*	*Art Papers: The possibility of an airport*	*2018*	W
11.16.2	*Atlanta Hartsfield aerial view (5th runway at top of photo)*	*Flickr MFMinnMFMinn*	*2012*	W
11.17.1	*London Stansted, stage 1 expansion of terminal*	*New Civil Engineer*	*c2015*	J
11.17.2	*London, Stansted cross section through terminal*	*Foster & Partners*	*1991*	A_3
11.18.1	*Osaka, Kansai aerial view showing second runway*	*Pinterest i.pinimg.com*	*c2018*	W
11.18.2	*Osaka, Kansai, landside canyon, airside gates & check-in*	*Fondazione Renzo Piano*	*1994*	A_3
11.19. 1	*Hong Kong, Chek Lap Kok, Master Plan 2030 ultimate development of satellite to terminal 2 on the left and the existing Fosster designed terminal to the right*	*HKIA*	*2030*	A_2
11.19.2	*Hong Kong, Skypier and Sky City land, sea air Interchange*	*SOM.com*	*2003*	A_3
11.20.1	*Original KLIA Master Plan*	*skyscrapercity.com*	*1998*	W
11.20.2	*Kuala Lumpur International Masterplan 2017*	*Malaysia Airports @ FIATA conference*	*2017*	A_2
11.21.1	*Seoul, Incheon, Aerial views of T1 &T2 phase*	*fromabove.altervista.com & IIAC*	*2001& 2018*	W
11.21.2	*Seoul, Incheon Interchange*	*Ken Eckert / WikiCommons*	*2001*	

Figure	Description	Source	Date	Type
11.22.1	Bangkok, Suvarnabhumi, 2030/2040 Master Plan	Skyscraper City	2030/ 2040	W
11.22.2	Bangkok, Suvarnabhumi, terminal gate layout and aerial view	Airport Builders and Chukoh Chemical Industries Ltd	2006	B & W
11.23.1	Madrid Barajas, Masterplan	Aena	2020	A_2
11.23.2	'Magic Carpet' Roof Concept	Rogers Stirk Harbour + Partners	2006	A_3
11.23.3	Madrid Barajas, 'Magic Carpet' Roof	Rogers Stirk Harbour + Partners	2006	A_3
11.24.1	Early Concept for Heathrow T5 with a motorway under the terminal	BAA	1976	A_2
11.24.2	Heathrow T5 'Toast Rack' Master Plan	Rogers, Stirk Harbour + Partners	2008	A_3
11.24.3	Heathrow Terminal 5 Sections	Architects' Journal	2008	J
11.24.4	Heathrow Expansion Project	Grimshaw Architects	2020	A_3
11.25.1	Beijing Capital Terminal 3 Aerial	Google Earth	2008	W
11.25.2	Beijing Capital Interior	Foster & Partners, Photographer: Nigel Young	2008	A_3
11.25.3	Beijing Capital sections through satellite	Foster & Partners	2008	A_3
11.26.1	Layouts of Underground Terminal Departures and Arrivals Areas	Dubai Airports	2008	A_2
11.26.2	Dubai International Underground check-in concourse –	Qantas Magazine	2008	A_1
11.26.3	Dubai International Retail Mall in the satellite concourse	getbybus.com	2008	W
11.27.1	Istanbul Grand, Aerial View	IGA by Havilimani Vaz Aci, via Architectural Digest	2019	A_3
11.27.2	Istanbul Grand – CGI of Departures Concourse	Grimshaw	2019	A_3
11.27.3	Istanbul Grand CGI of Airside Lounge & Retail Mall	Haptic Architects	2019	A_3
11.28.1	Beijing, Daxing Master Plan	kaskus.co.id	2019	W
11.28.2	Beijing, Daxing, Aerial View, nearing completion	Wikipedia Photo:王之桐	2019	W
11.29.1	Mexico City, Masterplan with 6 runways and 2 terminals	Landrum and Brown	2019	A_3
11.29.2	Mexico City International, Departures Forecourt –	Dbox for Foster & Partners	2019	A_3
11.29.3	Mexico City International, Departures Lounge –	Dbox for Foster & Partners	2019	A_3
11.30.1	Dubai World Central, Model	Leslie Jones Architecture	2050	A_3
11.30.2	Dubai World Central, Satellite	Leslie Jones Architects	2050	A_3

1. Aims and Objectives

1.0 Introduction

This opening chapter covers the aims and objectives in undertaking research into the evolution of airport design. It identifies the literature that has been reviewed to ensure that this work will not duplicate existing research and will be a real contribution to knowledge. It then addresses Reyner Banham's critique that 'airport architecture is inherently transient and doomed to obsolescence'. Following that it puts forward a methodology for undertaking the research, and a structure for presenting the results.

1.1 Rationale

As a practising architect who has been involved in airport design for over thirty years, and has delivered several major airport projects it is important to understand where the design ideas we regard as current practice today originate from and whether they can have lasting value. I have, however, not found in my investigation a comprehensive history concerned with the evolution of airport design and have concluded that there is a gap in the literature. Design evolution of airports is therefore planned to be the focus of this research.

1.2 Aims and Research Question

The aim of this research is to explore the evolution of the historic relationships between the design philosophy, functional requirements, new technological opportunities, environmental constraints and the resultant physical form of airports. The research question is to determine;

The line of development of airport design,

and consider as a secondary research topic,

Is airport architecture inherently transient and doomed to obsolescence?

This research is supported by the collection and interpretation of supporting evidence such as drawings, photographs and designers' and contemporaneous writings. It identifies the particular contribution made by individual architects, engineers and planners. It also seeks to identify whether there are any key turning points or step changes in the evolution of airport design.

1.3 Objectives

The aim of this research is fulfilled by considering the following objectives that will assess:

1. The uniqueness of airport design.
2. How design philosophies have impacted airport design and how have they varied between the various design disciplines- Architecture, Engineering and Planning.
3. The impact of increasing scale and changing functional and operational requirements and how they have influenced the organisation and planning of airport terminals.

4. The impact of technological innovations in areas such as air navigation, communication, mechanisation, automation and digitisation on airport development.
5. The evolutionary trends in the master planning, terminal layout, sectional development, and architectural expression of terminals.
6. The engineering design of the airfield including how runways, taxiways and aprons developed and its relation to the evolution of international standards.
7. The emergence of the idea of the airport as an interchange as related to urban planning concepts.
8. The emergence of the airport city and aerotropolis.
9. The response to the challenges of environmental sustainability.
10. A series of case studies to illustrate the evolution of airport design.
11. The key turning points in the evolution of airport design.

1.4 Sources of material and development of a research methodology

As an initial step in developing a methodology for the research the available literature on airport design was reviewed, firstly to understand the types of literature available and secondly to confirm that the proposed area of research did not duplicate previous work.

Concurrently with completing a literature review primary sources of material have been sought out. These include; drawings, photographs, film clips and eyewitness accounts, contemporary publications and government reports, papers presented at conferences and academic societies, published airport master plans and development proposals. These are complemented by benchmarking comparisons. Secondary sources that have been made use of include individual airport histories on airport websites, local aviation histories and airport design reference books.

The literature on airport design can be categorised as follows:

- books, journals and magazines that describe and illustrate airports and terminals that are contemporary with the era in which the airports were designed.
- monographs on individual architect's and designer's works
- airport planning and design manuals and text books that explain the theoretical basis on which airports can be designed
- international standards and design guides
- short essays that introduce some of the historical context
- local histories and monographs of individual airports
- airline histories
- airport benchmarking studies

- individual airport histories and web sites
- travelogues and eye witness accounts
- books that illustrate thematically some of the ideas that influence airport design
- PhD theses that focus on social, political and cultural influences on airports
- airport conference papers.

Writings seldom consider from where the design ideas originate, and how designers have responded to the many influences on airport design. PhD theses such as 'Airport Age: Architecture and Modernity in America' by Janna Eggebeen (Eggebeen, 2007), or 'The invention of airports: A political, economic and technological history of airports in the United States by Deborah Douglas (Douglas, 1996) focus solely on the USA and have relatively little to say about design questions. David Brodherson's thesis 'What can't go up can't come down, the history of American airport policy, planning and design' (Brodherson, 1993) focuses on a very narrow field, American airports of the 1930s. Other theses have concentrated on individual designers in the States such as Eero Saarinen (Santala, 2015) or Norman Bel Geddes (Morshed, 2002).

However many of the important airport design innovations originate from Europe and more recently the Middle East and Asia about which very little has been analysed in a historical context. A few of these airports were considered in John Stroud's books on airport designs that span from the 1950s to 1980s (Stroud, 1956) (Stroud, 1973) (Stroud, 1980). He was the air transport correspondent of the Journal of Commerce and editor of a series of Puttnam Aeronautical Books.

John Zukowsky's 1996 book Building for Air Travel - Architecture and Design for Commercial Aviation (Zukowsky, 1996) is arguably one of the best introductions to the history of airport design but contains only a few short essays, so is not comprehensive and is now over twenty years old..

William Lethaby wrote in 1912 during the early days of the Modern Movement:

'We know those too capricious monuments which popular insight has named "Follies". All modern buildings have too much that is merely capricious. Little in ancient architecture was ''designed.'' Things designed by a single mind are mostly ''sports,'' which must quickly perish. ***Only that which is in the line of development can persist****.*' (Lethaby, 1912, p. 252)

This research aims to discover whether airport design is indeed an honourable exception to this critique, and that the collaborative approach that is inherent to airport design has led to a recognisable **line of development**.

Conversely if form really does follow function in airport design, and the functional requirements change radically over time, can the resultant built forms have lasting value? In an article titled 'The obsolescent airport' the architectural historian and advocate for the modern movement Reyner Banham bemoaned '*the perennial drag of airport design behind airport operation … never completed, always inadequate, always sprawling slummily into* *their surroundings in a manner that reveals, only too clearly, the standards of hostilities-only expediency carried over into peace-time operations.*' and noted that '*the status of practically every building on the airfield is being questioned*' and envisaged that *'the emphasis lies increasingly on the continuity of the process of transportation, rather than the monumental halting places along the way'.* He asked ***'Is airport architecture inherently transient and doomed to obsolescence?'*** (Banham, 1962, p. 124)

He was not alone in this view but some of the airport community saw constant change as a virtue. The 1960 Los Angeles Department of Aviation annual report explained:

'An airport system is never completed. Constant change is routine in airport operations; maintaining the status quo is synonymous with being out of date' (LA, 1960).

Now 50 years after Banham wrote those words it is proposed to re-evaluate this proposition, and re-consider the evolution of airport design and whether airport architecture is inherently transient and doomed to obsolescence by reviewing the **Evolution of Airport Design** and identifying the **Line of Development.** This will include considering the philosophy, function and form of airport design to identify whether design concepts can endure and continue to be relevant despite changing functional requirements.

A bibliography that has been compiled as a part of this research is included at the end of this thesis.

1.5 Focus of the Research

The primary focus has been on the airports as they were originally designed and opened rather than on subsequent modifications, although the latter have been helpful in exposing any initial shortcomings, or showing the impact of changing external factors such as the requirement for increasingly rigorous security control or need to increase retail revenue. This approach that focuses on the airports as they were originally conceived is complemented by a series of studies of selected airports to see how well they have adapted to growth and change. These studies have been gathered together in Chapter 11.

An advantage of this area of research is that some significant airports and terminals still exist in more or less their original form and are retained as museums such as London Croydon, Paris Le Bourget and Berlin Tempelhof airports. Others such as the New York JFK, TWA and Washington Dulles terminals, and most of the airports in the UK have been modified and adapted but original drawings, photographs, film strips and designers' accounts still exist.

While much of this research has been qualitative some has been quantitative, for example establishing the organisation, size and capacity of airports and terminals as originally designed and subsequent capacity in use. Considerable work has been needed to organise the material so that it can be understood as a coherent line or multiple lines of development. For this a timeline of the evolution of design ideas has been established and is attached as Appendix B and the abbreviations used are summarised in Appendix I. A particular challenge was to identify when and where there have been any key evolutional shifts in design of airports and to what these were due.

A limitation of this type of research is that architects, engineers and planners are often reluctant to attribute where some of their ideas came from, so evidence has been sought as to whether the designer might have been exposed to earlier influences, for example by attendance at the numerous airport conferences that were held from the 1930s onwards or by reading the books and journal articles that focused on progressive airport design.

The cross-fertilisation of ideas between Europe and the United States has also been largely ignored, so that previous research has often focused on one continent to the exclusion of the other. But Colonel Stedman Hanks' book (Hanks, 1929), published in1929 after his trip around the new European airports addressed an American audience while Nigel Norman's lecture to Royal Aeronautical Society in 1932 following his extensive research into airport design in the USA in collaboration with his partner Graham Dawbarn, introduced new ideas such as the retractable boarding canopy that were later to find favour in UK airport design.

Earlier researchers have chosen instead to concentrate on the political and legislative context driving the development of airports. They have also mainly focused on airports in the USA, but at an early stage of research it became obvious that American experience does not translate well to an international context because American airports have an unusually high level of domestic traffic flow and a uniquely unsatisfactory way of dealing with international transfer traffic.

European and more recently Asian and Middle Eastern airports have also played a very large part in informing the evolution of airport design, and may be regarded as mainstream, but the contribution of these airports is seriously undervalued and underrepresented in existing literature. This research sets out to remedy this bias.

1.6 Structure of the Thesis

Chapters 1-5 introduce the scope of the research and identify the key factors that have influenced the evolution of airport design.

> Chapter 1: introduction to the aims and objectives of the research.
>
> Chapter 2: consideration of why airport architecture and design is unique.
>
> Chapter 3: appraisal of the design philosophies that have influenced airport design from an architectural, engineering, planning and multi-disciplinary design perspective.
>
> Chapter 4: investigation of the external factors that have influenced the evolution of airports.
>
> Chapter 5: consideration of the opportunities that technological innovations have created and review some of the recurring engineering dreams that have either been unrealised or short lived.

Chapters 6 - 10 form the heart of the research and focus on the evolution of the designers' responses to the external factors identified previously, concentrating on the designs as they were originally conceived, to identify the **line of development** of airport design.

Chapter 6: evolutionary trends in airport layout and architectural design.

Chapter 7: advances in airfield design from an engineering perspective.

Chapter 8: development of the airport as an interchange.

Chapter 9: emergence of the airport city and aerotropolis.

Chapter 10: challenges of environmental sustainability.

Chapters 11, 12 and 13 turn the focus to the secondary purpose of this research which is to consider Reyner Banham's challenge that **airport architecture is inherently transient and doomed to obsolescence** and then identify key turning points and finally draw together the various threads of research in a concluding chapter.

Chapter 11: case studies of thirty of the most significant and innovative airport designs and the resultant evolution of those airports over time.

Chapter 12: identification of the key turning points in the evolution of airport design by synoptically considering the thematic research in the main chapters and the case studies in the previous chapter.

Chapter 13: conclusions of the research, and identification of opportunities for further research and discussion of the line of development and the question of obsolescence.

2. Is airport architecture and design unique?

2.0 Introduction

This chapter introduces the background to the design response to the growth of commercial air travel. It then discusses the idea that airport design is unique in scale, the speed of change it has to respond to and its complexity. Finally it considers how airport design can respond to the demands of growth and change that are inherent to this fast moving industry.

2.1 Background

Few people remember the glamour associated with the beginning of the jet age, let alone the pioneering days of air travel but a visit to the 1928 terminal at the former Croydon Airport, the oldest terminal building in the world still standing reveals that, in comparison with the current experience at Heathrow's Terminal 5, opened eighty years later in 2008, much of the basic organization and processes of the terminal remain unchanged (figure2.01).

There were, and still are, paved forecourts to set passengers down and pick them up again, a grand reception area for passengers to check-in, separate departing and arriving processing though customs and immigration and waiting areas supported by retail and catering offers for passengers to use before boarding their aircraft and lastly areas for passengers to reclaim their bags.

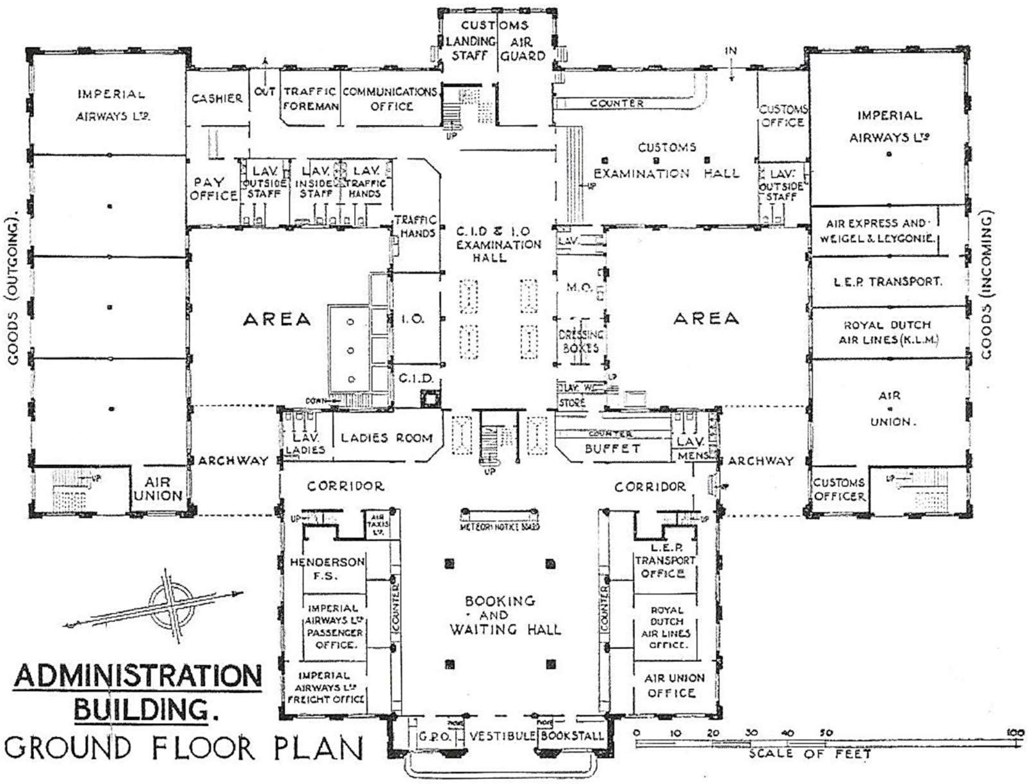


Figure 2.01 – London, Croydon 1928 – Source: Guide to the Airport of London (Croydon), Air Ministry UK

The appearance and experience for the passenger moving through Terminal 5 is, however, totally transformed compared with Croydon, in part due to the immense scale of the development and volumes of passengers handled, but also because of the imposition of safety and security requirements, the introduction of new technology, and a very different response to the commercial imperatives of operating an airport. Airport design has also developed because architectural, engineering and planning philosophies, and cultural values have evolved.

The airfield has undergone an even more radical transformation from the small bumpy grass field, of early airfields such as Berlin Johannisthal (figure 2.02), the location of the first scheduled flights, to the large modern concrete and asphalt runways and taxiways of today. No longer do aircraft need to point directly into the wind but can take-off and land in quite severe cross winds. Again the scale of and sophistication of development and the space required have totally changed, and the level of comfort and safety enjoyed have greatly improved.

Figure 2.02 - Berlin Johannisthal Aerial Photograph 1927:
Source: Abandoned, Forgotten and Little Known Airfields in Europe: grin.com

The airport terminal is an unusual building type, as it is rarely a destination that the user chooses to experience. Rather its raison d'être is to facilitate the efficient transfer of passengers from one mode of transport to another, or in the case of the larger hubs, between journeys on the same mode. No longer is air travel the preserve of an exclusive wealthy and adventurous elite, who were prepared to brave the dangers and discomforts of early flying, but is an everyday experience for many people.

Images of airports, and the role they can play as a public transport interchange of a planned city and its transport network, have existed long before it was possible to put those ideas into practice, as can be seen in the competition entry for the Canberra Federal Capital City competition (figure 2.03). The idea of the airport as an interchange has evolved with concepts such as the multi-modal transport hub, airport city and aerotropolis emerging. These developments recognise the increasing importance of commercial aviation to contemporary society, and the need for the airport to be woven into the built environment. Allied to planning issues are environmental sustainability concerns that have grown in importance in recent years, focusing on noise, emissions, traffic impact and global warming.

Figure 2.03 - Canberra Aerostatic Station 1912 – Source: National Archives of Australia, Entry No. 4, Federal Capital City Design Competition, Donat-Alfred Agache

There have been a series of small steps in design development to reach this point, and many blind alleys as architects, engineers and planners have sought to define a new type of built environment, part architecture, part engineering infrastructure and part urban design, with each discipline bringing very different perspectives to the task.

2.2 The Uniqueness of Airport Design

Airport design is different from other forms of architecture, engineering and planning by virtue of the sheer scale of development which is more akin to city planning. Large airports in the United States such as Dallas–Fort Worth and Denver are considerably larger than Manhattan Island. Manhattan is admired as a vibrant city precisely because it regenerates itself with every generation. However airports also differ from cities because no-one lives there giving rise to the view that airports are non-places despite major hub airports having city scale working and transient populations. Airports are also different in the speed of response required when faced with the challenges of growth and changed circumstance, in part because unlike the airlines they handle, when they reach a certain scale, they are hugely profitable organisations that can afford to reinvent themselves on a regular basis.

The third aspect that sets airports apart from other developments is the complexity of the operation that allows an aircraft to land and take off again often within an hour. This includes uniquely complex passenger and baggage processes and aircraft turn-around logistics not found in other public buildings or complexes.

The airport, like air travel is an invention of the 20th century. Airports are arguably a unique synthesis of architecture, planning and engineering design, and no one discipline can create an airport on its own. This research aims to understand the interdependence between these various disciplines and how this influences the evolution of airport design. Airport design has always been driven primarily by a rigorous philosophy and attention to functional and operational requirements, and as such can be regarded as the epitome of the modern movement, in that form follows function, despite the variety in the resultant form of development.

Reyner Banham's article 'The Obsolescent Airport' appeared as a part of short series in the Architectural Review in 1962 titled 'The Landscape of Hysteria' which focused on airports. The introduction still holds good today. It stated *'Airports have produced some of the finest architecture and some of the most squalidly subtopian landscapes and most intractable ground-transport problems of the century'*, but his corollary that the changes in air-transportation have rendered most airports permanently obsolete does not have to follow as this analysis of the evolution of airport design over both the preceding and subsequent fifty years reveals.

The phrase 'Landscape of Hysteria' originates from a poem by Stephen Spender

The Landscape near an Aerodrome (Spender, 1933)

More beautiful and soft than any moth
With burring furred antennae feeling its huge path
Through dusk, the air-liner with shut-off engines
Glides over suburbs and the sleeves set trailing tall
To point the wind. Gently, broadly, she falls,
Scarcely disturbing charted currents of air.
Lulled by descent, the travellers across sea
And across feminine land indulging its easy limbs
In miles of softness, now let their eyes trained by watching
Penetrate through dusk the outskirts of this town
Here where industry shows a fraying edge.
Here they may see what is being done.

Beyond the winking masthead light
And the landing-ground, they observe the outposts
Of work: chimneys like lank black fingers
Or figures frightening and mad: and squat buildings
With their strange air behind trees, like women's faces
Shattered by grief. Here where few houses
Moan with faint light behind their blinds,
They remark the unhomely sense of complaint, like a dog
Shut out and shivering at the foreign moon.
In the last sweep of love, they pass over fields
Behind the aerodrome, where boys play all day
Hacking dead grass: whose cries, like wild birds

Settle upon the nearest roofs
But soon are hid under the loud city.
Then, as they land, they hear the tolling bell
Reaching across the landscape of hysteria,
To where larger than all the charcoaled batteries
And imaged towers against that dying sky,
Religion stands, the church blocking the sun.

This romantic view of mechanical flight was characteristic of Futurist poetry and other poets writing in the 1930s but by the 60s Banham's more cynical view was more prevalent in an era that marked the beginning of mass air travel.

The images that accompany these articles in Architectural Review show that Heathrow did indeed suffer from a hotchpotch of unrelated elements that represented a blot on the landscape. If Heathrow in the early 1960s was representative of airport design worldwide then there might be a case to answer. This research will endeavour to discover whether there are other more farsighted examples of forward planning and good airport design.

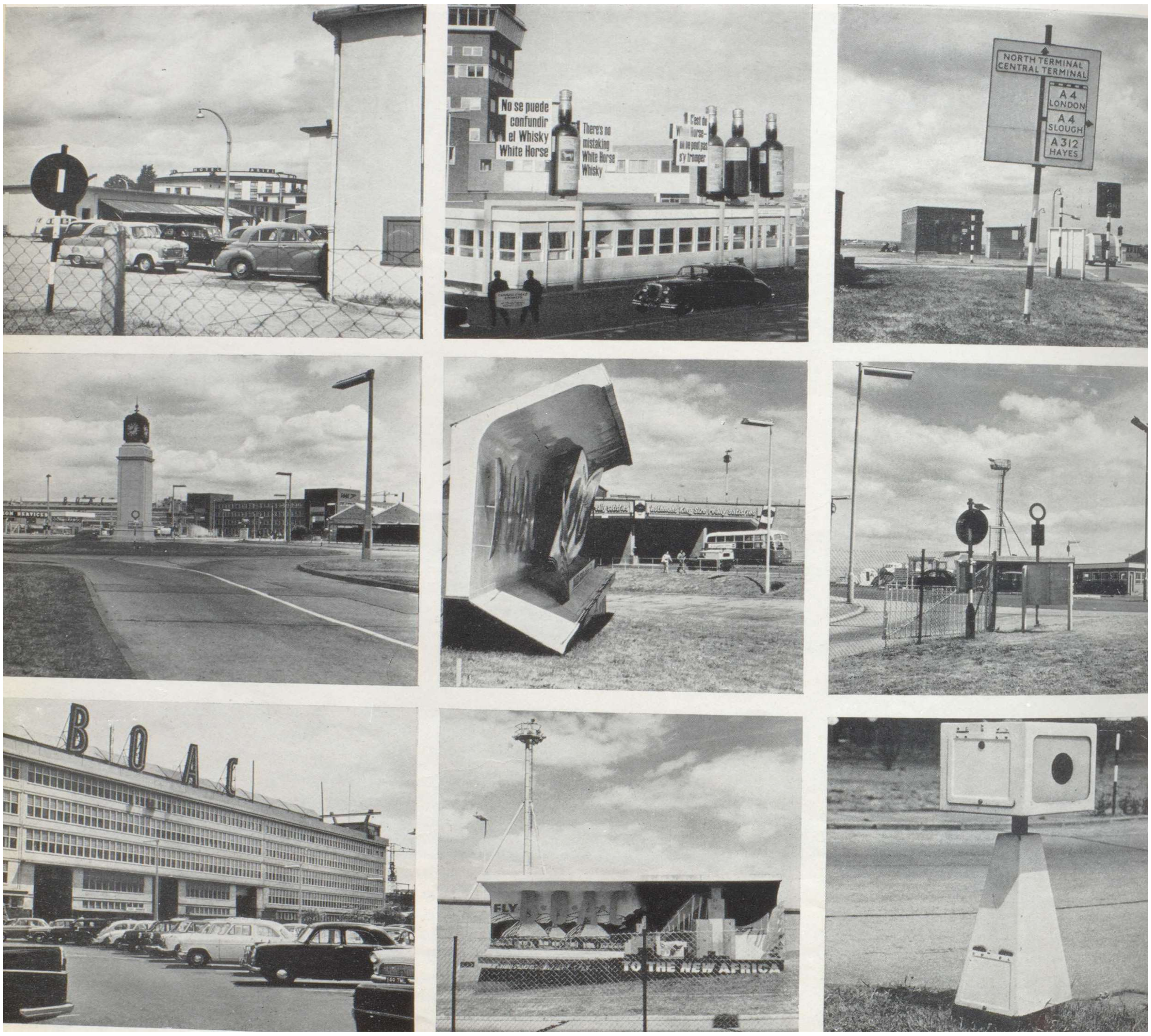


Figure 2.04 - Photographs of Heathrow in 1962 – Source: Architectural Review

2.3 Growth and Change

It has been argued that this decade saw the emergence of two rival design philosophies: design for obsolescence to reflect a disposable consumer society and design for sustainability to reflect the increasing interest in conservation. In the same decade John Weeks started to promote the concept of indeterminate architecture, to make hospital architecture more adaptable and responsive to changing requirements and emerging technologies and protect them against obsolescence (Abramson, 2017). This research shows that there were parallels in contemporary airport design.

So it was timely that in the very next issue of Architectural Review Michael Brawne introduced some of the new airport designs that have responded well to changing circumstance. Notable among them were Saarinen's designs for the TWA terminal (1962) at Idlewild (JFK) (figure 2.05) and Washington Dulles (1962) (figure 2.06), which are now recognised as historic monuments. The former, although no longer a terminal, has been converted into a hotel while preserving its original form. The latter terminal was designed from the outset to be expanded and now handles far more traffic than originally intended while retaining its original character.

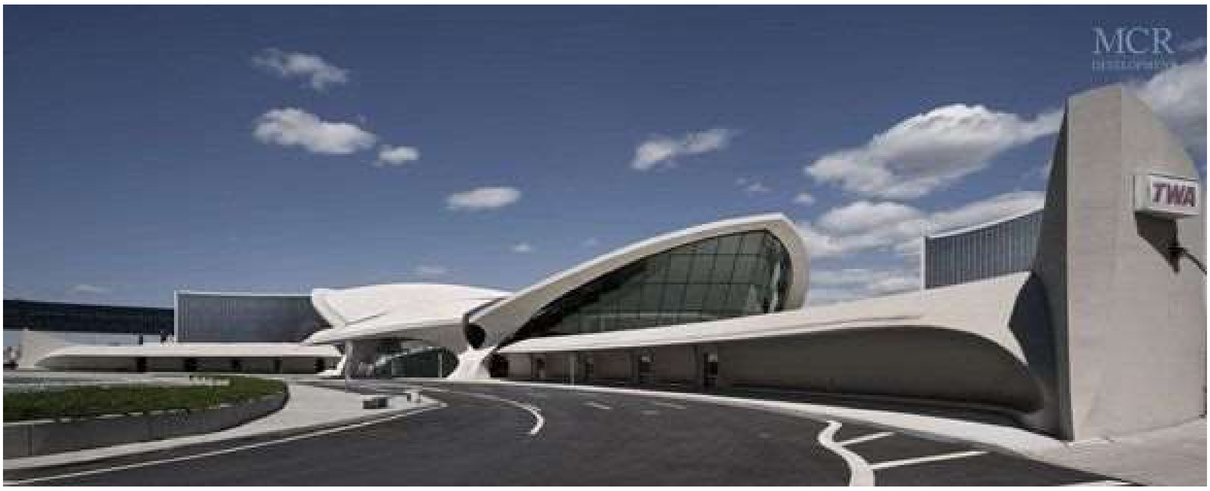


Figure 2.05 - A rendering of how the 1962 TWA Flight Center at John F. Kennedy International Airport will appear when redeveloped as a hotel by MCR Development LLC - Source: MCR Development

Figure 2.06 – Washington Dulles after 1996 Extension – Source: Wikipedia -photo: Joe Ravi license CC-BY-SA3.0

An early approach to the issue of providing flexibility for growth and change can be seen in Albert Kahn's 1937 design for an aircraft assembly plant for the Glenn L. Martin aircraft company. He was architect to the Ford Motor Company and responsible for designing not only Ford's manufacturing plant but also Ford airport at Dearborn in the 1920s. Albert Kahn characterised himself as an industrial architect dedicated to serving efficient manufacturing processes. In a speech to the 'Adcraft Club' he said;

'In spite of the fact that architecture today is in my opinion only about 10% art and 90% business, the architect must have constantly before him the final result - the artistic, the practical and the economic'. (Kahn, 1937)

Glenn L. Martin, an early aviation pioneer and aircraft manufacturer (later part of Lockheed Martin), convinced that the wingspan of airplanes would soon reach 300ft (91 metres), commissioned from Kahn an unobstructed space measuring 300 by 150ft (91 by 46 metres), with one end entirely open for the finished airplane to exit through (figure 2.07).

Albert Kahn borrowed bridge technology to design steel trusses of a size previously unequalled. The longevity of the structural shell would be maximised by its capacity for internal reorganisation (Abramson, 2017, p. 80).

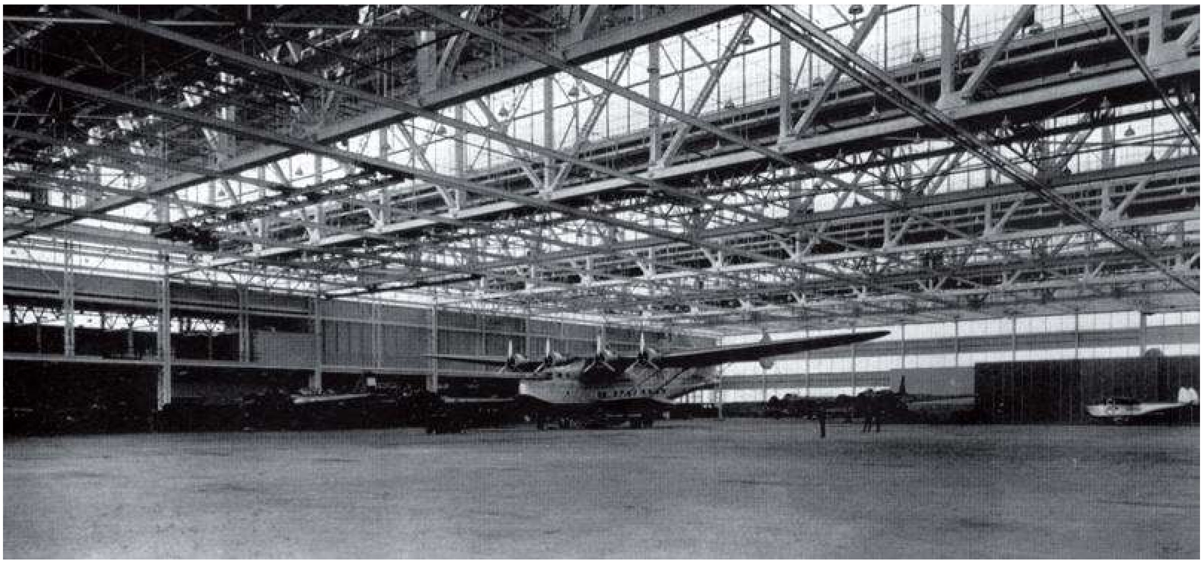


Figure 2.07 - Glen Martin Aircraft Assembly Plant, Baltimore 1937– Source: arquitecturaminorista.com/wordpress

Mies van der Rohe explored the opportunities offered by such a large flexible space to propose in 1942 such a space could be suitable as an art gallery or concert hall, showing that aviation buildings could be re-used when they had outlived original purpose, a concept that previews much later concepts of sustainable design (figure 2.08).

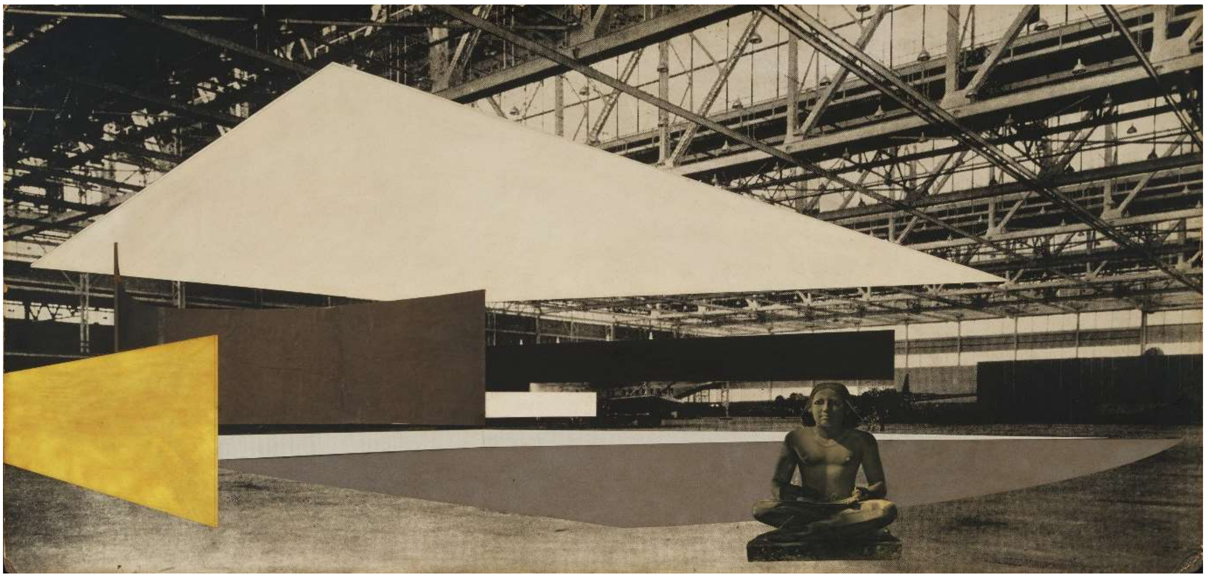


Figure 2.08 -Mies van der Rohe, Project for Concert Hall, 1942. Museum of Modern Art (MoMA)
Source: MoMA © 2018 Artists Rights Society (ARS), New York © Photo SCALA, Florence

By contrast Ernst Sagebiel's monumental second terminal for Berlin Tempelhof was designed in the 1930s to promote the Third Reich and contribute to Albert Speer's vision of Germania. It was designed to last to the year 2000 and has a parallel to the Glen Martin factory in that everything was radically oversized. At the time of construction it was the largest building in the world with an overall length of 1200 metres. In practice it was so large and had the ability to handle vast increases in traffic that the terminal survived largely unchanged until 2007 when it closed primarily because the associated noise nuisance was no longer considered tolerable near the city centre (figure 2.09).

Figure 2.09 - Berlin Tempelhof 1939 – Source: Stefan Schulz, Welt.de – 17. 11. 2007

2.4 Conclusion

These examples raise enough doubts about Banham's despair of the quality of airport design to include the debate within a programme of research about the evolution of airport design. Banham was farsighted in understanding that the processes in changing from one mode of transport to another were to become a prime driver of airport design but he seemingly did not consider it a legitimate basis for great architectural design.

Airport design has had more than 50 years to evolve since that article was written and airport master plans and terminal designs are now often undertaken by internationally famous signature architects and engineers who can draw on a whole series of technological innovations and design philosophies that embrace growth and change.

3. The impact of design philosophies on airport design

3.0 Introduction

This chapter introduces the key airport design philosophies: Architectural Philosophy, The Futurist Manifesto and the designs of Antonio Sant'Elia, Engineering Approach, Urban Planning Vision and Multidisciplinary Design.

3.1 Airport Design Philosophies

Airport design brings together an unusual combination of architectural, engineering and planning disciplines each of which brings its own approach:

- Architects have typically focused on satisfying the travelling public with an effortless process through the terminal, despite sometimes contrary commercial pressures, and creating a look and feel that is in character with the spirit of flight and their concepts of modernity.
- Engineers have largely concentrated on improving the safety and efficiency of the operation and developing internationally recognized standards.
- Planners have been primarily concerned with an airport's location, with how it might be integrated into the fabric of society, and how passengers might transfer from one mode of transport to another. More recently they have also sought to minimize any negative environmental impacts.

While collaboration between disciplines is an essential ingredient, leadership of individual projects and therefore the design focus often varies.

All disciplines have been driven by a number of evolutionary factors:

- increasing size, weight, performance, capacity and characteristics of aircraft
- greater numbers of flights and volumes of passengers handled
- introduction of new technologies
- improving standards of safety and security
- evolving passenger expectations
- increasing commercial pressures
- innovations from airlines to gain competitive advantage
- changing perceptions of society to social, economic, political and environmental issues.

3.2 Architectural Philosophy - The Futurist Manifesto and Antonio Sant'Elia

The Futurists' "Foundation Manifesto" was published in Le Figaro on the 20th February 1909, written by Filippo Tomaso Marinetti, the founder of the movement. It was the first design manifesto to consider an attitude of mind that embraced aircraft and aviation while celebrating the twentieth century as a new machine age. The eleventh and last proposition stated:

> *'We will sing of the stirring of great crowds – workers, pleasure seekers, rioters – and the confused sea of colour and sound as revolution sweeps through a modern metropolis……….We will sing …[of]… the easy flight of aeroplanes, their propellers beating the wind like banners, with a sound like the applause of a mighty crowd.'* (Banham, 1960, p. 104)

He also foresaw the darker side of the possibilities aviation offered when he wrote that he would find his friends:

> *'Squatting fearfully by our aeroplanes…. and all, exasperated by our daring will rush to kill us, driven by hatred made more implacable by the extent to which their hearts are filled with love and admiration.'* (Banham, 1960, p. 104)

This was written just a year after the Wright brothers first toured Europe and took part in exhibitions of flying that attracted massive crowds at locations such as Berlin, Frankfurt and Reims. In 1911 Marinetti updated his ideas in "Le Futurisme" where he again celebrates the beauty of machinery where he postulates:

> *'Aesthetics, responding directly to utility, have nothing to do nowadays with royal palaces of imposing line and granite basement…………we oppose them with a fully mastered and definitive Futurist aesthetic of giant locomotives, spiral tunnels, Ironclads, torpedo boats, Antoinette monoplanes and racing cars.'* (Banham, 1960, p. 124)

The Futurists therefore envisaged an aesthetic based on technology and machinery, a philosophy that has ever since underpinned much of the best airport architecture and design. Part of the Futurist "Messagio" of 1914 to which Antonio Sant'Elia contributed includes the statements:

> *'I affirm that the new architecture is the architecture of cold calculation, temerious boldness and simplicity; the architecture of reinforced concrete, iron, glass, textile fibres and all those replacements for wood, stone and brick that make for the attainment in maximum elasticity and lightness.'* (Banham, 1960, p. 129)
>
> *'That oblique and elliptical lines are dynamic, and by their very nature possess an emotive power a thousand times stronger than perpendiculars and horizontals, and that no dynamic architecture can exist that does not include these.'* (Banham, 1960, p. 134)
>
> *'That from an architecture so conceived no stock answers, plastic or linear, could arise, because the fundamental characteristics of Futurist architecture will be expendability and transience.'* (Banham, 1960, p. 135)

These are phrases that would still resonate with airport designers today, although Sant'Elia could not have realised how apposite and prescient was the last statement.

The drawings in the 1914 manifesto included Sant'Elia's dramatic vision 'Statione per Treni e Aerei' (station for trains and aeroplanes) an imaginary multi-level interchange between road, rail and air linked by dramatic external escalator enclosures (figure3.01). It was his architectural concept for the redevelopment of Milan station and part of his vision for La Citta Nuova (The New City). It was arguably a more grandiose, monumental and static vision of the future than his manifesto suggested, but the Futurist Manifesto and Sant'Elia's words and drawings did provide an intellectual basis and inspiration for generations of architects, planners and engineers who designed subsequent airports. A more recent full translation of the Sant'Elia's 1914 Futurist manifesto is included as Appendix F.

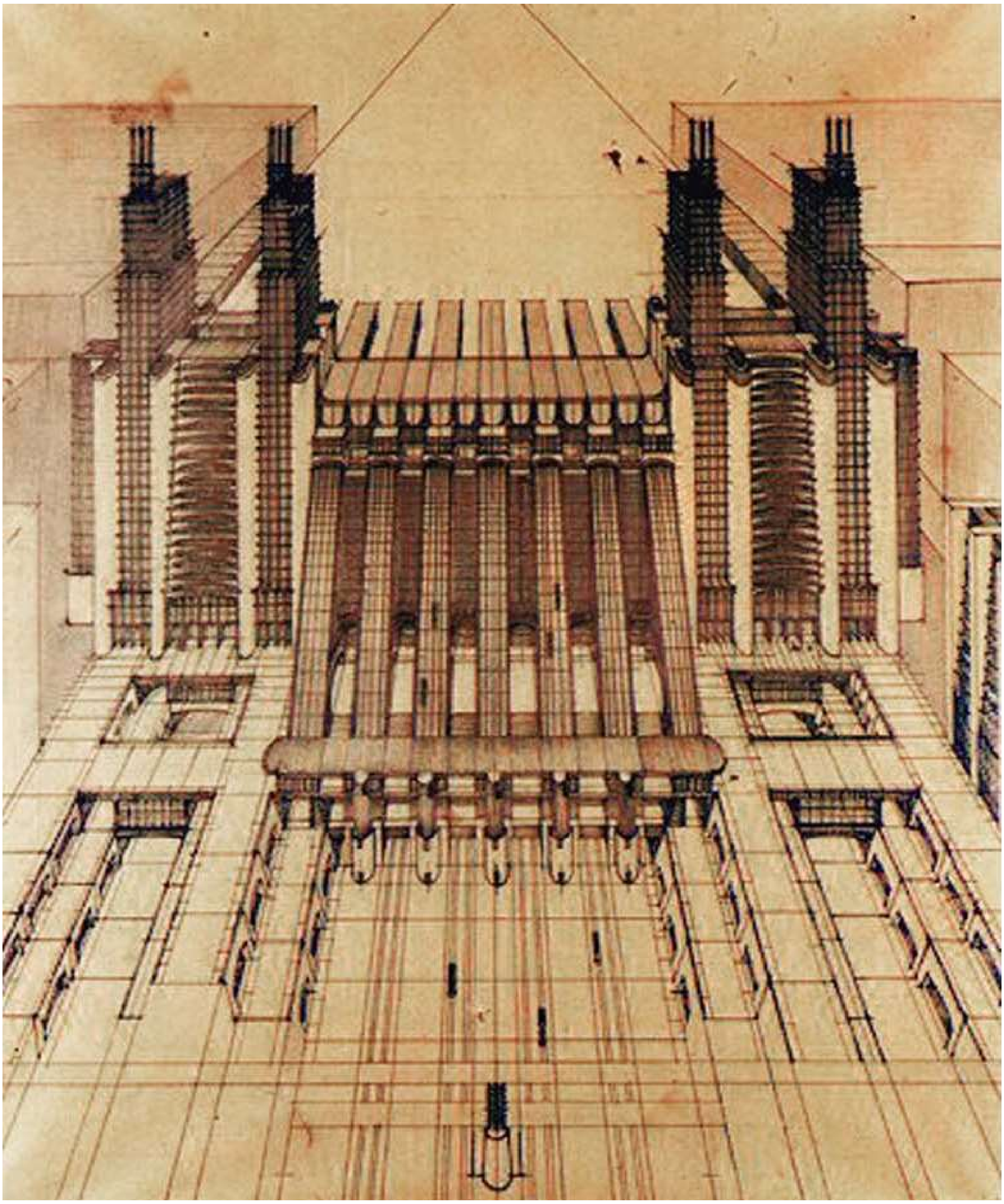


Figure 3.01 - 'Statione per Treni e Aerei'- Antonio Sant'Elia – 1914 – Source: wordpress

3.3 Engineering Approach

1919 marks the start of scheduled flying services and the signing of the first international aviation agreement, the International Air Navigation Convention (IANC) (Hanks, 1929, p. Appendix 1), the predecessor of today's international regulatory body the International Civil Aviation Organisation (ICAO). The annexes to IANC were subject to amendment by the International Commission for Air Navigation (ICAN) which set down standards and guidelines and issued bulletins to regulate civil aviation that have evolved in time to respond to the developing traffic characteristics and performance of aircraft.

In the same year Wilbur Wright somewhat optimistically argued in a special editorial for Aviation magazine that:

> *'The airplane has already been abundantly safe for flight. The problem before the engineer today is that of providing for safe landing.'* (Wright, 1919, p. 676)

Thus he attempted to transfer the focus of attention on safety from the aircraft to the airport. The engineering contribution to the evolution of airports has from the start concentrated on safety as the first priority, focused initially on organising fields for the safe take-off and landing of aircraft based on the military experience of the First World War.

Henry Ford entered the aviation business in 1924 when he took over the Stout Metal Airplane Company and created one of the earliest American airports to handle passenger services at Dearborn. He recognised that safety and the public perception of safety was a key to encouraging nervous passengers to fly. He adopted the slogan;

> *'Safety – First, Last and Always'* (Gordon, 2008)

From 1925-1931, the Ford Motor Company sponsored annual air tours to promote reliability and safety in commercial aircraft. Planes were rated on the ability to take off and land quickly and maintain consistent speeds and schedules. The following photo, taken at the end of the 1930 tour, shows the newly-built Henry Ford Museum at Dearborn in the background (figure 3.02).

Figure 3.02 - Ford Dearborn at the end of the 1930 Reliability Tour – Source: www.thehenryford.org

While the USA initially lagged behind Europe in the development of commercial aviation they brought military experience developed in the First World War to the organization and engineering design of the airfield and started to set down design and safety standards. These have been adopted and progressively updated and promulgated worldwide by organisations such as the International Civil Aviation Organisation (ICAO), which was set up as the result of the Chicago Convention of 1944.

The credit for developing the concept of runways to aid the safe take-off and landing of aircraft, which is now a feature of all the main commercial airports must be given to the US Army Air Service Engineers, working in America and looking for new outlets for their talents at the end of the First World War. Ford Airport later also pioneered a further innovation, the concrete runway.

The latter was further promoted by the Lehigh Airport competition of 1929, although there was debate at the time as to whether a grass field provided a softer, and it was argued, therefore safer arrangement for landing aircraft. Concrete or tarmac runways progressively gained the upper hand initially for departing flights and later for arrivals as the safety benefits and immunity from waterlogging in wet weather were recognised.

Engineers such as Archibald Black sometimes overplayed the safety card to promote personal agendas such as when he promoted the square airfield over the more commonly adopted circular layout, but in general the innovations promoted by aeronautical and civil engineers were geared to making airports safer places, and included advances such as airfield lighting, radio navigation, radar and satellite communications as well as the planning, design and construction standards for runways, taxiways and aprons.

3.4 Urban Planning Vision

The debate about whether to locate an airport near to the city centre or on the periphery was discussed by John Nolan in 'Airports and Airways' in 1928, in which he compared the siting of airports with previous experience of siting railway stations:

> *"In earlier days, when the railroad was in the pioneer stages, the aim was to get a central situation in a city for its stations or terminal. In more recent times it has often been found that it would be better on the whole to be farther from the centre of the city. What is true of the railroad stations is true of other semi-public buildings and municipal buildings. All have a tendency to move out. The principal of decentralization is being more and more widely applied. The reasons are: First, the increasing congestion of the built up sections of cities: second, the desire to get rid of noise and other nuisances; and finally, the new means now available in the motor vehicle for convenient supplementary, closely related transportation service.*
>
> *Consideration should be given early in the location of airports to this correlation by linking of the air service with other forms of transportation. The main point is that planning for aircraft should be related coordinated planning. After all, airports and landing fields are merely terminals or stations or transfer points in a larger transportation system.''* (Grief, 1979, pp. 84 - 85)

The concept of an airport as an interchange can also be found in the organization of the earliest air shows. The entry ticket to the Frankfurt air display of 1909 (Treibel, 1992, p. 165) included a map which showed the layout of the site with many of the key elements of the modern airport interchange, a railway station, a tram terminus, a runway and a transit system to take visitors around the site to the hangars and Zeppelin mooring point (figure 3.03).

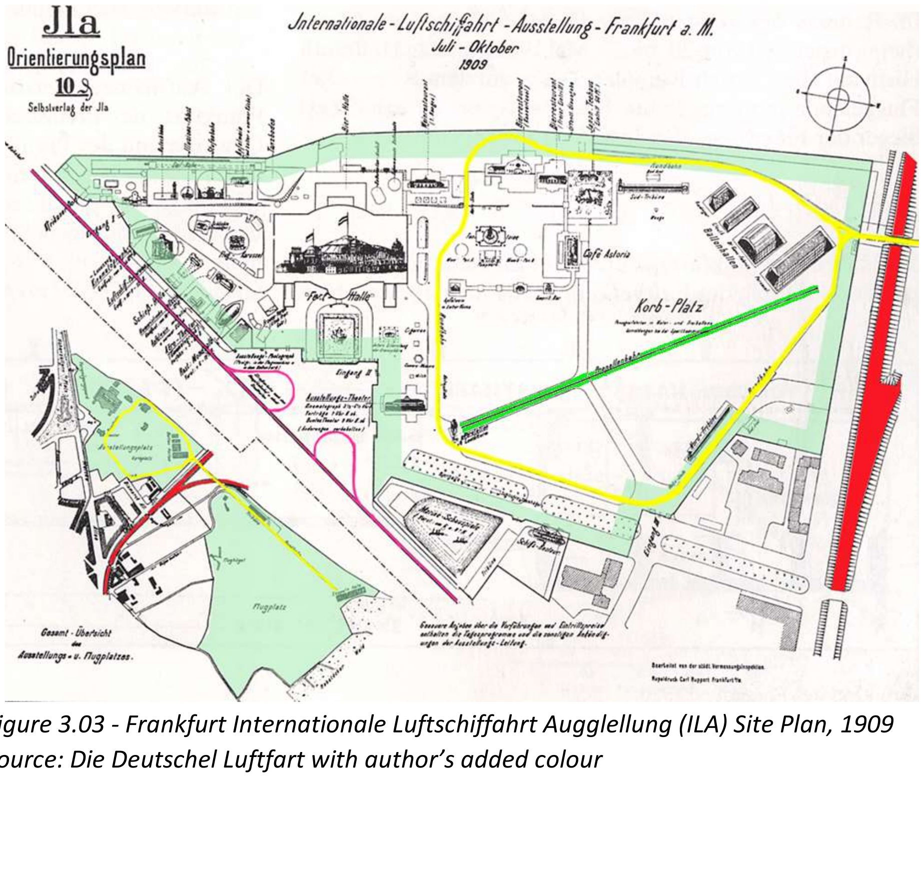
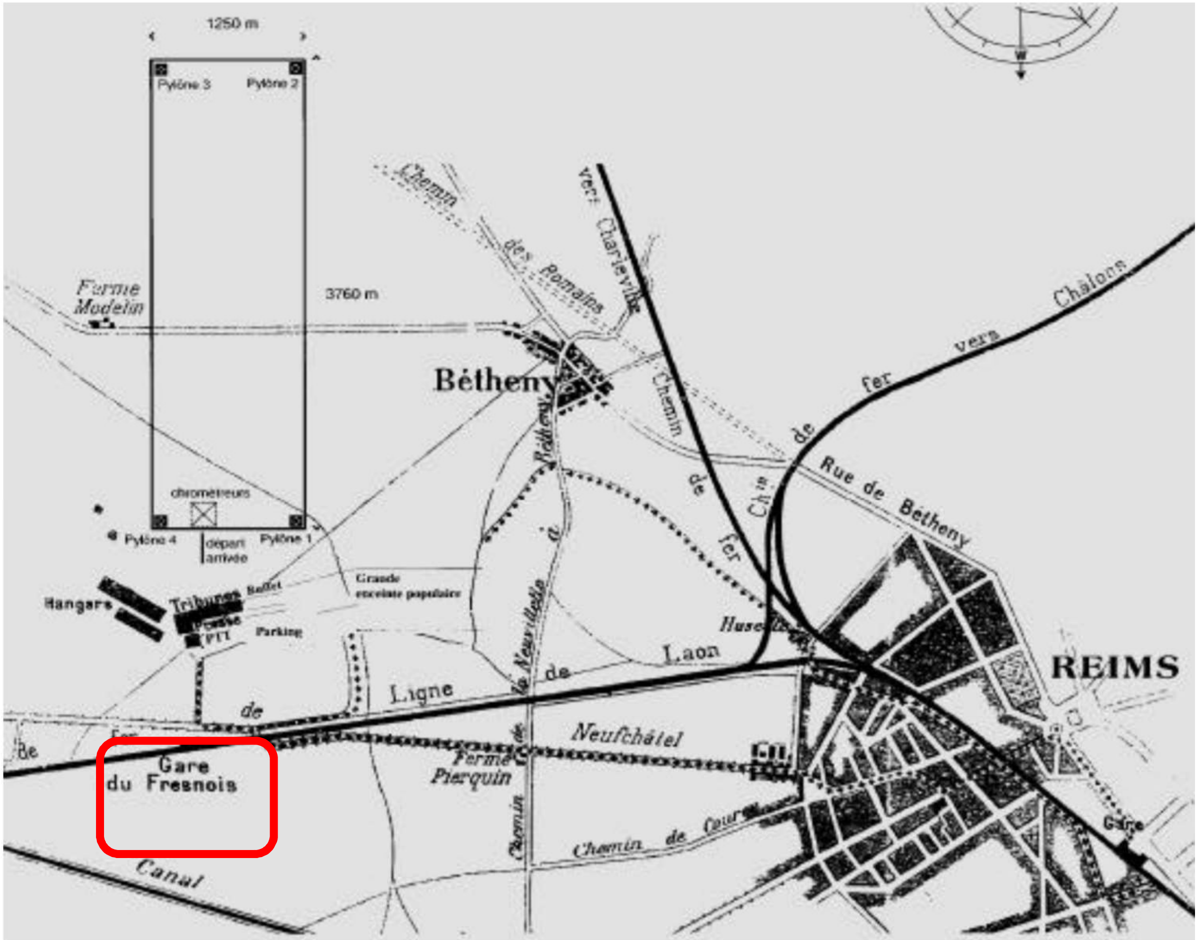


Figure 3.03 - Frankfurt Internationale Luftschiffahrt Augglellung (ILA) Site Plan, 1909
Source: Die Deutschel Luftfart with author's added colour

The same year, 1909, many of the 500,000 visitors to the famous air show at Reims, 'Grand Semaine d'Aviation de Champagne' during the week of 22 – 29 August (Grant, 2002, p. 44), reached the venue by rail via a purpose built extension to the railway with a new station, Gare de Fresnois (figure 3.04).



Le circuit de Bétheny est un hippodrome, situé au nord est de Reims. (Cliché l'Illustration 1909).

Figure 3.04 - Grand Semaine d'Aviation de Champagne 1909 – Site plan - New Station highlighted in red
Source: aviation.maisons-champagne.com

The difference between developing an urban site with good transport links, as at the Frankfurt Air show, or creating a new site away from the city, as at the Rheims Air show, and providing new transport links has been the subject of controversy ever since then and has fuelled many debates on the appropriateness and sustainability of these alternative approaches to airport siting.

3.5 Multidisciplinary Design

Le Corbusier, writing in 'Towards a New Architecture', Paris 1923 showed how important aviation was to him in formulating his architectural ideas, by dedicating a whole chapter to airplanes to justify his approach to functional design, stating that:

> *'The airplane is the product of close selection. The lesson of the airplane lies in the logic which governed the statement of the problem and its realisation'*. (Corbusier, 1923, English Edition 1927, first paperback edition 1970, p. 100)

He went on to cite the functional design of the airship hangar at Orly by engineers Freyssinet and Limousin to illustrate the new architecture. This emphasis on the interdependence of architects and engineers has characterised the development of airport planning and terminal design.

Walter Gropius was one of the first to recognise that aviation had changed the way that architecture could be viewed. In his book 'The New Architecture and the Bauhaus' first published in 1935 he wrote: *'With the development of air transport the architect will have to pay as much attention to the bird's-eye perspective of his houses as to their elevations'* (Gropius, 1935, p. 30). This concern with the aerial view has become a particular focus for airport architects and planners. Gropius was also a key proponent of the multidisciplinary approach and organised the Bauhaus design curriculum to foster cross discipline learning.

In the same year Le Corbusier published his book Aircraft in which he stated:

> *'The bird's eye view: The eye now sees in substance what the mind formerly could only subjectively conceive. It is a new function added to our senses. It is a new standard of measurement. It is a new basis of sensation. Man will make use of it to conceive new aims. Cities will arise out of their ashes.'* (Corbusier, 1935, p. 96)

In the late 1930s the design for New York La Guardia brought together architectural, engineering and town planning disciplines but added to them from the early planning stages designers of air navigation systems, and communications technology. The air traffic control tower became the focus of the airport design and a new player was introduced to the airport design team the Civil Aeronautical Authority with its overriding concern for safety.

Eero Saarinen later said when designing Washington Dulles Airport:

> *'No one asked us to grapple with the problem of a jet-age terminal beyond the question of pure architecture. But I believe the architect has to assume that kind of responsibility. Therefore, together with the team of Ammann & Whitney, engineers; Charles Landrum, airport consultant; and Burns and McDonnell, mechanical engineers, we decided to make a fundamental analysis of the whole problem and we wanted to solve it in a hard boiled way. 'We sent out teams with counters and stopwatches to see what people really do at airports, how far they walk (and) their interchange problems. We analysed special problems of jets, examined schedules, peak loads, effects of weather. We studied baggage handling, economics, methods of operations, and so on. We reduced this vast data to a series of about forty charts.'*

'We found there were three very critical areas.....the tremendous distances passengers.... would have to walk in jet terminals.....the heavy cost of taxiing jet planes.....(and) the increasing need for the greatest possible flexibility in operations and servicing of aircraft.' (Federal Aviation Administration, Department of Transportation, 1962) - See Appendix G for full text.

Airport designers would recognise the same issues today but not their solution – the mobile lounge which has been demonstrated to be flawed, slow, expensive and unreliable. Washington Dulles has since been updated with satellites served by an underground transit.

Norman Foster wrote in his 1996 essay on airports about the blurring of distinctions between the various design disciplines:

'A further shift can be discerned in the nature of such infrastructure projects. The edges between infrastructure and architecture are becoming more blurred. We can see this in structures concerned with information transmission — communication towers and platforms, for example. But we can also see it in structures for physical communication, such as the airport. Is the airport infrastructure or is it architecture? Or is it perhaps inhabited infrastructure? As these edges become less finite, the distinctions between the role of the architect, the engineer, and the other professions become similarly blurred. New infrastructure projects are typically becoming more publicly accessible, more multifunctional (and) less unidirectional. Together these trends have the potential to create a new kind of airport building.'
(Foster, 1996, p. 1)– See Appendix H for full text.

Norman Foster also pointed to a new type of airport architecture, based on the work of Buckminster Fuller, dominated by an interior experience (figure 3.05 &3.06). He wrote:

'The Climatroffice project, dating from 1971, points to a direction where the architecture is determined by a world of 'interiorised' buildings, which live within an envelope so diaphanous that its presence is perceived as being closer to the sky or clouds than to any conventional structure. The form of this minimal envelope is a manipulation of Bucky's optimum sphere, which can envelop the maximum volume within the minimum surface area. It is the sheer scale of the single volume membrane that reverses the traditional hierarchies. The mechanisms for creating order, orientation and routes through the interior space are independent of the enclosure, which from inside and out is anonymous and without scale, except for that of its surroundings which are reflected on its skin.' 'The vast new airport terminals have some characteristics in common with these Fuller-influenced visions. The form of an airport terminal is of necessity extruded to provide linear frontage and although the exteriors are closer to a traditional building, the interior is increasingly determined by an architecture of individual buildings housed beneath the protective umbrella of a vast lightweight roof. This is an approach that we pioneered with the design of Stansted, which has subsequently become a model for airport terminals worldwide.'
(Foster, 1996, p. 6) – See Appendix H for full text.

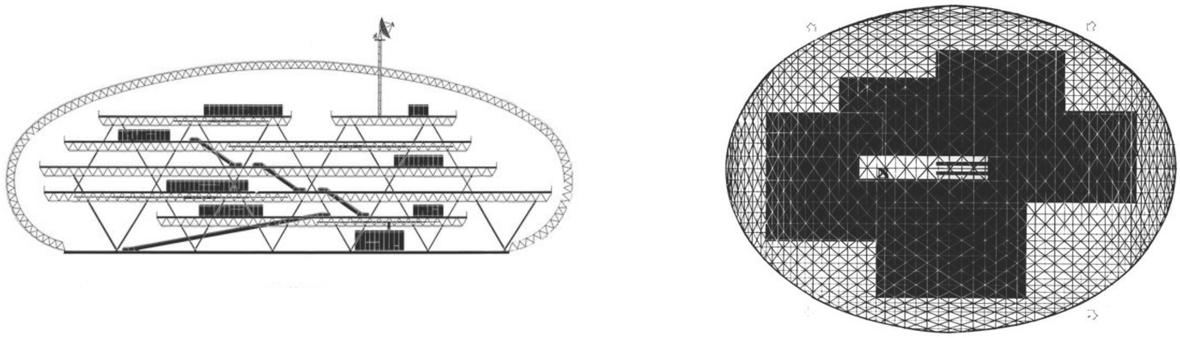


Figure 3.05 - The Climatron office – 1971
Source Foster + Partners

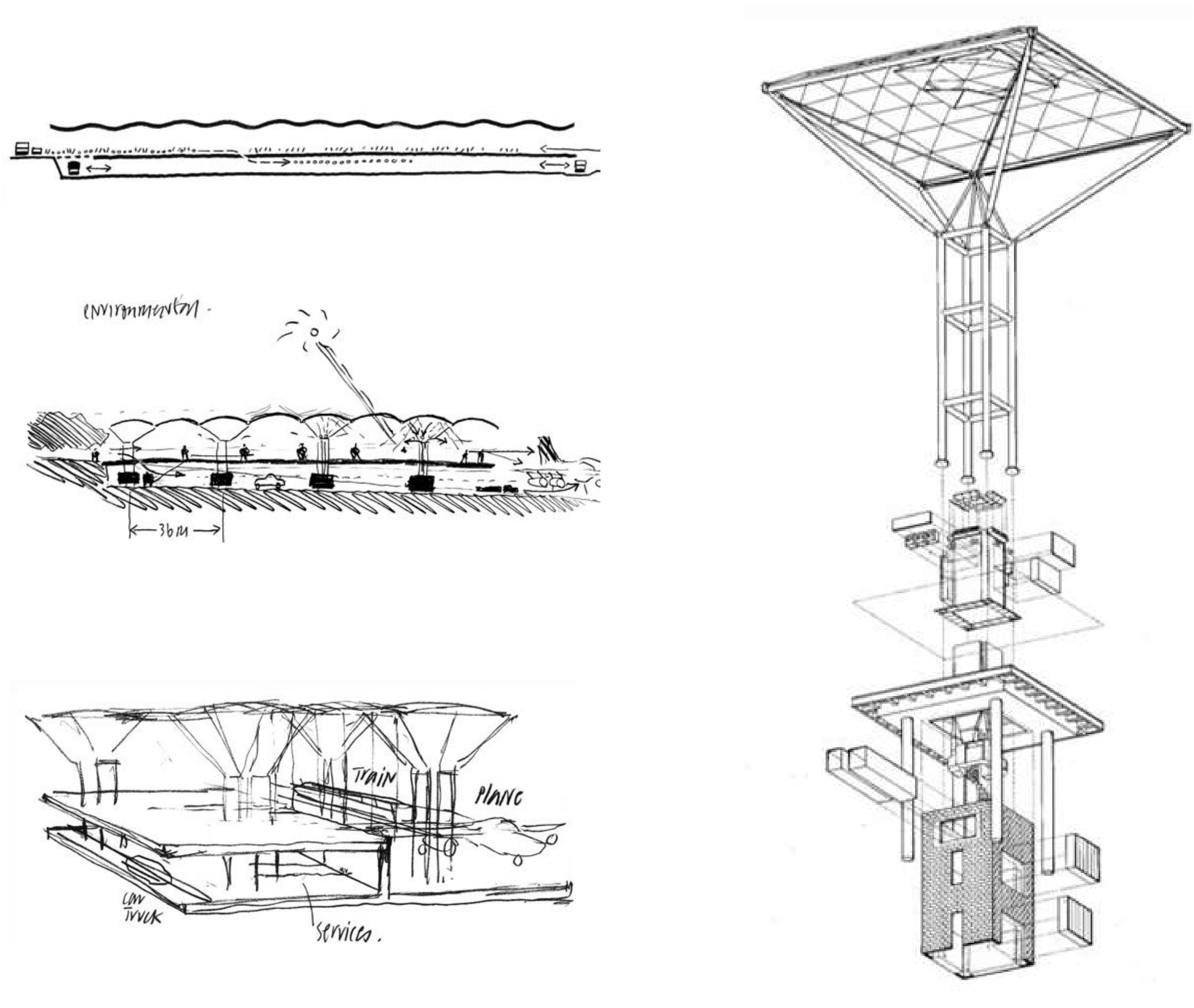


Figure 3.06 – London, Stansted Design Concepts
c1990 - Source: Foster+ Partners

Consideration of other contemporary designs indicate that Foster was perhaps over ambitious in his claims to have pioneered the lightweight roof as there were earlier precedents at St Louis and New York and parallel development at Hamburg, but he is right about the change of scale and that the interior now dominates passenger experience.

Terminals are now so large that they can only be partially understood by the passenger who can only make sense of their immediate surroundings. In this regard they can be regarded as complex city systems.

3.6 Conclusion

The multidisciplinary design philosophy developed by Foster at Stansted has had a world-wide impact on terminal design. Since then the lightweight floating roof has become a symbol of the spirit of flight, and coupled with a flexible freestanding interior fit out have become the most noticeable features of contemporary terminal design.

Mike Davies, the director leading the RSHP team, made the following comment on the architecture of Terminal 5 to Jonathan Clancy of the Guardian recognising the particular contribution of the architectural philosophy of Stansted;

'I don't really dare to make the comparison, but I like to think that we've been inspired and challenged by, well, Barlow's train-shed at St Pancras, the Galeries des Machines built for the 1889 Paris World Fair and Eiffel and Koechlin's Garabit Viaduct in the Massif Central. Oh, and of course, we've all been influenced one way or another by Stansted. '
(Clancy, 2008)

The evolution of the design for Heathrow Terminal 5 is discussed as a case study in section 11.24. Now 10 years after opening, there have been the inevitable internal changes, but the concept as represented by the exploded view of the terminal has to date stood the test of time (figure 3.07). Changes include incorporating an even more onerous security regime, an increased transfer passenger flow and a more intrusive retail layout but without significantly diluting the original concept.

The architects' preoccupation with using daylight to enhance passenger experience still rewards the passenger entering or leaving the terminal, in stark contrast to the gloomy covered interchange that was subsequently designed for Heathrow Terminal 2.

RSH+P has demonstrated that it is possible to produce great airport architecture both at Heathrow T5 and at Madrid Barajas, despite an evolving brief, and create a sense of lasting permanence and quality with a terminal concept design that is both rigorous but flexible enough to withstand subsequent changes of use. In this they are in good company with other earlier designs including those by Saarinen and Foster.

With thoughtful and skilled design, as will be seen again later in this research, the airport terminal is not inevitably a transient phenomenon that quickly becomes obsolescent. It does, however, require the collaboration of a multidisciplinary design team that is sympathetic to the lead designer's philosophy, and consciously seeks to facilitate growth and change as a response to the architectural challenge of '*expendability and transience'* envisaged by Sant'Elia.

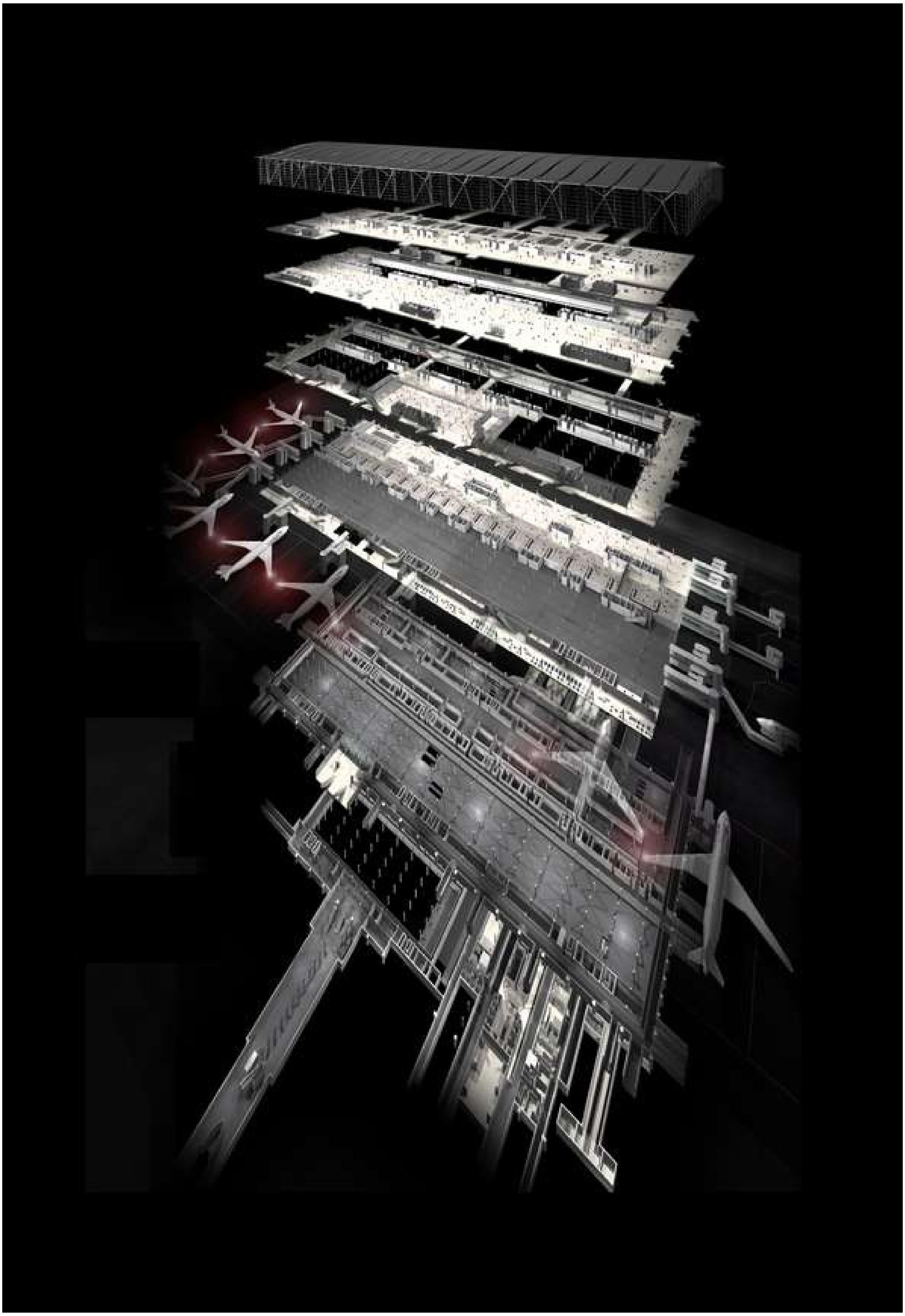


Figure 3.07 – Heathrow Terminal 5 – Exploded view of the multiple levels of Terminal 5, showing the complexity involved in housing the various passenger, baggage and transportation functions under the single 'Great Hall' roof 2005 – Source: YRM - (reproduced with permission from RMJM)

4. The influence of increasing scale and changing functional and operational requirements on the organisation and planning of airports

4.0 Introduction

This chapter summarises some of the key external influences that have affected airport design: Scale of Operation, Safety and Security, Airline Operations, Commercial Imperatives, Airfield and Airspace Requirements, Planning Considerations and Environmental Issues.

4.1 Scale of Operation

After a slow beginning, in the US for instance, the number of passengers grew fivefold from 462,000 to 1,900,000 between 1934 and 1939. Air traffic has grown exponentially since the Second World War, with volumes of passengers doubling every fifteen years (figure 4.01). This has been driven by an increase in gross domestic product (GDP), with the associated increase in disposable income, and a radical reduction in the cost of flying, due to the introduction of jet aircraft in the late 50s which doubled the speed of flights and thus increased productivity and a steady improvement in aircraft load factors (Bowen, 2020). Statistics of world airline traffic growth between 1929 and 2018 are set down in Appendix K.

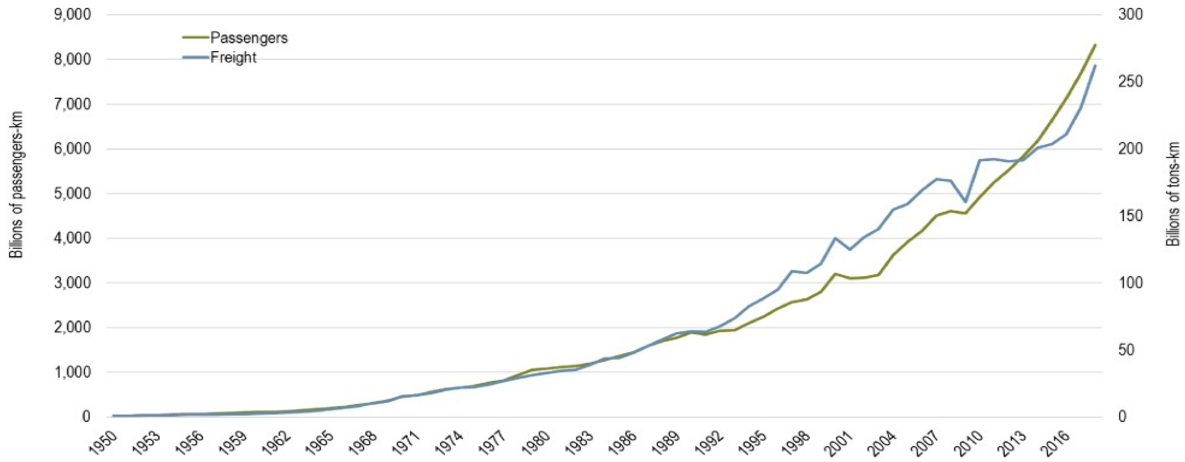


Figure 4.01 Historic Air Traffic Growth – Source: Airlines for America via 'The Geography of Transport Systems'

The greatest influence on the evolution of airport design is undoubtedly the increase in the scale of operation and volume of traffic handled; it has led to a constant evolution in the design approach to the terminal, the airfield and urban planning. Quite simply, designs that work at a certain small scale often no longer work as the scale of operation changes.

The evolution of Schiphol airport, the oldest airport in the world, having reached its 100th year of commercial operation shows this in practice. It started as a small muddy field on land that was reclaimed from the sea. It covered just 76 hectares and has progressively expanded ever since and is now some 2,700 hectares or nearly 40 times larger, has 6 runways and a terminal that handles over 50 million passengers a year. It is with good reason that Schiphol uses as its motto, '*Never finished but always ready*', (Benthem, 2013, pp. 130-131) for they are currently planning to expand it further beyond today's 80 million passengers a year (figure 4.02).

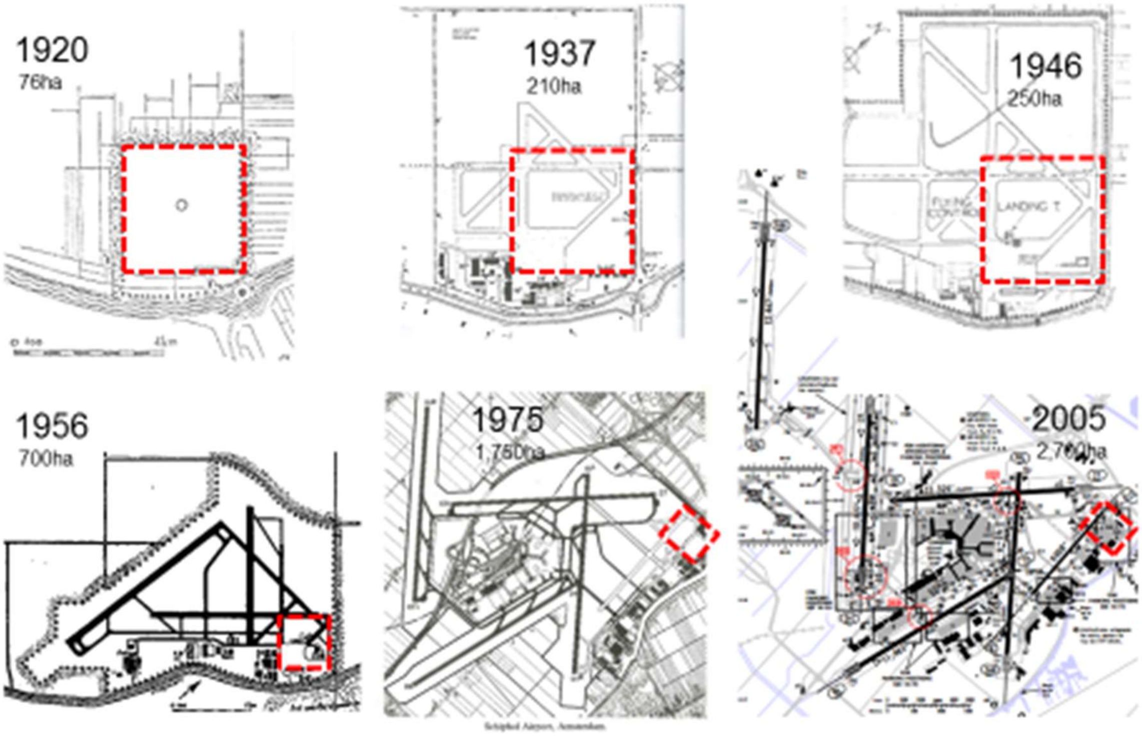


Figure 4.02 – Amsterdam, Schiphol Airport – Growth 1920 – 2005 - Authors Analysis: Red outline represents the original 1920 site

The change in scale of aircraft has provoked many of the step changes in the evolution of airports. The earliest planes were very flimsy, light and vulnerable to cross winds, hence the first building type to appear at airports was the hangar to shelter the aircraft in unfavourable conditions. The first commercially successful airliner (ie one that did not require a subsidy to operate) was the Douglas DC 3, first delivered to American Airlines in 1936. It could carry up to 36 passengers but its size and weight was already imposing a strain on grass airfields leading to the steady adoption of hard surfaced runways.

Following generations of aircraft increased in size and weight even further, with step changes when four engine aircraft were introduced, again with the 707 jet, the 747 jumbo and the A380 superjumbo. Each step required the reconfiguration of the airfield and at least parts of the terminal to accommodate the larger sizes and increasing weights of aircraft.

The changes in aircraft sizes also affected terminal design as seating capacities of aircraft have progressively increased to over 500 passengers per flight on an Airbus A380. The increasing frequency of flights has also directly affected terminal design as more passengers have to be handled every hour.

An early schedule at Croydon Airport reveals that there were about ten flights a day handling on average about a dozen people each, about a hundred and twenty passengers a day, while today Heathrow handles about 1400 aircraft a day each holding on average 160 passengers or over 200,000 passengers a day. It is this change of scale that has been the primary influence on the development of different terminal organisational concepts as designers needed to increase the perimeter of the terminal to provide an interface with the growing numbers and sizes of aircraft.

4.2 Safety and Security

The introduction of security comes comparatively late in the development of airports in response to the increasing numbers of hijackings in the 1970s. Safety and security standards have gradually grown more stringent as legislators and aviation authorities have sought to respond to events. For example both people and their hold and hand baggage now have to be security screened.

The initial challenge was to frustrate potential hijackers carrying guns or bombs onto aircraft. Later the focus switched to preventing terrorists taking over or blowing up aircraft, or even launching rocket attacks from outside the airport.

After the bombing of a Pan Am aircraft over Lockerbie in December 1988, the International Civil Aviation Organisation (ICAO) adopted an eight-point aviation security plan that became the basis for improvements in aviation security throughout the world: screening of checked passengers' baggage, baggage reconciliation, screening of cargo and mail, control of access to sensitive areas at airports, carriage of items that cannot be easily opened, better detection of explosives, building security into the design of aircraft, strengthening of the powers and organisation of ICAO to enable it to implement more actively the safety standards (Butcher, 2011).

While some airports had already introduced x-ray screening this mandated the general introduction x-ray scanning of all hold baggage. Initially x-ray machines were introduced in a variety of locations, at the main entrance, limiting entry to the terminal to passengers only, at check-in which involved introducing bulky equipment adjacent to the check-in desk or as part of the baggage system. The latter has become the norm and has progressively resulted in much enlarged and more sophisticated baggage screening systems.

Since January 2001 it has been a legal requirement for security-screened passengers to be separated from arriving passengers in the UK. However, while UK airports have agreed time scales to achieve that, it is not done at all airports. In the meantime, compensatory measures, such as extra gate searching, are in place.

As the result of the terrorist attack on New York and Washington of 11th September 2001 the Transportation Security Administration (TSA) took over aviation security in the United States and imposed a series of requirements to screen passengers and luggage including the mandatory electronic inspection of all hand and hold baggage. Advanced screening technologies have been now been introduced to screen for non-metallic threats such as powder or liquid explosives.

More recently attention has switched to preventing vehicles being used as truck bombs and being driven into the terminal, and to stopping terrorists blowing themselves up on busy concourses. In the UK this had led to the construction of barriers to keep vehicles over 30 metres away from terminal entrances. The introduction of security checks has arguably given rise to the greatest change to the character of a terminals in the last hundred years, changing the departing passenger experience into a long and really quite intrusive process (figure 4.03).

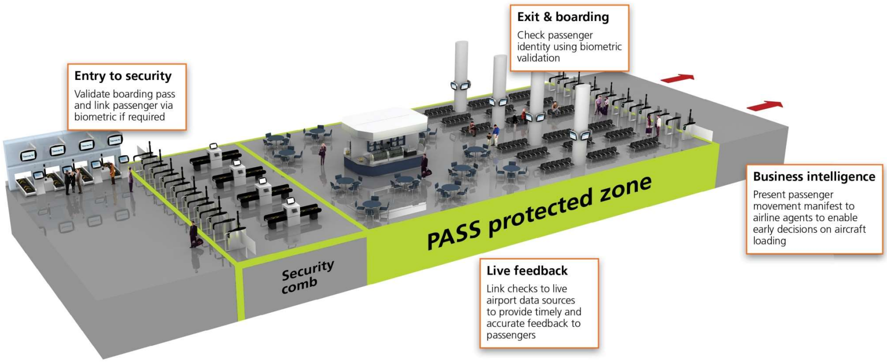


Figure 4.03 - Heathrow Passenger Authentication Scanning System (PASS) 2018 - Source: Atkins

4.3 Airline Operations

Airline operations have progressively become more focused and specialised, with Global Alliances, Niche Airlines, Low Cost Carriers and Inclusive Tour Operators having different operational requirements and varying customer service perspectives, that affect not just the terminal but the apron and stands and the airport operation overall. No longer does one size fit all, either in terms of facility provision or performance standards or indeed willingness to pay (figure 4.04).

Figure 4.04 – Cartoon illustrating the characteristics of Global Alliances, Niche Airlines, Inclusive Tour Operators and Low Cost Carriers 2006 – Source: YRM – Graphics: Bo Mahaddie (reproduced with permission from RMJM)

Legacy or full service carriers had their origins in Europe as government subsidised organisations that 'flew the flag' and sponsored national technological advancement. These include Imperial Airways, and its successor BOAC, BEA and latterly British Airways, KLM, Lufthansa and AirFrance. For many years their key objective was to enhance the prestige of their home country without a particular focus on profitability. Quality of service rather than efficient operation informed airport design, but all that was revolutionised by privatisation.

In the USA initial development involved the vertical integration of aircraft manufacturers and airlines until government intervention forced the separation of Boeing Airways from the manufacturing parent company to become United Airways. Initially loss making passenger handling was heavily subsidized by the airmail service in the USA, but as larger aircraft such as the DC3 were introduced passenger services could be self-supporting. Airlines in the USA have always been very influential in the development of airport concepts. These initiatives have all had a profound effect on the design of airports and terminal buildings, particularly in the United States where the norm is for terminals to be designed for and by individual airlines.

For example:

- Pan American designed the first terminal for an individual airline at Miami in 1930.
- American Airlines opened the first airline lounge at La Guardia in 1939.
- United Airlines proposed the concept of the unit terminal in 1944.
- Eastern Airlines explored the concept of both the pier and the aerobridge in 1946.
- Delta Airlines pioneered the hub and spoke concept at Atlanta in 1955.
- South West introduced the low cost carrier (LCC) concept of point to point travel from Dallas Love Field in 1979, following the Airline Deregulation Act of 1978.

The idea of integrating land and air travel was initially a uniquely European concept. For the pioneering scheduled services operated by Deutsche Luft-Reederei (DLR) and later Lufthansa passengers were picked up from home by a chauffeur and provided with special protective flying clothing. Imperial Airways ran coach services from the London headquarters at Victoria to Croydon Airport from 1924.

Integrated air (day) and rail (night) services were inaugurated in the USA by Transcontinental Air Transport (TAT) rail air service on July 7th 1929. The service was unique in that traveling passengers would take trains operated by the Pennsylvania Railroad and Santa Fe Railroad to travel at night by Pullman car and then board one of TAT's Ford Tri-Motor aircraft during the day to continue their trip. As early as 1936 it was possible to travel by an integrated rail and air ticket from London Victoria to Gatwick and then to Paris by British Airways. More recently Lufthansa have introduced integrated rail and air services in Germany where the rail services are actually allocated a flight number.

Among full service carriers the development of multiple classes of travel, has led to the provision of differentiated services within the terminal. For example British Airways introduced a dedicated check-in zone in Heathrow Terminal 3 (1976) for Concorde passengers linked by an exclusive staircase to a segregated lounge. The development of differentiated services has become more ambitious culminating in the provision of complete floors for Emirates Business and First passengers at Dubai Airport.

South West Airlines pioneered the development of no frills point to point services, using existing secondary airports such as Dallas Love, Houston Hobby and Chicago Midway airports. They, along with other Low Cost Carriers (LCCs), such as Ryanair and EasyJet, have led airport and terminal design in a different direction. Instead of competing with ever more elaborate product offers, simplification, speed and economy have been the drivers. The much copied South West strategy was to fly one type of aircraft to keep down engineering costs; keep overheads low; turn aircraft around as quickly as possible; and forget loyalty or air miles schemes. While they typically make use of underutilized existing airports some new terminals such as Brussels Charleroi, Bordeaux Billy and Copenhagen Go have been built. These terminals return to an earlier generation of simplicity and are typically laid out on a single level. While they contain some of the retail and catering facilities of main stream terminals they typically employ lower space standards and lower quality finishes (figure4.05). They make heavy use of new digital technology such as self-service and internet check-in to reduce staffing levels and space requirements.

Short haul LCCs have standardised their aircraft fleets either to Boeing 737 or Airbus A320 type aircraft. This has in turn allows the standardization of the aircraft stands on the apron. The need for speedy and low cost boarding procedures means that LCCs typically avoid the use of air bridges, and require passengers to walk to the departing aircraft, to climb steps to board through front and the back of the plane simultaneously. On arrival they unload using a similar approach in reverse (figure 4.05).

Figure 4.05 Brussels, Charleroi, Low Cost Terminal showing the standardised walk in/walk out apron, and the lower standard of finish to commercial offer c2015 – Sources: Tripsavvy, meggaconstrucciones.com & Charleroi

Long haul LCCs are still in their infancy, with airlines such as Air Asia X and Norwegian pioneering their development. A list of emerging long haul low cost airlines is included in appendix D. One terminal specifically designed for LCCs, the Budget Terminal at Singapore has proved to be very short lived. Opened in 2006 and formed from a converted warehouse it closed again in 2012 (figure 4.06). It has been replaced by a conventional terminal with full air bridge service, perhaps because the Budget Terminal’s operation coincided with a noticeable drop in passenger satisfaction ratings. Satisfaction ratings improved again followed its closure despite the resulting reduction in overall capacity.

Figure 4.06 - Singapore, Changi Budget Terminal 2015 – Sources: destinasia.com and Flickr

4.4 Commercial Imperatives

Commercial imperatives have always driven airport design, but priorities have changed over time. In the 1920s and 30s the major source of income came from spectators not passengers so terminals had to be designed to suit the large crowds of people who gathered for air shows and just to watch the spectacle of aircraft taking off and landing. Later the focus shifted to dining as airports sought to make themselves a destination for people to visit. In Europe during this period airport developments and operations were heavily subsidised as a part of national aviation development strategies and at least in Germany as a cover for re-armament.

Privatisation in the 1980s brought a radical change to the financing of airport development. For with privatisation came economic regulation of airport charges. Airports, with the then British Airports Authority (later BAA) to the fore, recognised that retail activity was not then covered by the regulations. The Authority developed the retail offer in a way that radically affected the way terminals were perceived and experienced by passengers. It has changed the experience of the terminal departures lounge from an outward looking building to an inward looking shopping centre.

Property opportunities have also influenced airport design, as hotels, offices and especially car parking have contributed to making airports profitable enterprises. Commercial income now often generates more than half an airports total income and is very important in cross subsidising other airport charges and is therefore a prime briefing consideration.

While there has been convenience retail and catering offers from the beginning of air travel, the major innovation of the 1980s and 1990s, by BAA, was to introduce high street brand names. Terminals are now provided with much more retail than lounge space, and particularly for those going on holiday the retail offer is often valued as an integral part of the passenger experience.

To encourage higher levels of spending concepts such as the walk through duty free shop and deliberately extended walking routes with diversions to pass as many shops as possible to create the maximum footfall have been introduced. It is interesting to note that the internationally respected passenger experience survey Skytrax, ranked Heathrow's Terminal 5 as both the best terminal in the world in 2016 and the best shopping experience in the world for several years indicating that many passengers do value shopping as an inherent part of their travel experience (figure 4.07).

These commercial trends are discussed in Chapter 5 - The evolutionary trends in master planning, terminal layout, sectional development and architectural expression of terminals.


Figure 4.07 - Heathrow Terminal 5 Departures lounge surrounded by retail and catering 2008 - Source: Flickr

On the other hand Paul Andreu, formerly chief architect of ADPI, spoke of commercial development at airports in the following derogatory terms:

'The very first commercial airports started to appear in the 1920s. So by 2000, working on airports for almost 40 years, I was involved in designing this building type for half of its existence, and it really started to grow and change dramatically right at the time when I started. Airports no longer change; they just grow in size; there is no new concept. And, unfortunately, now many seemingly different building types converge around shopping experience. So many projects have become very commercial. There are airport versions of commercial malls, railway station versions, museum versions... Everything is a commercial centre.' (Belogolovsky, 2017)

4.5 Airfield and Airspace Requirements

Airfield design has also evolved to make the movement of aircraft on the ground and in the air safer, generating requirements for ever more sophisticated and reliable navigation aids. These aids have taken the form of air traffic control towers, radio, radar and other communication devices, airfield ground lighting and navigation lighting to assist night flying. These all affect the layout, design and appearance of airports.

For example there are over 14,500 lights in Changi's airfield, across the taxiways and two runways. When the three-runway system is completed, the number will almost double to 25,000 airfield lights.

Among them, there are more than 20 types of airfield lights in different colours and combinations, each serving a different function. Besides those that light up the runways and taxiways, some are specially designed to aid pilots in landing at the touchdown zone, while some are for traffic control and guidance. For example, threshold lights, which are green, indicate the start of the runway, while runway end lights are red.

The variety of colours helps pilots navigate their way around the airfield. This is especially important at night and during periods of low visibility and adverse weather conditions, such as heavy rain. An example would be the runway centre line lights. These white lights which are usually 30m apart, indicate the centre of the runway. In the last 900m of the runway, these lights alternate between red and white, allowing the pilot to be situationally aware. The red runway centre line lights at the end warn the pilot that he is approaching the last 300m of the runway (figure 4.08).

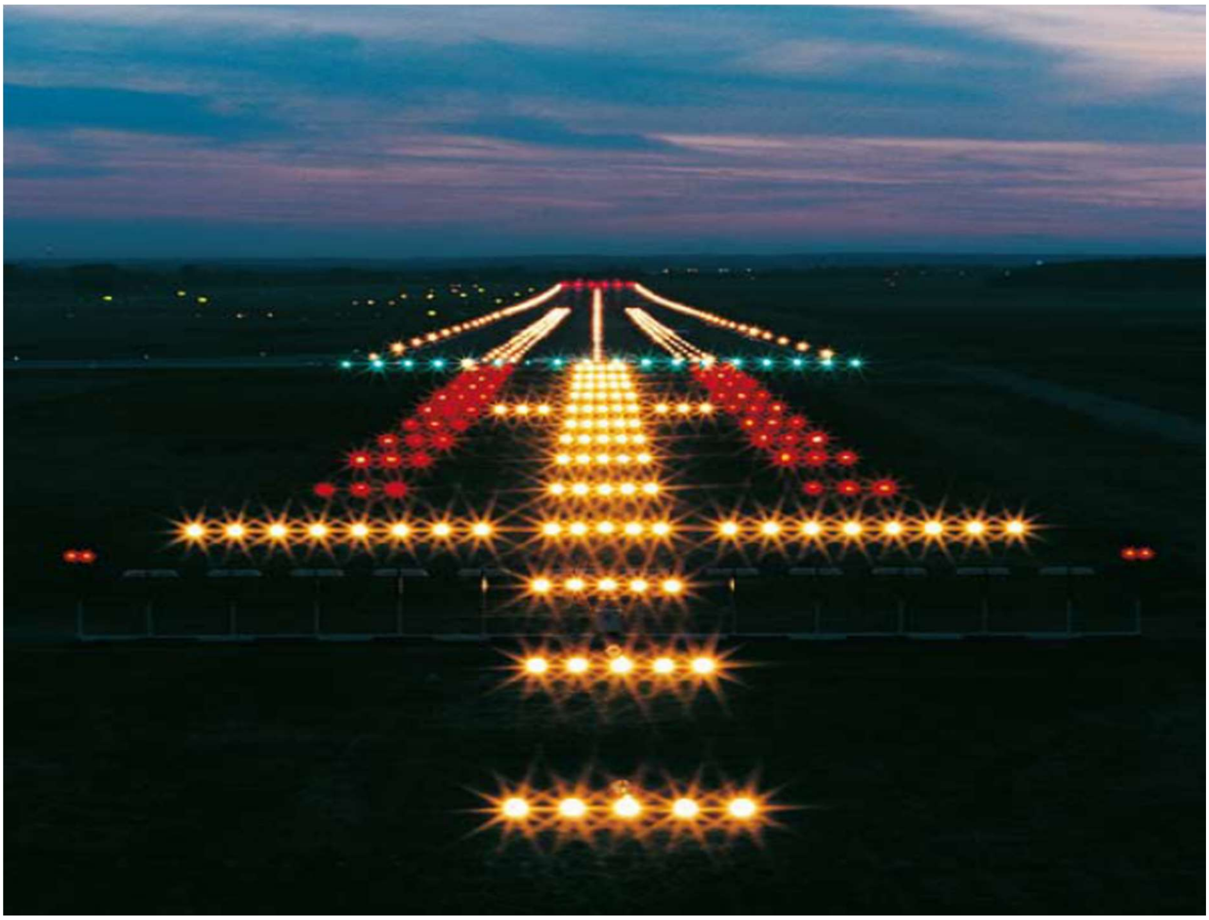


Figure 4.08 - Runway Approach Lighting c 2010 – Source: Changi Airport Group

The common factor behind all these innovations is the drive for operational safety, reliability and resilience while handling ever increasing volumes of traffic. Another factor that has led to innovation in this field is reduction in operational cost as can be seen by the introduction of remote air traffic control operations.

These issues are discussed further in Chapter 7 –The Engineering Design of the Airfield

4.6 Planning Considerations

Higher volumes of traffic and the choice of more remote locations for new airports have increased the emphasis on planning for the provision of rail links and other public transport networks. Occasionally airport locations have been chosen that are simply too remote, the most notorious being Montreal Mirabelle (1975) that closed to passenger traffic after most airlines refused to move from Dorval Airport. These issues are discussed further in Chapter 8 – The Airport as an Interchange and Chapter 9 - Airport City and Aerotropolis

4.7 Environmental Issues

Environmental considerations have also played an increasing part in the choice of airport sites and the extent of mitigation measures. Noise has from the beginning been the biggest objection to airports. The first recorded objection being a 1924 letter to The Times complaining about flying activities at Croydon Airport.

The annoyance and scale of protest increased radically with the introduction of jet aircraft in the 1950s. The siting of airports, orientation of runways and operational restrictions to reduce noise impact are now a major factor in airport design. More recently emissions and the resultant air quality have become increasingly important for airports located close to conurbations. The impact of aviation on climate change is also affecting the design of airports. They now seek to reduce emissions and be greener.

The following topics appear to be the primary focus for environmental management at airports: noise, air quality, carbon emissions leading to climate change, ecology/biodiversity, water, and waste management.

Airports, supported by the international organisations ICAO and IATA, have sought to widen the definition of sustainability beyond that of environmental impact to include social and economic benefits as a counterbalance to the negative impacts. Politicians now have to balance these negative impacts against the economic benefits and job opportunities that airports create. Airport design is now an intensely political activity.

In many developed countries, there is significant and increasing opposition to airport expansion on environmental grounds. The primary arguments used include:

- The internet is reducing the demand for face-to-face business meetings, particularly as demonstrated by the response to the Covid 19 pandemic, and airports have been adept at increasing volumes of traffic within their existing boundaries.
- Alternatively, some argue that demand should not be met or it should be diverted to other secondary airports with room to grow.
- People should restrict travel to limit climate change to which aviation is an important and increasing contributor. Carbon trading is not accepted as an appropriate response.
- Public transport such as high speed rail should be taken in preference to air travel as being more environmentally responsible.

Environmental and sustainability issues are discussed in Chapter 9 - The Challenges of Environmental Sustainability.

4.8 Conclusion

The key external influences that have affected airport design have been identified in this chapter: Scale of Operation, Safety and Security, Airline Operations, Commercial Imperatives, Airfield and Airspace Requirements, Planning Considerations and Environmental Issues. The followings chapters will consider the design responses to these challenges and identify when a change of concept is indicated as a result.

5. The opportunities offered by technological innovations to airport development

5.0 Introduction

This chapter discusses some of the major technological innovations that have enabled the advance of airport design: Air Navigation, Communication, Mechanisation, Automation and Digitisation. In considering the evolution of airport design it is also informative to consider technological ideas that did not catch on or were short lived and have therefore not formed part of the mainstream of airport development, because not everything that is technically possible is appropriate for an efficient operation. Persistent ideas include, the circular runway, the floating airport, the drive-through airport and mechanical movement of aircraft.

5.1 Air Navigation

Air traffic control towers originally took inspiration from a ship's bridge or a lighthouse, as at London Croydon (figure 5.01), to provide an observation platform of the airfield and were supported by back rooms housing radio and direction finding equipment (Stroud, 1973). One of the first was built at Berlin Tempelhof (figure 5.02), in advance of the main terminal as a relatively low freestanding structure with a glazed observation platform at the top. Initially they were often integrated into the terminal building and provided a vertical feature in the composition of the terminal as the asymmetrical layout at Amsterdam Schiphol (figure 5.03).

Figure 5.01 - London, Croydon 1928 Source: wordpress.com

Figure 5.02 - Berlin Tempelhof 1928 Source: Flickr

Figure 5.03 - Amsterdam, Schiphol - 1928 Source: Pinterest

Later they became freestanding, as at Heathrow (1955) (Flight, 1955) and Gatwick (1958) (Powers, 1992) where they were located to provide a vantage point view of the whole airfield and the runway ends in particular.

In 1962 the FAA commissioned I.M. Pei to design a standardised independent air traffic control tower, of which 16 out of the original commission of 70 were constructed (Herberta, 2016) (figure 5.04).

While there are good functional arguments for the separation of control towers from terminals from the viewpoint of long term flexibility this separation can also be seen as a reflection of the separate funding of control towers by the FAA while terminals were funded by the airlines. Subsequent control tower structures have typically been designed as free standing structures either in concrete as the I M Pei design but also in steel as the Richard Rogers design for the control tower at Heathrow constructed as a part of the Terminal 5 project (figure 5.05 & 5.06).

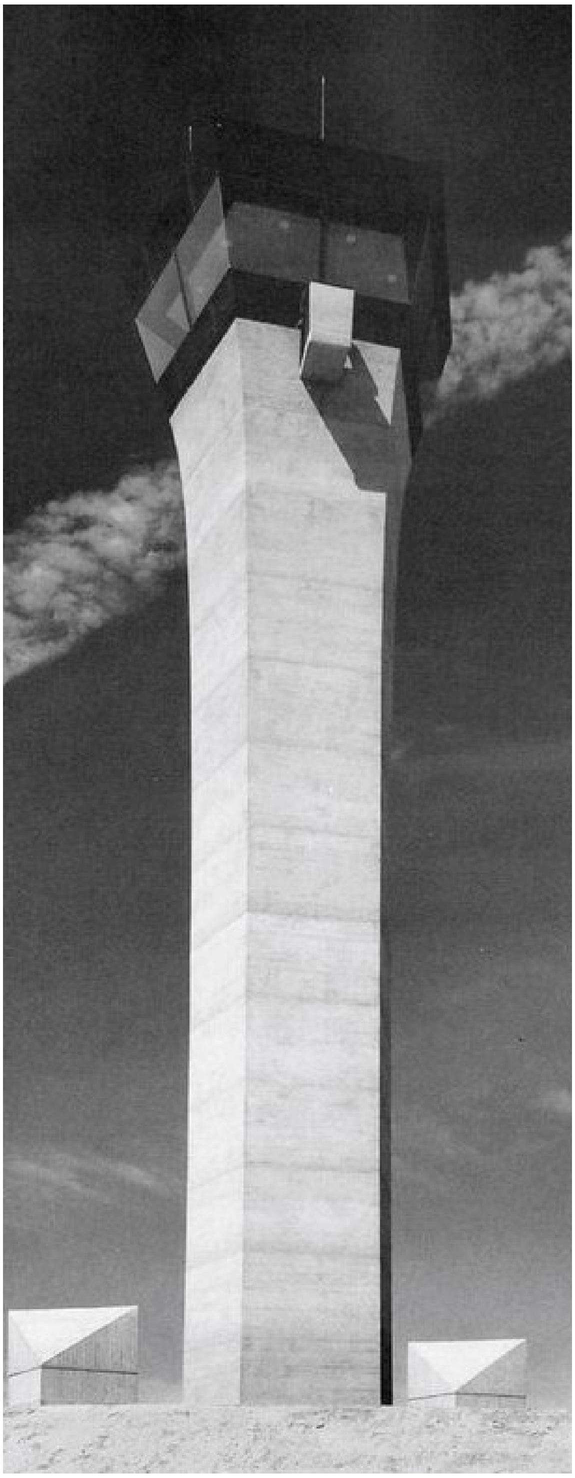


Figure 5.04 - FAA Control Tower, IM Pei 1962 Source: Reddit architecture

Figure 5.05 - Heathrow control Tower, Richard Rogers 2007 Source: Pinterest

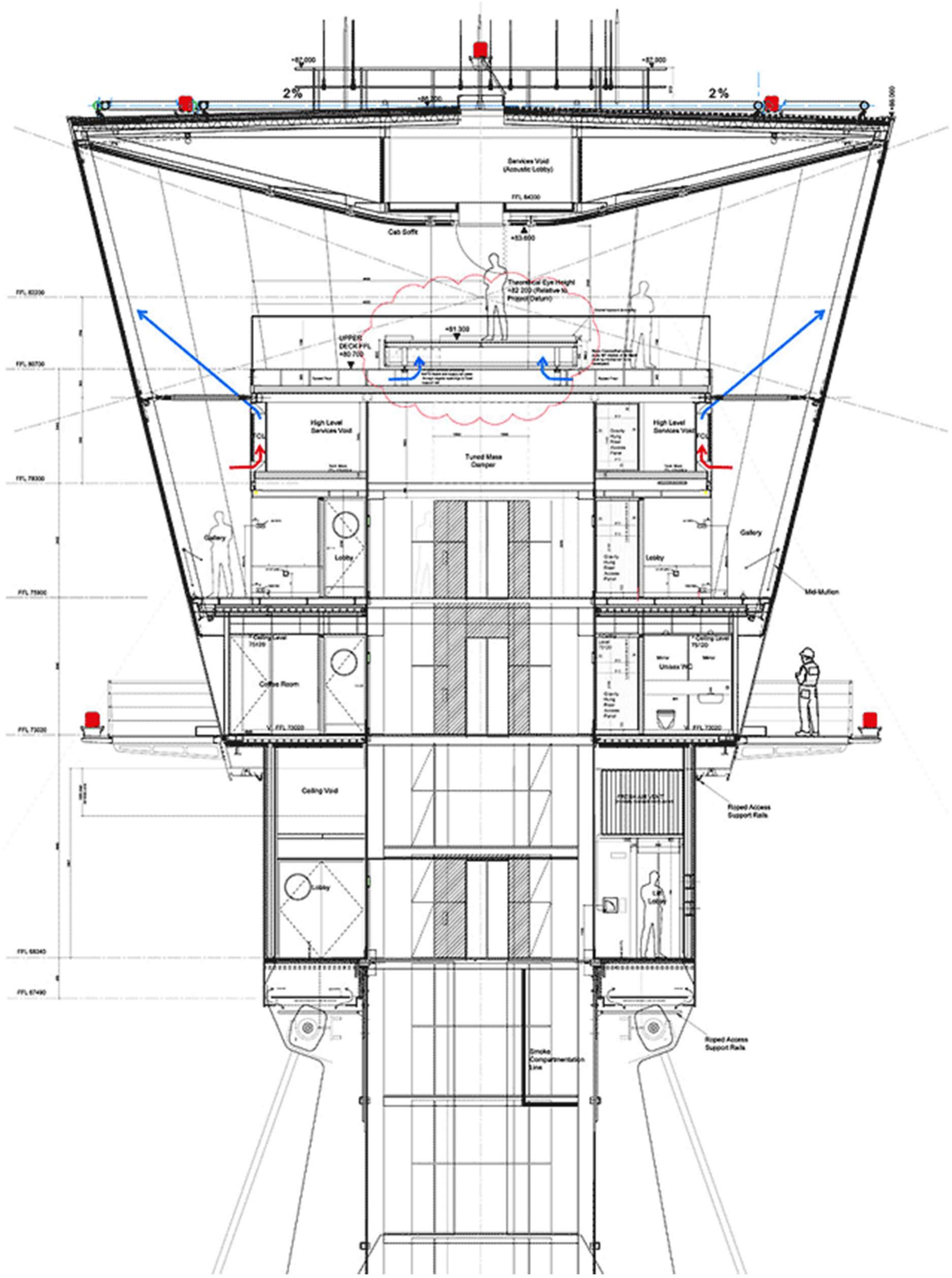


Figure 5.06 LHR Control Tower Cab Section 2007 - Source: RRP (now RSHP)

The photograph and section show how much attention was paid to the downward view to allow controllers to see the apron immediately below as well as the more distant view of the runway (5.07).

Figure 5.07 - Heathrow Control Tower Visual Control Room 2007 – Source: Airport Focus International

There is an increasing interest in digital remote towers as a replacement for primary visual control towers. In 2009 Heathrow's virtual contingency facility was the first virtual tower to receive certification to provide contingency operations if the main visual control tower became inoperable. This virtual tower can provide air traffic control services at up to 70% of the capacity of the main tower and was thus considered a better investment than a secondary physical control tower.

Omskoldsvik Airport in Sweden was the first to use a remote tower as a primary tower and there are now several other test sites around the world. In May 2017 NATS announced London City Airport will become the first in the UK to use a remote tower as its primary control tower. A prototype system is already in place and there are plans to move operations from the existing visual control tower. (Mason, 2018)

Unlike physical control towers, the electronic communications systems are highly dependent on data links that transmit the information from the CCTV cameras to the remote control room, so are more vulnerable to cyber-attack. However, commercial pressures will mean it is inevitable that remote towers will be more widely adopted and change the landscape of many airports for ever, potentially ending the competition to build the tallest or most exotic tower. This could be the beginning of the end for that most iconic of airport symbols the control tower.

5.2 Communication

Flight information was relayed to passengers with chalk messages handwritten on a blackboard at the first Croydon Airport in the early 1920s (Hooks, 1997). This included recording a flights progress as it passed over the English Coastline.

When the new terminal opened in 1928 (Hooks, 2002) the major innovation was a novel form of displaying flight arrivals and departures using multiple clock faces on a freestanding purpose made piece of furniture. Changing weather information was kept up to date on a giant wall display in the departures concourse, indicating just how vulnerable early aircraft were to adverse weather.

The 1950s and 60s saw the introduction of large format flight information boards, most memorably in the futuristic display at Saarinen's TWA terminal at New York JFK (Stoller, 1999). Standard signage using both upper and lower case San Serif black letters and internationally recognizable pictograms on a yellow background was introduced at Gatwick in 1958 and widely adopted by others (King, 1980).

To provide information coverage over a wider area including spaces with lower ceilings, especially catering outlets where passengers might linger and delay flights, TV monitors were introduced. These have more recently been updated to flat screen LED monitors. The latter have almost entirely superseded large format screens as they are more economical and flexible. The most recent stage has been to introduce interactive and personalized information via wireless networks to mobile phones.

5.3 Mechanisation

All early terminals kept passenger movement at a single level, but the introduction of lifts and escalators in the 1950s facilitated level changes as can be seen at the Heathrow Europa Passenger Building (1955) (Chandos, 1956) and St Louis Lambert Airport (1956) terminal (Pickens, 1956). The next step can be seen as the introduction of the passenger conveyor at Los Angeles International Airport (1962) which made longer travel distances more palatable (Blankenship, 1974, pp. 82-83; Department of Trade, UK, 1974).

The introduction of aircraft boarding bridges has also had a significant impact on terminal design, by raising the height of passenger movement to approximately aircraft sill level, and is discussed in section 6.11 Dry Boarding.

Mechanical baggage handling has also transformed the way terminals are laid out both in plan and section. Early examples of mechanization can be found at Tempelhof (1939) (Hecker, 2005) and La Guardia (1939) (McMullen, 1940) where lifts were used to transport baggage from check-in to apron level. At Washington National (1940) spiral baggage chutes were used to achieve a similar level change (Stuart, 1940).

The Europa Terminal at Heathrow (1955) (Chandos, 1956) saw one of the earliest uses of conveyors to take bags through the customs process while St Louis Lambert (1956) (Pickens, 1956) is the first example of mechanized conveyors being used to move baggage from check-in level to apron level.

5.4 Automation

The introduction of the automated people mover at Tampa (1971) (Blankenship, 1974, pp. 104-105) has allowed passengers to be moved over a far greater distance and permitted the separation of gates from the main terminal processor. The use of an automated people mover has both allowed a change of scale for existing concepts such as the Kansai linear terminal (1994) (Welsh, 1994, pp. 22-29) and the introduction of new concepts such as the multiple satellites at Atlanta (1980) (Braden, 1989).

Baggage systems have gradually increased in scale and complexity as automated security scanning and sortation has been introduced. The special requirements to handle transfer bags at hub airports, such as Heathrow, Schiphol, Atlanta, Dubai or Hong Kong has also led to the introduction of innovations such as early bag stores. In a large hub terminal such as Heathrow baggage now occupies more space than the main passenger concourses and so is a major driver of the overall organization of the terminal.

The Check-in process has also evolved over time with an early innovation being to integrate the departures customs process with check-in. Developed at Paris Orly (Architects' Journal, 1958, p. 236) in the 1950s it was a feature of check-in at the new terminal at Gatwick (1958) (Architects' Journal, 1958, pp. 235-250). More recent developments include the provision of Common Use of Terminal Equipment (CUTE), Common User Self-Service check-in (CUSS) and Automated Ticket and Boarding Pass (ATB) (The Institution of Civil Engineers, 1991, p. 55). This standardisation of automated processes allows the sharing of facilities between airlines and reduction in space requirements.

The growth of the internet has permitted another change: self-service and home check-in and more recently self-bag drop. Pioneered by some of the low cost airlines such as Southwest and Alaska Airlines in the USA, it allowed a completely new check-in concept developed by YRM to be introduced by British Airways at Heathrow Terminal 5 (Stewart, 2006) whereby passengers followed processes according to their state of readiness as they arrived at the terminal. A three stage process was developed for the check-in concourse, firstly registering and printing a boarding card, secondly bag drop in a walk through configuration, and thirdly a back-up process for more complex transactions such as flight change or visa check. The result is that, for many, queues are radically reduced or even eliminated.

Passenger and hand baggage security check is a relatively recent innovation, retrofitted to terminals in the 1970s in response to flights being high-jacked. Heathrow’s Terminal 4 (1986) (Blow, 1991, pp. 29, 36,61-63) was the first new terminal to have security designed as an integral part of the departures sequence, adding to the processes passengers have to negotiate. Recent trends in security processes are increasing the space needed for passenger search which is now nearly as large as check-in. The UK requirement to keep vehicles thirty metres from the front of the terminal led to the Heathrow Terminal 5 solution whereby the forecourt was moved away from the terminal and repositioned over the short term car park, the benefit was the creation of a memorable landscaped lung between the forecourt and the terminal which passengers passed through.

5.5 Digitisation

The Digital Age is now upon us, and many changes to passenger processes and opportunities for additional experiences are being investigated. In general this is expected to result in more passenger activated events, check-in, immigration, self-boarding etc. with resulting reductions in staffing. So for those on the right side of the 'Digital Divide' the future is expected to become more interactive and personalised, while for others the experience will simply feel that there is less human interaction.

Passengers are increasingly expecting the digital revolution to give them more freedom to make choices for themselves. 'E' technology is beginning to change the ways people use airport terminals, as more and more people elect to check-in 'online' at home and print their own boarding card, or use the app. on their mobile phone. So people are arriving at the airport in different states of readiness depending on which operations in the check-in process they have completed off site.

In the 1990s Alaska Airlines saw this gave them an opportunity to change the way check-in could function and developed a check-in process where registering and check-in were separated from baggage drop, changing the way the check-in concourse was organised. Alaska Airlines was the first airline in North America to sell tickets online and first in the world to allow customers to check-in and print boarding passes via the Internet.

British Airways embraced this concept at Heathrow Terminal 5. With the help of their architects YRM they introduced a new way of organising the check-in concourse, with three waves of processing, self-service check-in, followed by flow-through bag drop, and backed-up by full service desks for more complex transactions, such as visa checks. This design responded to the 'state of readiness' of the passengers, rather than according to class of travel or destination (figure 5.08).

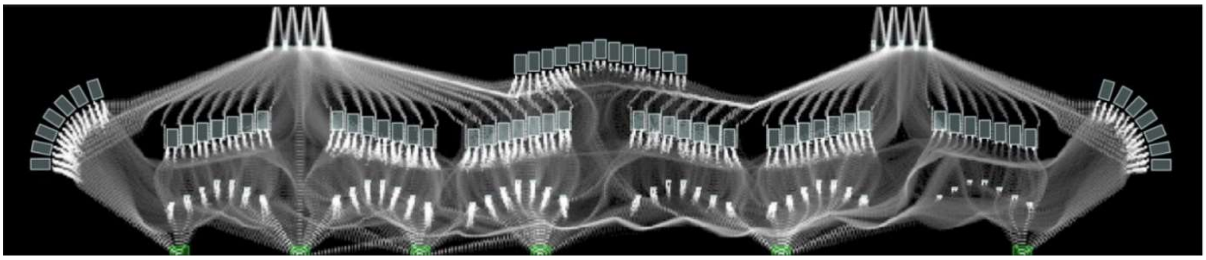


Figure 5.08 - Heathrow Terminal 5, 'Skywalker' Check-in simulation as exhibited at the Royal Academy Summer Exhibition 2004 – Source: YRM Architects and Planners (reproduced with permission from RMJM)

Predicting how people would behave given this level of choice led YRM to develop its own interactive passenger flow modelling simulation –'Skywalker' which allowed the user to change inputs while the model was running. Desks could be opened and closed during the working day, transaction times varied, and individual passenger characteristics altered during the simulation. This gave the opportunity to design a freeform passenger reception layout that responded directly to the new approach to passenger segmentation and to the natural desire lines for passenger movement while incorporating clear wayfinding.

An image of the trails left behind by passengers becomes a work of art in itself, as shown in the almost 'Futurist' image in figure 5.08 above, with its celebration of speed of movement. It was exhibited at London's Royal Academy Summer Exhibition in 2004. (Stewart, 2006).

The adoption of new processes and technologies to automate the journey, such as the self-service bag drop recently deployed for easyJet at Gatwick North Terminal, already means that departing passengers spend less time landside, with the result that the focus of passenger experience has shifted towards the airside departures lounge.

As processes such as security screening become more efficient and less time consuming, we can expect more passengers to reach airside lounges sooner, creating new opportunities for service and experience. This increased automation of processes combined with new capabilities in digital technologies also enables true personalisation of the passenger journey. The opportunity this presents is to make the age of mass air travel feel once again a personally exciting and glamorous experience.

The use of biometric data for individual passenger processing is already commonplace – whether for management of domestic and international passengers within a shared departure lounge or to reduce immigration queues at e-gates. The development of high resolution imaging and ever more powerful data processing make it possible to pick out and recognise individual faces within a crowd of people, opening up new opportunities for flow management or security processing.

In parallel, Artificial Intelligence analytics provides the opportunity to build a comprehensive view of individuals – their preferences, habits, likes, dislikes – and thence allow us truly to individualise the passenger journey by recognising and responding to their particular needs at all points of the journey. Of course, these new technologies and processes have to be implemented effectively within the context of a complex building environment. Good use of technology might improve our processes, but it can never fully compensate for a badly planned terminal that delivers a miserable experience. The space provisions and equipment layouts may change, but the fundamentals of good interchange design will remain, including: Sufficient processing capacity to eliminate queues: Non-intrusive safety and security, simplicity and clarity of organisation, intuitive wayfinding supported by up to date information, short walking distances with mechanical assistance where required, quality spaces that have been designed and maintained with care (Stewart, 2016).

Facilities also still need to be designed with growth and change in mind, with flexibility to re-zone areas as processes change. Whilst off-site and on-line check-in, for example, is reducing some of the pressure on departures concourses, the current generation of safe and efficient security checks involve ever increasing space.

5.6 Circular Runway

The Circular (Endless) Runway has been proposed on a number of occasions from the beginning of commercial aviation in 1919 to the present day, but to date none have proved viable (figures 5.09 & 5.10).

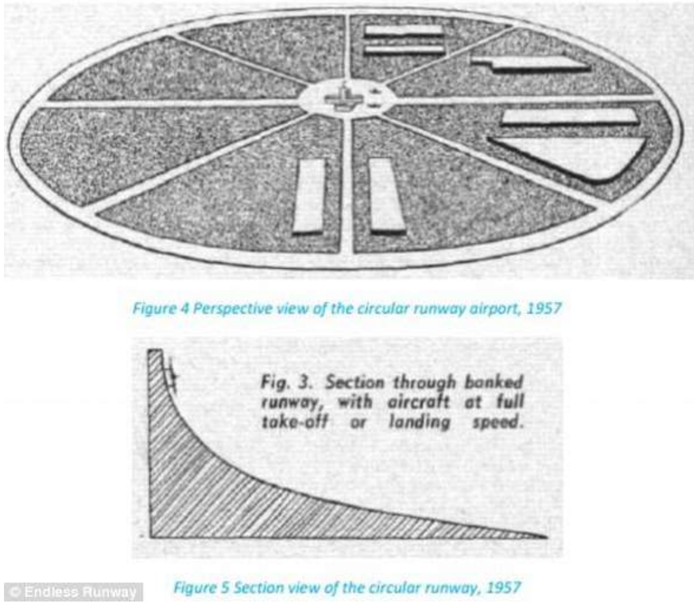


Figure 5.09 Rooftop Circular Runway
Source: Illustrated London News 1919

Figure 5.10 Circular Runway Airport
Source: Flight 1957

Figure 5.11 The endless circular runway 2017 - Source: Airport International Review

The Endless Runway (figure 5.11) is a radical idea for a new concept of operating a runway that affects the operations and construction of the whole airport. NLR led a consortium of research centres that investigated the idea of a circular runway. The work has been carried out with partners in The Netherlands, Germany, France, Spain and Poland. The work was partly funded by the Framework 7 programme of the European Commission. The European Commission recognises that mobility will be stressed the next decades and that new breaking technology will be necessary. The design proposes a runway of 3.5 Kilometres diameter giving a total length of 10 kilometres. However the runway system will result in an omnidirectional noise contour that may not be compatible with local communities.

5.7 Floating Airport

The idea of a floating airport originally arose when aircraft were incapable of crossing the Atlantic without refuelling and was envisaged as a staging post. The best known of these proposals was ’Seadrome’, which would have been similar to a static aircraft carrier (figure 5.12). The idea was rendered obsolete when after the Second World War aircraft were capable of crossing the Atlantic without stopping.

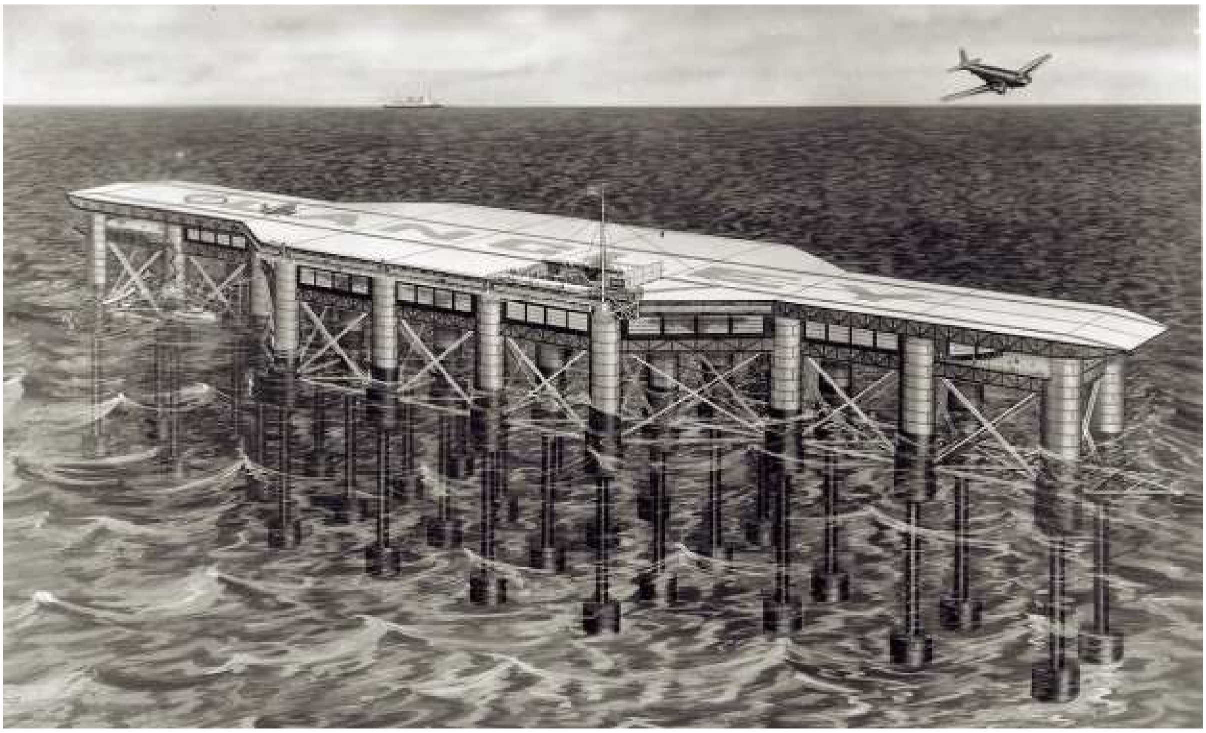


Figure 5.12 ‘Seadrome’, Engineer - Edward Robert Armstrong 1927 - Source: The Airport Book, Martin Grief

More recently the concept of a floating airport has been revived as ‘Megafloat’ but to date only one prototype has been built in Tokyo Bay (figure 5.13).

Figure 5.13 Megafloat, Tokyo Bay 1999 – Designer - Technological Research Association of Megafloat (TRAM) Source: researchgate.net

The ‘Megafloat’ offshore airstrip is said by its builders to be the largest floating metal structure in the world. At one kilometre long, ''Megafloat'' is a movable airstrip that can be split into four or five parts and manoeuvred by barges over any body of water. It was moored at the port of Yokosuka, south of Tokyo in 1999. Three metres thick and anchored in four places, the floating tarmac can withstand typhoon winds and powerful waves.

Gensler, in partnership with TESTRAD (The Thames Estuary Research and Development Company), proposed a floating airport as an alternative to expanding Heathrow in 2013. Known as Britannia Airport it was sited in the Thames Estuary (figure 5.14). It is claimed that the maritime location would have limited noise and environmental impact by directing flight paths largely over water, while allowing ample space for future expansion.

In reality it offered no environmental benefit over alternative proposals put forward by Atkins and Foster for a new hub airport on the Isle of Grain, and the issue of linking fixed infrastructure to a floating airport subject to the tides would have had to be overcome.

Figure 5.14 London Britannia Floating Airport in the Thames Estuary 2013 – Gensler, in partnership with TESTRAD (The Thames Estuary Research and Development Company) – Source: Gensler

5.8 Drive - Through Airport

A proposal by D.H. McMorran for the 1928 RIBA competition for an Aerodrome for London in 1943 won first prize. Taxiing aircraft followed the white lines to 3 covered stands for arrivals then moved on to new covered stands for departing aircraft. A semi-circular row of hangars separated the boarding area from the air-field (figure 5.15).

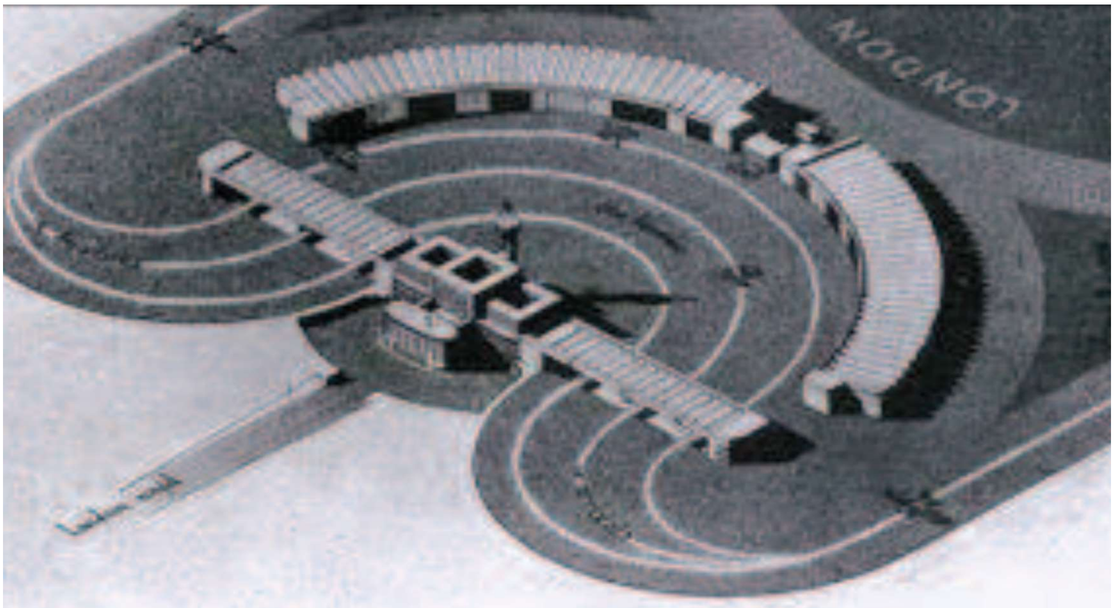


Figure 5.15 First Prize, RIBA Airport Competition of 1928 – Architect – D H McMorran - Source: Flight Global

The idea of moving arriving aircraft after passengers had alighted but before the next departure was also considered in the Lehigh competition of 1929 and in one of the early options for the Chicago O'Hare master plan of 1944 (see figure 6.119), and has recently been revived (figure 5.16). However, moving aircraft from one location to another during turnaround, which can be as short as 30 minutes, adds time and complexity to the operation, as for most of the passenger, catering, cleaning, refuelling and engineering processes the aircraft needs to be static.

Figure 5.16 Drive through airport by Buro fur MEHR 2012 - Source: wordpress

5.9 Mechanical Movement of Aircraft

The efficient use of apron space in front of the terminal is a perennial issue for which the conventional approach was initially to park aircraft parallel to the terminal and more recently nose in and rely on tractors or tugs to push the aircraft out on departure.

However, there have been a number of short lived alternative proposals. In his 1940 book John Walter Wood proposed that aircraft should be dragged towards the terminal at right angles to their normal direction of movement, using a conveyor as illustrated below that supported the aircraft's undercarriage, and so minimise aircraft parking space requirement while allowing them to park parallel with the loading platform (pier)(figure 5.17). The intention was to simplify, speed up, regulate and standardise aircraft movement near the terminal (Wood, 1940, pp. 286, 324).

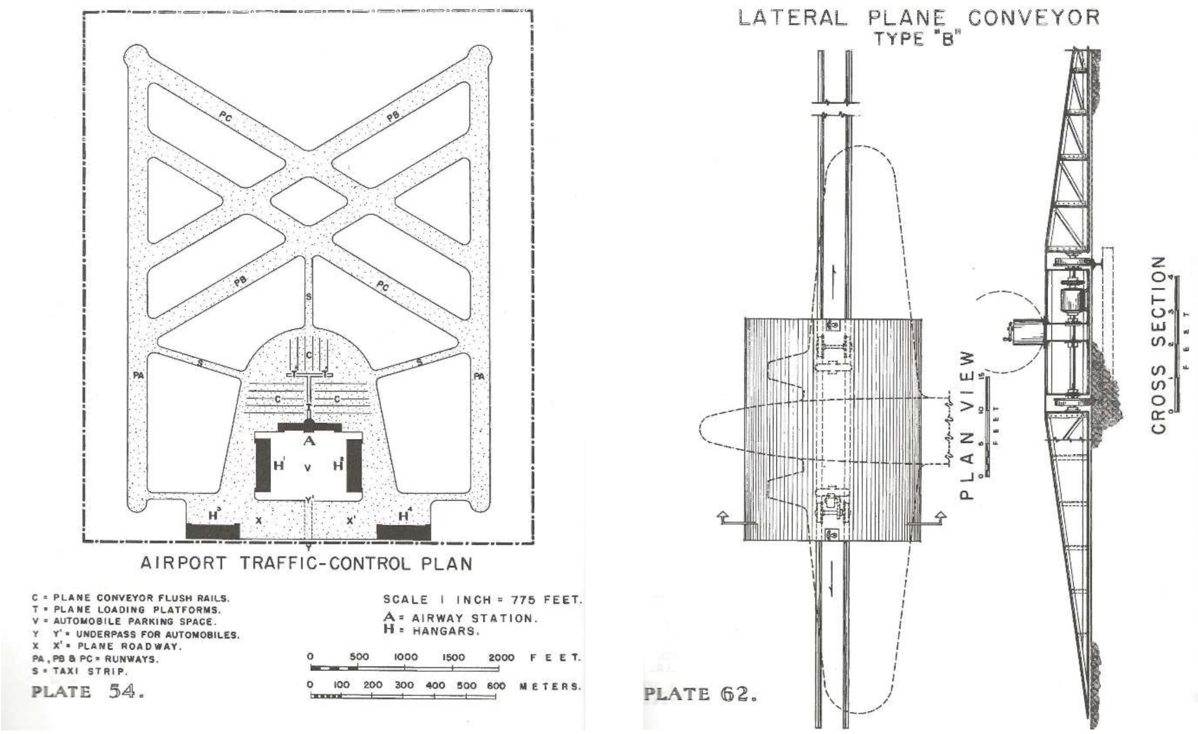


Figure 5.17 Lateral Plane Conveyor – Designer: John Walter Wood 1940 – Source: Airports, Some Elements of Design and Future Development

A development of this idea was tried experimentally by the manufacturer Whiting Loadair in the 1950s. The Columbian national airline, Avianca, was one of the few companies in the world to try out the Whiting Loadair system. It was installed at the Soledad airport, Barranquilla. By its use the aircraft was hauled to a passenger dock by underground cables and winched into position with its main door against the loading ramp (figure 5.18).

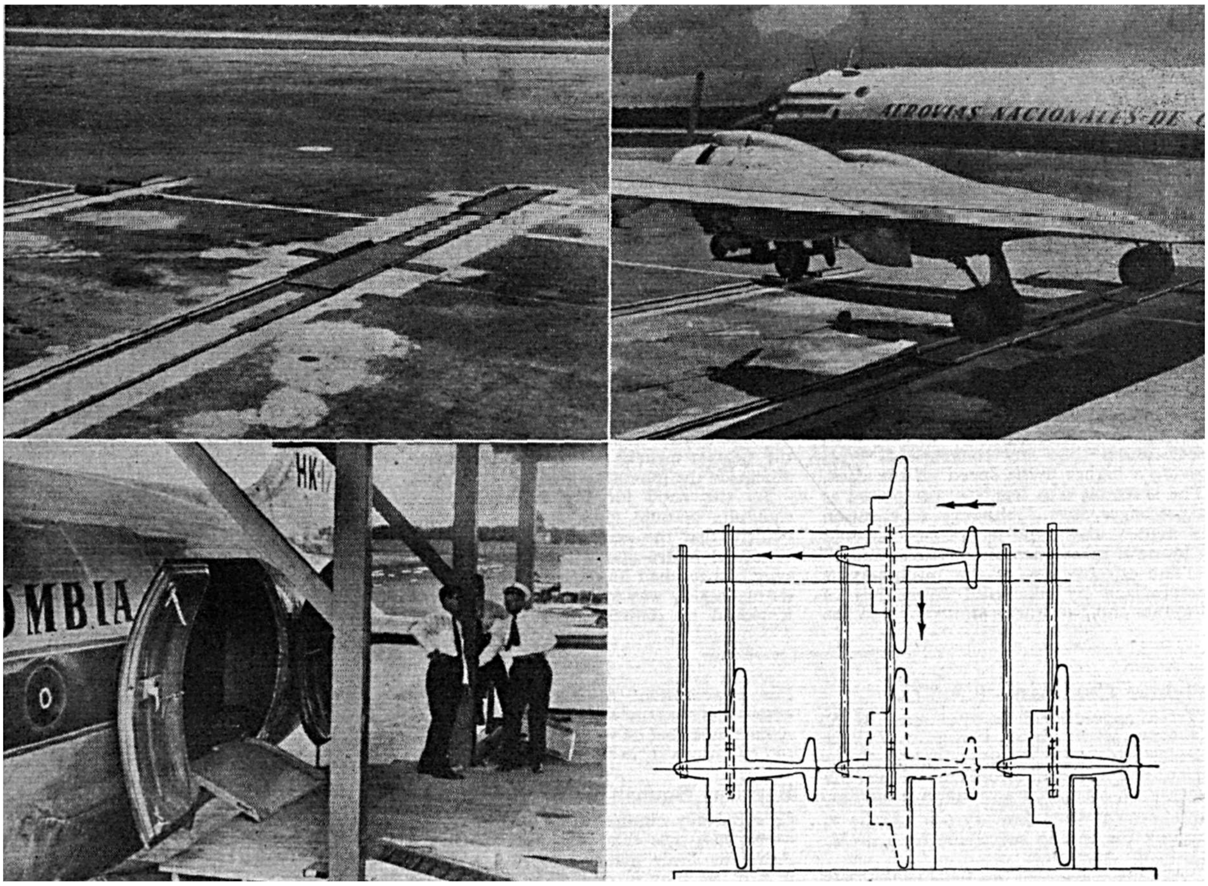


Figure 5.18 Whiting Loadair automated aircraft turnaround and passenger boarding 1955 - Source: Flight

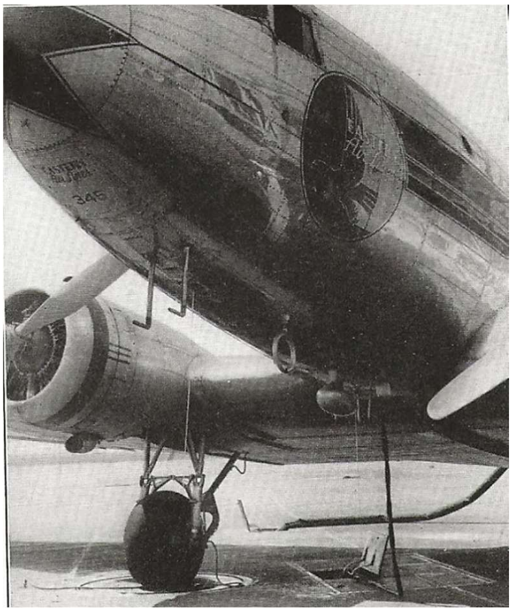


Figure 5.19 Washington National 1941, aircraft turntable – Source: Airport Planning

Another early approach can be seen at Washington National Airport where turntables were installed to allow aircraft to pivot around one of their undercarriage wheels, to allow them to park parallel with the terminal minimising the space needed for aircraft manoeuvring. (figure 5.19)

Both ideas worked for specific aircraft types such as the Douglas DC3 and DC4 but proved unsuitable for the newer and larger aircraft types that were being introduced, and were made obsolete when nose-in parking was adopted at larger airports.

More recently fixed automated aircraft push back mechanisms recessed into the apron have been installed at Stockholm Arlanda Airport for smaller sizes of aircraft but those too have been superseded by the adoption of robotic electric automated and remote controlled push back using driverless tugs. The latter have recently been installed at a number of airports rendering previous fixed aircraft movement systems obsolete.

5.10 Conclusion

While the previous chapter considered the external pressures that airport design has had to respond to, this chapter has reviewed some of the major technological innovations that have enabled the advance of airport design: Air Navigation, Communication, Mechanisation, Automation and Digitisation.

It has also considered those technological ideas which continue to interest airport designers because they are intellectually intriguing but have failed to be accepted generally either because they technically flawed as in the case of the circular runway, or are uneconomic like the floating runway, or the ideas have been superseded by simpler processes or alternative technical solutions as with the drive through airport or the mechanical movement of aircraft and have therefore not formed part of the line of development.

The next major technological innovation is anticipated to be the widespread electrification of all aspects of airport energy use including the heating of buildings and the movement of vehicles and aircraft. This will in turn require more investment into renewable electrical supplies and energy storage.

6. The evolutionary trends in the master planning, terminal layout, sectional development, and architectural expression of terminals

6.0 Introduction

This chapter focuses on the development of the Terminal in a largely chronological sequence: Pioneering Concepts, Simple Terminal, Linear Terminal, Unit Terminal, Finger Pier, Satellite, Mid-field Hub and the Underground Terminal. It also discusses the key issues faced by the designer of the terminal including: Integration/ Concentration or Separation/Specialisation of Functions, Dry Boarding and Commercial Design including: Spectator Venue, Catering, Retail, Duty Free Shopping and Leisure and Recreation. Finally it investigates how architects have sought to capture the spirit of flight, and what it means to be modern and forward looking in the architectural design of the terminal.

6.1 Pioneering Concepts

The configuration of a terminal is determined by a series of factors, principally the volume of traffic handled, the physical constraints of the site and the operational philosophy adopted.

The earliest scheduled flights in 1919 were handled from hangars as at Berlin Johannisthal, 05.02.1919 (Przychowski, 2011, pp. 24-35)(figure 6.01 & 6.02, London Hounslow Heath 01.05.1919 (Stroud, 1973, pp. 10-11) (figure 6.03 & 6.04), Paris, Le Bourget 01.05.19 (Stroud, 1956) (figure 6.05 & 6.06), and in the following year Amsterdam, Schiphol 1920 (Stroud, 1956) (figure 6.07 6.08).

These airports were makeshift legacies created from redundant First World War airbases giving weight to Banham's contention 'that standards of hostilities-only expediency were carried over into peace-time operations' (Banham, 1962).

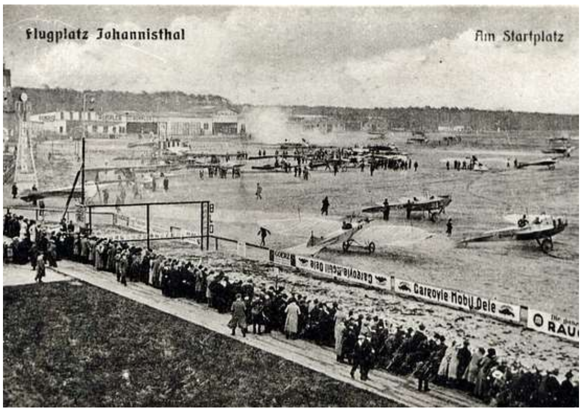


Figure 6.01 – Berlin, Flugplatz Johannisthal, 1911 Source: Clemens Kurz Stadtspaziergange – WordPress.com

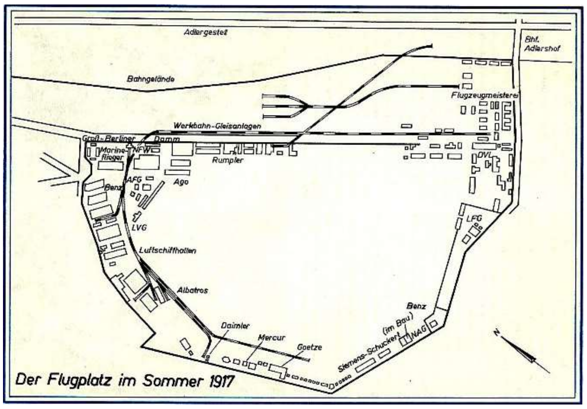
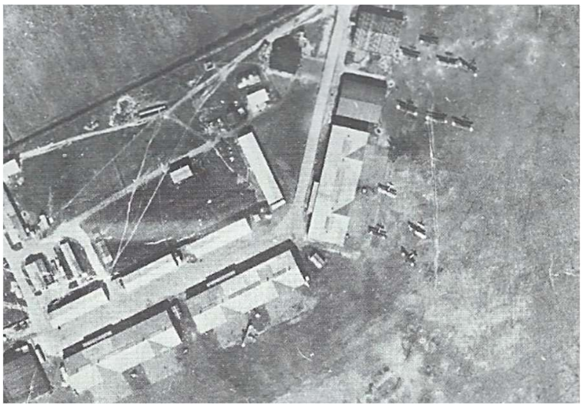


Figure 6.02 - Berlin Flugplatz Johannisthal, Site Plan 1917 Source: berlinsstadtbezirkegeschichte.jimdo.com



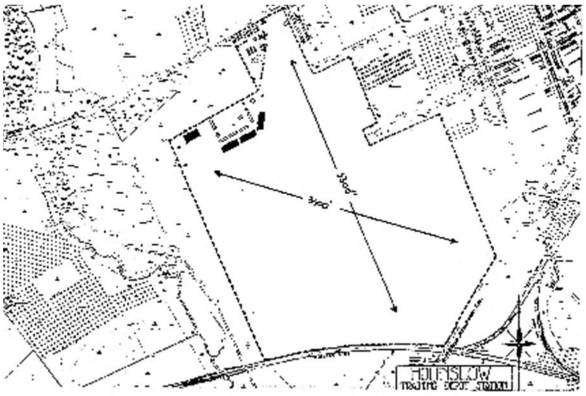


Figure 6.03 – London, Hounslow Heath 1919, Aerial view - Source: The World's Airports

Figure 6.04 – London, Hounslow site plan 1919 – Source: The World's Airports

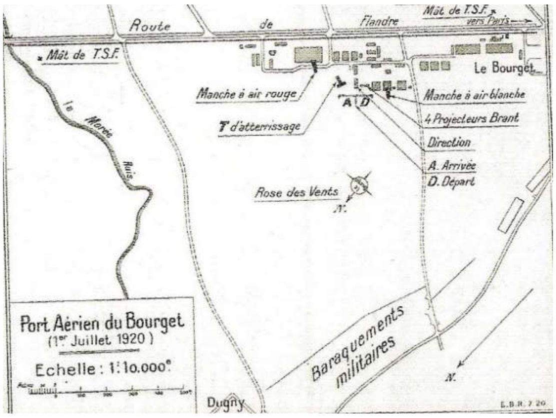


Figure 6.05 – Paris, Le Bourget Aerial View 1920 –: Source: Site Officiel de la Marie du Bourget

Figure 6.06 – Paris, Le Bourget, Site Plan, 1920 – Source: Wikimedia

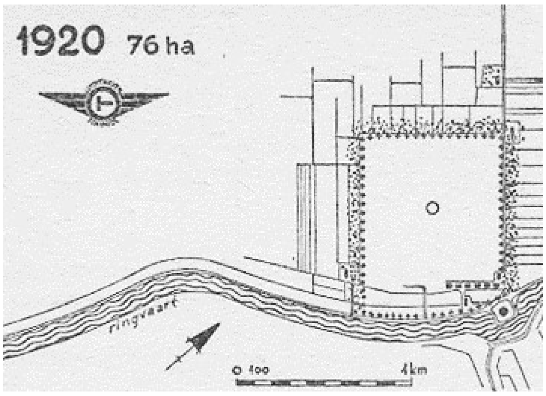


Figure 6.07 – Amsterdam, Schiphol 1920 Aerial View Source: Schiphol

Figure 6.08 – Amsterdam, Schiphol Site Plan 1920 Source: spl –olddays-map

Both Le Bourget and the first Croydon Airport had been established as military airfields during the First World War. For the start of commercial aviation they featured makeshift dispersed buildings with separate discrete functions - check-in, customs or immigration as can be seen at the first Croydon airport (Cluett, 1977) (figure 6.09 6.10).

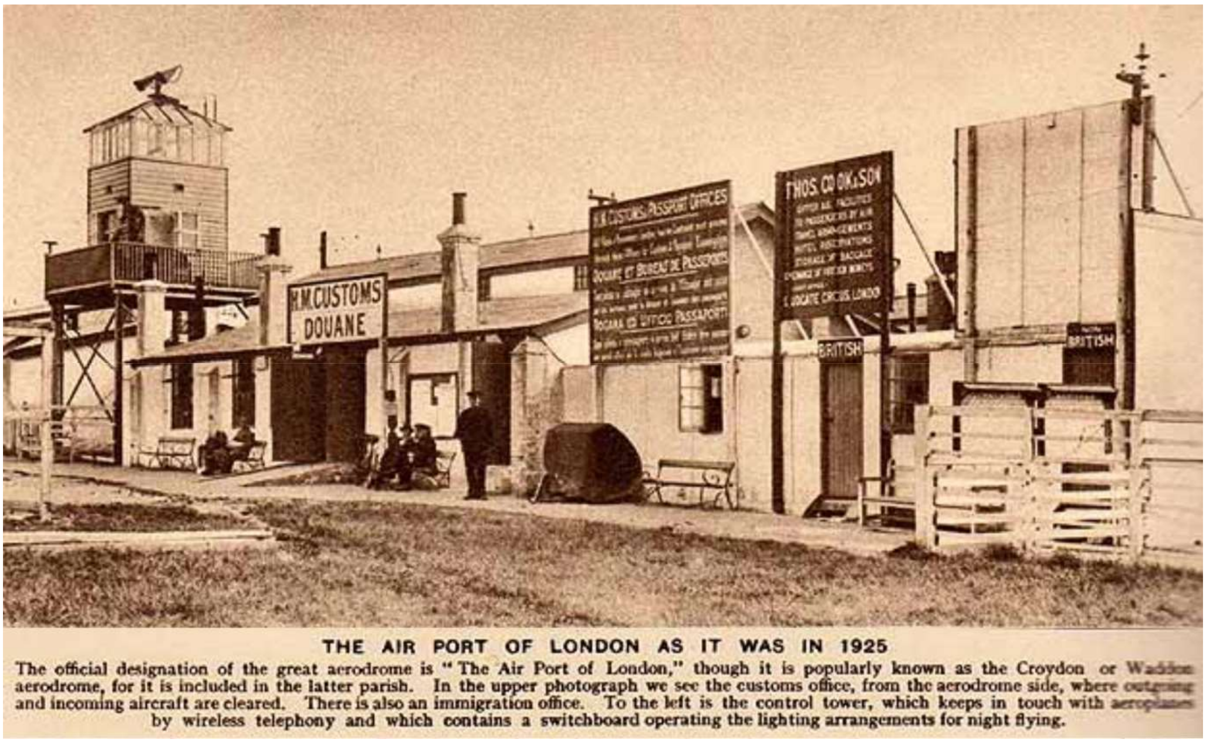


Figure 6.09 – London, Croydon 1925 - Source: controltowers.co.uk (© via David Young)

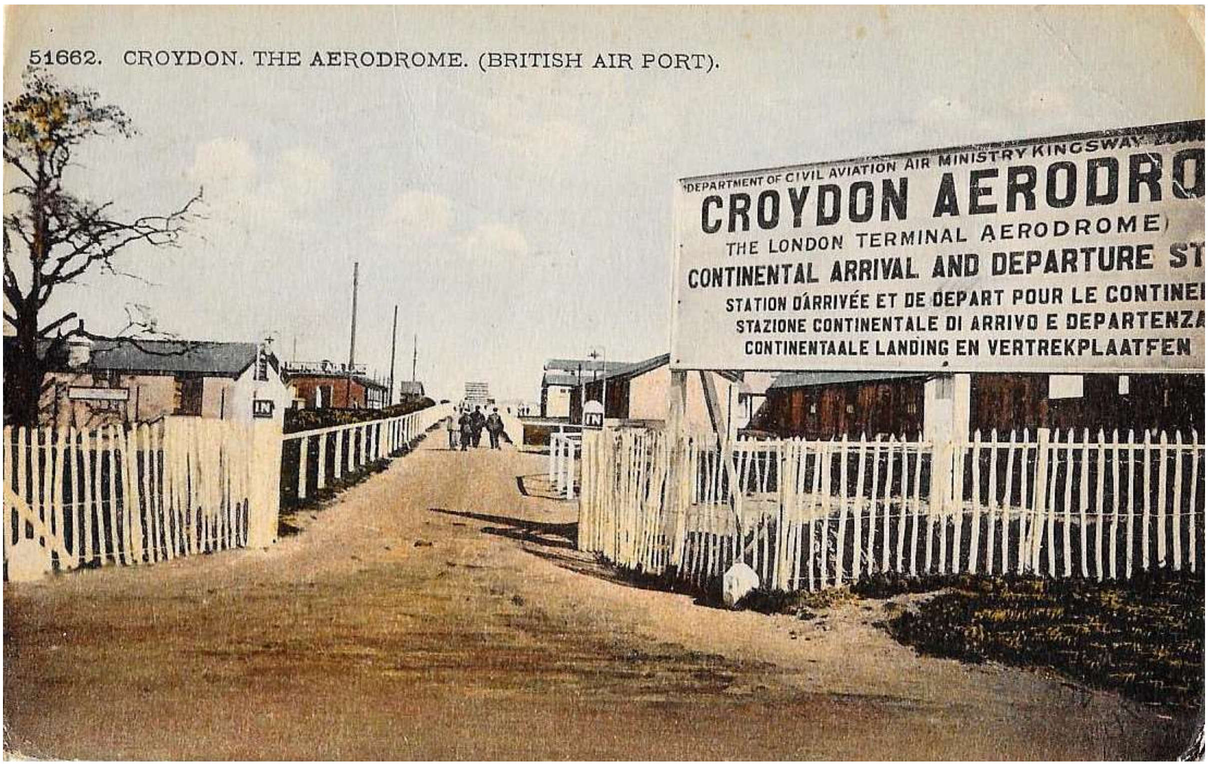


Figure: 6.10 London, Croydon 1920, - Source: UK Airfields and Airports

A 1924 film strip of Croydon Airport: https://www.youtube.com/watch?v=-VE4ukEHuKo shows what it was like to travel through the primitive facilities at the first Croydon Airport, which largely comprised dispersed temporary facilities left over from the First World War. The airport is also illustrated in this aerial view (figure 6.11).

Figure 6.11 – London, Croydon Aerial View 1920 - Source: Control Towers.co.uk © via David Young

The dispersed layout was even rebuilt as a permanent installation at Le Bourget in 1923 where a series of discrete buildings were arranged around a square and passengers had to progress from one building to another to complete all the formalities (Stroud, 1973, p. 16) (figures 6.12 & 6.13).

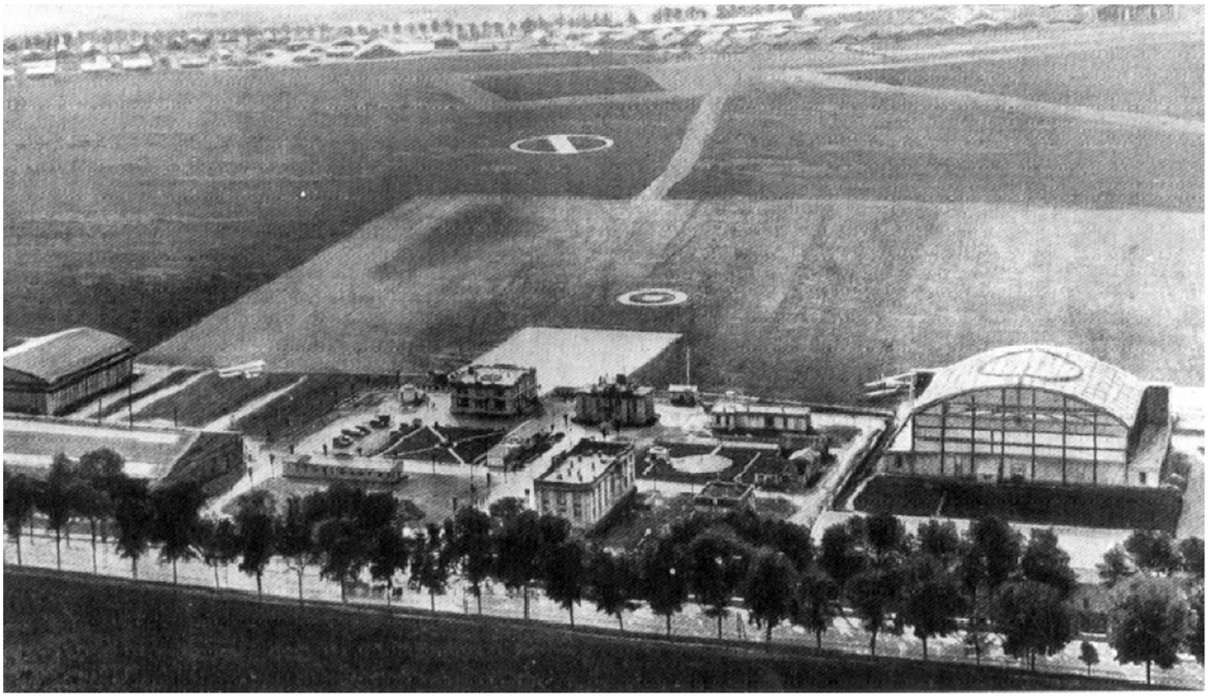


Figure 6.12 - Le Bourget 1923, with terminal buildings arranged around a square – Source: Building for Air Travel

Figure 6.13 - Le Bourget 1927, with hangars in the foreground and dispersed passenger facilities beyond – Source: Aėroports de Paris SA

Le Bourget became internationally famous when Charles Lindbergh landed there on the 21st May 1927 having flown single handed non-stop across the Atlantic in the Spirit of St Louis, to be greeted by thousands of spectators at the airport. Here the aircraft is photographed after landing and before taking off again for Croydon Airport (figure 6.14). This single event was a major factor in promoting the subsequent growth of air travel in the United States, as Charles Lindberg later travelled around the United States and used his fame to promote the growth of air travel and the development of airports.

Figure 6.14 - Charles Lindbergh arriving at Le Bourget 1927 - Source: Pinterest

6.2 Simple Terminal

The first recognisable terminal building that brought together all these disparate functions into a single building was at Konigsberg Airport in East Prussia and designed by Hans Hopp (1922) (Museum Der Stadt, Konigsberg) (Freeman, 2017) (figures 6.15 & 6.16).

Figure 6.15 - Konigsberg 1922 – architect, Hans Hopp - Source: https://www.bildarchiv-ostpreussen.de

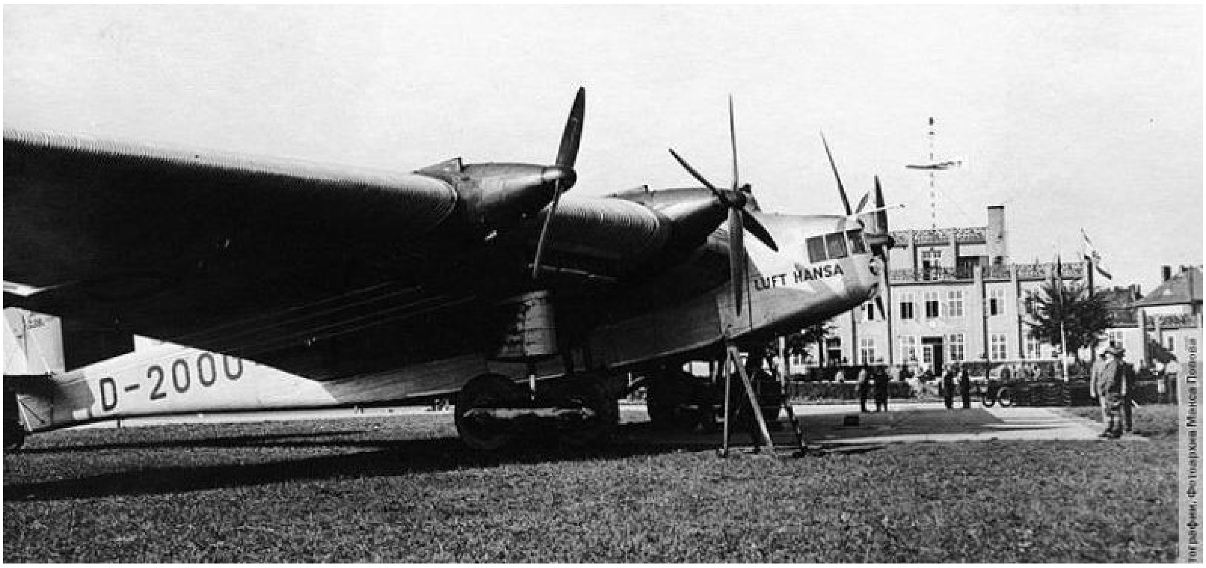


Figure 6.16 - Konigsberg Airside View c1930 – Source: julius1880-d5fmuzl

Konigsberg was followed by a series of purpose designed terminals in Europe in the late twenties at London Croydon (1928) (Cluett, 1980) (figure 6.17), Berlin Tempelhof, architects Paul and Klaus Engler (1928) (Treibel, 1992) (figure 6.18 & 6.21), Amsterdam Schiphol, architect Dirk Roosenburg (1929) (Hanks, 1929)(figure 6.19) and Hamburg, architects Dyrssen & Averhoff, (1929) (Voigt, 1999) (figure 6.20).

Figure 6.17 -London, Croydon 1928 –
Source: Croydon Airport Society

Figure 6.18 Berlin, Tempelhof 1928 -
Source: http://peterpapke.de

Figure 6.19 – Amsterdam, Schiphol 1929 -
Source: ANP Foundation

Figure 6.20 - Hamburg, Fuhlsbuttel 1929 -
Source: Building for Air Travel

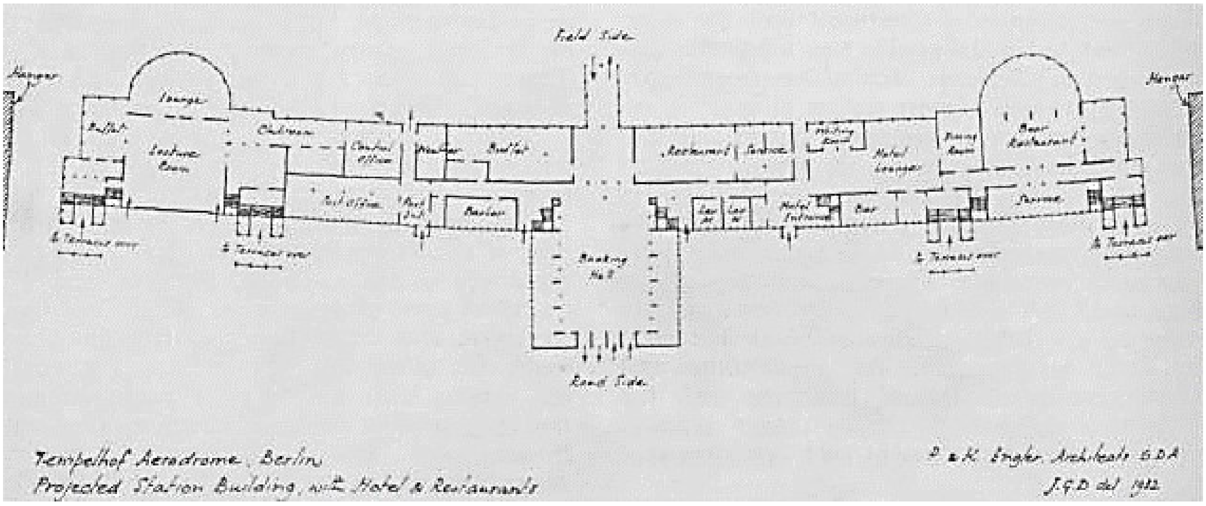


Figure 6.21 - Berlin Tempelhof 1932 (proposed 3rd phase – with unbuilt extensions) – Source: RIBA Journal

In the USA the design challenge was rather simpler at the time as the earliest flights were domestic rather than international so the earliest terminals were little more than waiting rooms, as can be seen at Ford's Dearborn Airport, architect Albert Kahn (1927) (Freeman, 2017) (figure 6.22), or the new terminal at Chicago Municipal Airport (1930), City Architect, Chicago, Paul Gerhardt Jr. (Gerhardt, 1932) (figures 6.23 & 6.24).

Figure 6.22 - Ford Dearborn 1927
Source: Abandoned and little known Airports

Figure 6.23 - Chicago Municipal 1930
Source: Flickr.com/photos/twa1049g/7257500956

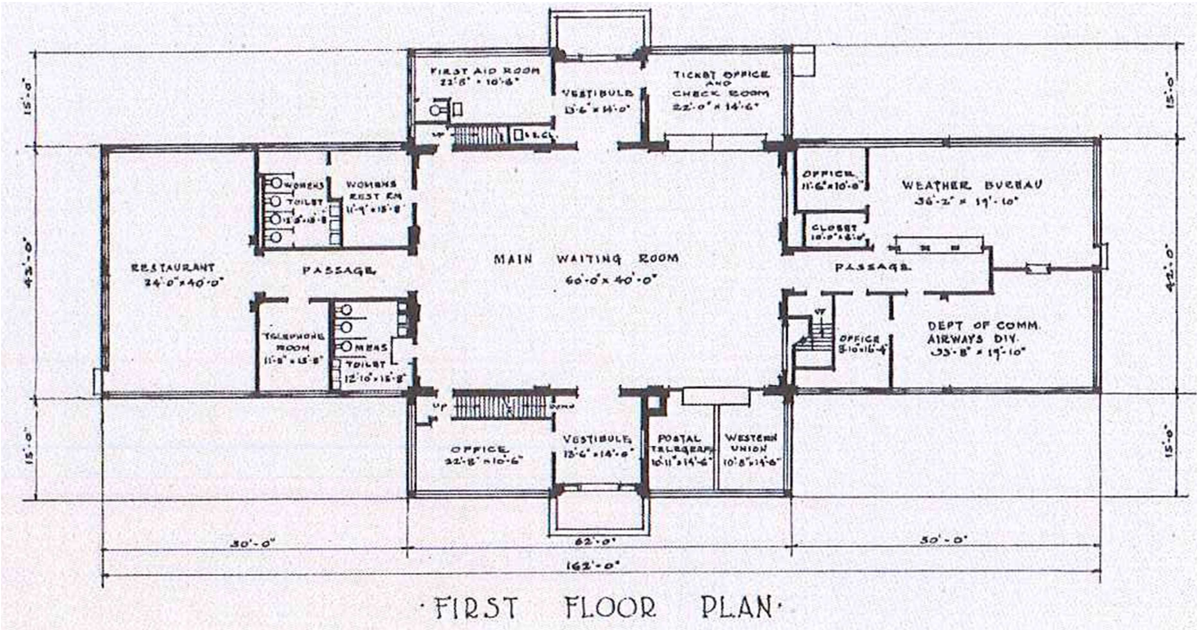


Figure 6.24 - Chicago Municipal Airport 1930 – Source: The Architectural Record

Terminals were originally organised so that they could only handle a single departing and arriving flight at the same time and were always located at the perimeter of the airfield. This type of terminal still has a place today, though typically now handles several aircraft at a time, and can be found where smaller communities are served by low cost carriers (LCCs) or traffic volumes are small. It is sometimes also known as the Open Apron concept and involves passengers either walking or being bussed to and from their aircraft.

One of the largest international airports designed as a simple terminal with an open apron was Zurich Kloten, architects Alfred and Heinrich Oeschger, (figure 6.25). It was the first new European airport to be developed after the Second World War but preserved a number of pre-war concepts such as the large spectator gallery and open apron and so might be regarded as obsolescent when it opened in 1953.
The layout required passengers to walk a long way across the apron to reach their aircraft at a time when in the USA concepts such as the unit terminal and finger pier had addressed the changing scale of operation and had extended the terminal building to bring the passenger to the aircraft side.

Figure 6: 25 - Zurich Kloten 1953– Source: Postcard, Swissair Photo AG, Zurich, Switzerland No.14557

The simple terminal is still relevant in smaller regional airports today where passengers walk or are coached to the waiting aircraft. The following sections explore the terminal concepts that have been developed to serve larger traffic volumes.

6.3 Linear Terminal

The centralised linear terminal can be regarded as a linear extension, on a larger scale, of the same basic form of the simple terminal. This layout was first seen at Georges Labro's design for the terminal building at Le Bourget Airport (1937) (Hamlin, 1940) a building some 243 metres long and 30 metres wide, with a far greater number of check-in and airline ticketing desks and larger reclaim area than earlier designs but still with only a single exit to board aircraft and a single entry point for arriving passengers (figure 6.26).

Figure 6.26 - Paris Le Bourget 1937 – Source: Building for Air Travel

The second terminal at Tempelhof (Elke, 2005) was designed by Ernst Sagebiel in 1935-7 and was largely complete before the Second World War. The design was intended to handle far greater volumes of passengers and last until 2000AD. It introduced major breakthroughs in a number of areas but as regards planning typology the innovation was the provision of multiple gate rooms strung out either side of the main terminal which allowed up to eight aircraft to be handled simultaneously (figures 6.27 & 6.28).

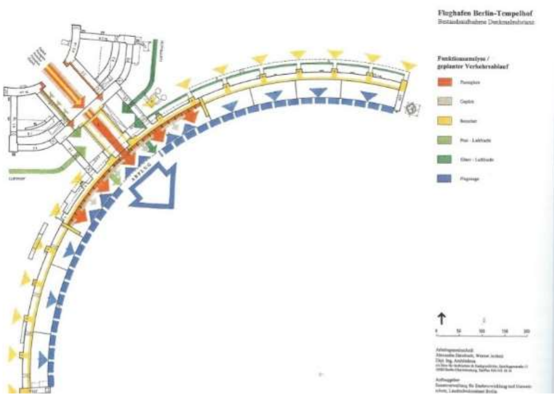


Figure 6.27. - Berlin, Tempelhof Layout Plan 1939
Source: Historic Airports

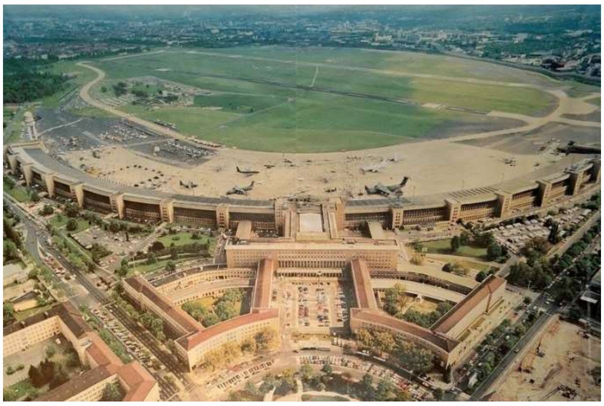


Figure 6.28 - Berlin Tempelhof, Aerial View c2007
Source: amusingplanet.com

A simpler approach to multiple aircraft enplaning and deplaning can be seen at New York's La Guardia Airport, architects Delano & Aldrich, (1939) (McMullen, 1940) where a covered walkway extended either side of the terminal to provide access to multiple aircraft (figure 6.29).

Figure 6.29 - New York, La Guardia 1939 – Source: Photo by W. Hoff Official Photographer La Guardia Field

The linear terminal continues to be an appropriate response where the site is long and thin. A more recent example is Heathrow Terminal 4, architects Scott, Brownrigg & Turner, which incorporates double sided piers. (1986) (Blow, 1991) (figure 6.30).

Figure 6.30 - London Heathrow T4 1986 – Source: British Airports Authority

Another example can be seen at Paris, Charles de Gaulle Terminal 2 (1981 onwards), architect Paul Andreu, where its modular design addressed the constantly growing traffic conditions. It is formed by 4 narrow 60 metre wide single sided buildings which allow travellers to see the aircraft from the road (figure 6.31).

Figure 6.31 - Paris, Charles de Gaulle Terminal 2A 1981, 2B 1982, 2C 1993, 2D 1989 and circular satellite 1999 – Source: ADPI

Planned on a much larger scale Kansai International Airport, architect Renzo Piano, incorporated a transit to assist passengers reach the end of the doubled sided piers from the terminal. (1994) (Jodidio, 2004) (figures 6.32, 6.33 & 6.34).

Figure 6.32 – Osaka, Kansai 1994 – Source: Japan-Guide.com

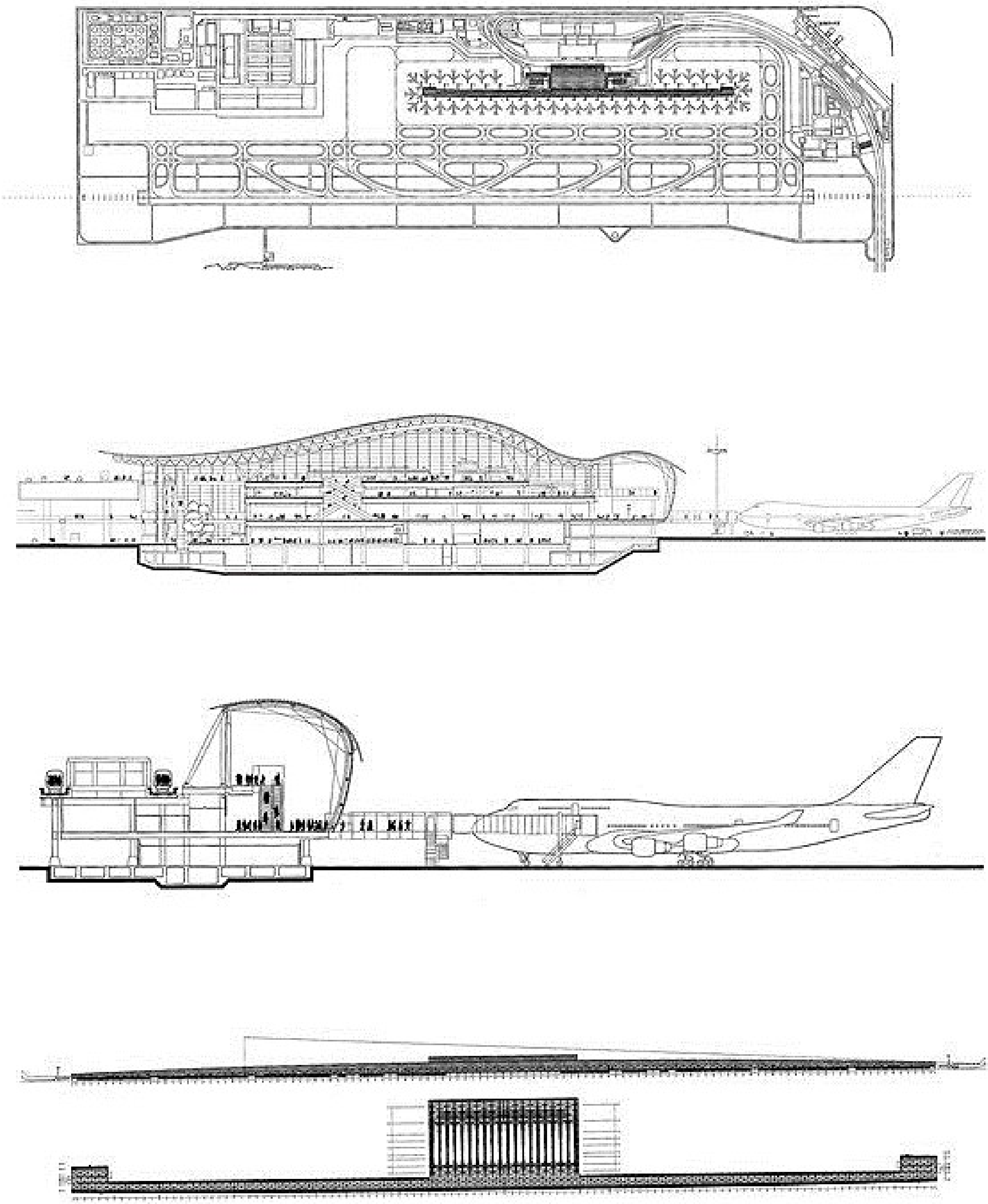


Figure 6.33 – Osaka Kansai 1994, showing the linear configuration with access to the end of the pier provided by an automated people mover: note the curvature of the roof towards the end of the pier to assist visibility of the apron – Source: Pinterest

The linear pier concept is most often found where the terminal is located parallel with the main runway, particularly where the airport only has a single runway.

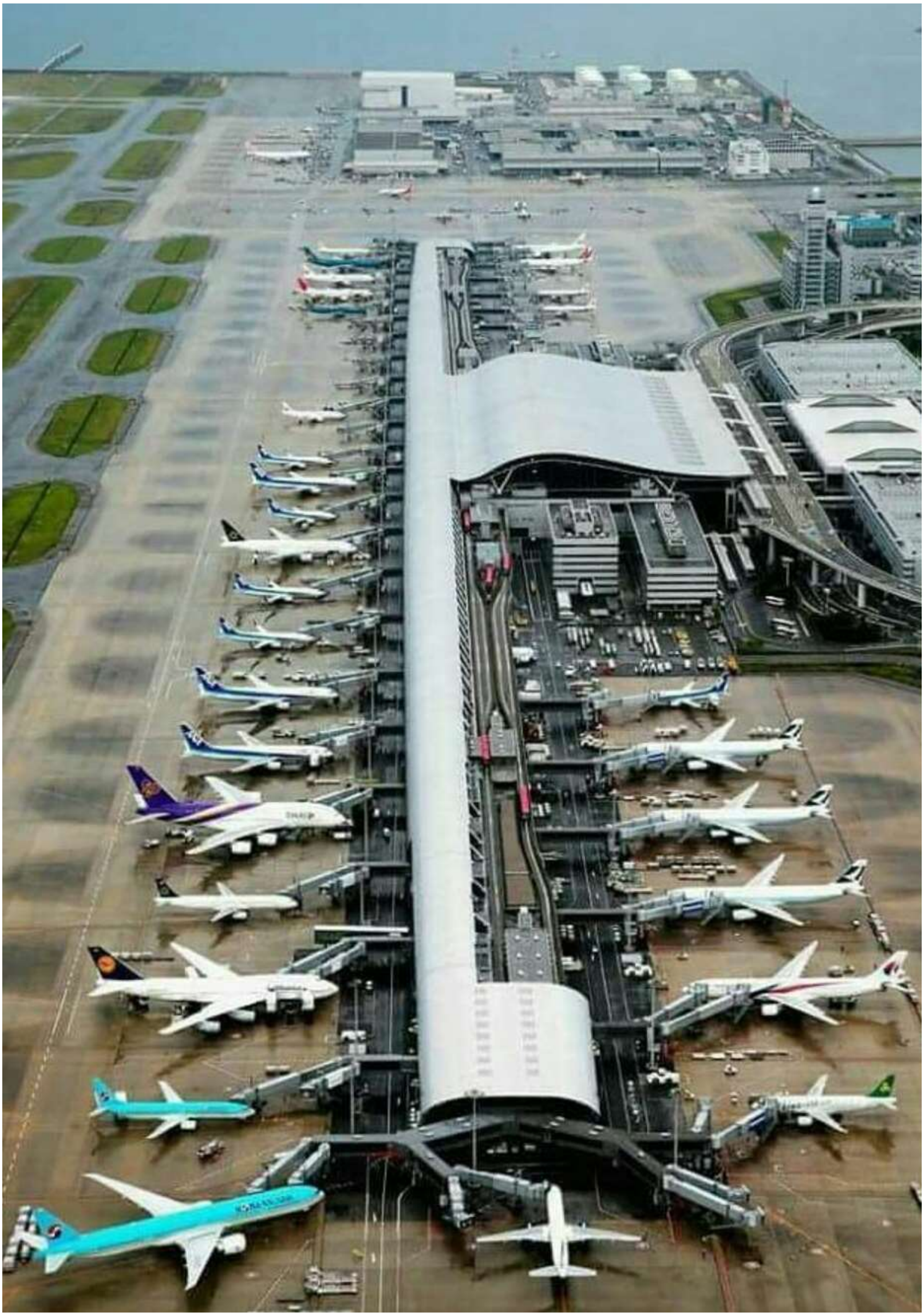


Figure 6.34 -Osaka Kansai 1994 showing curved and tapering pier and transit system – Source: Home Design Inspiration

6.4 Unit Terminal

A second type of linear terminal, the decentralised linear terminal, was developed in the USA airport masterplans during the Second World War and immediately afterwards. This is characterised as a series of small unit terminals, with aircraft parked on one side only, strung out in a line to maximize the landside/airside interface and shorten waking distances.

The unit terminal was first proposed by Albert F. Heino, architect to United Airlines, at the Midwest Airport Managers' Conference at Fort Wayne, Indiana in February 1944 (Heino, 1945). His proposal was for a separate small terminal for every aircraft parking space each with its own arrival and departures routes and manual baggage handling facilities.

The concept's adoption in the US was partly because almost all traffic at that time was domestic requiring no passport or customs checks and passengers almost all arrived by car as there was no public transport system, so it maximized forecourt length.

The concept also lends itself to development by individual airlines, which is a characteristic of the USA where State or Federal funding is seldom available. The earliest example of the approach can be found at Chicago Municipal Airport, City Architect, Paul Gerhardt which was renamed Chicago Midway Airport (Lynch, 2003) when it was rebuilt in 1946 (figure 6.35).

Figure 6.35 – Chicago, Midway 1946 Postcard – Source: Chuckman Collection volume 4

This approach was adopted on a much larger scale at Kansas City, architects Kivett & Myers, (1972) (Hart, 1985, pp. 185-193) and Dallas- Fort Worth, architects Hellmuth, Obata and Kassabaum (HOK) and Brodsky, Hopf & Adler, (1974) (Blankenship, 1974, pp. 118-121). The latter had an important additional feature, a rapid transit system that linked all eight linear terminals, allowing it to operate effectively as a transfer hub (figures 6.36, 6.37, 6.38 & 6.39).

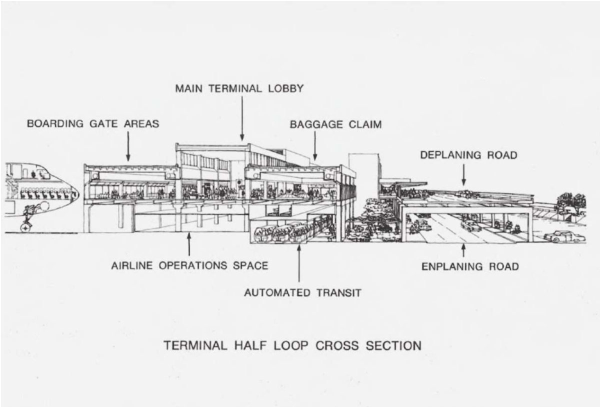


Figure 6.36 - Dallas / Fort Worth 1974 – Section
Source: Images of Aviation DFW, Bleakley, Bruce A.

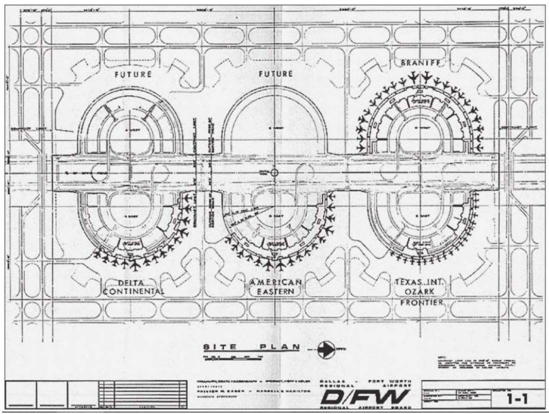


Figure 6.37 - Dallas / Fort Worth Master Plan c1970
Source: Images of Aviation DFW, Bleakley, Bruce A.

Figure 6.38 - Dallas/Fort Worth, Satellite View 2018 –
Source: Google Earth

Figure 6.39 – Dallas/Fort Worth, Terminal Layout
Source: DFW Airport Guide

The Heathrow Europa Terminal, architect Frederick Gibberd, and later renamed T2 (1955, now demolished) (Chandos, 1956) was a unique example of the single sided linear unit terminal in the UK, but was subsequently converted to a conventional centralised layout to make the operation more efficient and use the processing facilities all the time (figure 6.40).

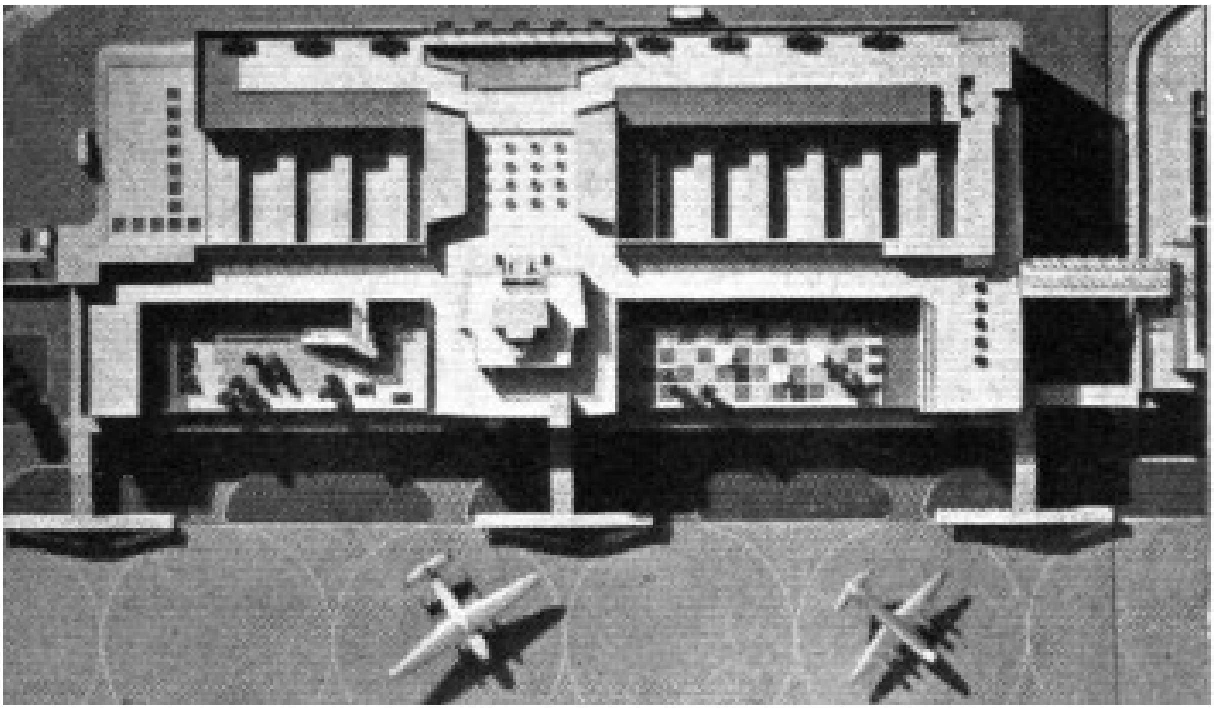


Figure 6.40 – London, Heathrow Europa Terminal 1955 Model – Source: Flight International

Berlin Tegel, architects Meinhard von Gerkan and Volkwin Marg, is an unusual example of the unit terminal in Europe, following a hexangular form around a giant roundabout forecourt (figure 6.41).

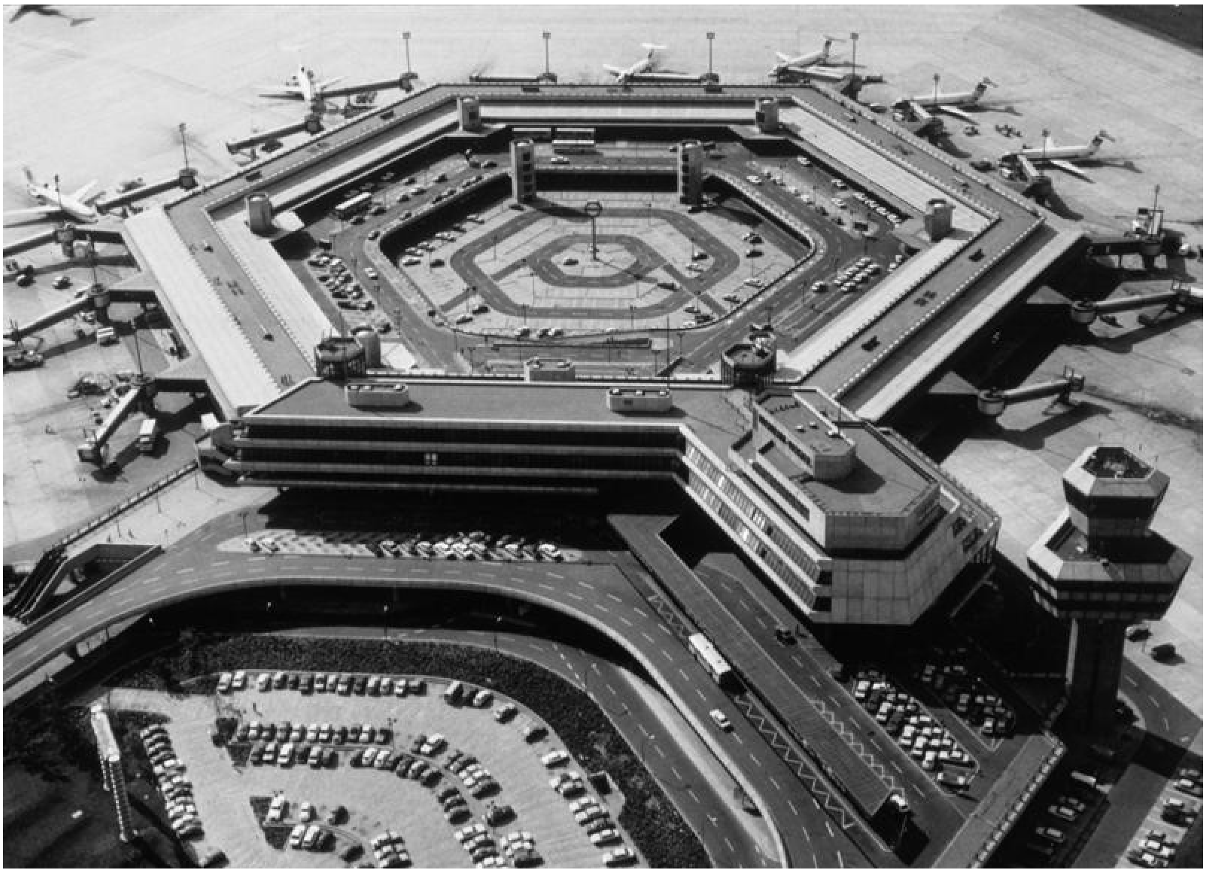


Figure 6.41 – Berlin, Tegel 1960 – Source: gmp-architekten.com

There are few recent examples of this type of terminal because minimising the number of staff required to meet passenger security search requirements and the need to maximise commercial revenue favour a more centralised approach.

Some centralised single sided terminals can be found at Munich Terminal 1, architect Hans-Busso von Busse, (1992) (Binney, 1999, pp. 158-163) Charles de Gaulle Terminal 2, architect Paul Andreu, (phased completions 1982 -1995) (Jodidio, 2004, pp. 46-51 & 92-97) (Allen, 1983) and Barcelona Terminal 2, architect Ricardo Bofill, (1992 (Binney, 1999, pp. 32-35).

However more recent developments at each of these airports show a movement away from this approach to double sided piers.

6.5 Finger Pier

Terminals began to be designed to project into the airfield to fill the gap between different runway orientations. This can be found for the first time at New Orleans Shushan Airport, architects Weiss, Dreyfous and Seiferth, (1933) (New Orleans Lake Front Airport , 2017) (figure 6.42), and reached its culmination at Birmingham Elmdon, architects Norman and Dawbarn, (1938) (The Architect and Building News, 1939, pp. 188-192) (figure6.43) where the whole terminal projected into the airfield with aircraft parking under a cantilever canopy on either side. The interface with the forecourt was on the narrow face of the terminal.

Figure 6.42 - New Orleans Shushan 1933 – Source: pontchartrain.net

Figure 6.43 - Birmingham Elmdon 1938 - Source: AirTeamImages.com

A major step change was proposed by Charles Froesch and Walter Prokosch, working for Eastern Airlines. Their 1946 book Airport Planning contained a series of radical proposals which included long finger piers projecting from the terminal (Froesch, 1946) (figure 6.44).

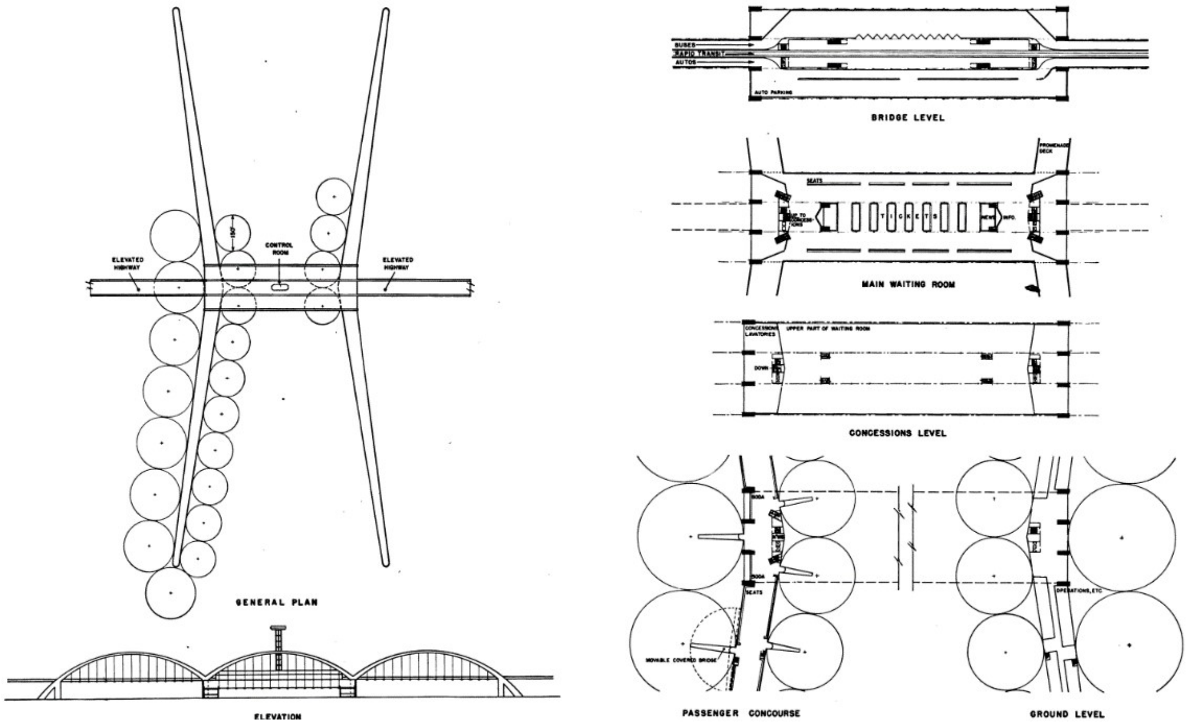


Figure 6.44 - Finger Pier Concept, 1946 – Source: Airport Planning by Charles Froesch and Walter Prokosch

This idea was picked up in the 1948 masterplan for the new Chicago O'Hare Airport, master planner Ralph Burke, which incorporated multiple radiating 'split finger' piers from a central terminal, reaching out towards multi-directional tangential runways (Burke, 1948) (figure 6.45). The early terminals (6.46) were designed by Naes & Murphy (later C.F. Murphy) with the 7 Continents restaurant in the Rotunda (1962) by Gertrude Kerbis in the foreground.

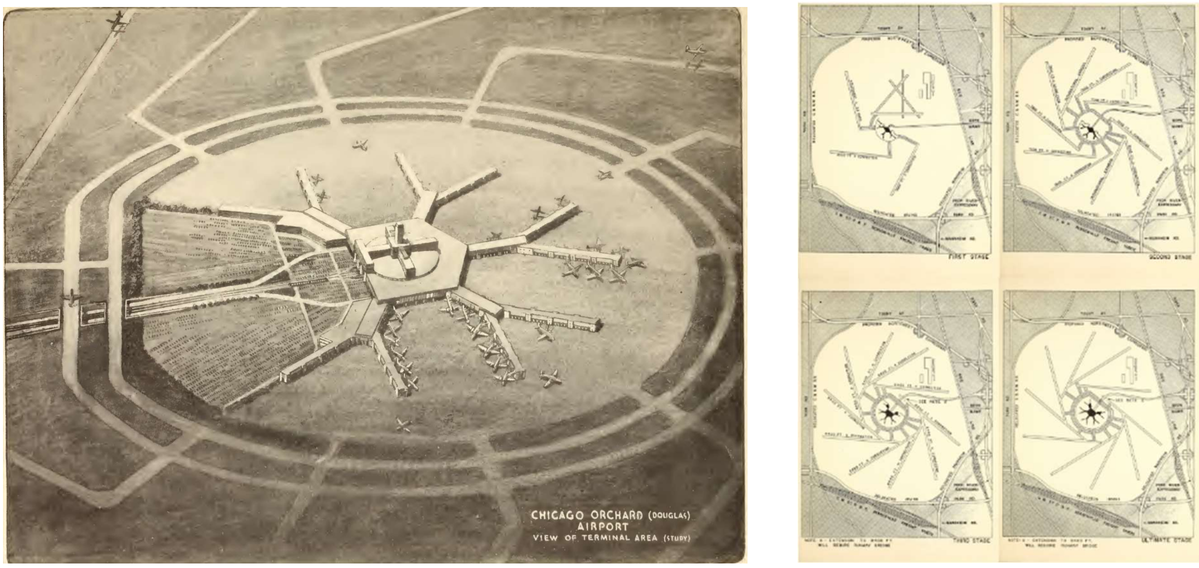


Figure 6.45 - Chicago O'Hare 1948 - Source: Chicago Master Plan (Burke, 1948)

Figure 6.46 - Chicago 1962 – Source: Cameo Greeting Cards

Chicago O'Hare took a long time to realise, and was redesigned several times in the intervening period, eventually opening fully in 1962. In the meantime simpler finger pier concepts were built at Washington Friendship (1950) (Baltimore) Airport, consulting engineers Whitman, Requardt-Greiner Co. and Associates, (Flight, Editor, 1952), (figure 6.47), Greater Pittsburgh (1952), architect Joseph W. Hoover, (Talbert, 1953) (figure 6.48), San Francisco(1954), architect William Peyton Day (SFO, 1960) (figure 6.49), St Louis Lambert (1956), architects Hellmuth, Yamasaki & Leinweber, (McCallum, 1959, pp. 166-167) (figures 6.50, 6.51, 6.52 & 6.53) and London Gatwick (1958), architects Yorke, Rosenburg & Mardall (YRM) (AJ, 1965) (figures 6.64 & 6.65).

Figure 6.47 - Washington, Friendship 1950 – Source: Postcard Playlea.com

Figure 6.48 - Greater Pittsburgh 1952 - Source: uk.pinterest.com

Figure 6.49 - San Francisco 1954 – Source: flysfo.com

Figure 6.50 – St. Louis Lambert 1956 view from pier – Source: globaldyn.ipnstock

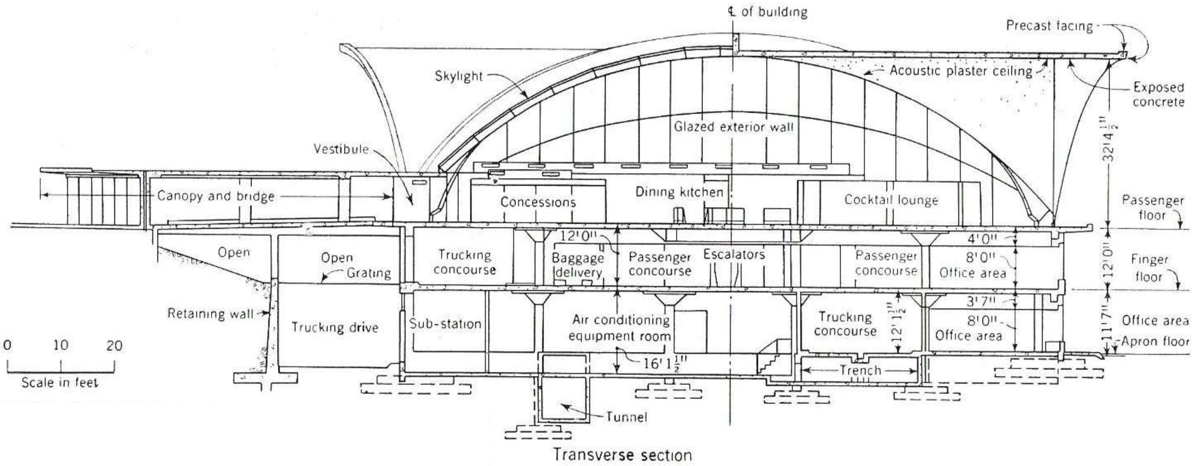


Figure 6.51 St. Louis, Lambert, 1956 section through terminal –
Source: Architecture USA, Ian McCallum, Architectural Press 1959

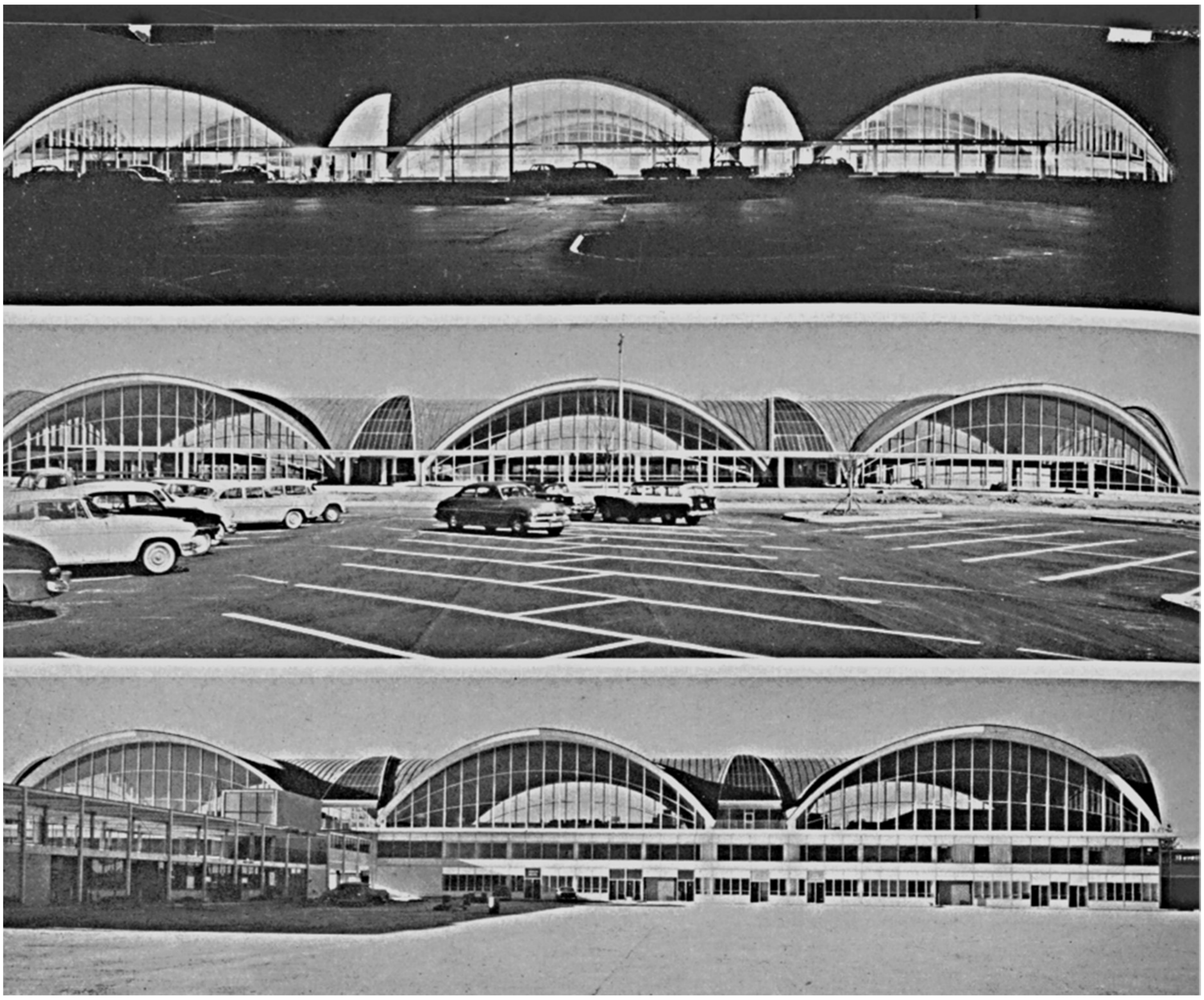


Figure 6.52 - St. Louis Lambert 1956 – Source: Architectural Record April 1956

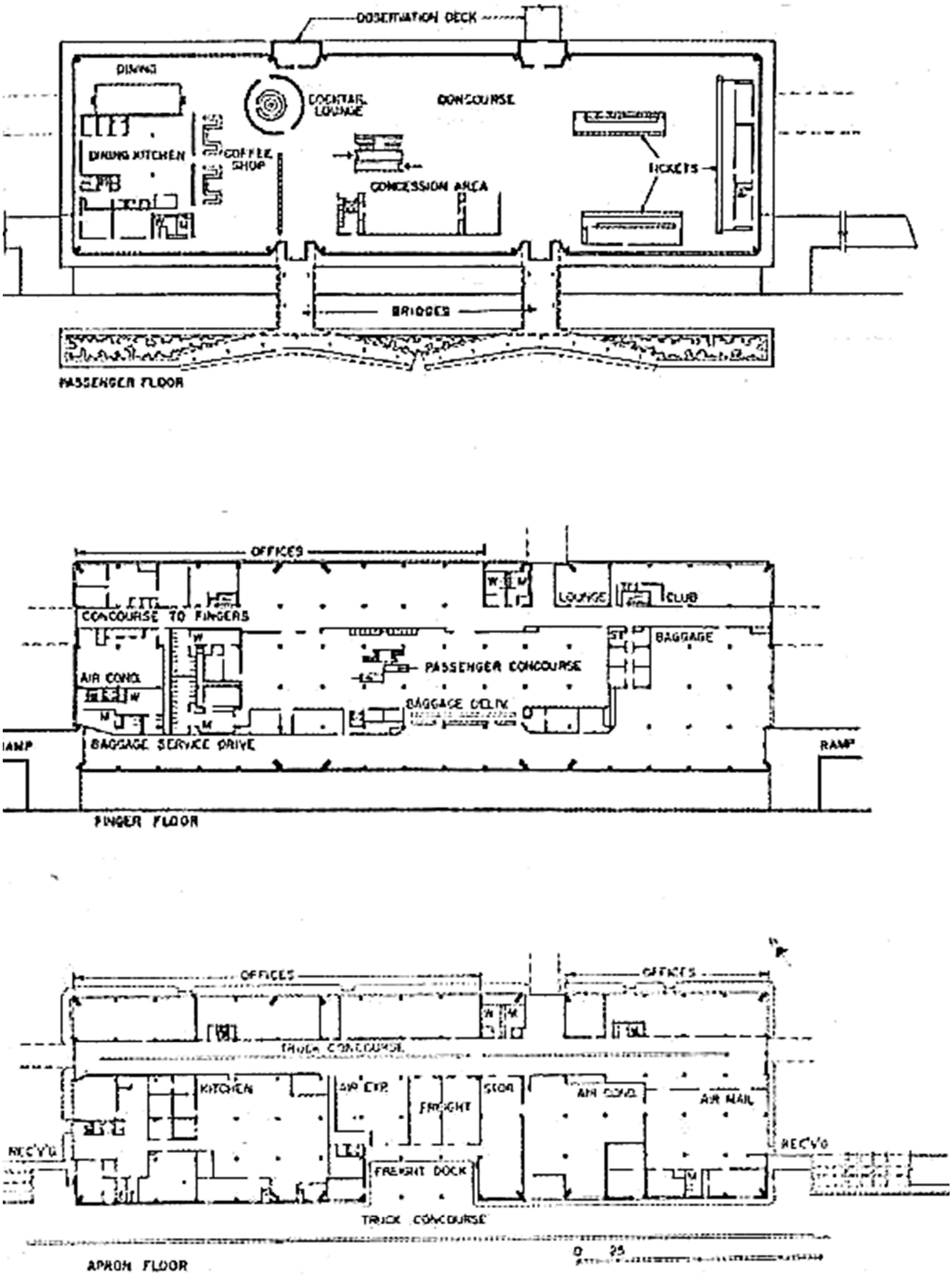


Figure 6.53 - St Louis, Lambert 1956 – Source: Architectural Record April 1956

Figure 6.54– London, Gatwick 1958 with a central pier – Source: YRM Architects and Planners

Figure 6.55 – London, Gatwick 1970 extended with three piers – Source: YRM Architects and Planners

The Chicago model was later adopted at Amsterdam Schiphol Airport (Dierikx, 1999) (figure 6.56) and Frankfurt Airport (Flughafen, Frankfurt/Main AG, 1996) (figure 6.57).

Figure 6.56 - Schiphol 1987 – Source: Postcard printed by Euro Color Cards, Sleeuwijk (no 1122)

Figure 6.57 – Frankfurt 1972 – Source: Business Traveller

A step change in the scale of the pier concept can be seen at Hong Kong International, architect Foster & Partners, where the addition of an automated people mover running under the pier to a station at the point where the pier bifurcates, transformed the scale at which the concept can operate satisfactorily while maintaining reasonable walking distances (figures 6.58, 6.59 & 6.60). Hong Kong has been able to operate for twenty years through the pier system and handle as many as 45 million passengers, before the satellite was added in 2019. A number of subsequent terminals have followed similar planning principles, including Doha (figure 6.61) and Singapore, Changi Terminal 5 (figure 6.62).

Figure 6.58 - Hong Kong International 1998, aerial view of Terminal and Y shape pier – Source: Wikipedia

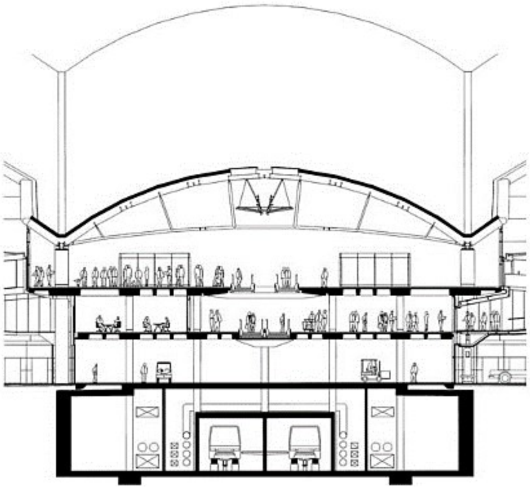


Figure 6.59 Hong Kong International 1998, section through central pier – Source: Foster & Partners

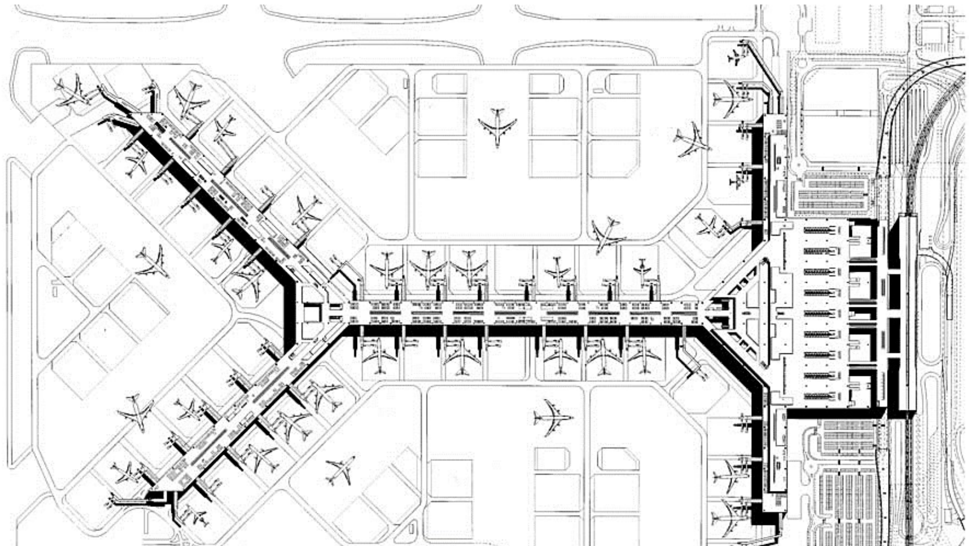


Figure 6.60 - Hong Kong International 1998, terminal plan - Source: Foster & Partners

Figure 6.61 - Doha, Hamad International 2014 Aerial View of model – Source: World Airline News

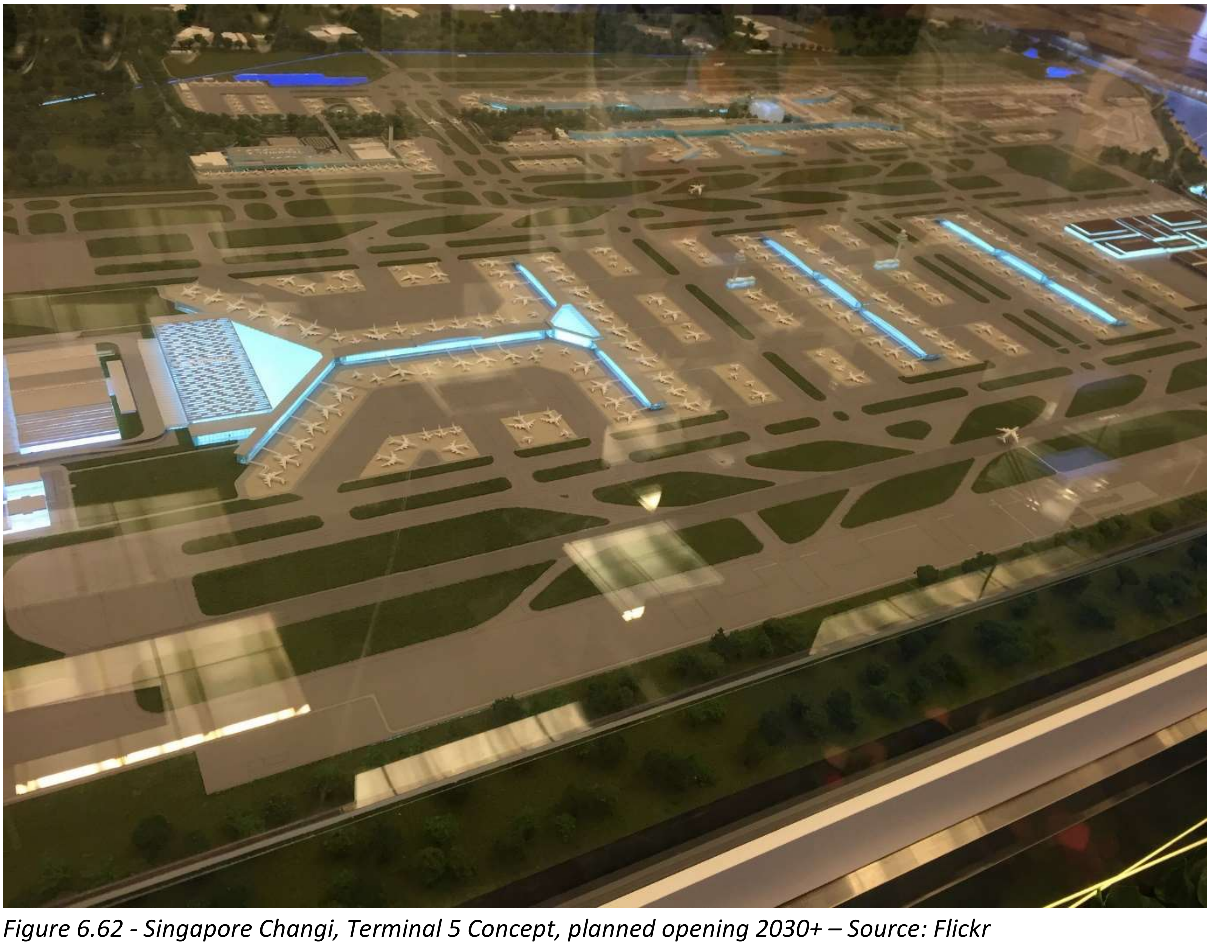


Figure 6.62 - Singapore Changi, Terminal 5 Concept, planned opening 2030+ – Source: Flickr

The pier concept continues to be relevant today at major hub international airports such as Bangkok Suvarnabhumi, Murphy/Jahn Architects (2006) (figure 6.63), Shenzhen Boan, architects Massimiliano and Doriana Fuksas (figure 6.64), Abu Dhabi International, architects Kohn Pedersen Fox Associates (KPF) (figure 6.65), and Seoul Incheon Terminal 2 architect Gensler, in collaboration with the HGMY Consortium (figure 6.66).

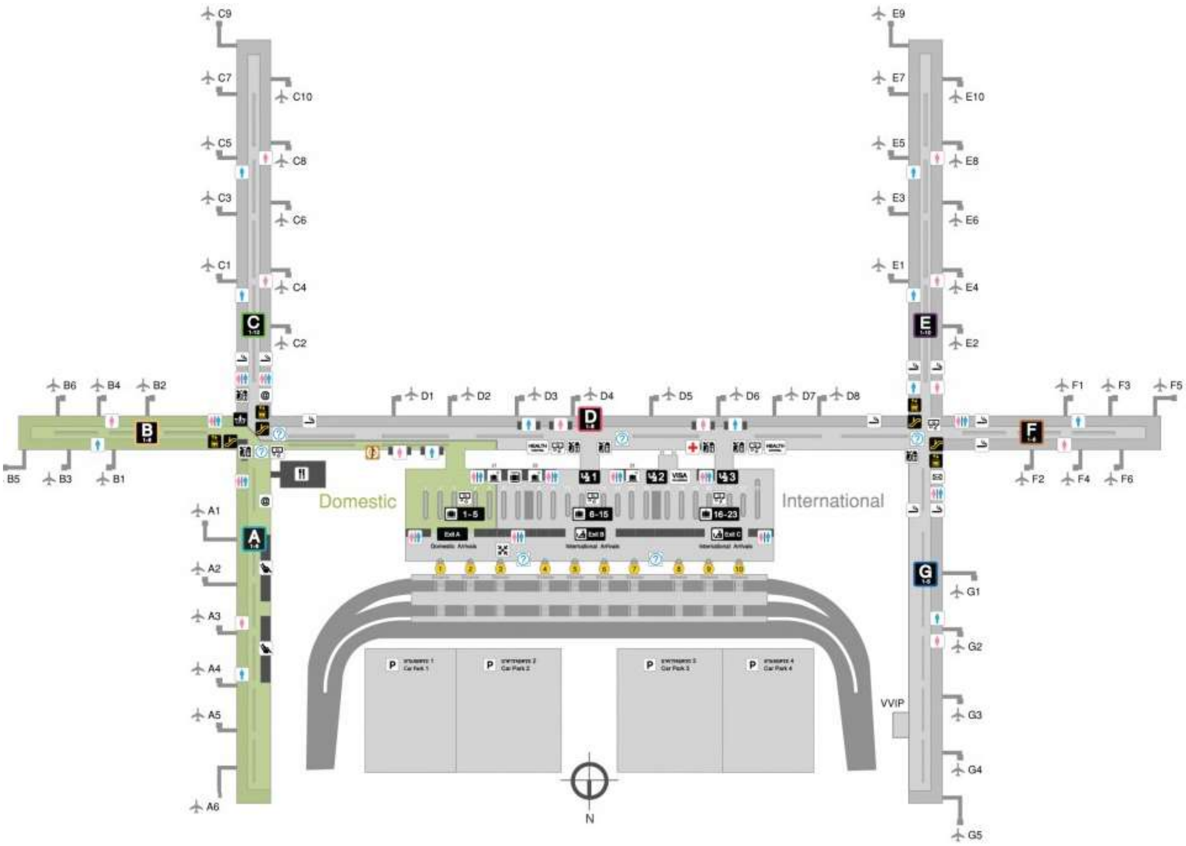


Figure 6.63 - Bangkok, Suvarnabhumi 2006 – Plan and aerial view -
Sources: luxuryvillasandhomes.com & http://www.suvarnabhumiairport.com

Figure 6.64 Shenzhen Boan 2013 - Source: Shenzhenshopper.com & ChinaAirlineTravel.com

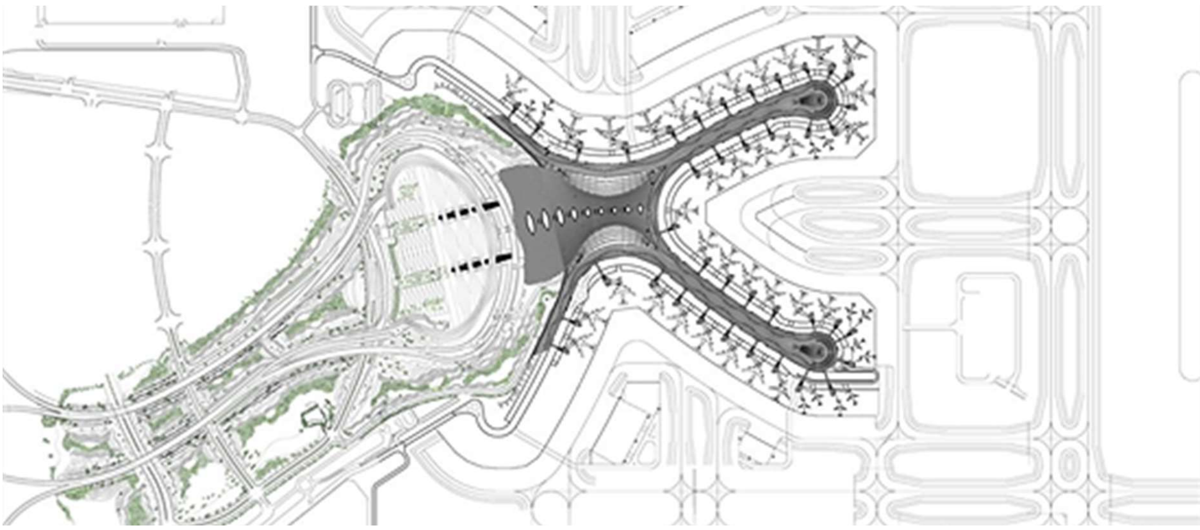


Figure 6.65 – Abu Dhabi International Mid-Field Terminal opening 2021– Source: Abu Dhabi Airports Company

Figure 6.66 - Seoul Incheon Terminal 2018 – Source: Gensler Architects

The largest of these, Istanbul Grand (2019), architects Grimshaw, Nordic and Haptic, benefits from a high proportion of narrow bodied aircraft which allows a more compact layout. It has, however, demonstrated that this concept can be appropriate for terminals of up to 90 mppa albeit at the expense of some extended walking distances (figure 6.67).

Figure 6.67 - Istanbul Grand 2019 – Source: Grimshaw Architects

The finger pier concept is the most commonly adopted of all. There is a revived interest in the finger pier concept, in recent designs, in order to deliver the maximum number of airbridge served stands from the main terminal without requiring the space or cost of a transit to link the terminal with a remote satellite.

6.6 Satellite

The satellite concept consists of a main passenger processor that is connected to separate passenger boarding concourses, known at satellites, which provide access to the aircraft. This concept was first seen in the winning entry by A.C. Zimmerman and William H. Harrison to the Lehigh Airport competition in the USA (1929) (Black, 1930). The architects proposed a terminal linked by an underground walkway to a hexagonal satellite, with parking positions for six aircraft around it (figure 6.68).

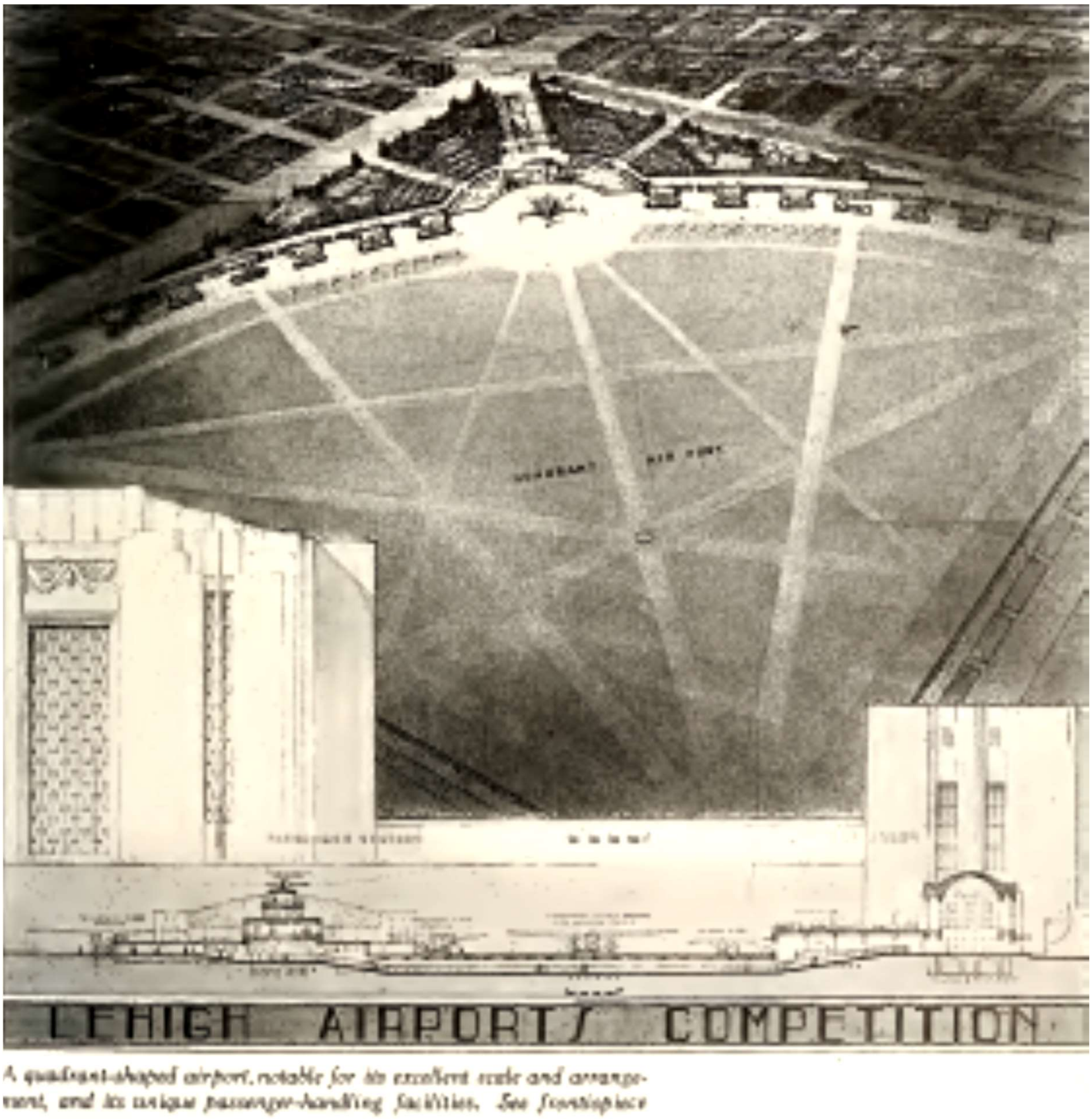


Figure 6.68 - Lehigh Airport Competition Winning Entry 1929: Source: American Airport Designs

Architect Sven Markelius proposed a mid-field circular four-storey station building in his competition entry for Stockholm Bromma airport (1934). The aircraft park around the terminal building, which held all the necessary functions under a control room on a fifth top floor (figure 6.69) (Beckman, 2014).

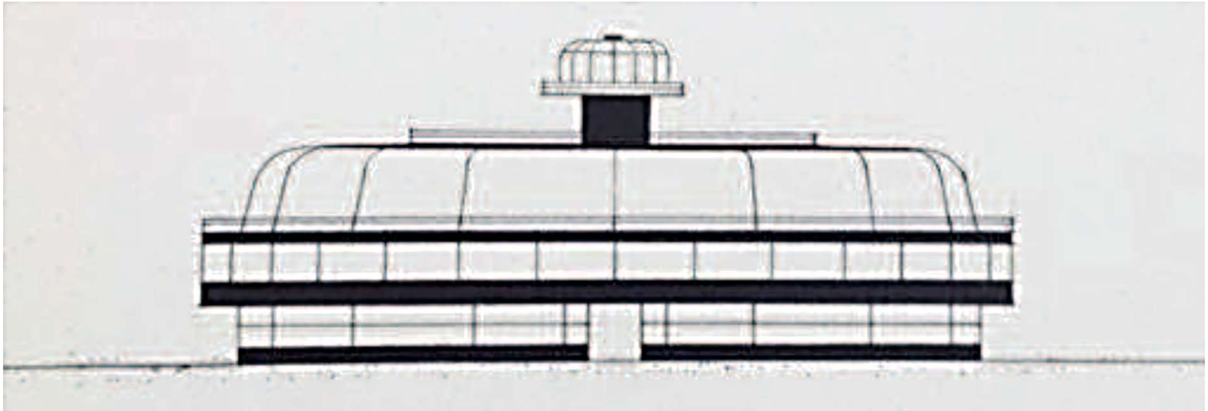


Figure 6.69 Stockholm Bromma, competition entry 1934 by Sven Markelius –
Source: Airports in Architectural Competitions 1920 -1940 Mats T. Beckman

An early reinterpretation of this concept can be found at the Gatwick 'Beehive', architects Hoar, Marlow and Lovett, (1936), a circular terminal with underground access from the adjacent railway station (King, 1980) (figure 6.70).

Figure 6.70 - 'The Beehive' Gatwick 1936 – Model – Source: Victoria and Albert Museum

A more complex and sophisticated variant of the satellite concept can be seen in the original design for the new Los Angeles Airport (1952) by architects Pereira and Luckman. A central glass domed, circular, multi-storey terminal was surrounded by six circular satellites and an entrance building (figure 6.71 & 6.72). This was the first multiple satellite design. It allowed many more aircraft to park with direct passenger access from the gates than previous concepts. The plan for Los Angeles was not executed because the city's building department thought it was too radical, requiring very expensive air conditioning. The airlines also wanted individual terminals. However the architects were later to design the futuristic LAX Theme Building and resurrect the satellite concept in a simplified form. The satellite idea was later taken up again in the design for Paris, Charles de Gaulle Terminal 1.

Figure 6.71 - Los Angeles, Aerial View 1952 – Source: The Guardian

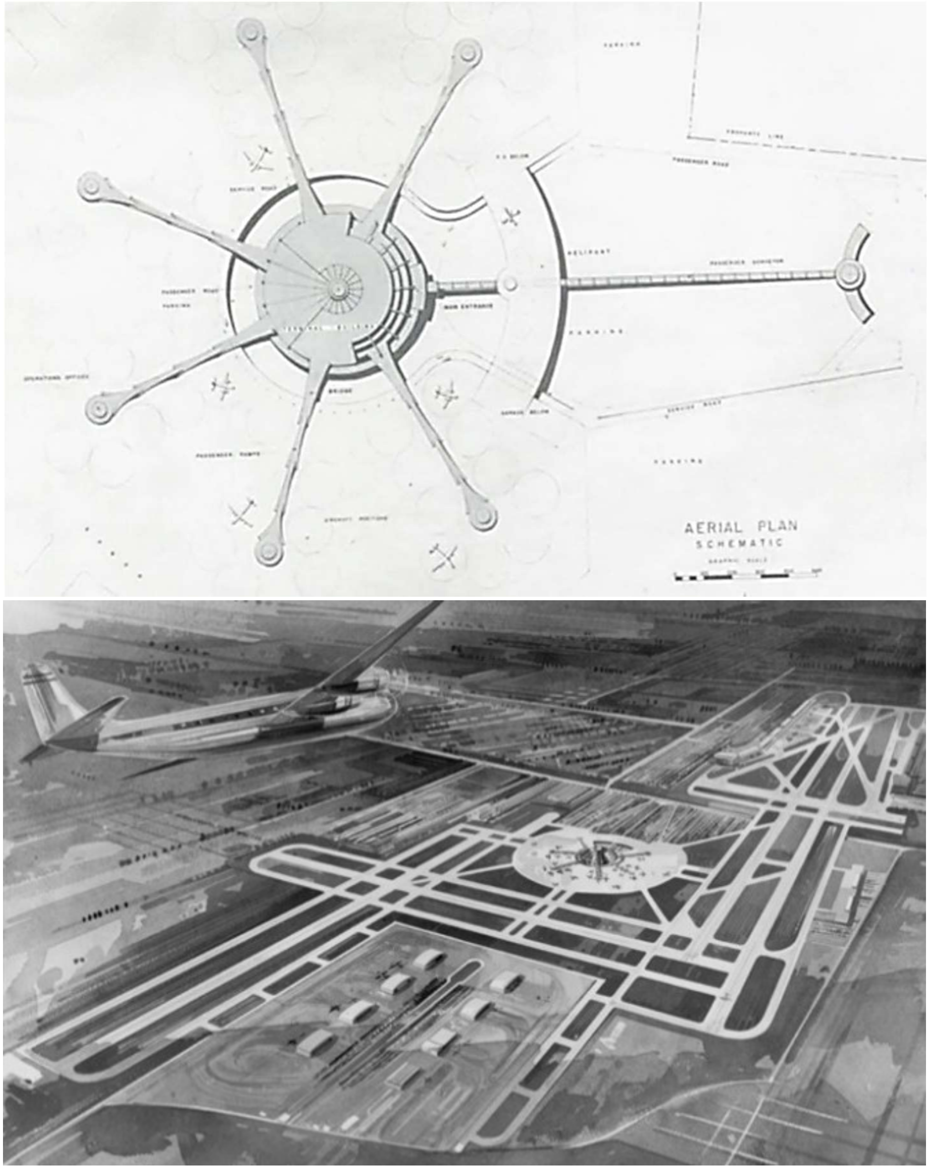


Figure 6.72 - Los Angeles 1952, Terminal and Satellite Plan and birdseye view – Source: Los Angeles World Airports Flight Path Learning Center

They continued to work on updating the concept at LAX to make it suitable for the Jet Age. There were no existing examples to draw on. Luckman summed up the challenge in his autobiography:

‘We were then, in 1955, planning an airport to be constructed in 1960, which was large enough for 1980. We had our work cut out for us. All architectural design anticipates future needs, but this was a different order: building to accommodate machines that existed only on drawing boards, and which were expected to lead to large but hard-to-predict changes in global travel. The jets would of course need new facilities, such as longer, stronger runways.’ But the aircraft themselves weren’t the greatest test the airport faced. *‘It is neither the number of airplanes, nor the number of operations which is significant,’* Luckman wrote, ‘*but the number of people. Jets could carry more passengers than propeller planes; more significantly, they promised to dramatically reduce the cost of air travel. The prediction for 1980 was 18 million passengers a year. (It turned out to be 33 million.) How would this human torrent get to and from the airport, and on and off their planes, without congestion and confusion?’* (Luckman, 1988)

So they re-invented their 1950s satellite concept for the 1960s Los Angeles Airport (1962), designing lozenge shaped concourses linked by underground passages to a series of separate entrance buildings designed to meet the needs of individual airlines (figure 6.73 & 6.74). Pereira & Luckman’s plan anticipated the separation of arrivals and departures passenger movement into two levels, so each could flow in one direction only.

More significantly, they broke away from having a single building, instead, a central complex was surrounded by elliptical satellite buildings. Luckman described the layout as looking like a gigantic horseshoe. *“At the open end of the horseshoe we placed the control tower, giving the controllers total peripheral vision of field and sky. Along the outside of the horseshoe plan were the two-level satellite buildings for each airline, which looked like bubbles rising from a sea of concrete’’* (Luckman, 1988)

Figure 6.73 - Los Angeles Satellite 1962 - Source: jonproctor.net

Figure 6.74 - Los Angeles Airport 1962 Aerial View, Theme Building and Satellites – Source: https://i.pinimg.com

The new Paris airport, designed to replace the ageing Le Bourget, originally known as Paris Nord, and later as Roissy and eventually Charles de Gaulle brought the satellite concept to Europe when it opened in 1974. The main circular terminal, designed by architect Paul Andreu, is linked by underground walkways to seven satellites which are in turn surrounded by parked aircraft. The concept was developed primarily to reduce walking distances when compared to the conventional pier layouts that were common at that date, but at the expense of multiple vertical passenger movements, both within the terminal building and between the terminal and satellites (figure 6.75).

Figure 6.75 - Paris, Charles de Gaulle, 1974 – Source: Copybook.com

The satellite idea was also taken forward by Eero Saarinen at the New York Idlewild (JFK) TWA Terminal (1962). The terminal was linked by over-ground walkways to the satellites designed to accommodate the new generation of jet aircraft (Blankenship, 1974) (figure 6.76).

Figure 6.76 - New York JFK TWA Terminal 1962 *Source: Flickr*

Satellites, with above ground links, have often been designed as extensions to existing terminals such as Orly-Sud (1971) (Blankenship, 1974) and Gatwick (1982) (Allen, 1983) (Powers, 1992). Circular satellites can also be found at Newark Terminals 1 and 2 (1973) (Blankenship, 1974) (figure 6.77) and Brisbane domestic terminal (figure 6.78). The major limitation of the circular satellite concept that has prevented its widespread adoption is that it is inherently incapable of expansion and was later abandoned as both Newark and Brisbane grew.

Figure 6.77 - Newark 1973 – Source: Tripsavvy.com

Figure 6.78 Brisbane Domestic 1988- Source: Brisbane

Another type of satellite, the linear satellite can first be seen in a 1950 concept for Heathrow Airport, by W.O. Biernacki, an architectural student at University College London. The design proposed a finger pier and two parallel satellites reached by underground walkways, serving aircraft via 83 telescopic loading bridges. Despite encouraging publicity in the architectural press the idea was not progressed (Biernacki, 1950) (figure 6.79).

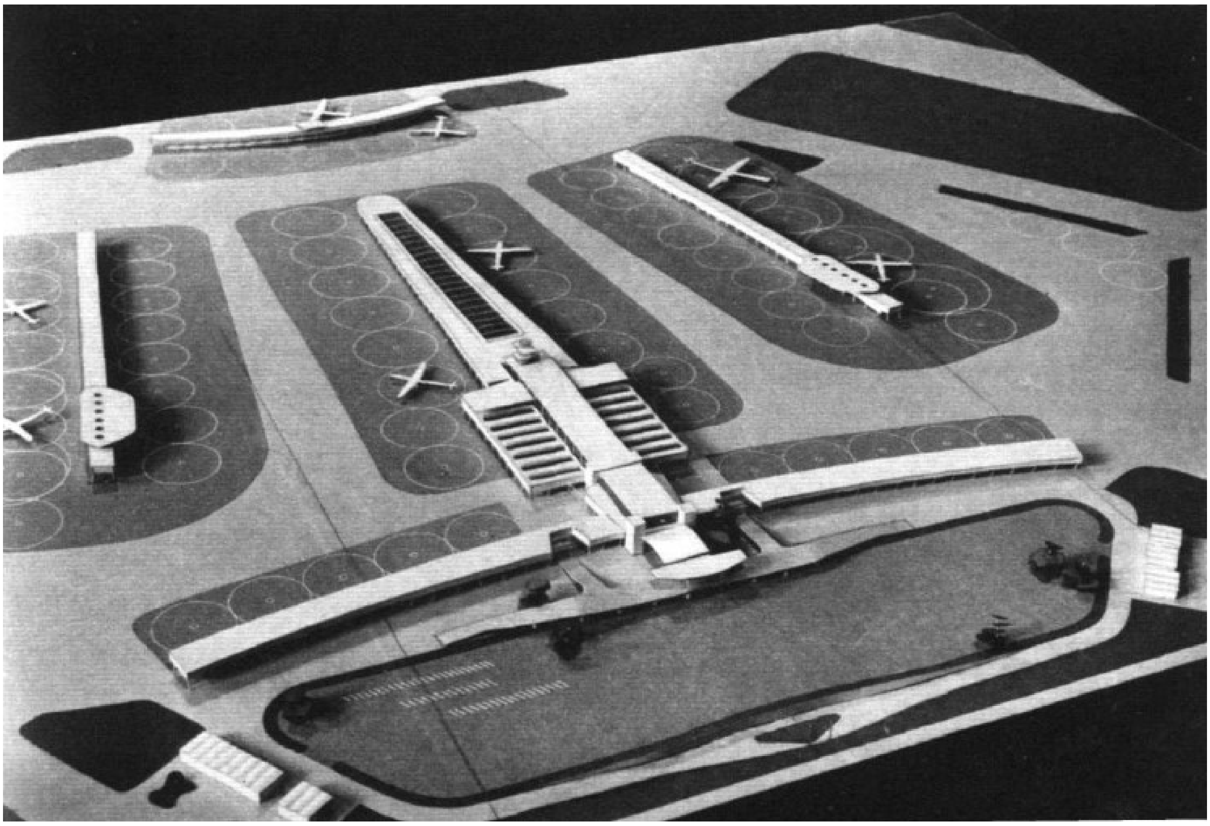


Figure 6.79 - Heathrow Satellite Concept 1950 - Source: Flight 04.05.1950 p552-3

A much more ambitious concept was developed for Atlanta Hartsfield (1980), by architects Stevens & Wilkinson, Smith Hinchman & Grylls (now called SmithGroupJJR), where several much larger and longer concourses (each over 1Km long), provided access to a large number of aircraft (Braden, 1989) (figure 6.80). The satellites were linked to the terminal building by an underground transit or automated people mover (APM).

Figure 6.80 - Atlanta Satellites 1980 - Source: City2map.com

Based on learning from Atlanta, about the ease of aircraft movement, the United Terminal at Chicago O'Hare was re-designed with a satellite to replace a previous finger pier.

The linear satellite configuration has since been used at Denver International Airport, (2000) by Fentress Architects, (Binney, 1999) and Heathrow Terminal 5, architects RSHP, (2008) (Anderson, 2014) and Terminal 2, architect Luis Vidal in succession to Foster & Partners (2014) (Vidal, 2013). It is generally recognised to be the most efficient way to develop a multi-runway airport both in terms of land use and aircraft ground movement but the concept relies on the provision of underground people movers. Much larger satellites accessed by underground transits can be found at Pittsburgh (1992), designed by TKA Architects, (figure 6.81) and Kuala Lumpur Airports (1998), by architect Kisho Kurokawa, (figure 6.82). They employ a cruciform configuration which offers improved passenger connectivity and shorter walking distances combined with the opportunity for a better consolidated retail offer but are less efficient in taxiway layout and land use.

Figure 6.81 - Pittsburgh Satellite 1992 - Source: http://wesa.fm

Figure 6.82 - Kuala Lumpur Satellite 1998 - Source: paradiseintheworld.com

Satellite concepts are typically associated with high cost transit systems. Some airports have sought to avoid this by using underground tunnels (Chicago, United Terminal) or high level bridges (Gatwick North Terminal) that substitute passenger conveyors for a transit system.

6.7 Mid Field Hub

An early precursor of a mid–field terminal can be found at Washington Dulles (1962) (Stroud, 1980); it was originally designed with an open apron with passengers conveyed by cumbersome and slow mobile lounges between the terminal and the aircraft, parked in a series of parallel rows placed at right angles to the runways (figure 6.83). This layout relied on the simplification of the runway layout into two primary parallel runways that was made possible by the introduction of jet aircraft that were less susceptible to cross winds.

The terminal, designed by Eero Saarinen, was then located between the runways with landside access to one face of the terminal and airside access the other. The Washington Dulles Airport master plan can therefore be described as the first of the jet age and a prototype for future mid field hub airports. It has subsequently been extended and reconfigured with satellites linked by an underground automated people mover (APM) as the mobile lounge concept proved expensive to operate, unreliable and increasingly impractical as traffic grew.

Figure 6.83 - Washington Dulles 1962 – Source: Washington Post

Atlanta Airport's 1980 rebuild is also internationally recognized as the first airport that was specifically designed as a 'Hub' airport to facilitate the new business model developed by Delta Airlines that was based on linking many smaller cities through a central hub where passengers transferred form one flight to another (Stroud, 1980).

Like Washington Dulles the Atlanta configuration involved placing the terminal between parallel runways, but its key innovation involved linking it by an underground Automated People Mover (APM), to a series of linear satellites. The layout was adopted to supersede the former Chicago like finger pier layout to reduce aircraft movement congestion and avoid runway crossings that limited the capacity of the former layout (figure 6.84).

Mid field terminals at major transfer hubs have been developed in both pier format such as Bangkok (2004) (D'Silva, 2006) and Istanbul Grand (due to open in 2018) (Welch, 2016), linear satellite Denver (1996) (Fentress, 2006) or Dubai International (Airports, 2017) and also cruciform satellites that minimize walking distances Kuala Lumpur (1999) (Binney, 1999), Dubai World Central (due to open 2025) (Airports, 2017) or the stillborn New Hub Airport for London on the Isle of Grain (Atkins, 2014).

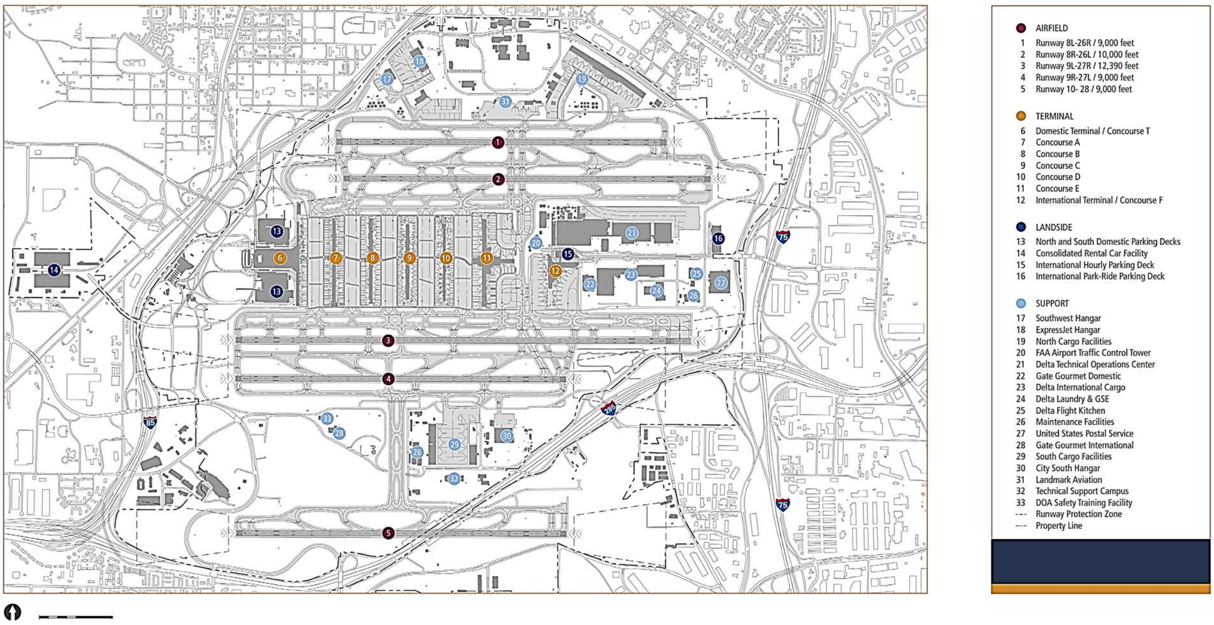


Figure 6.84 – Atlanta, Hartsfield Existing Master Plan 2015 – Source: City of Atlanta, Department of Aviation

A composite form with both finger pier and satellites can also be seen at Beijing Capital Airport, designed by Foster & Partners (Foster, 2010). Beijing terminal 3 is one of the biggest in the world, measuring 2,900 metres and having 120 gates. The building, opened in 2008, resembles a giant dragon and has an aerodynamic roof (figure 6.85). It helped Beijing Capital become the second airport in the world to handle over 100 million passengers a year.

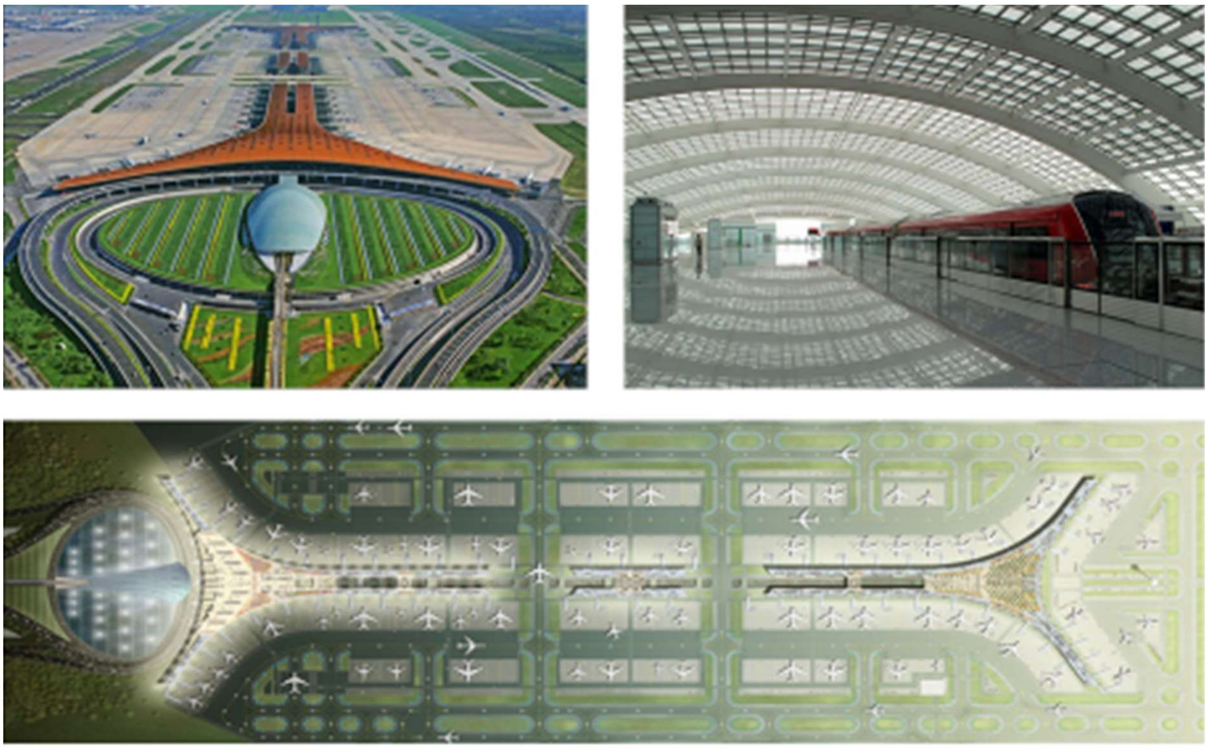


Figure 6.85 - Beijing Capital, 2008 – Source: Foster + Partners

The mid field terminal together with the satellite concept and associated transit can most often be found in the largest of airports, because it can create the greatest possible number of jetty served stands, within reasonable walking distance, and far more than any equivalent finger per concept.

6.8 Underground Terminal

Ideas of providing some or all terminal facilities underground have been considered since the early days of commercial flying and typically dismissed as interesting but impractical. An early example can be seen in the entry to the Lehigh Airports Competition (figure 6.86).

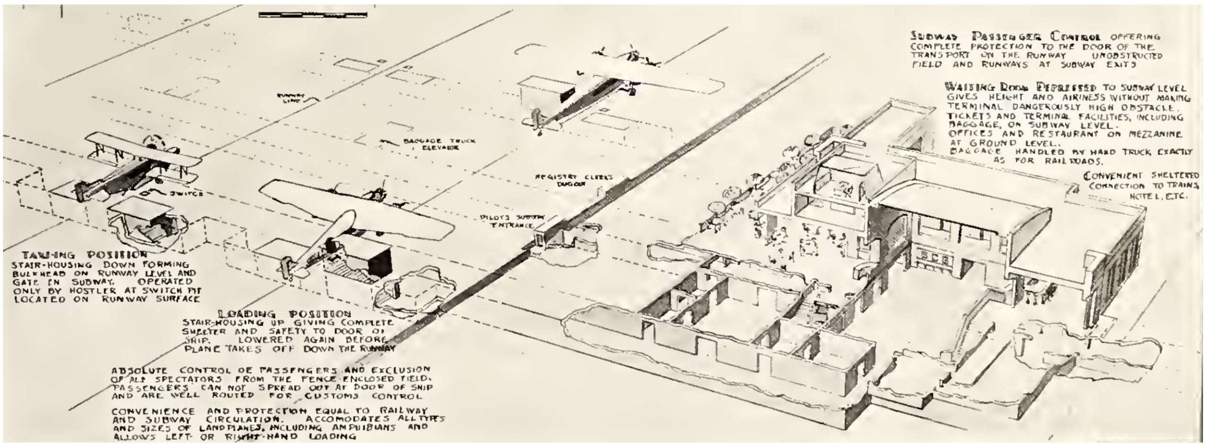


Figure 6.86 - Lehigh Competition - Honourable Mention - Edwin M. Stitt –
Source: American Airport Designs 1930

As part of this concept, by Edwin M. Stitt, the main concourse of the passenger terminal was below ground level. The judging panel's particular interest in the scheme was the passenger handling concept which involved the use of a series of tunnels beneath the paved loading apron, with elevating canopies over staircases which rose from the tunnel to the surface at airfield level.

The judges rated this as a very promising idea. When a plane had been brought to the loading and unloading point, a surface switch automatically brought the canopy into its elevated position. When the plane was about to leave, the canopy was again lowered for safe taxiing over the surface. A similar tunnel, equipped with baggage elevators was used for mail, express cargo and by the pilots.

The underground terminal concept was taken a step further in a number of theoretical designs where aircraft descended to a lower level by lift after landing, following the example of aircraft carrier technology, as can be seen in the 1935 model for an underground air terminal overleaf (figure 6.87). After landing, aircraft would go underground to various levels for passenger and cargo loading and, maintenance. Connections to the ground transportation system were at the lowest level.

A second even more fanciful scheme proposed in 1946 by William Zeckendorf, vice president of the New York real estate agent Webb and Knapp. It involved the construction of a multi-level, 900-acre airport along the West Side of Manhattan, in which all passenger handling facilities would be placed below the elevated runway eleven storeys in the air (figure 6.88).

Figure 6.87 - Underground Terminal 1935 - Source: National Air and Space Museum Archives

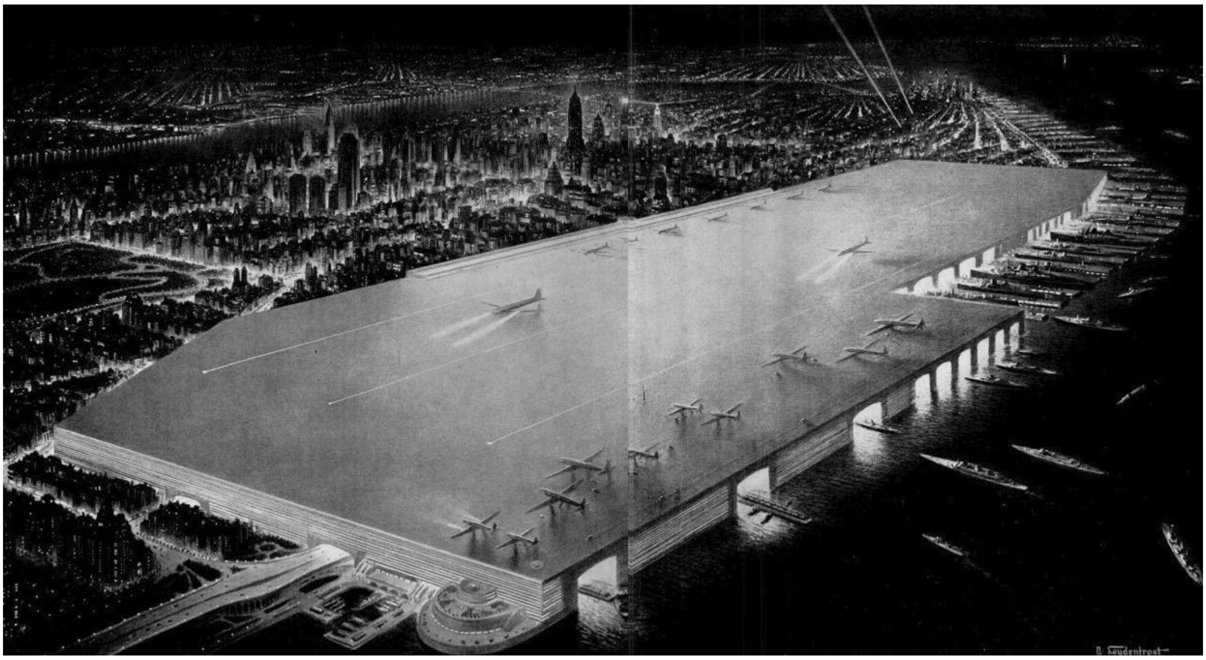


Figure 6.88 - Manhattan Super Airport 1946 - Source: Life

There is, however, a single example of a real underground Terminal operating today, Terminal 3 at Dubai International Airport. Dubai is a very large transfer hub primarily serving Emirates airline and handling more than 80 million passengers per annum (mppa) and anticipated to grow to over 100mppa. Faced with a very constricted site for such a large hub, airport planners Aéroport de Paris (ADPi) proposed that the terminal should be placed under the taxiway system that surrounded the satellite concourse.

The layout maximizes the number of aircraft stands provided in combination with providing an efficient taxiing system (figures 6.89, 6.90, 6.91 & 9.92). The underground concourses feature very high ceilings and are brightly lit with artificial lighting, so the passenger has no real perception that they are indeed underground, and the resultant vertical circulation is more effortless than other satellite designs.

Figure 6.89 – Dubai Terminal 3 2008 Entrance Canopy Source: Gulf News

Figure 6.90 – Dubai Terminal 3 Underground Reclaim Source: Business Today ME

Figure 6.91 – Layout of Underground Terminal 2008 - Source: Dubai International Airport

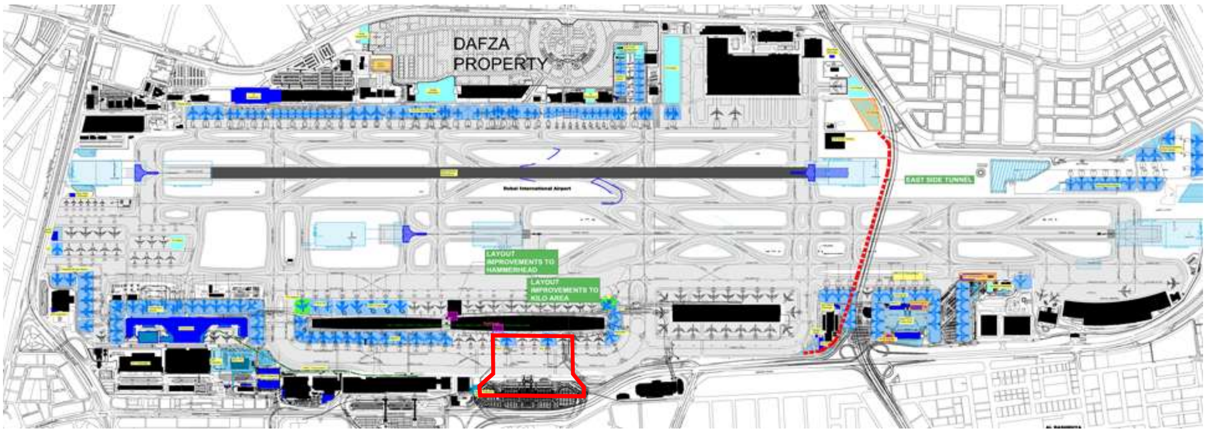


Figure 6.92 - Dubai International Site Plan 2008 – Underground Terminal outlined in red – Source: Atkins

An underground terminal was briefly considered for Heathrow Terminal 5 and the new Beijing Daxing airport to optimise the use of the available site area, but both airports have to date followed a more conventional approach. However, as airports reach capacity and run out of development space it is anticipated that the underground terminal concept will, in future, gain more support.

6.9 Integration/Concentration or Separation/Specialisation of Function

The first scheduled flights were handled out of corners of ex-military hangars that were newly redundant after the end of the First World War such as Berlin Johannisthal (Przychowski, 2011) (figure 6.93), Paris Le Bourget (Stroud, 1973, pp. 16-19) (Figure 6.94), London Hounslow Heath (Stroud, 1973, pp. 10-11)(Figure 6.95) or Amsterdam Schiphol (Dierikx, 1999) (figure 6.96).

Figure 6.93 – Berlin, Johannisthal 1919 – Source: Bundesarchiv Bild 183-T0126-510, Berlin, Flugpost nach Weimar, Feb 1919

Figure 6.94 - Paris Le Bourget 1919 - Source: British Airways

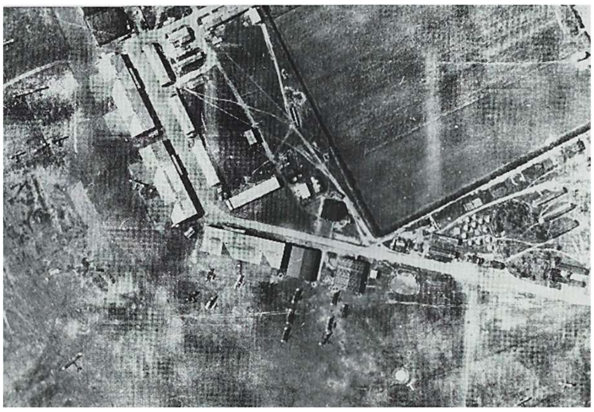


Figure 6.95 – London Hounslow Heath 1919 – Source: The World's Airports

Figure 6.96 - Amsterdam Schiphol 1920 - Source: Schiphol Airport

The earliest purpose designed terminals tended to concentrate many of the airport functions into a single building, including passenger processing, facilities for spectators, air traffic control, airport and airline administration, customs and immigration, cargo and mail as can be seen at Konigsberg (Museum Der Stadt, Konigsberg, n.d.) and Croydon Airports (Cluett, 1980)

Large spectator events such as air shows were an important source of income for early airports and helped subsidise their day to day operations, so most early airports made provision for viewing facilities often as a part of their roof design. The following photographs illustrate the Konigsberg (figure 6.97) and Croydon (figure 6.98) rooftop spectator facilities.

Figure 6.97 – Konigsberg 1922 showing spectator terraces
Source: Museum der Stad, Konigsberg–Image

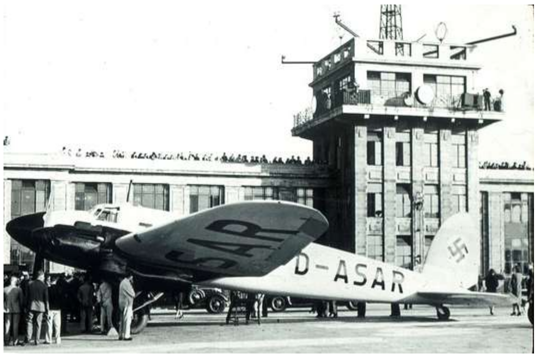


Figure 6.98 - London, Croydon, 1928 –
Source: The Royal Aeronautical Society
(National Aerospace Library)
Mary Evans Picture Library/YOONIQ

Aircraft were generally housed and maintained in separate hangars although there are several examples of terminals being integrated with the hangar in the 'lean to' or 'depot hangar' terminal concepts of the 20s and 30s in the USA. An early example can be found at Los Angeles, where Gable and Wyant designed a combined hangar, ticket office and waiting room terminal for the Curtis-Wright Flying Service (figures 6.99 & 6.100).

Figure 6.99 – Mines Field Los Angeles 1928, with Goodyear Blimp - Source: Water and Power Associates

Figure 6.100 - Curtis Wright Depot Hangar, Mines Field Los Angeles 1928 - Source: Water and Power Associates

The only comprehensively integrated terminal hangar complex handling scheduled services can be found at Berlin Tempelhof 2 (1935-9) (Dittrich, 2012). It seeks to make the complex more imposing by combining the massing of the hangar and terminal into a single curved architectural statement 1.2 kilometres long (figures 6.101 and 6.102). This was in line with the grandiose aspirations of Adolf Hitler and with Albert Speer's town planning proposals for Berlin to become Germania, the capital city of a new German empire. The terminal, with its rooftop seating and the airside apron, also acted as an amphitheatre for major Nazi rallies.

Figure 6.101 - Berlin Tempelhof 1939, Landside Aerial View – Source: The Guardian

Figure 6.102 - Berlin Tempelhof 1939, Airside View with the canopy to the terminal boarding area in the foreground and part of the hangar complex in the background - Source: Photographer, Danica O. Kus

The integration of terminals and hangars continues to this day in smaller terminals serving the private executive jet market, particularly where the environment is harsh, either very cold or very hot as it allows passengers to board their aircraft within the hangar and without being exposed to the harsh external environment.

This integration of hangar and terminal can also be seen at the Virgin Galactic Spaceport to create a dynamic visual experience (2012) (figure 6.103 & 6.104). The Hangar, astronauts' areas and visitor spaces are fully integrated with the rest of the building to convey the thrill of space travel, a modern re-interpretation of the earliest concept at Berlin Johannisthal.

Figure 6.103 – Virgin Galactic Hangar and Terminal, 2012 – Source: Foster and Partners

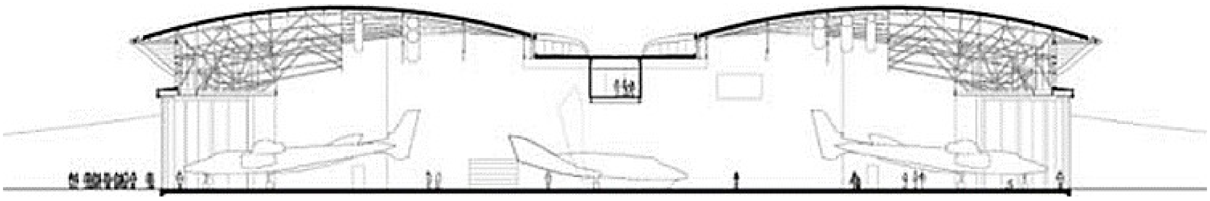
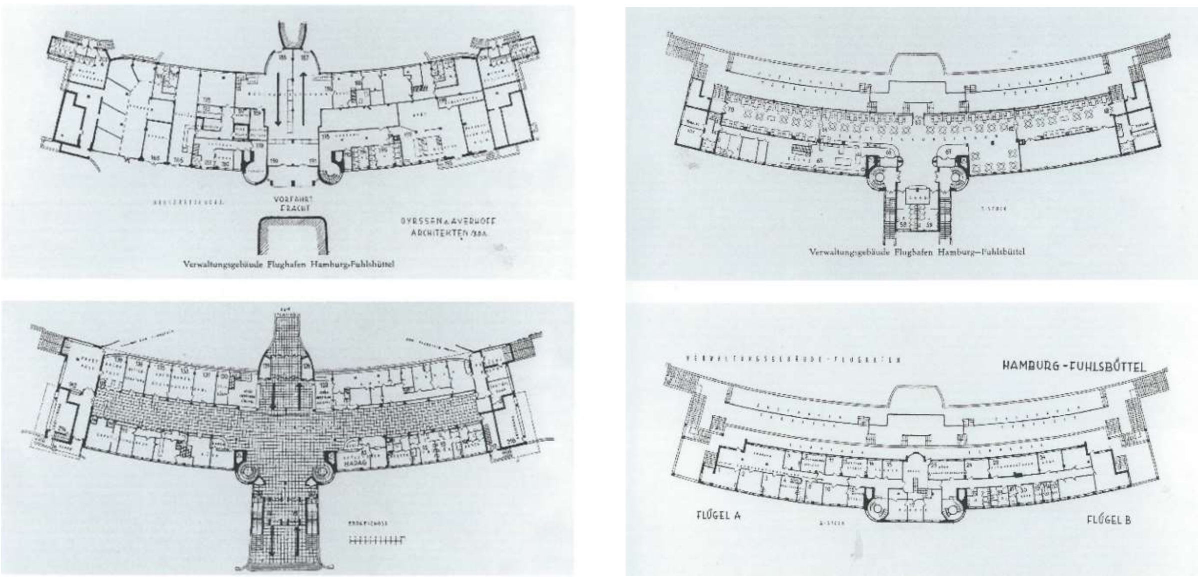


Figure 6.104 – Virgin Galactic Spaceport 2012, section and exploded view – Source: Foster + Partners

An early form of specialisation can be seen at Hamburg Airport (1929) (Voigt, 1999). This involved separating functions into different levels with baggage on the ground floor, passengers on the first floor, dining on the second floor and airport administration on the third floor. The section was also stepped back to provide spectator viewing balconies at all levels (figures 6.105 & 6.106).

Figure 6.105 - Hamburg Fuhlsbuttel, 1929 – Source: Building for Air Travel, ed. John Zukowsky



Ground Floor Baggage and cargo
First Floor Passenger Facilities

Second floor Dining room
Third Floor Administration

Figure 6.106 - Hamburg Fuhlsbuttel, 1929 – Source: Vom Flugbahnhof zum Terminal, Flughafen Hamburg 1929 -1999

Provision for cargo and mail has always been an integral part of an airport, indeed it was the primary driver of air traffic growth in the USA during the 20s and 30s and helped to subsidise passenger traffic which was not commercially viable until the introduction of larger aircraft such as the Douglas DC3 in the latter part of the 1930s.

Cargo was originally integrated with the terminal as at Croydon or Hamburg, and reached its culmination at Berlin Tempelhof 2 (Dittrich, 2012) where a rail line to bring airmail to the airport was integrated into the basement of the terminal (figure 6.107). Post war airports have almost all separated cargo into different buildings and ultimately different zones of the airport

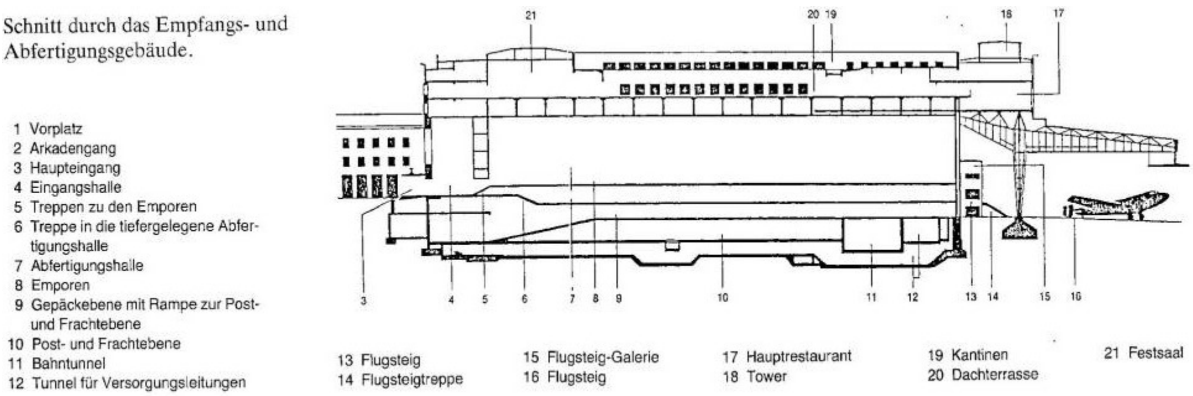


Figure 6.107 – Berlin, Tempelhof 1939, Section – Source: Der Flughafen Tempelhof in Entwurfszeichnungen und Modellen

Horizontal separation of arriving and departing passengers can be seen very clearly in Le Bourget (1937) (Hamlin, 1940, p. 639) (figure 6.108) and is a common feature of subsequent terminal designs such as Gatwick (1958) (AJ, 1965) and Stansted (1991) (Powell, 1992). This concept is still relevant today as can be seen in the Medina Airport (2016) (Atkins, 2013).

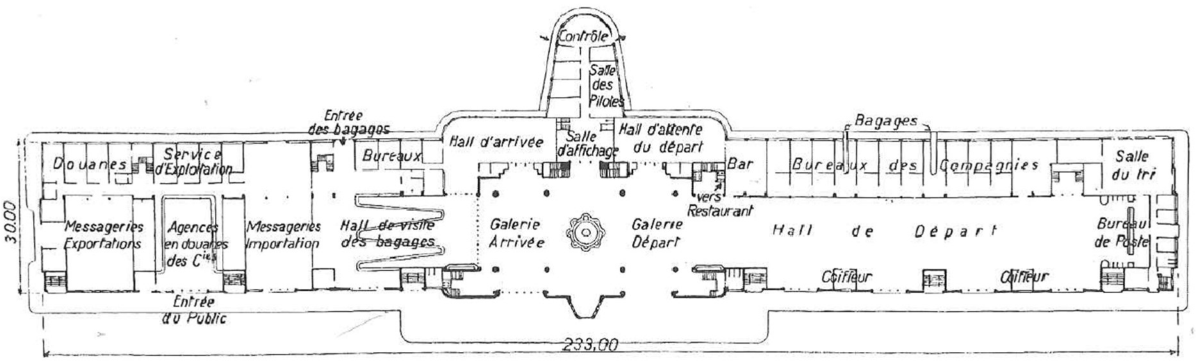
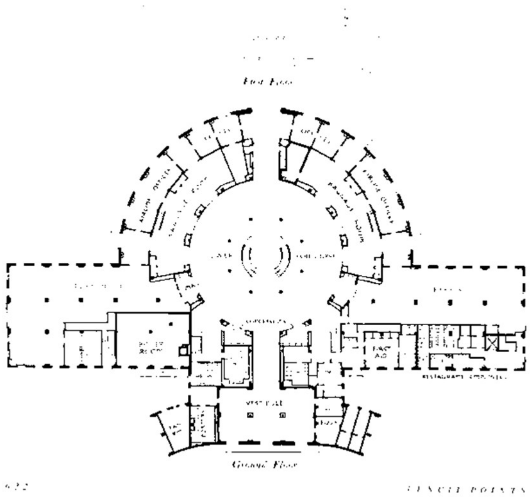
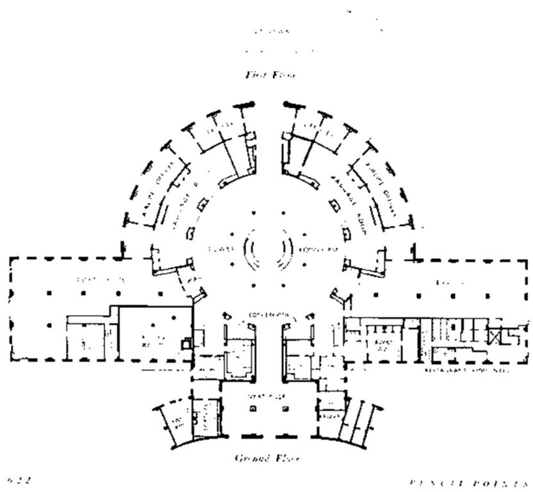


Figure 6.108 – Paris, Le Bourget, 1937 – Source: Pencil Points

The concept of separating arrival and departure forecourts into two levels originated at La Guardia airport (1939) (McMullen, 1940) to separate landside vehicle movements. This is in turn reflected in the internal planning of the terminal with check-in at the upper level and arrivals at ground floor level (figure 6.109 & 6.110).

Figure 6.109 - New York, La Guardia 1939, Aerial Photograph, – Source: http://stuckattheairport.com

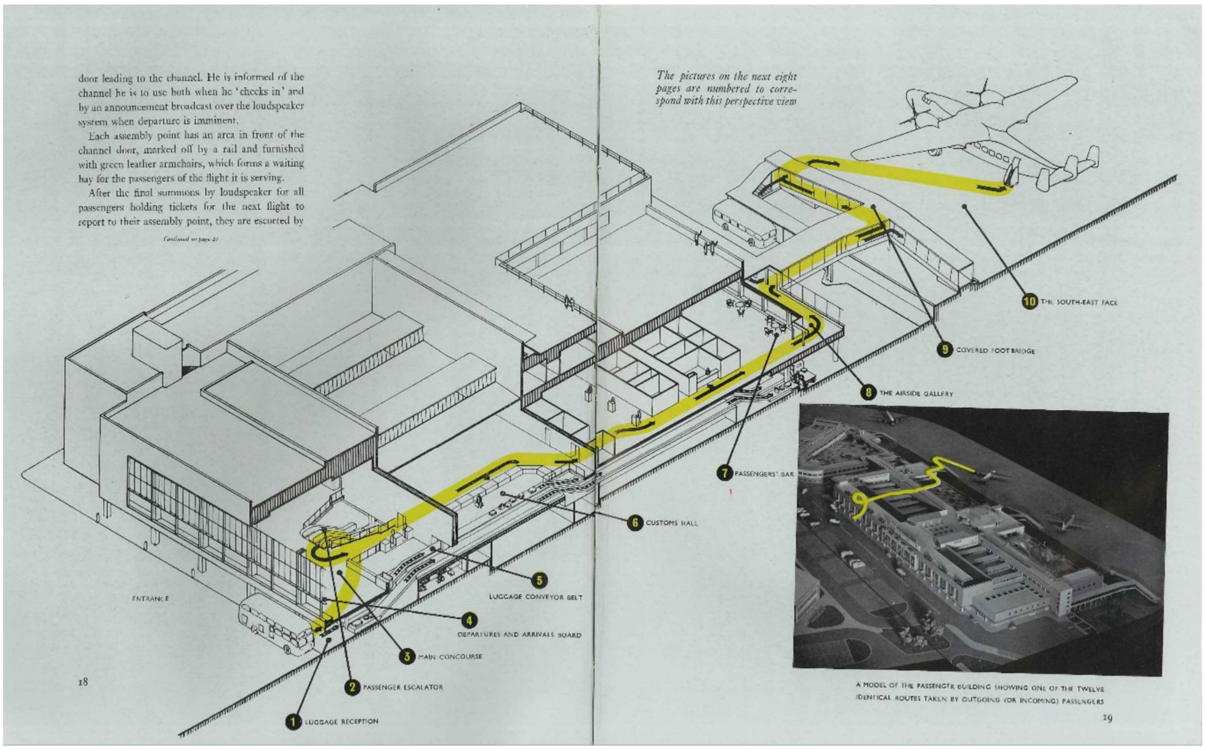




Ground Floor *First Floor*

Figure 6.110 - New York, La Guardia, 1939 – Source: Pencil Points

Time separation between arriving and departing passengers has also been used to make good use of infrastructure. A rare example can be found at the Heathrow Europa Terminal (later Terminal 2 (Chandos, 1956) and now demolished) (1955) which was designed with 10 reversible passenger lanes (figure 6.111).


door leading to the channel. He is informed of the channel he is to use both when he 'checks in' and by an announcement broadcast over the loudspeaker system when departure is imminent.

Each assembly point has an area in front of the channel door, marked off by a rail and furnished with green leather armchairs, which forms a waiting bay for the passengers of the flight it is serving.

After the final summons by loudspeaker for all passengers holding tickets for the next flight to report to their assembly point, they are escorted by

Continued on page 21

The pictures on the next eight pages are numbered to correspond with this perspective view

A MODEL OF THE PASSENGER BUILDING SHOWING ONE OF THE TWELVE IDENTICAL ROUTES TAKEN BY OUTGOING (OR INCOMING) PASSENGERS

18 19

Figure 6.111 - Heathrow Europa Terminal 1955 showing reversible passenger flow – Source: London Airport, the official story of the new world air centre

The idea was later abandoned and the terminal reconfigured in a conventional centralised manner. Terminals with a reversible flow still have a part to play in Saudi Arabia at Jeddah (1981) (Cuadra, 2002) and Medina (Atkins, 2013) where facilities are provided to handle pilgrims arriving for the Hajj and then leaving some two weeks later (figure 6.112). A similar concept was also used in a temporary tented terminal at Heathrow to handle athletes and their equipment for the London 2012 Olympic Games.

Figure 6.112 - Jeddah, King Abdulaziz Hajj Terminal, 1981 – Source: SOM

An early example of airside separation of arriving and departing passengers into two levels can be found at Hanover (1973) (Blow, 1991) which provided the model for Heathrow Terminal 4 (1987) (Blow, 1991) (figure 6.113) and has since been adopted as the most common terminal layout and the one recommended by IATA.

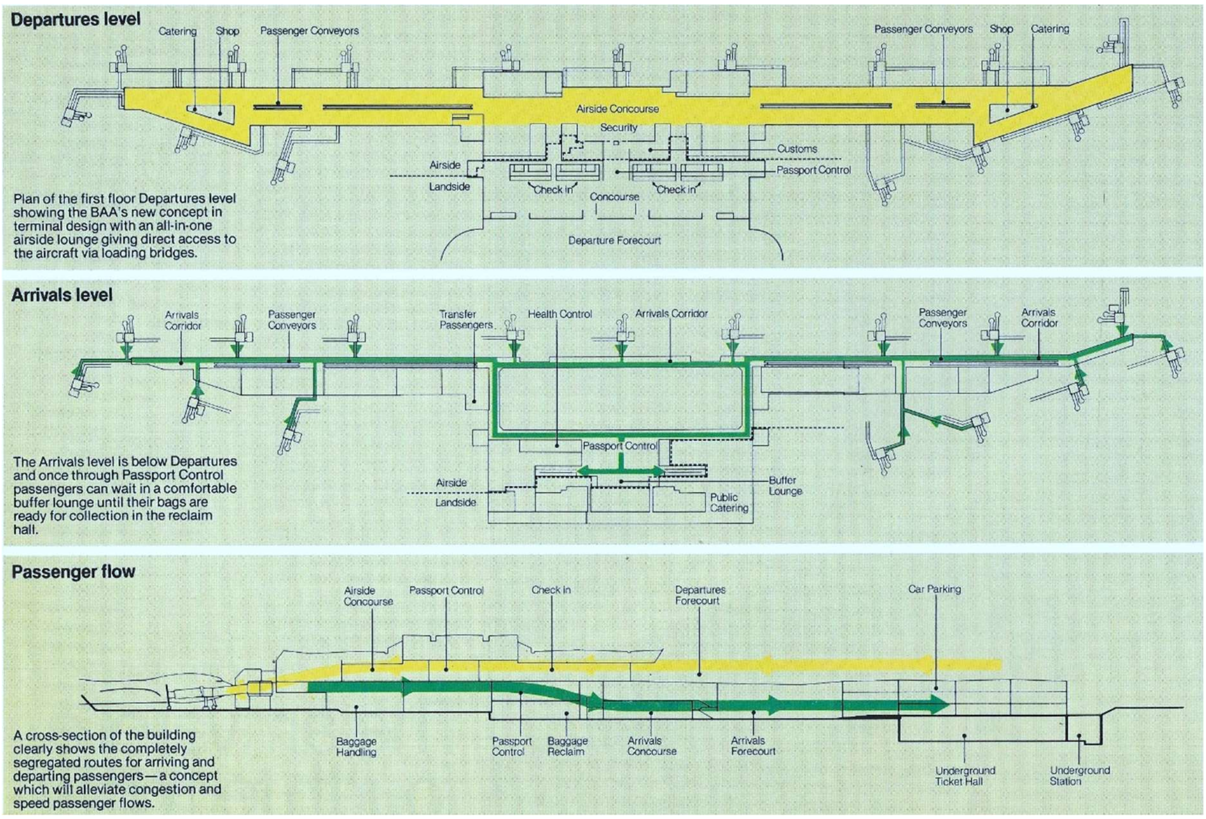


Figure 6.113 - Heathrow Terminal 4, 1987– Source: British Airports Authority

There was a revival in interest in integrating multiple airport facilities within the terminal building in the late 1960s and early 1970s. This was led in the USA by a desire to minimise the walking distances for departing and arriving passengers. A particular feature in common was the incorporation of car parking either under or over the terminal building as can be seen at Houston (1969) (figure 6.114), Tampa (1971) (figure 6.115) and later at Paris, Charles de Gaulle (1974) (figure 6.116).

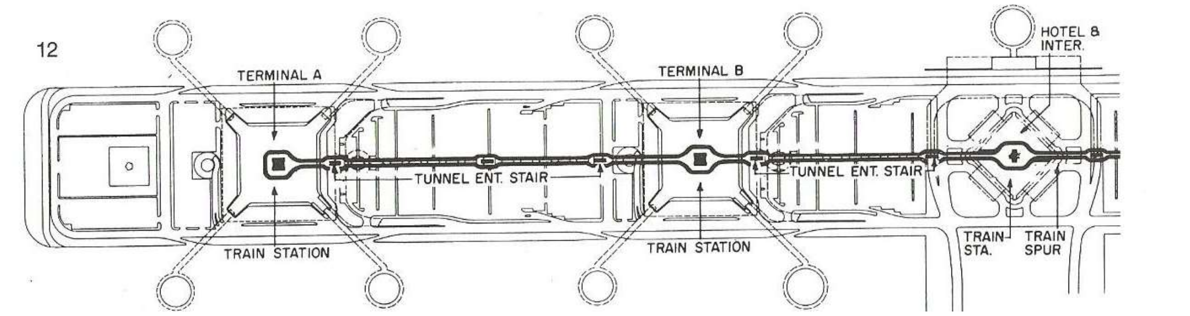


Figure 6.114 – Houston Intercontinental, 1969 Plan & Section – Source: The Airport, Edward G Blankenship

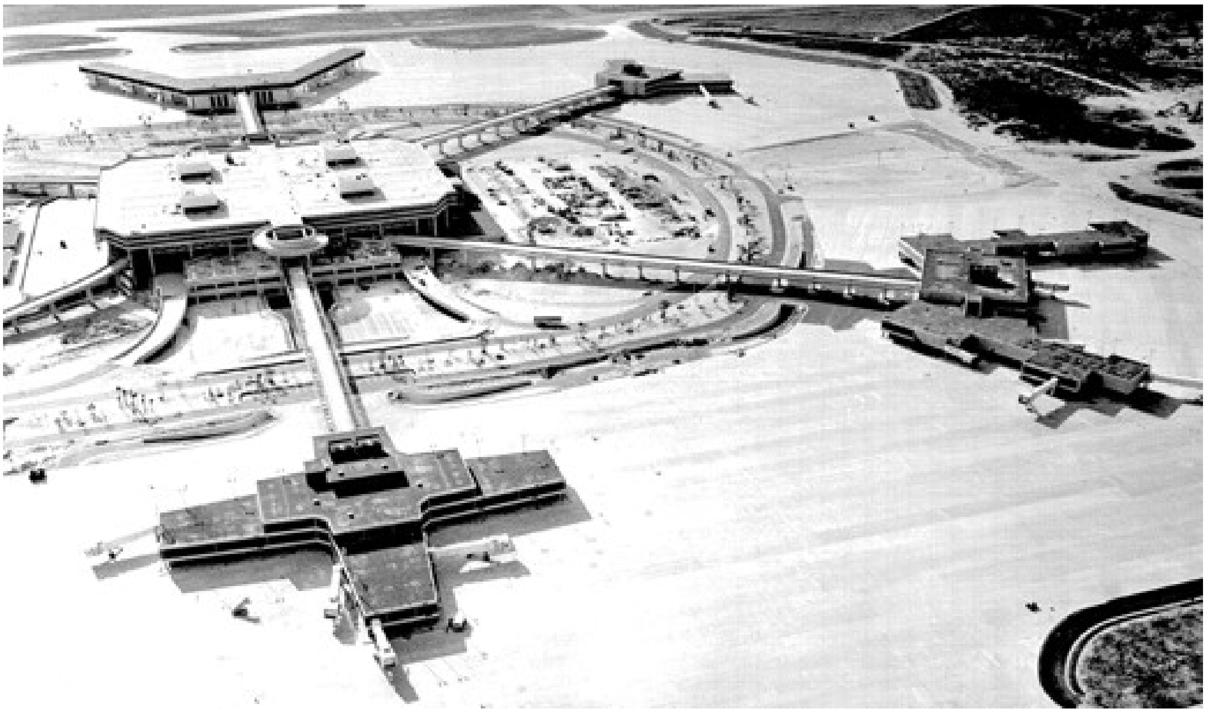


Figure 6.115 - Tampa Terminal 1971 showing roof level car park - Source: www.airports-worldwide.com

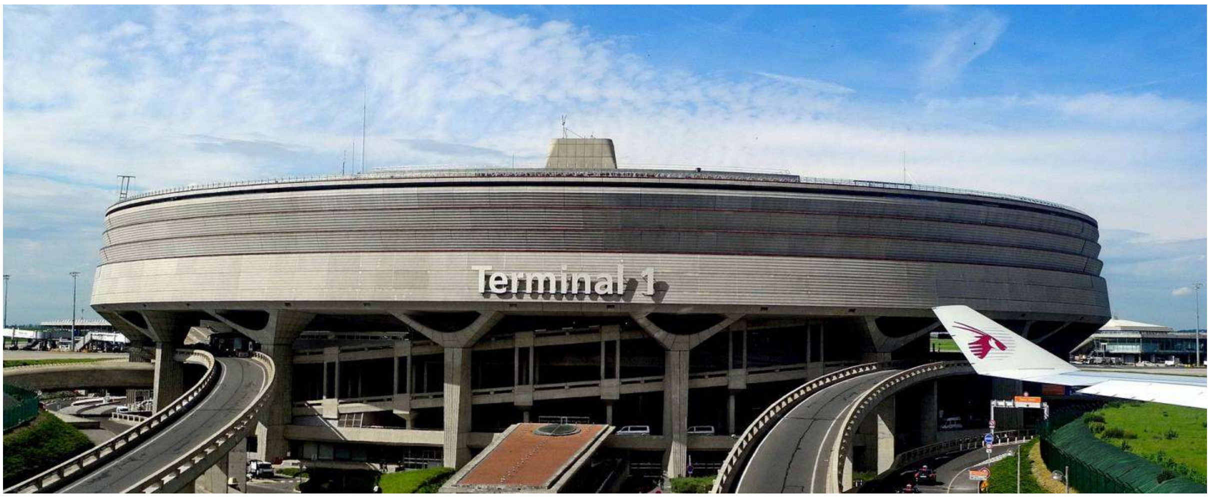


Figure 6.116 - Paris, Charles de Gaulle Terminal 1 1974 with car park over –
Source: www.france-justforyou.com

The idea of integrating parking within the terminal building complex was short lived as airport operators quickly recognised the inherent inflexibility of the concept. Today it is no longer possible to consider this strategy as security requirements normally now require vehicles to be kept well away from the terminal building to prevent terrorist attack.

Airlines have evolved passenger segmentation concepts, which have a direct impact on the physical form of terminals. Individual groups of passengers are singled out for special treatment. Initially this involved the provision of lounges for premium passengers and frequent flyers, but this evolved into the provision of separated check-in zones, streamlined processing through dedicated security and immigration lanes and priority boarding through separate passenger boarding bridges. Many terminals also make separate provision for inclusive tour operators checking-in large groups of passengers.

The most developed concept of specialised passenger segmentation can be found at Dubai International where premium business class passengers are provided with a completely separate floor level, and first class passengers another floor above the main departures level (figures 6.117 & 6.118)

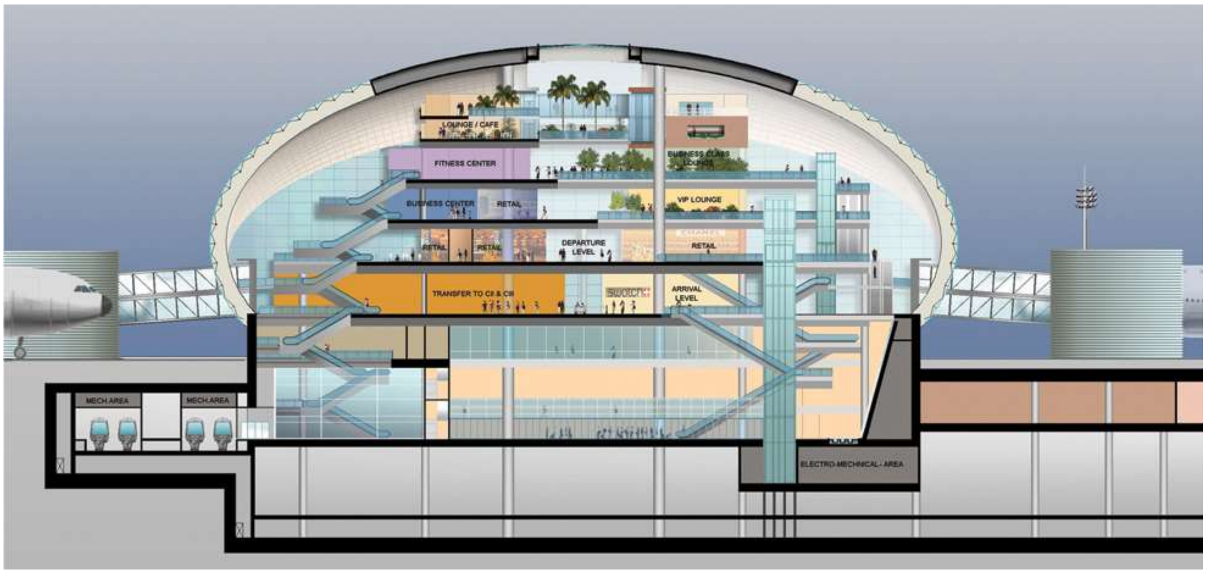


Figure 6.117 - Dubai International (DXB) Concourse A 2013 – Source: Perkinswill.com & uk.pinterest.com

Figure 6.118 – Emirates First Class Lounge Dubai 2013 - Source: loungereview.com

The organizational evolution of the passenger terminal is therefore one of increasing specialisation and separation of passenger flows and facilities either horizontally or vertically, to serve smaller and more targeted segments of the market.

6.10 Centralisation v Decentralisation

This was initially a largely American debate, associated with the radical expansion of airports immediately post war. Airport theorists and airport master planners prepared alternative concepts for large airports, as can be seen in the master plans for Chicago O'Hare (Burke, 1948) (figure 6.119) and New York Idlewild (JFK) (Hunt, 1961) (figure 6.120).

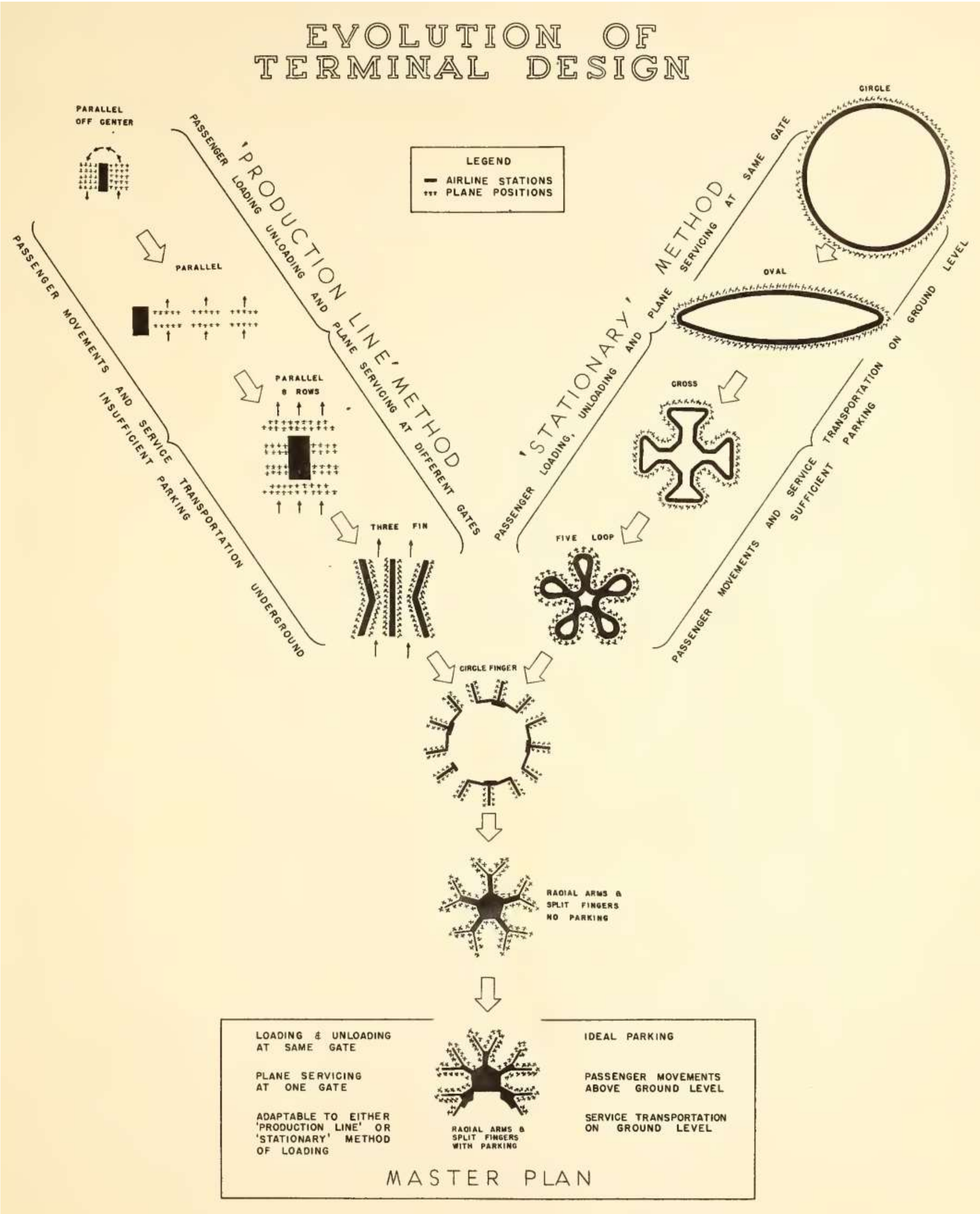


Figure 6.119 - Chicago Orchard (Douglas) Master Plan (later O'Hare) 1948 - Source: City of Chicago

The evolution of the New York Idlewild masterplan (JFK) (figure 6.120) illustrates the alternative centralised and decentralised concepts that were considered over time. The debate was over whether the economies of centralisation were outweighed by the benefits of decentralisation in shortening walking distances and providing additional set down and pick frontage for cars. The decentralisation trend was also influenced by airline funding of terminal development that led them to prioritise building their own individual terminals.

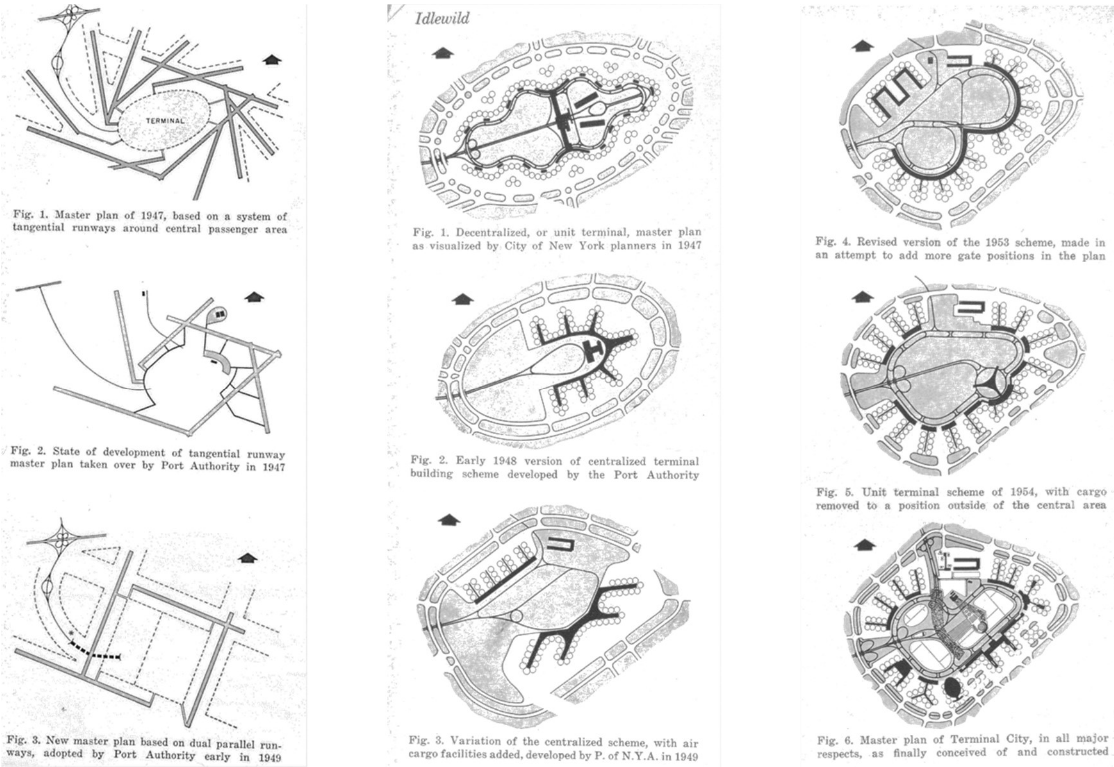


Figure 6.120 - New York Idlewild Master Plan Evolution 1947 - 1962 – Source: Architectural Record

In the USA the decentralisation concept held sway at Chicago Midway (1946) (Lynch, 2003), Kansas City(1972) (Hart, 1985, pp. 185-193) and Dallas Forth Worth (1973) (Blankenship, 1974, pp. 118-121) while centralised terminals were constructed at Chicago O'Hare (1948) (Burke, 1948) Washington Friendship (now Baltimore 1950) (Flight, Editor, 1952),San Francisco (1954) (SFO, 1960) and St Louis (1955) (McCallum, 1959).

In Europe the majority of terminal designs have followed the centralised approach including all UK airports, Amsterdam Schiphol and Frankfurt Main. A few decentralised terminals are to be found at Paris Charles de Gaulle 2 T2, Berlin Tegel and Munich Terminal 1 but in more recent developments they have all reverted to centralised concepts as they become transfer hubs.

A number of issues have subsequently undermined the advantages of decentralisation:

- The introduction of security search requires less space and fewer staff when centralised.
- Airside retail benefits from footfall of a critical mass of people.
- The growth of transfer traffic requires short transfer routes and convenient transfer processing.

Dallas Fort Worth addressed the latter issue by incorporating an airside transit system to link together the strung out terminals. All recent terminal designs have adopted the centralised approach.

6.11 Dry Boarding

A major preoccupation of designers has been to provide a safe and comfortable experience while boarding and alighting an aircraft. Normal practice at London Croydon and other early airports was to warm up the aircraft engine outside the hangar and then taxi the aircraft forward to the terminal. Passengers walked out to the aircraft, which had its engines still running, so some airports introduced devices to protect passengers from the engines as well as inclement weather. For example Croydon employed movable canopies to protect passengers as they passed the engine.

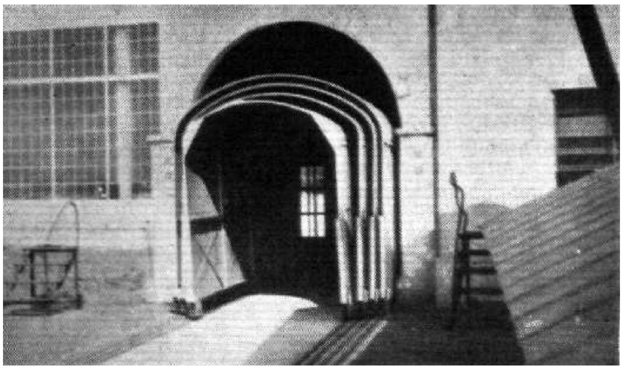


Figure 6.121 - Oakland, California telescopic canopy 1928 – Source: Flight

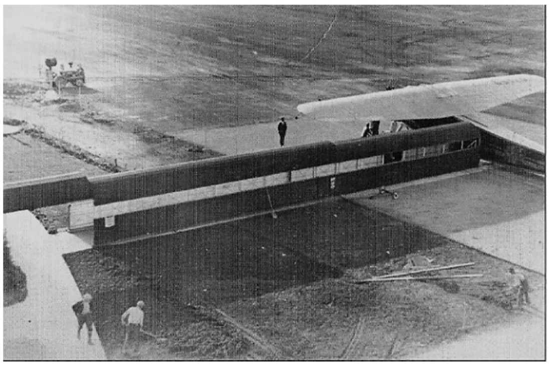


Figure 6.122 – Oakland 1928, telescopic canopy Source: Images of Aviation, Oakland Aviation

A more sophisticated approach appeared first at Oakland California (1928) which had a single telescopic covered walkway that extended on wheels guided by a track inset into the ground (figure 6.121 &6.122). As a contemporary film strip shows it was rolled out by hand just after an aircraft came to rest and then retracted just before departure.
https://youtu.be/BzVU3EcKdUI

This provided safe covered access all the way from the terminal to close to the aircraft side. It can be seen as the prototype for all subsequent designs.

The winning entry for the Lehigh Airport competition (1929) included six of these extendible canopies, one to each face of a hexagonal satellite (figure 6.123), based on the Oakland concept. A similar arrangement was employed at Burbank California (1930) (Grief, 1979) (figure 6.124).

English Architect Norman and Engineer Dawbarn visited Oakland airport on a benchmarking tour of American airports and reported on the Oakland initiative at a lecture at the RAeS in 1932. Architects Hoare and Lovett then incorporated extendible canopies in their circular 'Martello Tower' design for Gatwick Airport (1936) which became affectionately known as the Beehive (figure 6.125).

Figure 6.123 – Artist Francis Keally's illustration of the Lehigh Competition winning entry by A.C. Zimmerman, architect and William H. Harrison, engineer 1929 - Source: American Airport Designs, 1930

Figure 6.124 - Burbank 1930 – Source: The Airport Book

Figure 6.125 - Gatwick 1936 – Source: Building for Air Travel

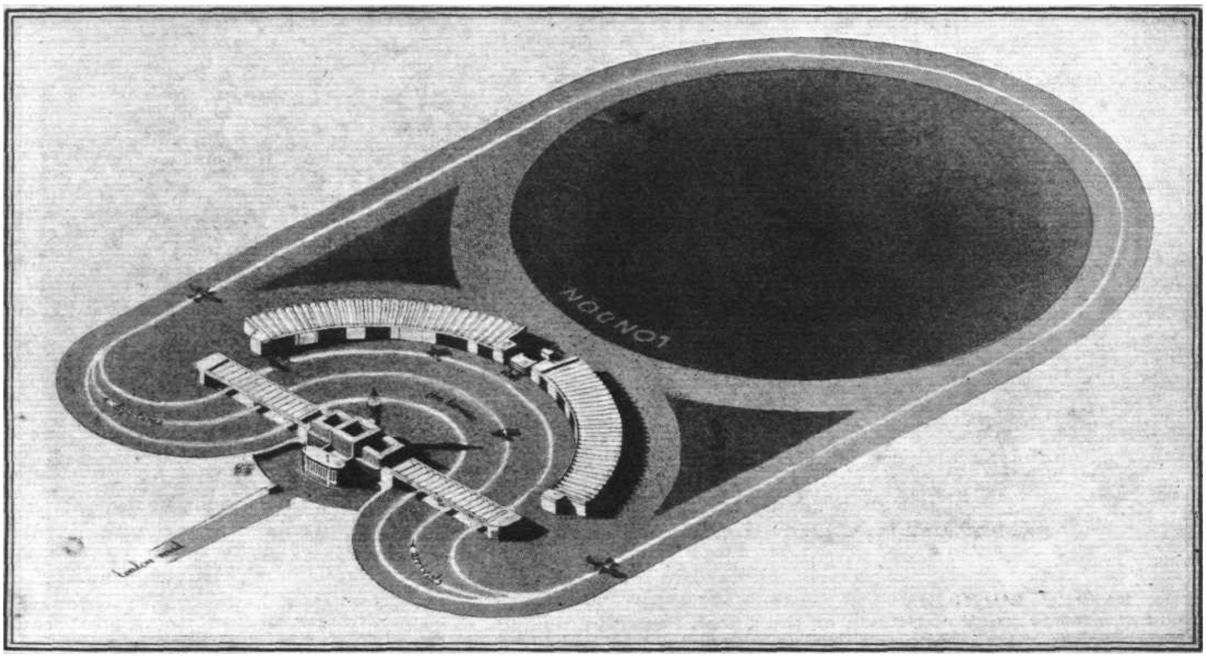


Figure 6.126 – RIBA Airport Competition Winner 1928 - Architect D.H. McMorran - Source: Flight

An alternative concept for dry boarding formed the basis for the winning entry to the RIBA airport competition of 1928, that of a drive through hangar with passenger access though a bridge arrangement with staircases that dropped down to ground level at the aircraft side (figure 6.126). The plan provided a group of hangars for arriving passengers, the aircraft then moved forward to a similar arrangement for departing passengers.

Similar arrangements can be found in the commended entries to the Lehigh competition, and was considered but rejected while developing the Chicago O'Hare master plan, but this concept has never been executed in practice. This is largely because the aircraft turnaround process requires the aircraft to be static, so moving it would just increase the time when the aircraft needs to be on the ground, reducing the available flying time and increasing operational costs.

A third concept, the cantilever canopy sheltering both passengers and the aircraft, appeared in a number of entries to the Lehigh Airport Competition. The concept was first realised at the second terminal at Berlin Tempelhof, where a dramatic steel curved canopy, which also acted as a spectator grandstand for 85,000 people, extends from the gate rooms. The aircraft park underneath the overhang (figure 6.127).

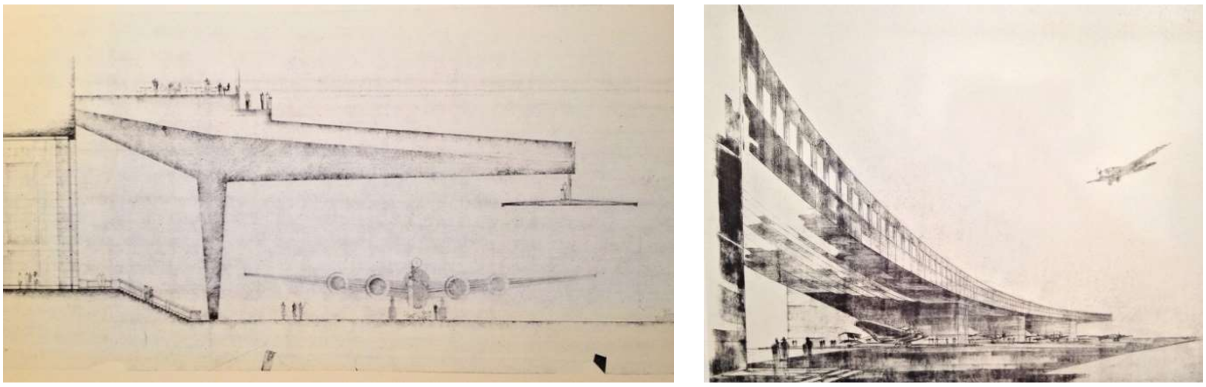


Figure 6.127 - Berlin Tempelhof, Ernst Sagebiel Drawings 1934 – Source: Technische Universitat Braunschweig

Following a visit to Tempelhof, when under construction, Norman and Dawbarn revised their concept for Birmingham Elmdon to include two wing shaped cantilever concrete canopies on either side of the terminal under which aircraft drew up (The Architect & Building News, Editor, 1939) (figures 6.128 & 6.129).

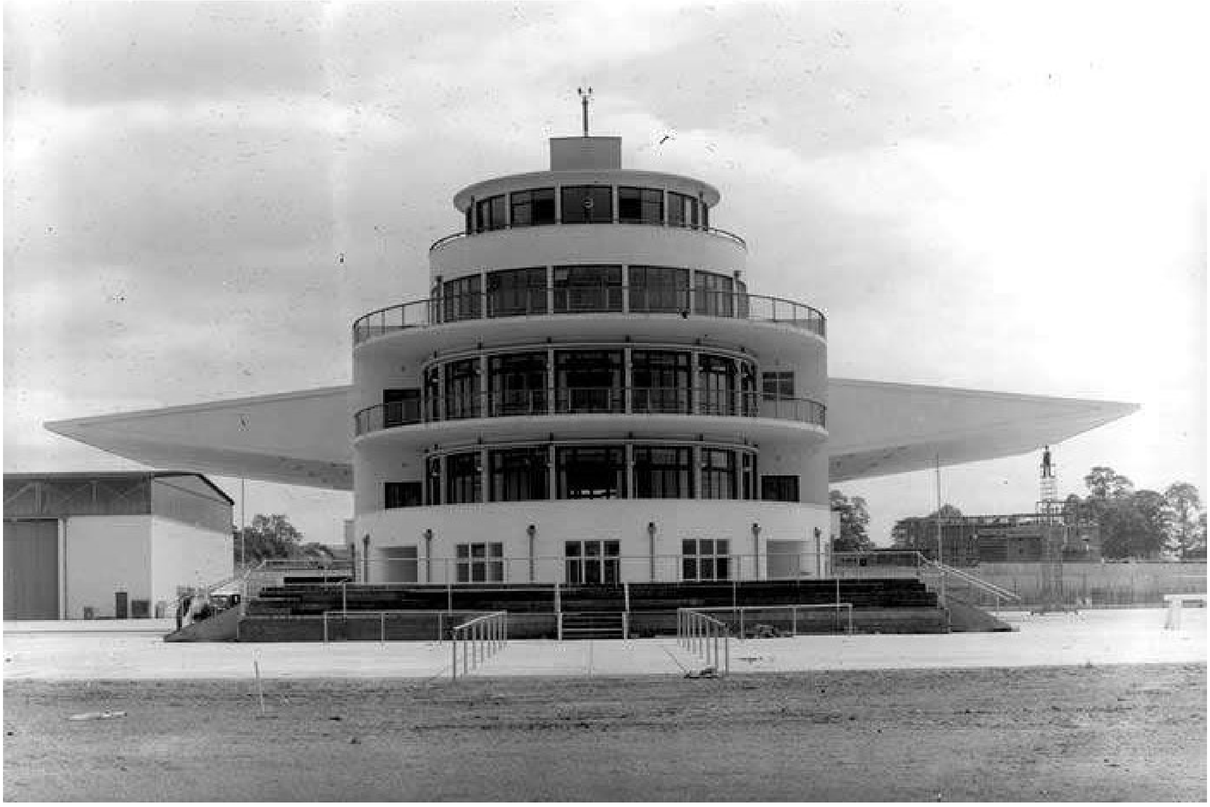


Figure 6.128 - Birmingham Elmdon 1938 - *Source: Historic England*

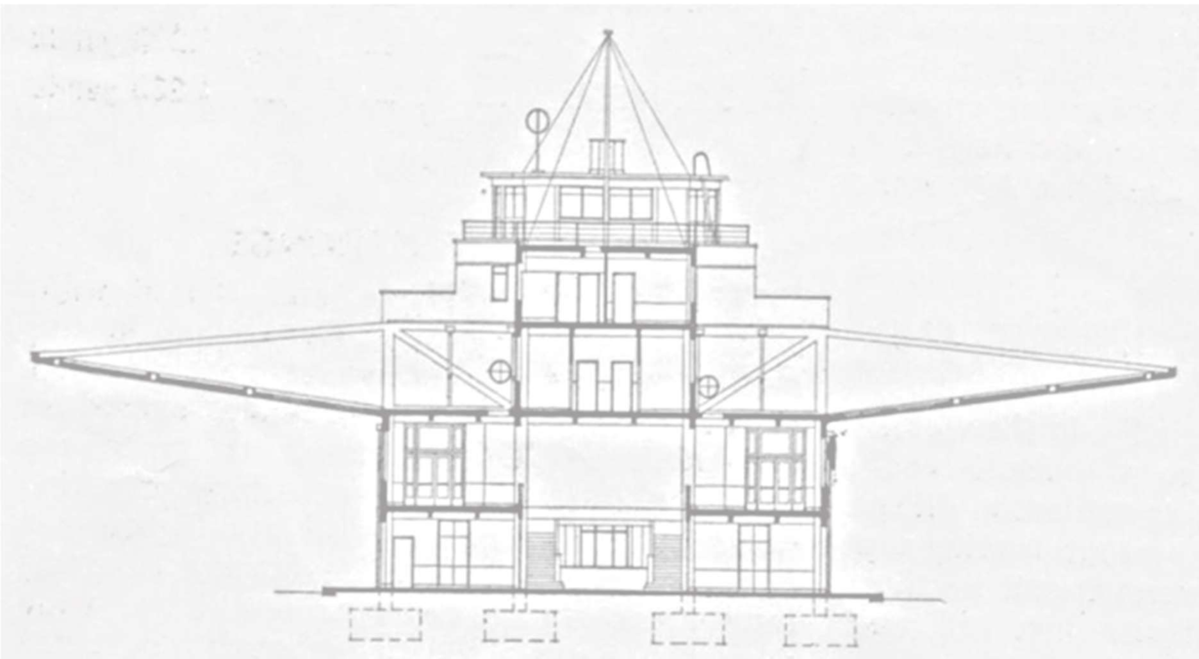
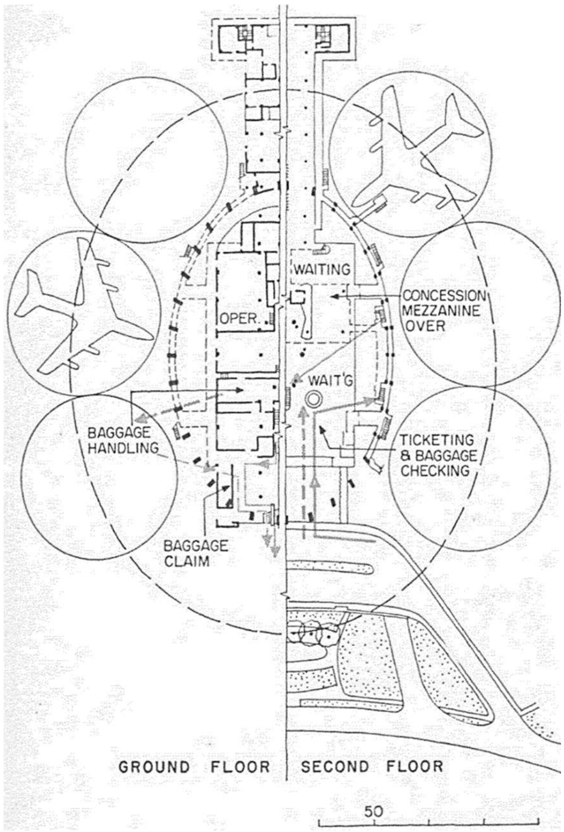


Figure 6.129 - Birmingham Elmdon cantilever section 1938- *Source: Architect and Building News*

One final iteration of the cantilever roof concept can be found at the oval Pan American Airways Terminal at New York JFK (1960). Early versions of the design in the mid-fifties provided for propeller driven aircraft to park parallel to the terminal and be accessed by moveable gangways under a giant cantilever canopy. This evolved during design development to accommodate the new generation of jet aircraft that had been ordered by Pan Am, and revised to a nose-in parking configuration. (Hunt, 1958) (figures 6.130 & 6.131). This can be seen as an interim step towards the passenger boarding bridge, but the terminal design was completed when the latter was only at early prototype stage. Later, conventional telescopic apron drive passenger boarding bridges were retrofitted to the terminal.



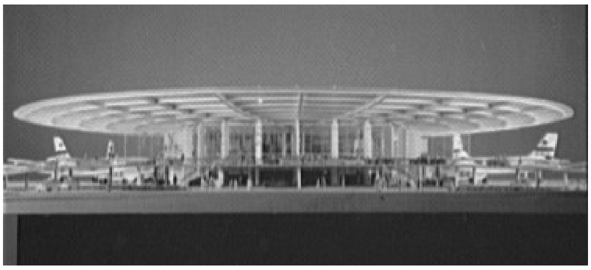


Figure 6.130 - Pan American Terminal, New York Idlewild (JFK) 1960. Floor plan, models and photograph of the gangway - Sources: Architectural Record September 1961, Wikipedia, Pan Am Library & airporthistory.com

The terminal was designed as a showcase for Pan American and to help them promote international jet travel and is particularly famous for its "flying saucer" roof suspended far from the outside columns of the terminal by 32 sets of pre-stressed steel posts and cables.

The architect, Walter Prokosch, adopted this obsolescent concept for the Pan American Terminal by persevering with the cantilever canopy, although he had previously invented the apron drive passenger boarding bridge as well as the finger pier, in conjunction with his engineering colleague Charles Froesch some fifteen years earlier (figure 6.132). Passenger boarding bridges, while at prototype stage, had not evolved sufficiently for adoption at the time of the terminal design.

Figure 6.131 - New York Idlewild (JFK) 1960 photo c2000 – Source: Wikipedia https://www.jetphotos.com/photo/6867311 GFDL 1.2 http://www.gnu.org/licenses/old-licenses/fdl-1.2.html

Walter Prokosch’s earlier idea was to develop a powered enclosed telescopic bridge, which could be raised and lowered to align with the aircraft door, and also adjusted for any slope inherent in the tail dragging aircraft such as the Douglas DC3.

The development of the airbridge was made much easier with the widespread introduction of tricycle undercarriages to aircraft such as the Douglas DC4 which meant that aircraft were approximately horizontal when parked rather than the previous tail dragging type of aircraft such as the Douglas DC3.

The first masterplan to include airbridges was Chicago O’Hare (1948) (Burke, 1948) (figure 6.133). However the arrangement illustrated was rather impractical, relying on a hinged arrangement and without a visible means of support. The concept did however fundamentally alter subsequent terminal design raising passenger movement to first floor level instead of ground level, a major step in the evolution of airport design.

There are numerous patents relating to airbridge design in the early fifties and an early prototype was unveiled by Jetway Aero Gangplank at Chicago (1958) (Hunt, 1958, p. 727). Airbridges were then more widely introduced at Chicago O'Hare (figure 6.134) and Los Angeles in 1959, both of whom claim to be first (Blankenship, 1974). Soon after San Francisco incorporated passenger boarding bridges to both front and rear aircraft doors (figure 6.135).

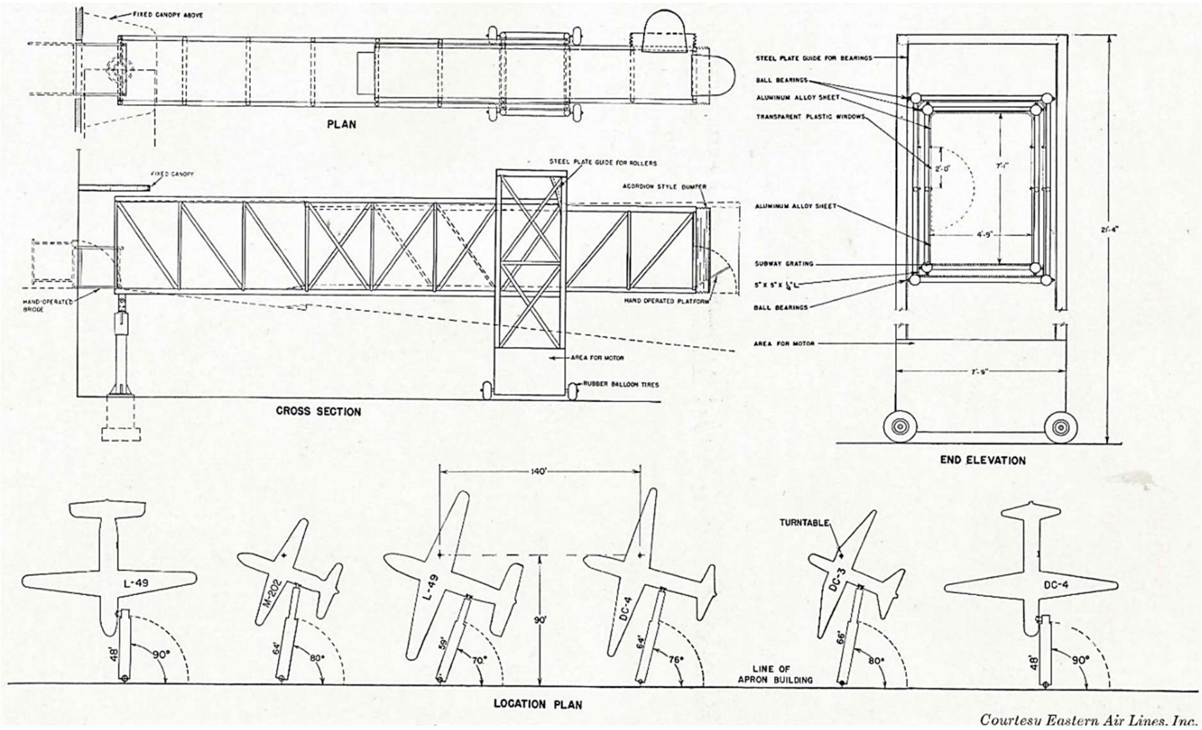


Figure 6.132 - Passenger Boarding Bridge, Eastern Airlines – Source: Airport Planning 1946

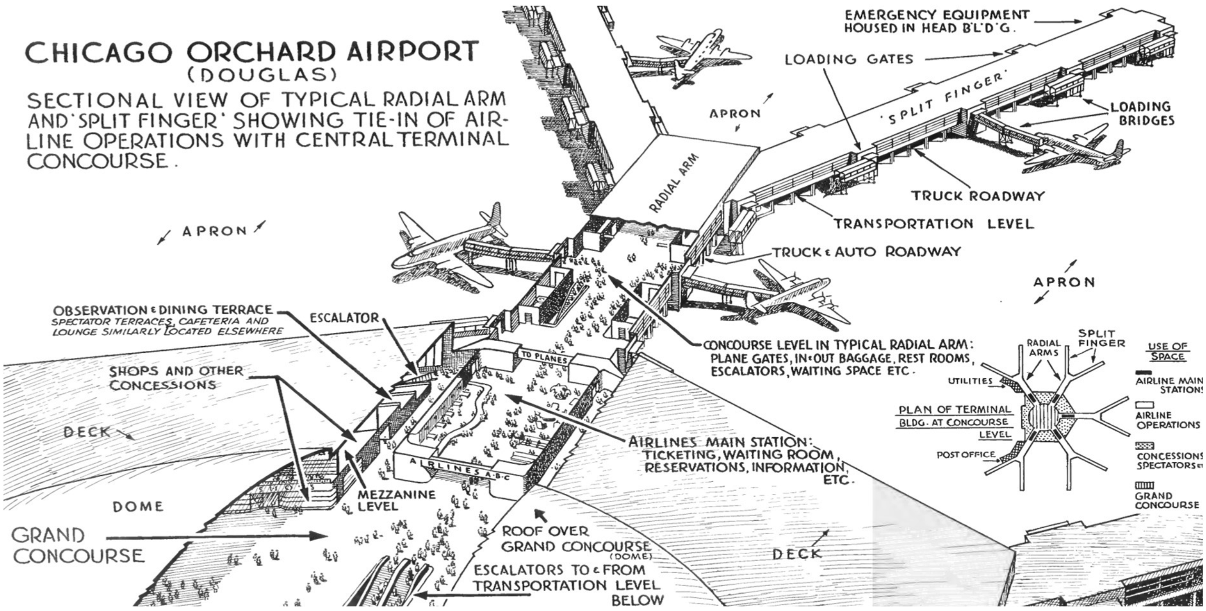


Figure 6.133 - Finger pier with passenger bridges – Source: Chicago Orchard (Douglas) 1948 Master Plan

Figure 6.134 - U A DC7s at Chicago O'Hare 1958 Source: Smithsonian Museum

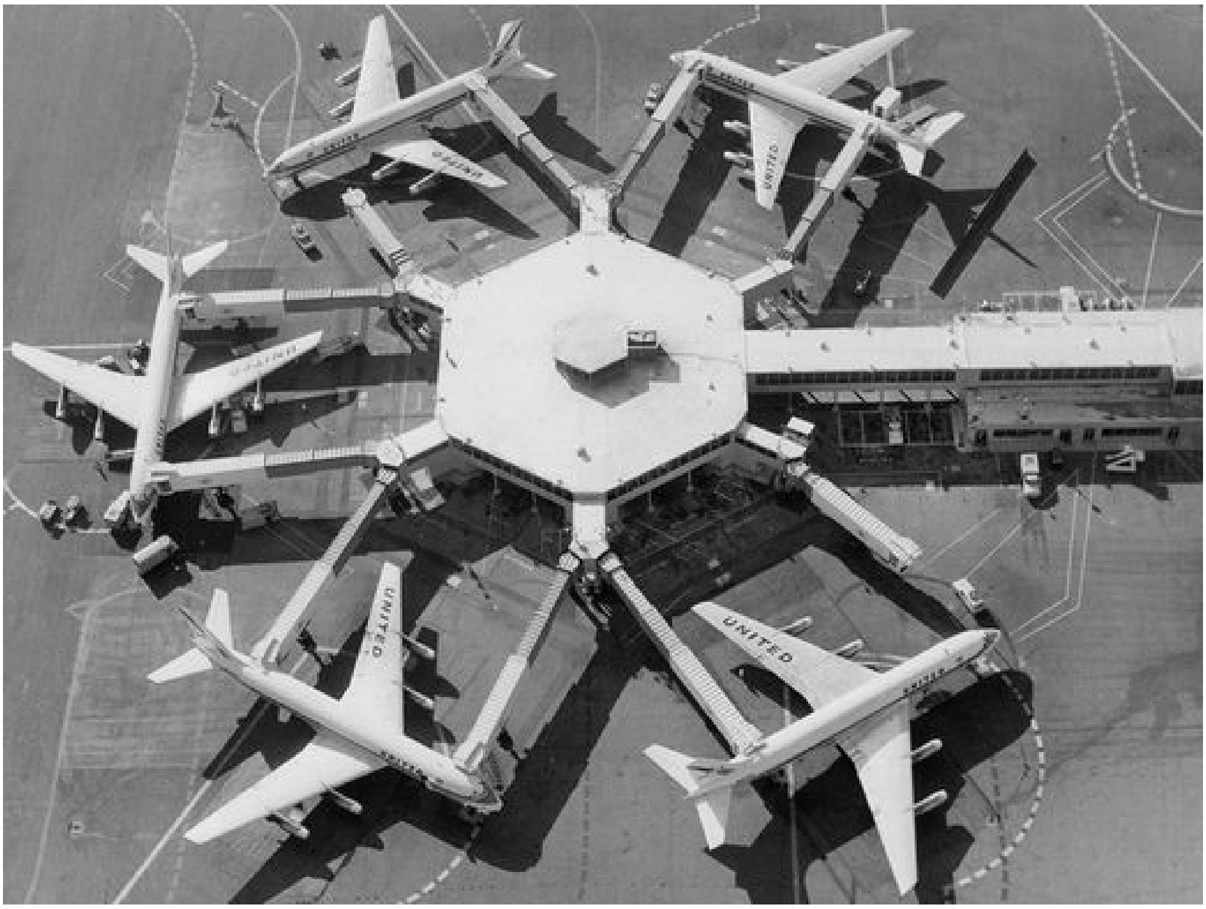


Figure 6.135 - United Airlines DC8s at San Francisco c1962 Source: SFO Museum

Initially aircraft parked parallel with the pier or satellite which allowed both front and rear doors to be reached by two airbridges, but economics and efficient land use has subsequently led to aircraft being parked nose in as seen at the International Arrivals Building and Pan American terminal at Idlewild (JFK), which generally resulted in only the front door being served (Hunt, 1958).

The new terminal at Schiphol opened in 1967 with aircraft parking parallel to the pier and served by passenger boarding bridges. Later Schiphol was converted to nose in aircraft parking layout as the pressure to handle more aircraft in the same space grew. Rather than make do with a single airbridge to the front door, which would have doubled the time for passengers to board or alight one of the new generation of wide bodied aircraft they developed a special suspended bridge type to reach the rear door in an over-wing configuration.

It has not been generally adopted because it is a very expensive and inflexible solution. Operationally there have been a number of minor clashes with aircraft, due to the very small spatial clearance as the bridge crosses over the aircraft wing, which is inherent to the concept (figure 6.136).

Figure 6.136 - Amsterdam Schiphol over wing airbridges c 2000 – Source: Airliners Net, Nick de Jong Photo

6.12 Commercial Design

All airports rely for a greater or lesser extent on commercial income to supplement direct aviation revenues, from charges and services provided to the airlines that are reflected in the fares that airlines charge. The main ways of generating additional revenue include:

- Spectator Venue
- Catering
- Retail
- Leisure and Recreation
- Property Development (which is discussed in section 9)

6.12.1 Spectator Venue

The earliest air shows were held in 1909 in Paris, Berlin, Frankfurt, Brescia and Reims, the latter making a notable commercial success of the event. 'La Grande Semaine d'Aviation de la Champagne', held between 22 August and 29 August 1909, was sponsored by many of the leading makers of champagne including Moët et Chandon and Mumm. A major spectacle was created by designing a 'Hippodrome' or circus style venue with temporary spectator stands. This concept was later to give rise to the name 'Aerodrome'. Amenities for the spectators included a restaurant that could seat 600 people, an area of specially laid lawn with bandstands and flowerbeds, and a post office, from which 50,000 postcards were sent each day and nearly a million words dispatched by press correspondents. A total of 500,000 people visited the event over the week (figure 6.137). Flight magazine commented on the event in glowing terms:

Figure 6.137 – Poster for the Reims Air Show 1909
Source: http://aviation.maisons-champagne.com

'The organisation of the untried thing is rarely an enviable task. It seldom reflects great credit. But in the case of the splendidly successful enterprise, promoted in chief measure by highly praiseworthy local initiation at Rheims, everything was planned with the most brilliantly imaginative foresight, so that, despite the gatherings being greater than on the occasions of any known French military review or race meeting, traffic facilities and accommodation of all sorts were on an adequate scale.' (Flight, 1909)

Spectator facilities were an integral part of the air show (figure 6.138 & 6.139) and of all early commercial airports.

Figure 6.138 – Grandstand at the Reims Air Show 1909 - Source: Wikipedia from Die Tribune

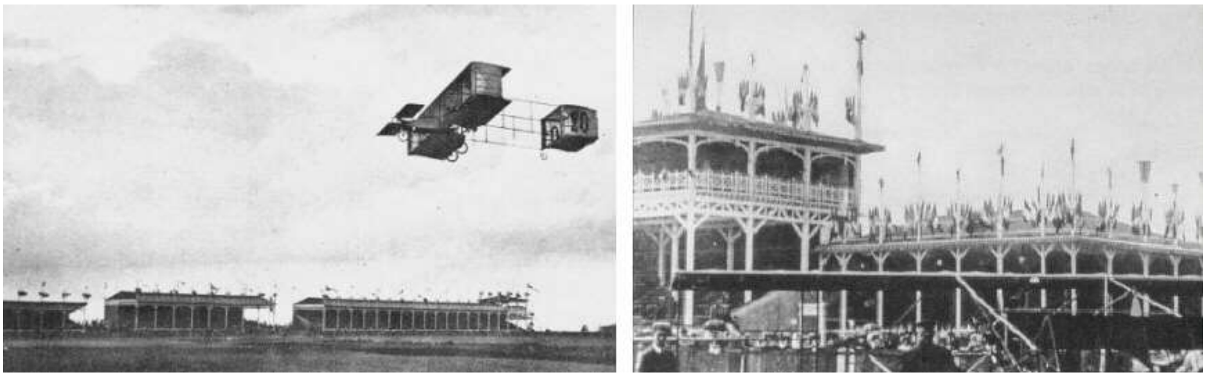


Figure 6.139 - Reims Air Show, Grandstand 1909 - Source: Society of Air Racing Historians

The first terminals such as Konigsberg (figure 6.140), Croydon, Tempelhof (figure 6.141) and Hamburg all incorporated facilities for spectators. At the pioneering stage there were far more spectators than passengers and air shows drew in spectators in hundreds of thousands, so they made an important contribution to airport finances and helped to subsidise early commercial aviation.

Spectator facilities continued to be provided until the 1970s when security concerns led to their demise.

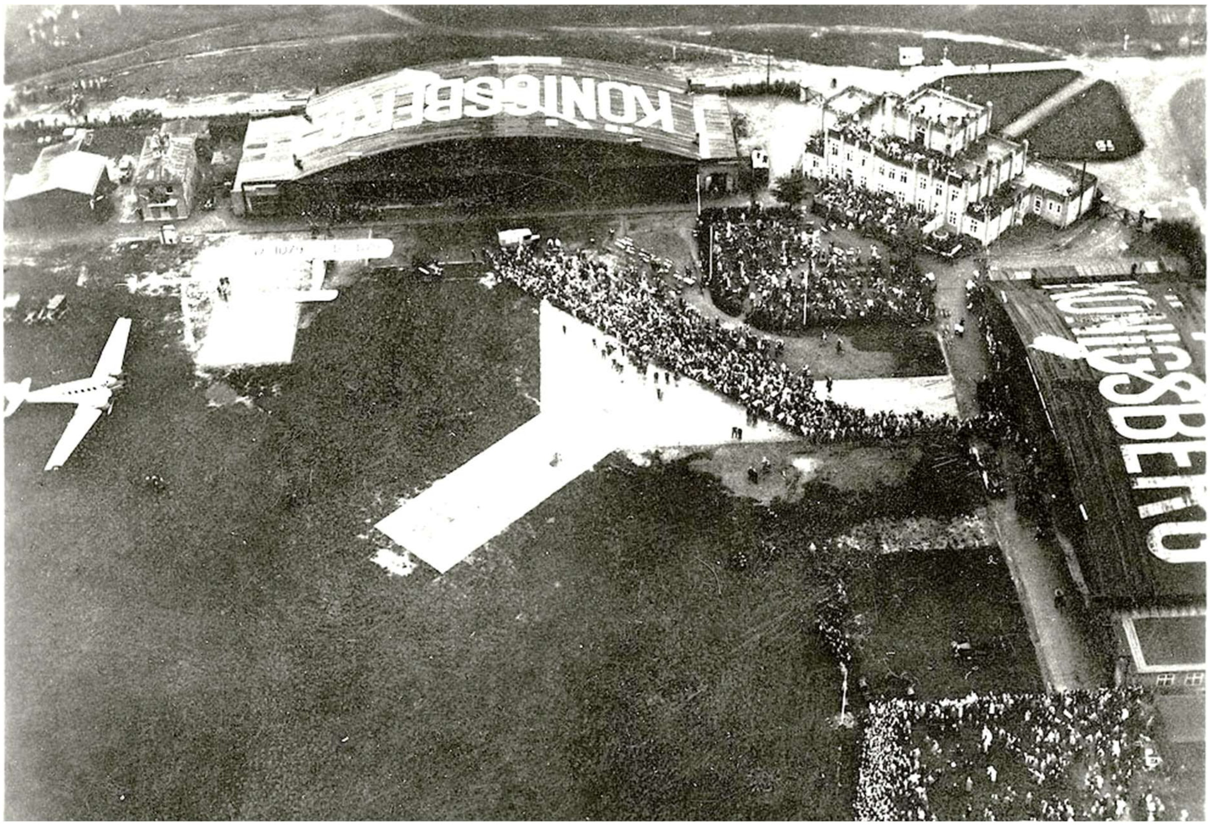


Figure 6.140 – Konigsberg "Flughafenbuch für das Deutsche Reich" in 1926 – Source:www.pennula.de

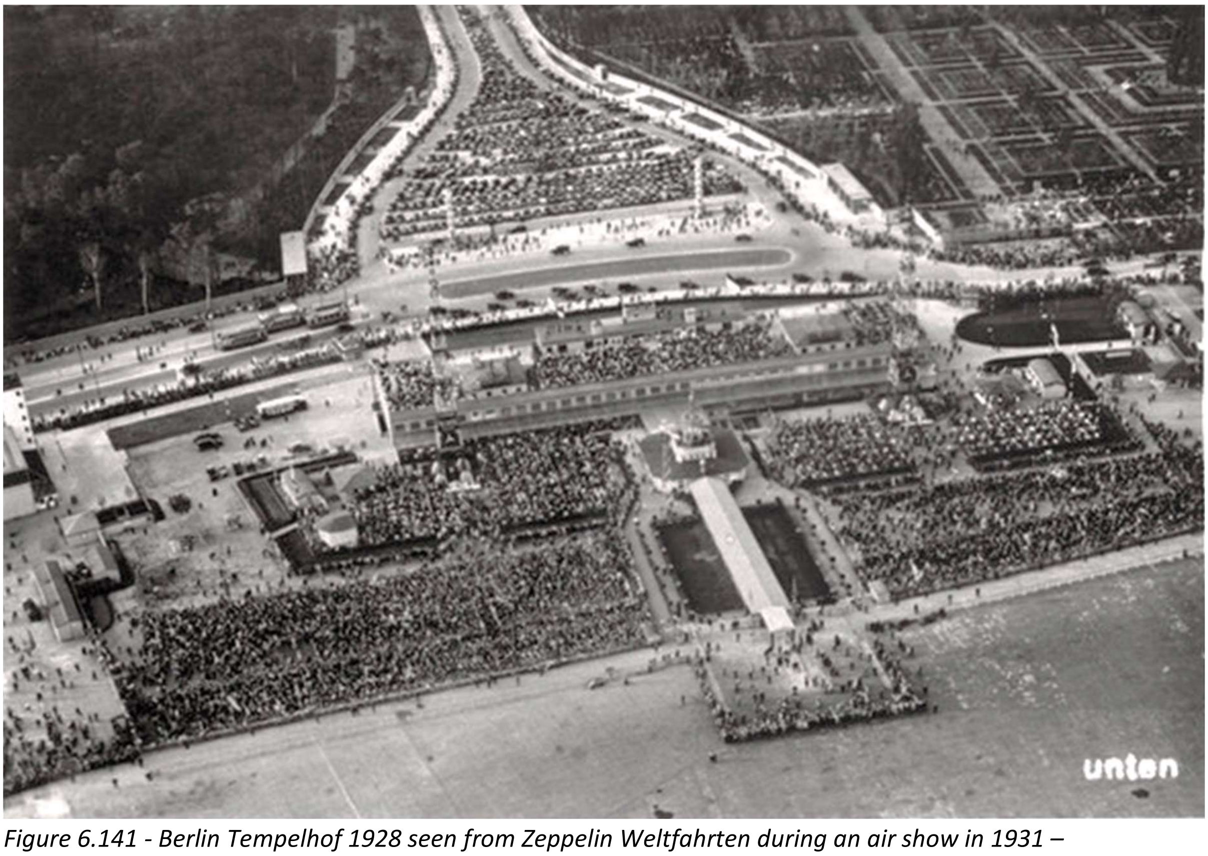


Figure 6.141 - Berlin Tempelhof 1928 seen from Zeppelin Weltfahrten during an air show in 1931 – Source: Magnolia Box Posters

6.12.2 Catering

Catering is a natural and indeed an inevitable complement to spectator events, so it is not surprising that early airports majored on dining facilities. Croydon may have only provided a small railway station like café for passengers but Berlin Tempelhof used the spectator terraces for large scale dining, as a natural adjunct to air shows (figure 6.142).

Figure 6.142 - Berlin Tempelhof 1928 Terrace - Source: Smithsonian Air & Space

Soon these terraces were supplemented by indoor dining rooms as seen in the photographs of Hamburg, located to provide a panoramic view over the activities on the airfield (figure 6.143).

Figure 6.143 - Hamburg Fuhlsbuttel 1929 Terrace and Dining Room – Source: Vom Flugbahnhof zum Terminal

Airport dining became a fashionable activity and airports, such as Chicago Midway, began to create catering venues as a destination in their own right for non–flyers to generate additional commercial revenue. Chicago Midway's Cloud restaurant became a very popular destination (figures 6.144 & 6.145).

Figure 6.144 Chicago Midway 1946 Cloud Restaurant - Source: Flickr

Figure 6.145 Chicago Midway 1946, Cloud Restaurant seen from the Apron - Source: Midway Historians

The design highpoint was arguably reached in the 1960s with the coming of the jet age. Two airport restaurant designs stand out. The first is the Los Angeles Theme Building Restaurant, which was designed as the futuristic space age focus to the airport. Initially, the restaurant on top rotated slowly, giving the visitors a 360-degree dining experience. However, it was later made stationary (figure 6.146 & 6.147).Los Angeles World Airports Executive Director Gina Marie Lindsey explained its eventual closure as follows:

'It was built when bringing your family out to have dinner and watch the airplanes was a cool thing to do, but now passengers won't leave the terminals to have dinner there because it's unpredictable how long it'll take them to get through security again ' (Forgione, 2014)

As a result, and despite a major refurbishment by Disney, the restaurant has fallen into disuse.

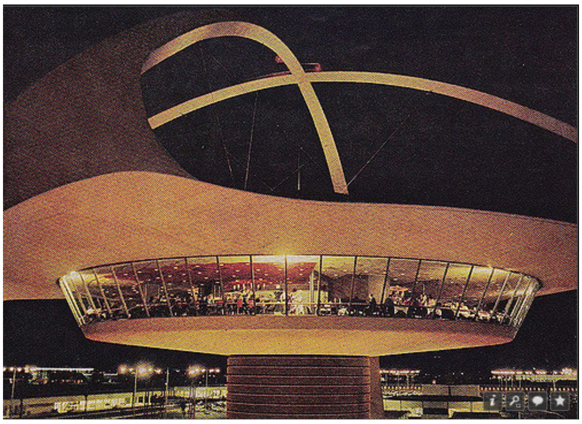


Figure 6.146 -Los Angeles, Theme Restaurant 1962 Architect Pereira & Luckman - Source: Flickriver.com

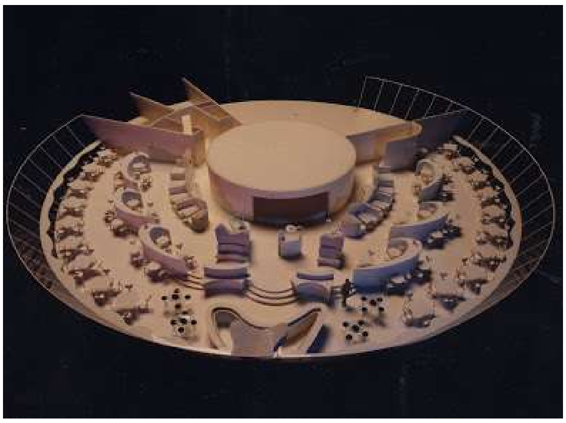


Figure 6.147 Los Angeles, Theme Restaurant Refurbishment Model - Source: Disney

Washington Dulles also makes a major feature of its main restaurant by incorporating it at high level within the control tower with spectacular views. Unlike the LAX theme restaurant it is integrated within the terminal complex (figure 6.148).

Figure 6.148 Washington Dulles 1962 Control Tower and Control Tower Restaurant Tulip Collection – Sources: Pinterest & TripAdvisor

Contemporary food and beverage offers are no longer provided in separate dining rooms but have become integrated with the shopping outlets, with much less formal seating layouts, to suit the casual browser and those in a hurry. International brand names have been introduced, so the people know what to expect from the outlet before they sample it, as can be seen in the two examples from Heathrow Terminal 5 below (figure 6.149).

Figure 6.149 Heathrow Terminal 5 2008, Food and Beverage – Sources: Fortnum & Mason and Gordon Ramsay

6.12.3 Retail

Early retail was just conceived of as a convenience for passengers as seen at Croydon (figure 6.150).

Figure 6. 150 - Croydon 1928 with news kiosk in the background - Source: Croydon Airport Society

The convenience shopping approach continued at airports for a very long time as can be seen from the 1988 Gatwick South Terminal 'Skyshop' image below (figure 6.151).

Figure 6.151 – Gatwick South Terminal Skyshop in the Gatwick Village in 1988 – Source: BAA

Greater Pittsburgh Airport, Architect Joseph W. Hoover, was one of the first to include a wider commercial offer. As well as a dozen shops it included a 62 room hotel, a night club seating 500, a theatre, a roof deck for 2,700 spectators and an outdoor dining terrace (figures 6.152 & 6.153).

Figure 6.152 - Greater Pittsburgh Aerial View 1952
Source: historicpittsburgh.org Photo: Don Bindyke

Figure 6.153 -Greater Pittsburgh 1952
Mobile – Alexander Calder Source: Pinterest

Two major changes in approach have influenced the evolution of airport retailing. The first is the invention of duty free shopping, while the second is the introduction of high street brand names in a shopping mall style airside lounge.

Also market research found that passengers spent as much as four times more money airside than landside because they were less stressed. The diagram below is a graphic representation of the opportunities for stress reduction on the journey to the airport, at check-in and avoiding the inevitable security queues (figure 6.154). The top red image is indicative of the level of stress felt by passengers passing through time critical processes, while the lower largely green diagram illustrates how much lower the stress can be if processes are undertaken early in the journey, such as using home check-in.

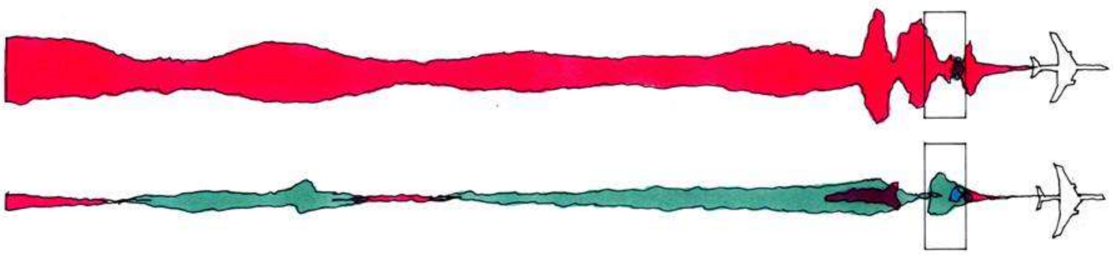


Figure 6.154 - Journey management stress diagram c2000 – Source: YRM – Artist: Andrew Mahaddie

So this realisation has led to the transfer of retail from landside to the airside lounge, as can be seen at Gatwick South Terminal, where the once very popular Gatwick Village has given way to a much larger security to reduce queues and lower stress, but the lost area has been replaced with an extended airside retail offer.

6.12.4 Duty Free Shopping

In 1947 the Irish Government passed the Customs-Free Airport Act by which transit and embarking passengers, goods and aircraft were exempt from normal customs procedures. Shannon Airport had become the first Customs'-Free Airport in the World and established Shannon as an International Industrial and Distribution Centre which stimulated further traffic growth.

The Shannon Sales and Catering Organisation was licensed by the Irish Department of Transport, enabling Shannon to conduct commercial and catering activities at the airport.

So in 1947 the world's first duty-free shop opened at Shannon Airport, and began as a simple kiosk measuring just a few square metres, selling souvenirs and gifts. The Duty Free shop became an immediate success and has been copied worldwide (figure 6.155).

Figure 6.155 - Shannon Duty Free in the 1950s - Source: Shannon Airport

In 1951 the first Airport Duty Free Liquor Shop was opened. It started as a ship's store where airline stewards purchased supplies for re-sale to passengers when the aircraft became airborne. The same applied to cigarettes and tobacco which began as supplies for crew only. Later, passengers were allowed to make direct purchases at tax free prices on a restricted basis and soon Shannon became famous for having the only airport duty free shop in the world. In the beginning, Shannon "Duty Free" applied only to liquor and tobacco, but it rapidly developed into an impressively large number of tax - free departments, which is how it remains today for transatlantic flights.

In 1957, Schiphol's first duty-free shops were opened. A bottle of Jenever (Dutch gin) cost 4 guilders and a bottle of whiskey was 8 guilders. In the first year, the total turnover of the tax-free shops was - converted to euros - around €3 million. 50 years later, that figure is €400 million.

In 1962 Duty Free Stores (DFS) opened duty free shops in Hong Kong Kai Tak and Honololu, Hawaii, the first in the USA.

The UK joined the duty free club relatively late. It was not until 1959 that Customs & Excise in the UK finally allowed duty-free shops airside, initially just for liquor sales but later in 1964 tobacco, perfume and other gifts were also allowed to be sold after passport control.

It took the privatisation of BAA in 1986 to launch the contemporary commercial exploitation of airport retail when they recognised that retail sales were not regulated as strongly as airport charges. They then exploited this capability with a worldwide expansion programme (figure 6.156).

Figure 6.156 - BAA World Duty Free global reach - Source: BAA.co.uk

After 30 June 1999 the concession to allow purchase duty-free or tax free goods on journeys within the European Union (EU) without VAT and duty was withdrawn, but despite this and the differential pricing that resulted airside retail has continued to expand and flourish.

6.12.5 High Street Brand Names

W.H. Smith and Son was one of the earliest brand names introduced at airports as can be seen in the 1946 photograph of the tented terminal at the New London Airport (now known as Heathrow) (figure 6.157).

Figure 6.157 Heathrow North 1946- Temporary Tented Terminal with W.H. Smith Bookshop in the background Source: Heathrow Airport

It was only after privatisation in 1986 that BAA regularly recruited retail experts that brought some of their learning from designing retail malls to airport commercial design. They introduced to the airport familiar shopping mall concepts such as maximising retail footfall, including anchor tenants and destination outlets that would help draw passengers past other shops.

The following plans show how retail design has evolved at Gatwick Airport's North Terminal from its opening in 1988 to the present day. The lounge was originally planned as an outward looking space with views over the airfield with an island duty and tax free shop. It has progressively morphed into an inward looking space with the seating area surrounded by shops.

The most recent development is to introduce a walk through duty free shop that meanders from the exit of security screening to the lounge, but introduces additional walking distance as designers contrive to lead passengers past as many offers as possible. At its most extreme IKEA like routings, but without their short circuit options, can be found in recent airport airside retail planning.

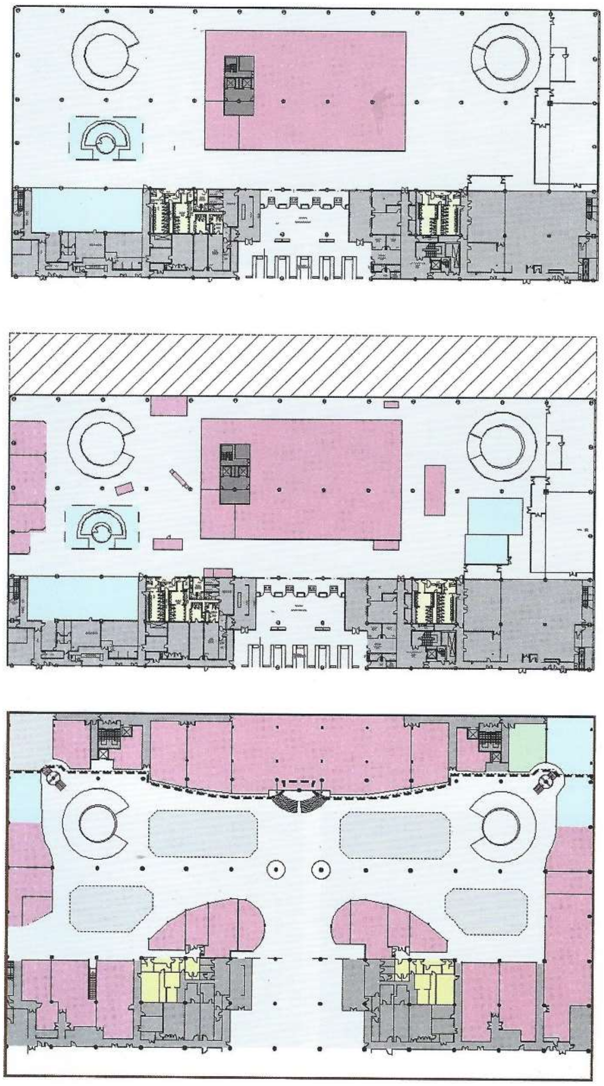


Figure 6.158 - Gatwick Airside Lounge Retail Evolution 1988/1991/1994 – Source: Airport Interiors

The evolution of Gatwick North Terminal Airside Retail over 30 years since opening in 1988, shows the progressive enlargement of the airside shopping area. Further planned works include creating a walk through Duty Free Shop (figures 6.158 & 6.159).

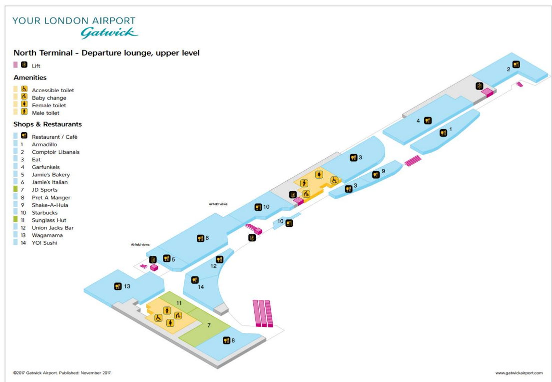


Figure 6.159 Airside Departures Lounge Map 2017 Source: Gatwick Airport Ltd

Retail concepts can be divided into three main families:-

1. Out of the way -such as when retail is located at a mezzanine level away from the direct passenger routing so that passengers have to make a conscious decision to deviate from the shortest walking route to visit the shops as seen in the landside retail mall at Gatwick North Terminal (figure 6.160). This has largely fallen out of favour.

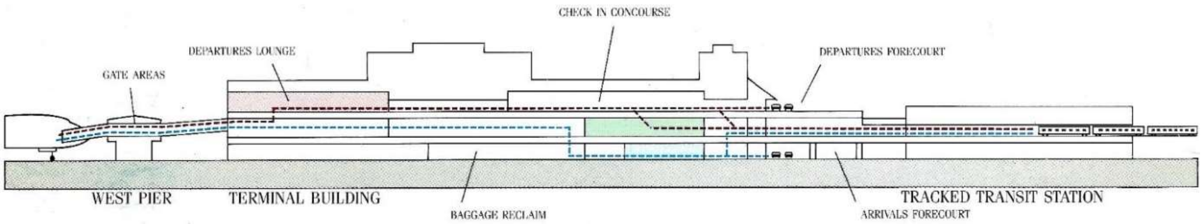


Figure 6.160 - Gatwick North Terminal 1988, retail in light green at mezzanine level between departures and arrivals – Architect YRM - Source: Gatwick Airport

2. In the way – such as the walk through duty free shops that deliberately force passengers to take a roundabout route to expose them to many offers as possible and so extend the walking distance as can be seen at Heathrow Terminal 3 and Gatwick South Terminal (figures 6.161 & 6.162).

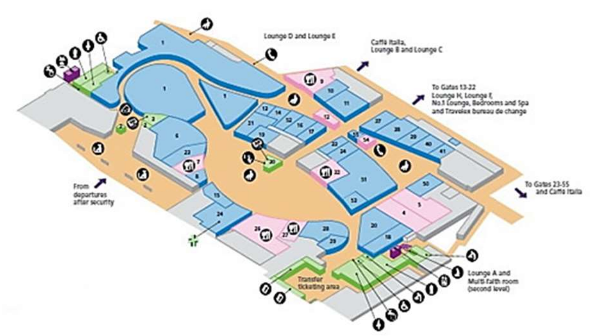


Figure 6.161 Heathrow Terminal 3 Airside Loung – Source: Heathrow Airport

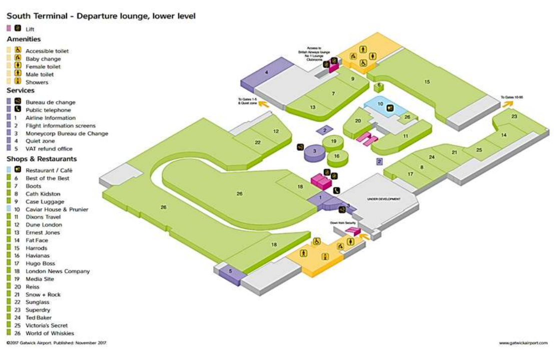


Figure 6.162 Gatwick South Terminal Airside Lounge Source: Gatwick Airport

3. On the way – where the retail is placed along the normal passenger route, but without distorting the route and adding to overall passenger walking distance as can be seen in the map of Bangkok (figure 6.163). However although the retail concept was retrofitted into the concept during construction some retail designers argue that the layout is sub-optimal because the symmetrical bi-furcated plan means that departing passengers only have to pass half of the retail offer.

Figure 6.163 – Bangkok 2006 airside retail in magenta - Source Bangkok Airport

Airports have also brought other elements of the shopping mall to add to the quality of passenger experience, such multi-level atria and leisure facilities, seen at Atlanta (figure 6.164),Tokyo Haneda (figure 6.165) and Dubai International (figure 6.166) aimed particularly at those transfer passengers in large hub airports who have several hours wait between flights.

Figure 6.164 - Atlanta Hartsfield Atrium 2016 – Source: pedrocarrion.com

Figure 6.165 – Tokyo, Haneda Atrium c2010
Source: academic.csuohio.edu

Figure 6.166 – Dubai International Atrium c2015
Source: www.shoppingcentrenews.au

Many of the top rated airports in the Skytrax survey boast a range of leisure offers the complement the shops and catering outlets:

- Amsterdam Schiphol – Museum, casino and library
- Tokyo Haneda – Observation Decks, massage suites, planetarium, a replica of a traditional Japanese village and kids lounge
- Seoul Incheon – Transfer hotel, transit tours, concert venue, sauna, skating rink and Korean cultural museum
- Singapore Changi - Waterfall, swimming pool, airside hotel, cinema, butterfly/actus/water lily gardens, and the Jewel

There is a possible correlation between passenger satisfaction and the provision of leisure facilities, points of interest and events. Provision of a wide range of facilities is a particular strategy of Singapore Changi and Seoul Incheon airports which is possibly why they have ranked as the top two airports in passenger satisfaction surveys over the past few years.

Passenger surveys, such as Skytrax and Airport Service Quality (ASQ), suggest there is a linkage between the quality of facilities and high levels of passenger satisfaction. For example the step changes recorded in satisfaction at Heathrow following the opening of T5 and later T2, and the opening and then closing of the low cost terminal at Singapore Changi suggests passengers are appreciative of high quality facilities.

For the future, airports still have to come to terms with internet shopping, but the change of focus towards experiences rather than consumption can already be seen. This may lead to airport retail being regarded as showrooms rather than points of sale. Whether that will allow Rem Koolhaas to withdraw his critique of airport retail areas as 'Junkspace', or retail areas evolve into more than ephemeral stage sets is for future research.

6.12.6 Leisure and Recreation

In the 1950s Robert Pereira had the idea of creating Los Angeles Airport as a total leisure experience with a circular terminal at the heart of the airport serving a series of circular satellites (figure 6.167). After that idea was rejected he proposed a much more low key strategy but with the futuristic Theme Building at its heart. His original concept below bears a striking resemblance to the Changi Jewel, Architect Moshe Safdie, which opened in 2019 (figures 6.168, 6.169, 6.170 & 6.171).

Figure 6.167 - Los Angeles (LAX) Circular Terminal 1952 – Source: Never Was Magazine

Figure 6.168 - Singapore, Changi, The Jewel 2019 –- Source: Architectural Record

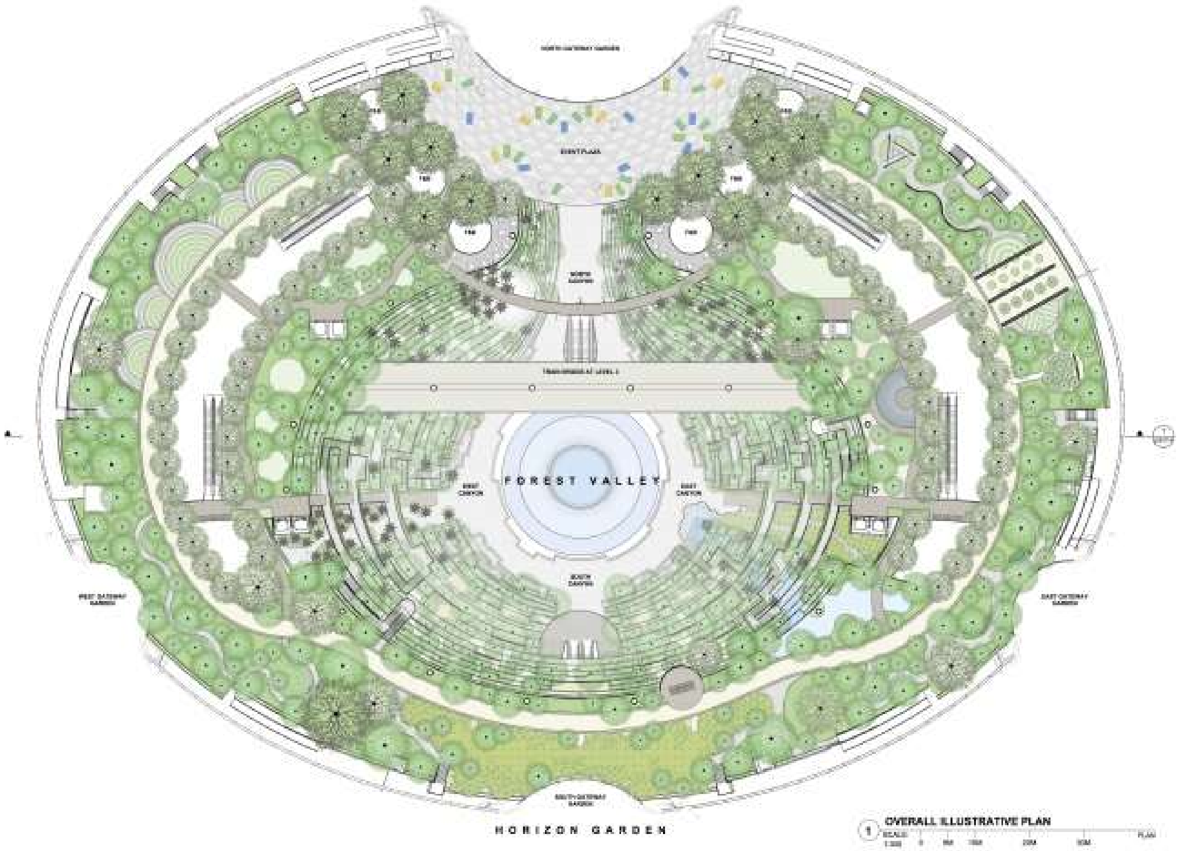


Figure 6.169 - Singapore Changi, The Jewel Plan 2019 –
Source: Architectural Review – Once Glamourous Gateways to freedom 2017

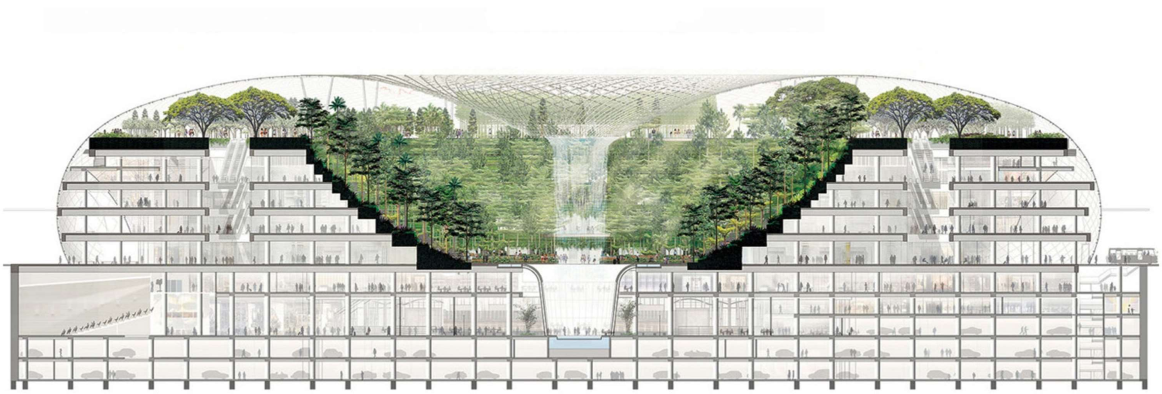


Figure 6.170 - Singapore Changi, The Jewel Section 2019 - Source: Safdie Architects, LLC

The Jewel at Changi Airport re-imagines the centre of an airport as a major public realm attraction and an opportunity to relax. The Jewel offers a range of facilities for landside airport operations, indoor gardens and leisure attractions, retail offerings and hotel facilities, all under one roof. A distinctive dome-shaped façade made of glass and steel reinforces Changi's appeal as one of the world's leading Global Hubs Airports.

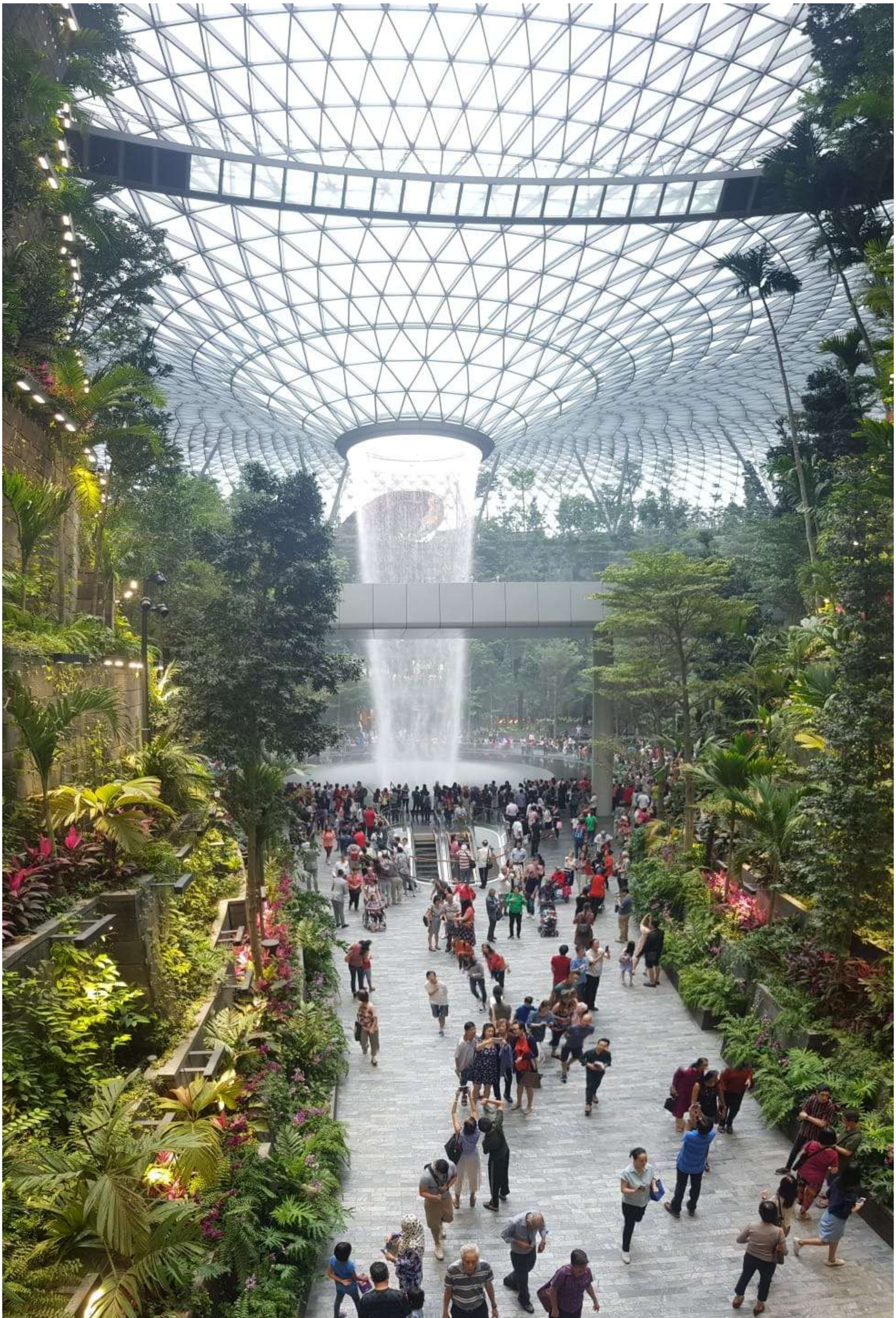


Figure 6.171 - Singapore Changi, Rain Vortex – 2019 - Source: Team HardwareZone

Many other leisure and recreational facilities, which might promote relaxation and wellbeing and reduce stress, can be found in the major international transfer hubs. These provide relief from the dominant retail offer and help the airport differentiate itself from other airports. Selected examples of the range of facilities can be seen below (figures 6.172 to 6.177). Most of these can be retrofitted without affecting the basic layout of the airport, and are typically thought of as being interchangeable with commercial concessions. The exception is the roof top swimming pool illustrated here at Singapore Changi (figure 6.178) which has a major effect on the section and structure of the terminal and has to be integrated from the outset.

Figure 6.172 Schiphol, Rijksmuseum
Source: amsterdam.info/airport-museum

Figure 6.173 Singapore, Changi, Atrium Cinema
Source: Straits Times – Photo: Ariffin Jamar

Figure 6.174 Schiphol, Casino 1995 -2016
Source: Inside Flows

Figure 6.175 Seoul Incheon, Showers
Source: The Korea Herald

Figure 6.176 Sleep Box, mobile hotel rooms
Source: Arch Group

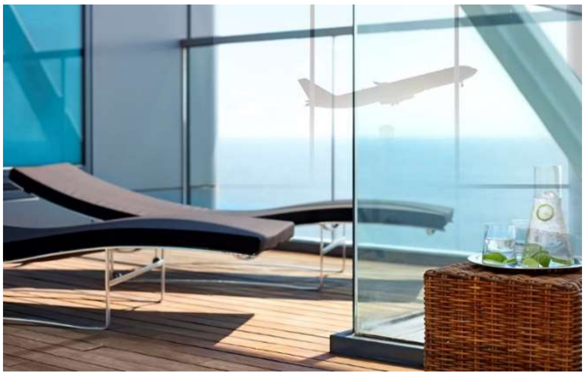


Figure 6.177 Well Being, Spa
Source: Author's Collection

Figure 6.178 Singapore, Changi roof top swimming pool   Source: Changi Airport Group

By contrast airline lounges, which allow premium passengers to relax, can have a profound effect on the design of the terminal, in part because of their shear physical size but also their location which is typically at mezzanine level above the main departures concourse. Some lounges are open planned terraces as illustrated by the Cathay Pacific Lounge (figures 6.182 & 6.183) that has been retrofitted floating above the retail offer. Others like the British Airways lounges by YRM at Heathrow T5 (figure 6.184) are largely enclosed to offer more privacy and exclusivity. Many offer facilities like business centres, spas and showers, while all offer catering outlets and bars that compete directly with airport facilities.

Figure 6.179 - The Deck, Cathay Pacific Lounge 2018 at Hong Kong International Source: Cathay Pacific

Figure 6.180 – The Terrace, Cathay Pacific Lounge at Hong Kong International Source: Cathay Pacific

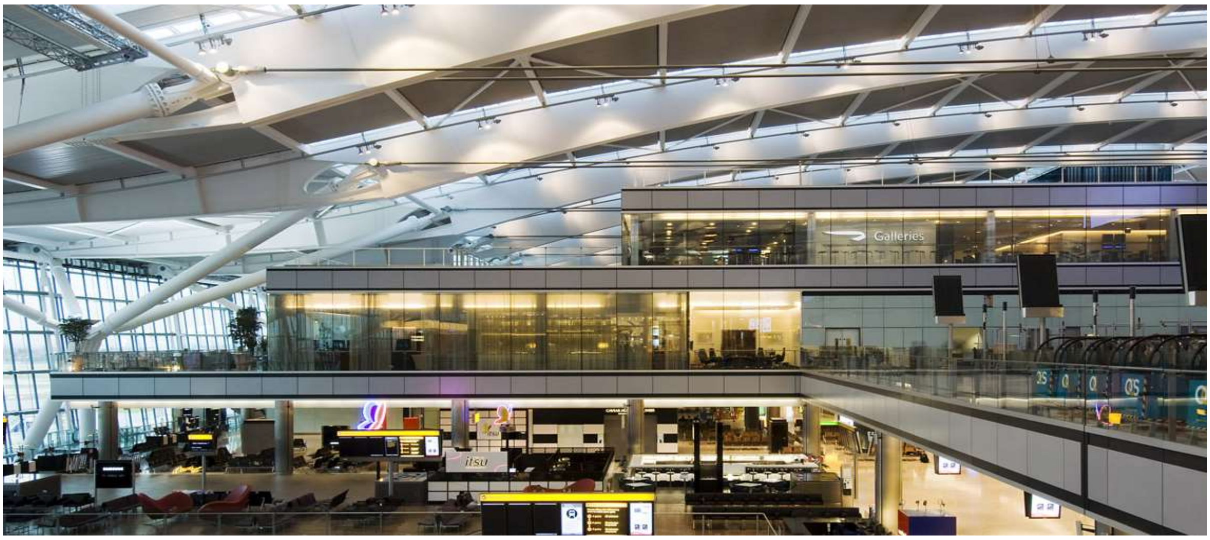


Figure 6 .181 Heathrow T5, British Airways Concorde, First and Galleries Lounges 2008 - Source: British Airways

6.13 Architectural Expression

There have always been a multiplicity of styles at airports; no individual style has prevailed. The variety of styles adopted at airports include:

- Neo-Classical
- Art Deco
- International Style
- High Tech
- Contextual Design
- Expressionism
- Megastructure: Aerial & Interior Architecture

6.13.1 Neo-Classical

Neo-Classical designs can offer a sense of solidity and security from familiar heavyweight construction. Architects who have used this form of expression have sometimes argued that the familiar provides reassurance to nervous passengers. Examples can be found at London Croydon, architect UK Air Ministry, (figure 6.182), Berlin Tempelhof 2, architect Ernst Sagebiel , (figure 6.183), Washington National, architect Charles M. Goodman, (figure 6.184 & 6.186) and Moscow Domodedovo (figure 6.185). This approach has not normally been seen since the end of the Second World War.

Figure 6.182 - London Croydon 1928
Source: Photo Wikimedia

Figure 6.183 - Berlin Tempelhof 1939
Source: Structurae.net

Figure 6.184 - Washington National 1941
Source: Flyreagan.com

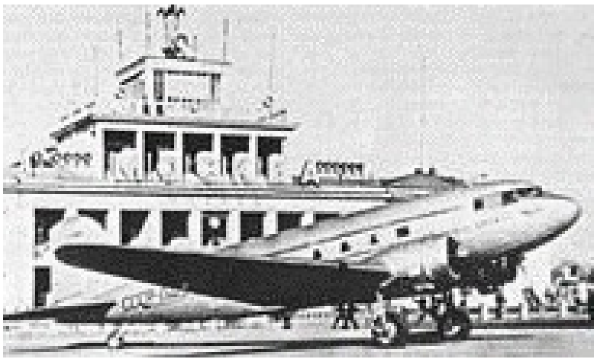


Figure 6.185 - Moscow Domodedovo c1939
Source: McDonnell Douglas

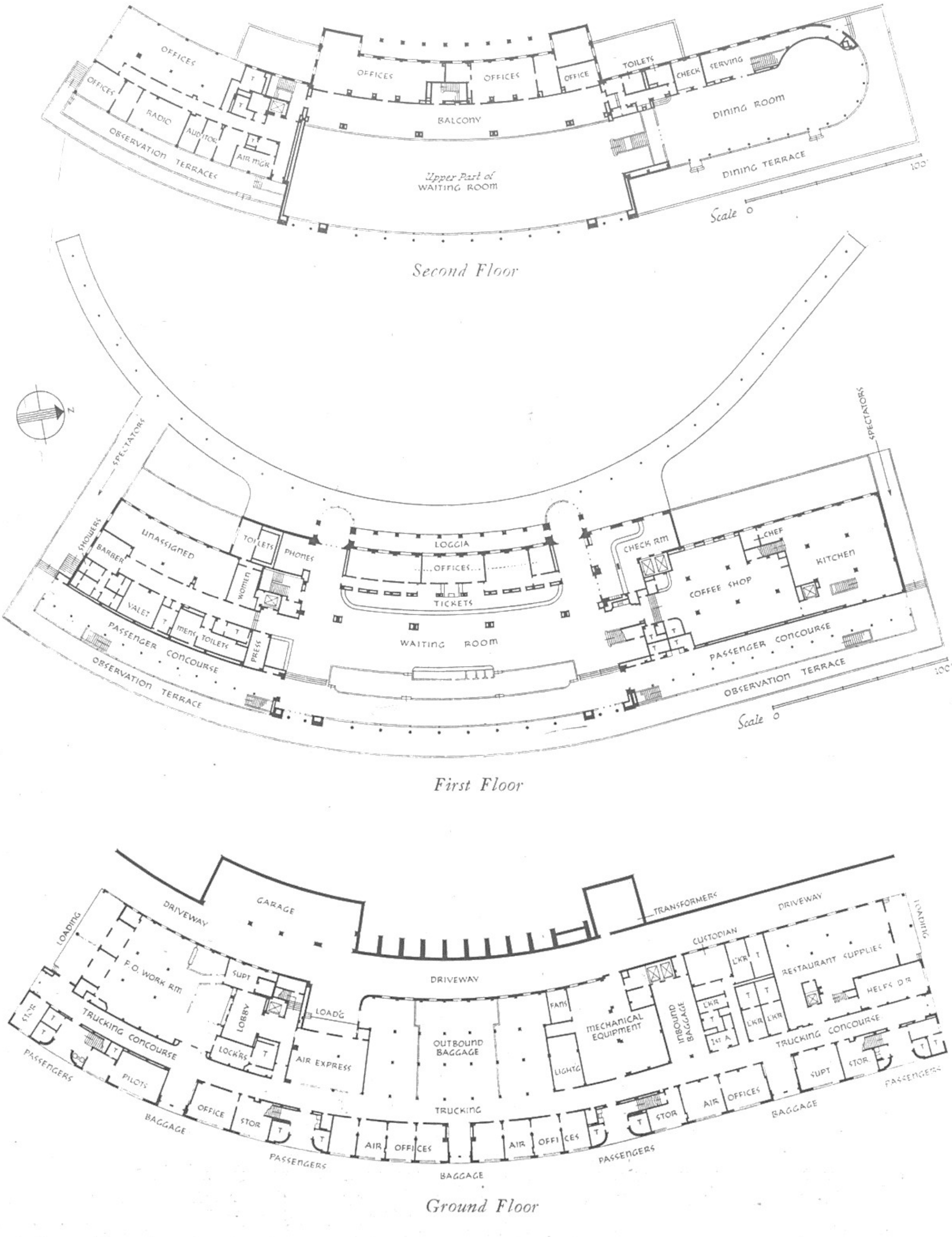


Figure 6.186 - Washington National 1941 – Source: Pencil Points October 1942

6.13.2 Art Deco

Art Deco, also known as Classic Moderne or Streamline Moderne, celebrated concepts of being modern with streamline design features and new forms of applied decoration in the 20s and 30s. Typically this involved curved corners and long lines, that were intended to reflect the streamlined aesthetic of aircraft. This was complemented by decorative features and artwork that often made reference to flight. Examples include New Orleans Sushan, by Weiss, Dreyfous and Seiferth, (figure 6.187), Miami 41st Street (figure 6.188) and LaGuardia (figure 6.189) in the USA, by Delano and Aldrich, Le Bourget by Georges Labro (figure 6.190) in France, and Shoreham, by R. Stavers Hessell Tiltman, (figure 6.191) and Liverpool, by Edward Bloomfield, (figure 6.192) in the UK.

Figure 6.187 - New Orleans Sushan 1934,
Source: Earl K. Long Library

Figure 6.188 - Pan American Miami 41st Street 1929
Source: US Library of Congress

Figure 6.189 - New York - La Guardia –1939
Source: panynj.gov

Figure 6.190 - Paris Le Bourget - 1937
Source: Aviationclub.aero

Figure 6.191 - Shoreham – 1936
Source: Passenger Terminal Today

Figure 6.192 - Liverpool Speke – 1938
Source: SkyscraperCity

Inside the Marine Air Terminal at New York's LaGuardia Airport is a piece of transport art called "Flight" by American painter James Brooks (figures 6.193 & 6.194).

'*It's a mural a massive 3.7m tall and 72m long, and it depicts the human obsession with taking to the skies, from our very first desires to emulate birds right up to the latest form of air travel. It's had something of an interesting history in its own right, but it also provides an answer to the question as to what an airport might be doing hosting a terminal called 'Marine'…. "Flight" was completed in 1940, and the most modern aircraft it depicts is that lost beauty and pinnacle of stylish transport, the flying boat*.' (The Beauty of Transport, 2017)

Figure 6.193 - New York, La Guardia 1939 – 'Flight' Mural by James Brooks –
Source: Photo by AtDisneyAgain (Own work) [CC BY-SA 4.0], via Wikimedia Commons

Figure 6.194 – 'Flight', Mural by James Brooks, La Guardia 1939 –
Source: Murals of New York City: The Best of New York's Public Paintings from Bemelmans to Parrish

6.13.3 International Style

International Style is not often found at airports in the 1930s.but includes Chicago Midway and Rio de Janeiro Santos Dumont, architect Manuel Cuadra, (Cuadra, 2002) (figures 6.195 & 6.196). The latter was designed in the 30s, although its opening was delayed until after the Second World War.

After the Second World War International Style became more prevalent and includes London Gatwick, architect Yorke, Rosenburg and Mardall (YRM), (figures 6.197, 6.198, 6.199, 6.200 & 6.201), Paris Orly, architect Henri Vicariot, (figure 6.202) and the New York Idlewild International Arrivals architect SOM, (figure 6.203) and National Airlines Terminals, architect I.M. Pei (figure 6.204). This group of airport terminals typically express the structural frame construction and employ modular factory made components, but avoid the decoration that is characteristic of Art Deco.

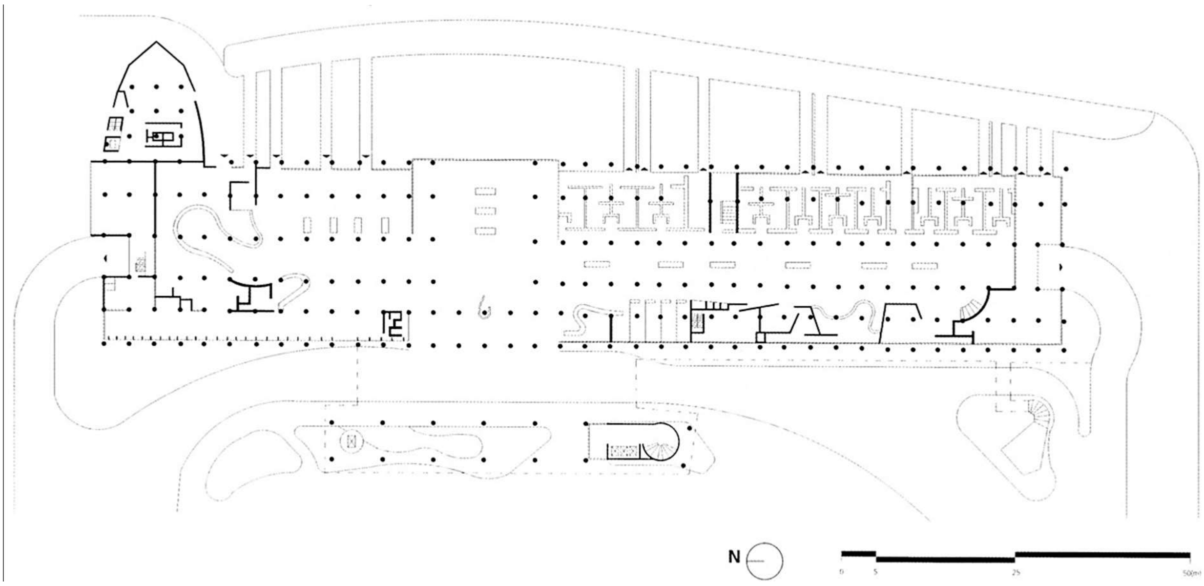


Figure 6.195 - Santos Dumont Plan, Rio de Janeiro 1939 –- Source: World Airports,

Figure 6.196 - Santos Dumont, Rio de Janeiro, Aerial Photograph c1955 – Source: Pinterest

Figure 6.197 Gatwick central pier 1958 - Architect Yorke, Rosenberg & Mardall (YRM)-
Source: British Caledonian

Figure 6.198 - Gatwick South Elevation 1958
Source: YRM

Figure 6.199 - Gatwick Apron 1958
Source: Gatwick Airport Consultative Committee

Figure 6.200 - Gatwick 1958, External View
Source: British Caledonian

Figure 6.201 - Gatwick Check-In Concourse 1958
Source: RIBA Library

Figure 6.202 - Paris, Orly 1961-– Source: LeZebre

Figure 6.203 - New York, Idlewild (JFK) 1958, International Arrivals Building – Source: Jon Procter

Figure 6.204 - New York, JFK – National Airlines Terminal 1969, Source: Photo by Gill Armitage, Amiaga

In the current decade there has been a revival of interest in simple 'Miesian' International style architecture in Europe as reaction against the excesses of High Tech, Expressionist and Contextual terminal design as can be seen at Berlin Brandenburg, architect Meinhard von Gerkan, (figure 6.205), Frankfurt, architect Christoph Mäckler, (figure 6.206), Schiphol, KAAN Architecten (figure 6.207) and Marseilles, architect Foster + Partners (figure 6.208) Airports.

Figure 6.205 - Berlin Brandenburg 2020 – Source: Seele.com

Figure 6.206 - Frankfurt Terminal 3 Visualisation, opening c 2025 – Source: frankfurt-airport.com

Figure 6.207 - Amsterdam, Schiphol Competition Winner KAAN Architecten, opening c 2023 – Source: static.dezeen.com

Figure 6.208 - Marseilles, Norman Foster Competition, opening c2023 – Source: Foster + Partners

6.13.4 High Tech

High Tech design, first seen at London Stansted, architect Foster + Partners, (figure 6.209), typically used long span tubular steel roof structures, lightweight materials and interchangeable components. Other examples include Hamburg, architect Meinhard von Gerkan, (figure 6.210), Kansai, architect Renzo Piano, (figure 6.211), Hong Kong, architect Norman Foster, (figure 6.212), Madrid T4, architect RSHP,(figure 6.213 & 6.214), Heathrow T5, architect RSHP, (figure 6.215) and Beijing Capital, architect Foster + Partners, (figure 6.216).

There is a particular emphasis on expressing the roof structure as a key generator of the architectural design, while treating the interior as a stage set reminiscent of Mies van der Rohe's proposal for Albert Kahn's Glen Martin aircraft assembly plant (figures 2.07 & 2.08). The terminals of this generation of airports have typically become so large that the passenger experience has become increasingly internal, as the building is often too large to grasp as a single entity.

Figure 6.209 – Stansted 1991
Source: weirdnews

Figure 6.210 Hamburg 1993
Source: Panoramio com

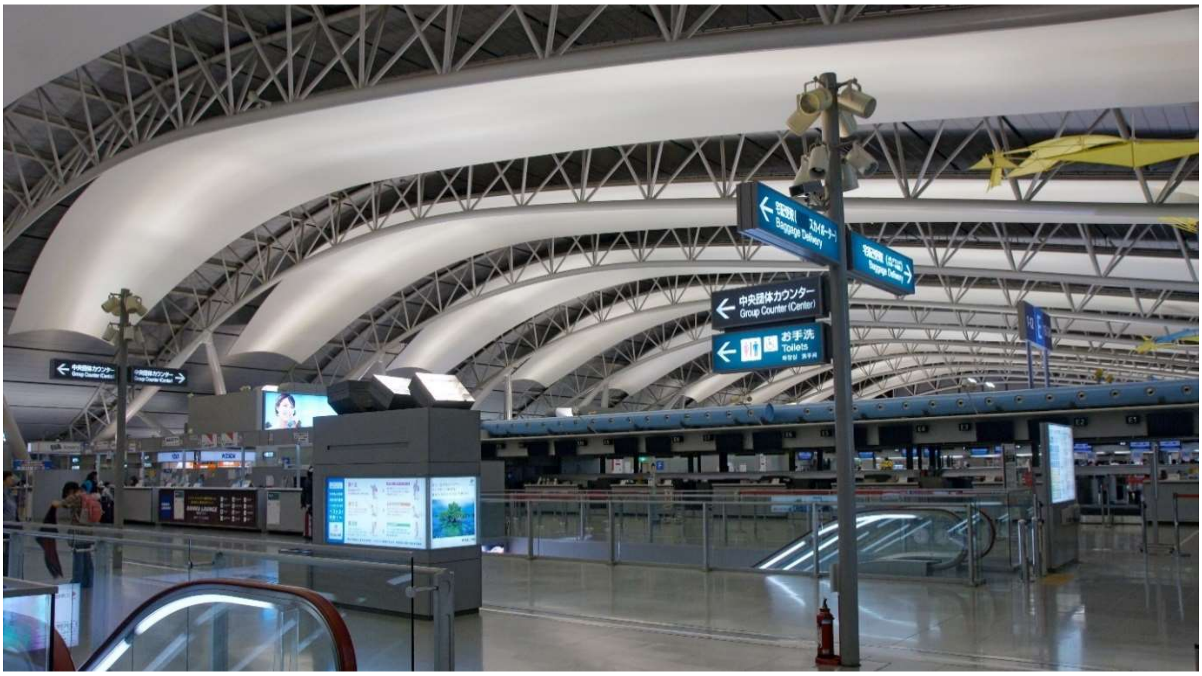


Figure 6.211 - Kansai 1994– Source: Wikimedia - https://ja.wikipedia.org/wiki/user:663highland-

Figure 6.212 - Hong Kong 1998– Source: Foster + Partners

Figure 6.213 - Madrid T4 2006
Source: Airports of the World

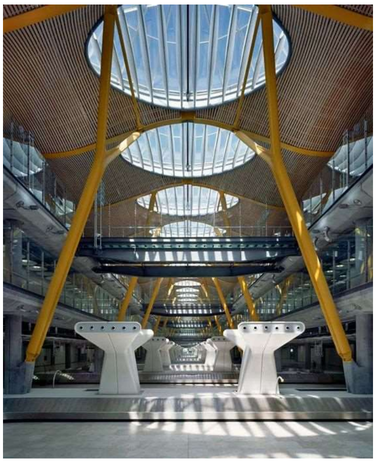


Figure 6.214 – Madrid T4 2006
Source: RSHP

Figure 6.215 - Heathrow T5 2008 – Source: BAA


Figure 6.216 - Beijing Capital 2008 – Source: Arup

6.13.5 Contextual Design

Contextual design is largely found in the USA or promulgated internationally by American architects including in the early years Californian Spanish at Grand Central, California, architect Henry L. Gogerty (figure 6.217). More recently Denver, Fentress Architects, (Binney, 1999) (figure 6.218), Jakarta, architect Paul Andreu ADPi, (Jodidio, 2004) (figure 6.219) and Siem Reap, Design Architype Group, (figure 6.220) have sought to create an identity in response to the local landscape, climatic conditions and vernacular architecture.

Figure 6.217 - Grand Central, California 1928 – Source: Airfields-freeman.com

Figure 6.218 - Denver with Rocky Mountains in the background 1995 –- Source: Architonic.com

Figure 6.219 - Soekarna Hatta, Jakarta 1985 –- Source: Tripadvisor

Figure 6.220 - Siem Reap, Cambodia 2006 – Source: Anton Ivanov/shutterstock

6.19.6 Expressionism

Expressionist Architecture, where the form is specifically intended to heighten the drama of flight, can be seen at Saarinen's TWA –JFK (figure 6.221) and Washington Dulles (figure 6.222) terminals, Calatrava's Saint-Exupery Airport Lyons-Satolas (figure 6.223 & 6.224) and Bilbao Sondica (Binney, 1999, pp. 36-39) (figure 6.225) and Farrell's Seoul Incheon Interchange (AT Profile 1 and Building Design, 2002) (figure 6.226).

Figure 6.221 - TWA Terminal, JFK, New York 1962 – Source: Conde Nast Traveler

Figure 6.222 - Washington Dulles 1962 – Source: flydulles.com

Figure 6.223 - Lyon Satolas Airport (Gare de Lyon Saint-Exupéry), TGV train Station 1994 – Source: Matt Feldman, inthedistance.net

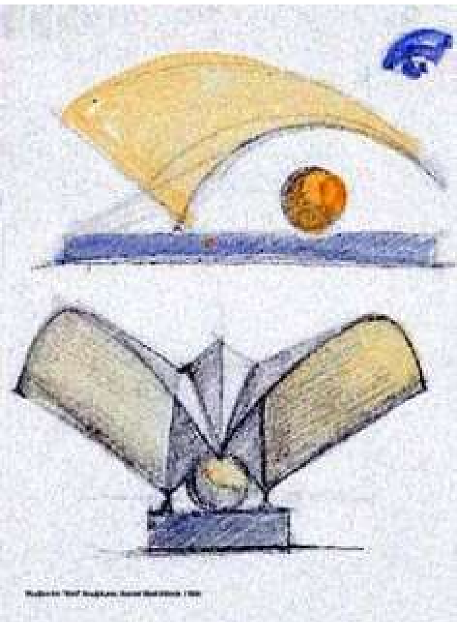


Figure 6.224 - Calatrava's Sketches for Lyon Satolas Airport Station 1994 – Source: slidesharecdn.com

Figure 6.225 - Sondica, Bilbao 2000 - Source: EpidemicFun.com

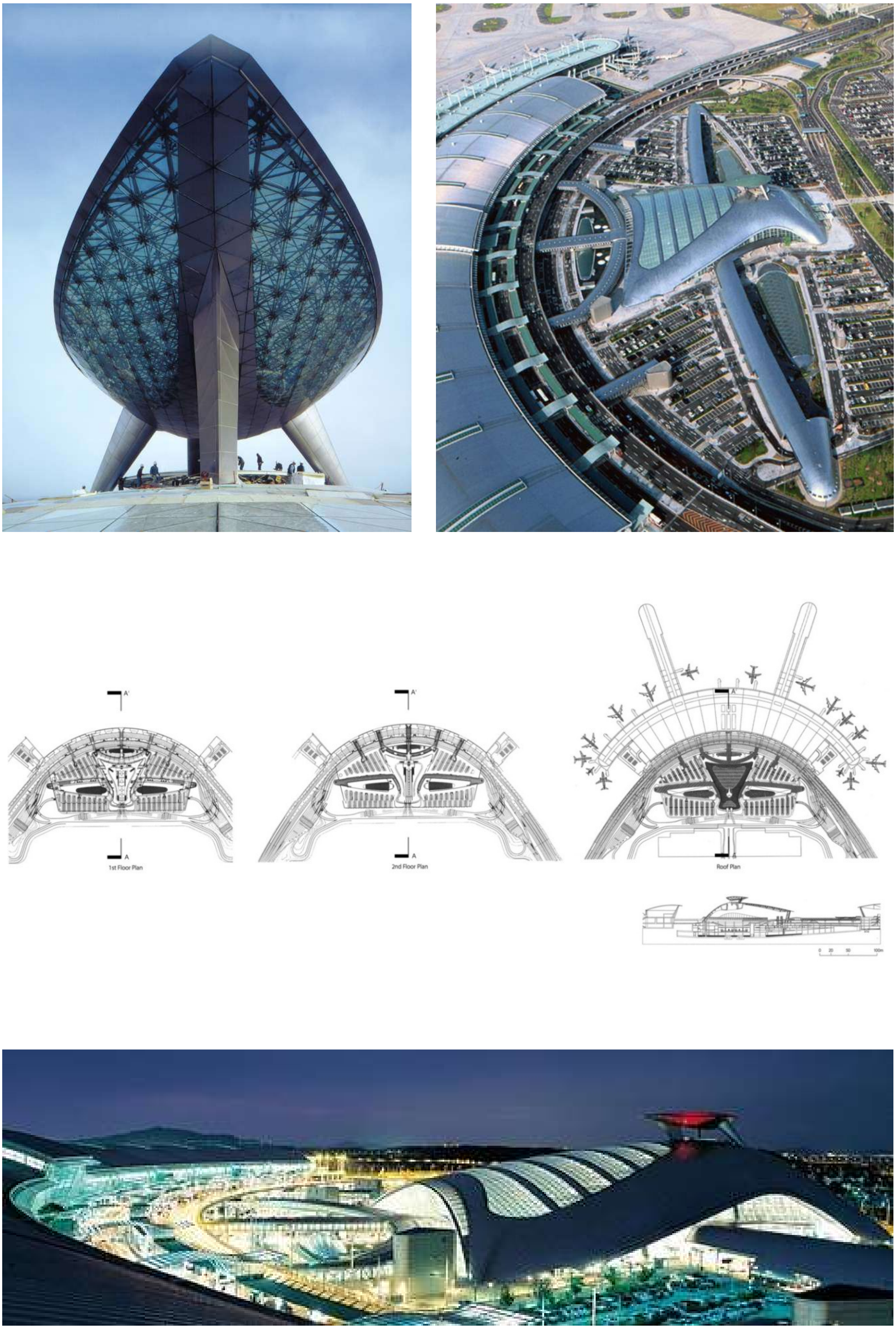


Figure 6.226 - Seoul Incheon, Interchange 2001 - Sources: Farrell's, & Pinterest

6.19.7 Megastructure – Aerial and Interior Architecture

As terminals have become so large that they cannot be understood as a whole, there is an increasing emphasis on the bird's-eye view of the roof, a concern that originates with Walter Gropius and Le Corbusier in the 1930s. It is a view that can never be seen in practice except by a photographer hovering in a helicopter. This is complemented by a focus on the interior view, which, however, can only give a partial understanding of the terminal and becomes an experience similar to walking around a city centre, simple if the route is well known but confusing to the first time traveller. No longer is the main entrance to the terminal the key view from which the building can be understood. While this trend has been developing for some time it can be seen most clearly in some of the most recent designs

Examples can be seen at Mexico City, Foster + Partners with Fernando Romero, (figure 6.227), Beijing Daxing, architect Zaha Hadid (ZHA), (figure 6.228) and. Shenzhen Bao'an, architect Massimiliano Fuksas, (figure 6.229).

Figure 6.227 - Mexico City, Winning Competition Design 2018, Source: Archinect & fr-ee.org

Figure 6.228 - Beijing Daxing, Visualisation and Interior 2019 – Sources: Business Traveller & china-underground.com

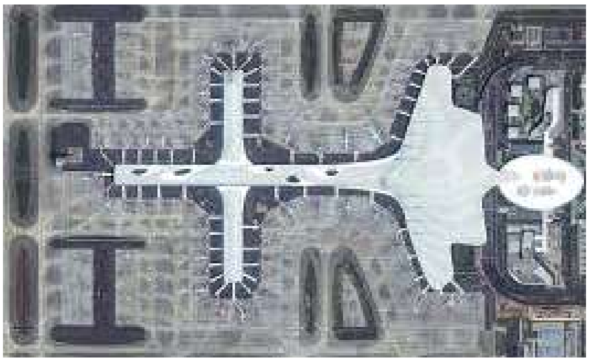


Figure 6.229 - Shenzhen Boan 2013 – Sources: Skyscraper City & Shenzhen-Bao'an International Airport

6.14 The Spirit of Flight

Architects have sought to capture the spirit of flight in a variety of ways through the application of streamlined imagery, in the use of the plan form, in the section, the flow of one space to another, the selection of materials and presentation of information. An early example of streamlined expressionist imagery can be seen in the drawings for a hangar and workshops for airships and airplanes by Erich Mendelsohn (1914) (figure 6.230).

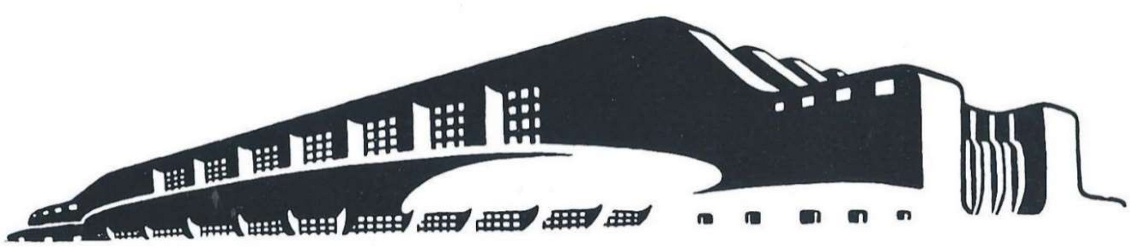


Figure 6.230 - 'Aerodrome', Hangar and Workshops for Airships and Airplanes c1930 – Source: Building for Air Travel

Georges Labro arguably based his plan for Le Bourget on the shape of the Farman Goliath aircraft of the 20s, the aircraft so admired by Le Corbusier. In an article published in L'Architecture in January 1938 Labro described his terminal design:

> *'Furthermore – and this is very important – my design, articulated around a central feature or, if you prefer, a kind of prow with long wings on either side, allows for the inevitable extensions of the future, with no obstacles placed at either ends of the wings.'* (Labro, 1938)

A comparison of the plan of Le Bourget airport with the plan of the Farman Goliath F60 aircraft reveals a remarkable similarity of proportions (Moyle, 2015) (figure 6.231 & 6.232).

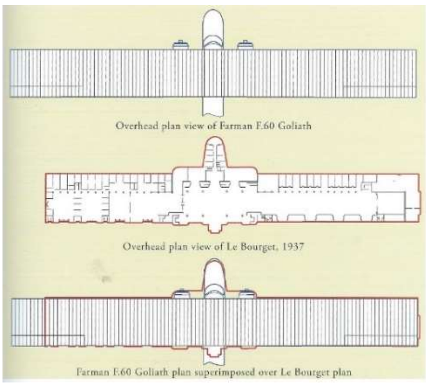


Figure 6.231 - Comparison of Le Bourget & Farman Goliath plans 1937 & 1919 Source: Art Deco Airports

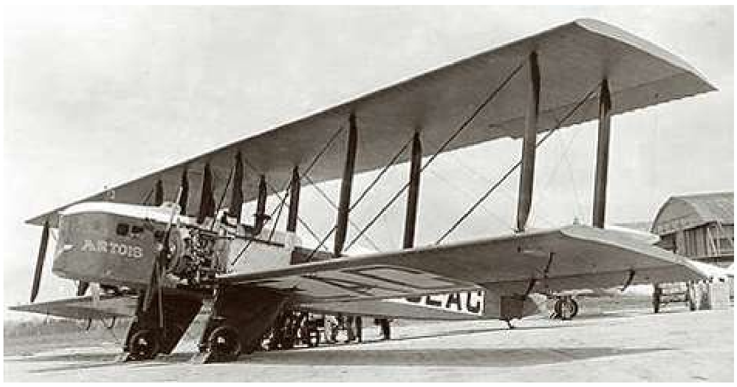


Figure 6.232 - Farman Goliath Aircraft – Source: vehiclepad.com

More recently Renzo Piano has compared the plan form of his design for Kansai Airport with the shape of a glider (see chapter 11.18).

As the aerodynamics of flight changed with the introduction of swept back wings so plan forms of the terminal evolved notably at Ramsgate, architect David Pleydell-Bouverie, (1938) with a wing shaped plan (Bouverie, 1937) (figure 6.233).

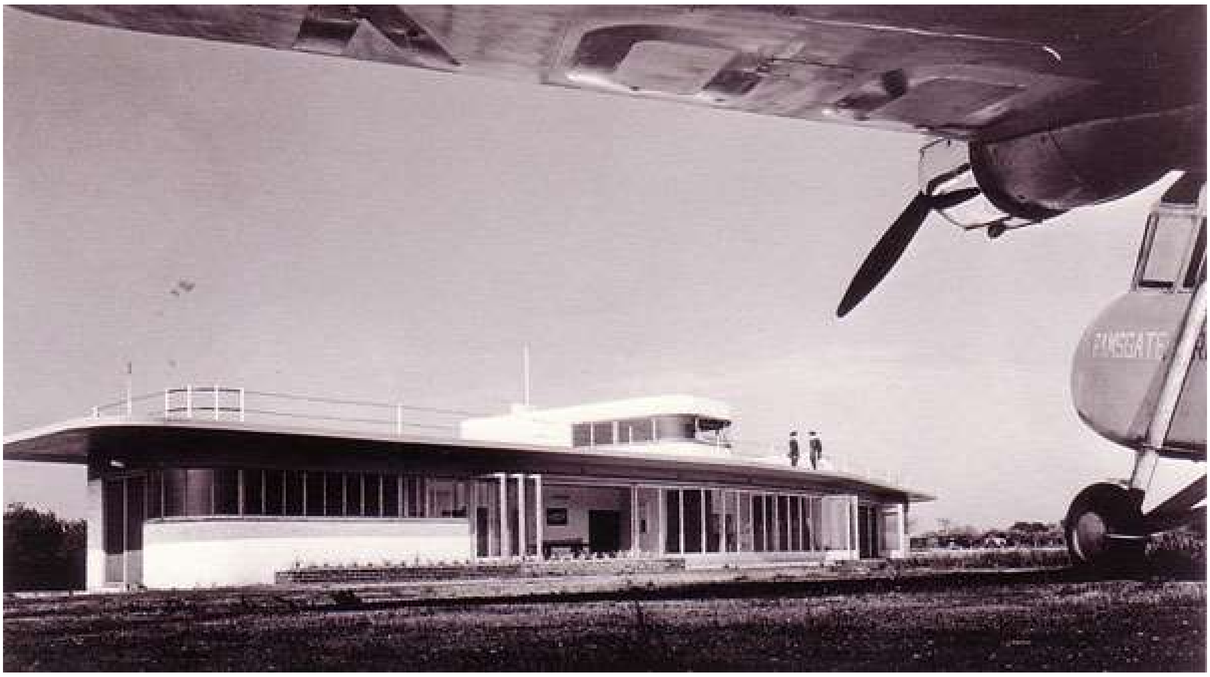


Figure 6.233 - Ramsgate 1935 – Source: Aviation Postcard Club

More recently the Foster design for Panama City, Tocumen, (2020) (figure 6.234) revives the concept. The description of the new terminal includes the following:

'Two symmetrical wings of piers extend to the east and west from the garden and central concourse, and the entire building is unified beneath an aerodynamic bronze-coloured roof' (Foster, 2020)

Figure 6.234 Panama City, Tocumen 2019 – Source: Foster & Partners

Bauhaus architect Frans Wittwer introduced the cantilever roof form to an airport restaurant at Leipzig (1929), that resembled a bird in flight, which in combination with fully glazed elevations created the sense of lightness to which the Futurists aspired (Cuadra, 2002) (figure 6.235).

Figure 6.235 - Leipzig – Halle Airport Restaurant 1929 – Source: Postales Inventadas

Bauhaus designers also contributed to lightness by designing the aluminium fixtures and furniture, including the tubular chairs, of the Hindenburg Airship.

Cantilever roofs have since figured regularly in terminal design, particularly those terminals that were designed to permit dry boarding such as Berlin Tempelhof, architect Ernst Sagebiel, (Hecker, 2005), (figure 6.236) Birmingham Elmdon, architects Norman & Dawbarn, (Negus, 1984) (figure 6.237) and the JFK Pan American Airways Terminal, architect Walther Prokosch of Tippets-Abbett-McCarthy-Stratton, (Hunt, 1958) (figure 6.238).

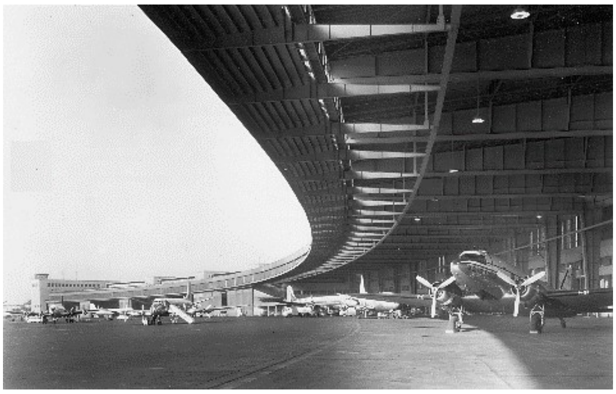


Figure 6.236 - Berlin Tempelhof 1939
Source: Arkhitecton

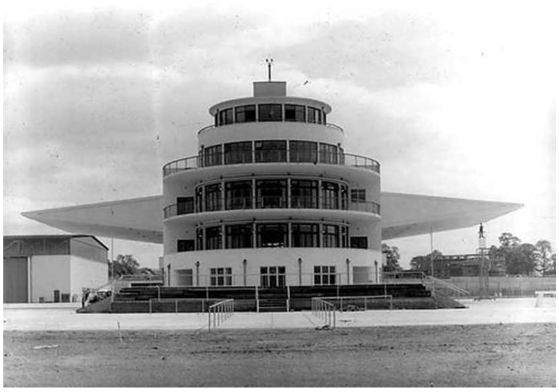


Figure 6.237 - Birmingham Elmdon 1938
Source: Pinterest

Figure 6.238 - Pan American, JFK 1958 – Source: Life

Minoru Yamasaki of Hellmuth, Yamasaki and Leinweber introduced the shell concrete roof at St Louis Lambert (1956) the first terminal where walls did not reach the ceiling but where all the elements of the fit out were designed like a self-supporting stage set (figure 6.239).

This concept was revived by Eero Saarinen at the New York, JFK TWA terminal and at the Washington Dulles terminal. Later it was reinvented by Foster at Stansted using steel technology and now is the norm in large terminals.

Figure 6.239 - St Louis Lambert 1956 – Source: Landmarks Association of St. Louis

More complex concrete floating roofs appeared at the Saarinen terminals at JFK TWA terminal (figure 6.240) and the new Washington Dulles Airport (figure 6.241). Both captured the spirit of fight for the jet age in the uplifting form of the roof. At the TWA terminal for New York's Idlewild airport Eero Saarinen articulated TWA's desire for one space to flow into another,

> *'We wanted to reveal the terminal, not as a static, enclosed space, but as a place of movement and transition'*. (Dawson, 1962)

It was described by TWA as the 'Winged Gateway to the World of Flight.'

Figure 6.240 - TWA Terminal, JFK 1962 – Source: Ezra Stoller photographer

As Saarinen developed his architectural vision further at Washington Dulles Airport. He wrote:

> *'The tradition of Federal architecture is static, but a jet airport should be essentially non static, expressing the movement and the excitement of travel. We thought that if we could bring these two things together into a unified design we could have a very interesting building.'*
>
> *'There was also the problem of the site – a beautiful flat plain. In a way, architecture is really placing something between earth and sky. We came to the conclusion that a strong form that seemed both to rise from the plain and to hover over it would look the best. The horizontal element, or roof, would be the highest element. It should be tilted forward so the building would be seen. The terminal should also have a monumental scale in this landscape and the vastness of this huge airfield.'*
>
> *'The roof is supported by a row of columns forty feet apart on each side of the concourse, sixty-five feet high on the approach side, forty feet high on the field site. It is like a huge, continuous hammock suspended between concrete trees. It is made of light suspension-bridge cables between which concrete panels of the roof deck fit. The concrete piers are sloped outward to counteract the pull of the cables. But we exaggerated and dramatized this outward slope as well as the wide compressive flange at the rear of the columns to give the colonnade a dynamic soaring look as well as a stately and dignified one.'* (Federal Aviation Administration, 1962)

Figure 6.241 - Washington Dulles Model 1958 – Source: The Atlantic.com

Another enduring image of modernity at the airport is provided by Los Angeles International Airport where the LAX Theme Building, architects Pereira & Luckman, (1961) (Szurovy, 2003), a rotating restaurant, adopted the imagery of a flying saucer (figure 6.242).

Figure 6.242 - Los Angeles, Theme Restaurant 1962 – Source: VCA Engineers.com

Norman Foster provided the intellectual basis for the current generation of large steel framed terminals, which have subsequently become the norm, at Stansted airport (1991) (figure 6.243). He wrote:

> *'Stansted represents a departure point, one that was achieved by demonstrating that the old order of the 'serviced shed' could literally be turned on its head. At Stansted, the heavy engineering of mechanical plant rooms, metal ducts and supporting structure that made up the traditional roof are all relocated in an undercroft below the concourse level……. Flexibility for change is a vital consideration in such a volatile and expanding industry. This is another reason for the services undercroft. The principle of a single lightweight roof flowing freely over a multitude of different activities makes a quantum leap in the new generation of airports…..*
>
> *The essence of these new large terminals, following the Stansted pattern, is a single roof, flowing freely over a fertile ground plane, on which fully-serviced instant buildings can grow within a tempered climate of unbroken space. The possibilities opened up by this evolutionary response to the realities of mass air travel can be grasped as a civic opportunity, or merely exploited for their commercial potential. In the tradition of the great nineteenth-century railway stations these new terminals are the noble halls of our age, evoking a sense of occasion and bringing a new thrill to air travel.'* (Foster, 1996)

Foster's essay, Reinventing the Airport, of which the above is an extract, is reproduced in full as appendix H.

Figure 6.243 - Stansted 1991 – Source: Foster + Partners – Photo: Ken Kirkwood

The uniqueness of the contribution of Stansted to airport design has, however, sometimes been rather exaggerated, as roofs flowing over open concourses can be found at Yamasaki's St Louis Terminal and Saarinen's JFK TWA and Washington Dulles terminals although these were in lightweight concrete shell construction. The structural concept of Stansted also owes much to Arup, the structural engineers, who had previously designed the structure for SOM's tented Haj terminal at Jeddah (Cuadra, 2002) (figure 6.244) and a number of laboratories that exhibited similar integration of structure and services characteristics.

Much longer span steel roofs at Stuttgart and Hamburg Airports (figure 6.245), architect Meinhard von Gerkan, (Blow, 1991) and (Von Gerkan, 1995) were also being designed in parallel with Stansted. All have in their own way sought to embrace in their designs the lightness and elasticity the Futurists sought.

Figure 6.244 - King Abdulaziz, Jeddah 1981
Source: SOM

Figure 6.245 - Hamburg 1993
Source: GMP Architekten

For the last 25 to 30 years the emphasis has been on creating a memorable architectural experience using the floating long span steel roof as the prime driver of architectural form, following the lead of Norman Foster at Stansted.

6.21 Conclusion

This chapter has shown why, when, where and how new terminal concepts have arisen. The drive for change has mainly been from the increasing scale of operation, and the particular spatial constraints of individual sites. Perfectly workable examples of each of the terminal concepts, can be found today, for example:

- The pioneering hangar/depot processor can still be found at the Virgin Galactic Spaceport and numerous executive terminals with boarding inside the hangar.
- The simple terminal is still being built at regional airports that focus on the low cost carrier market such as Bristol International, Bordeaux Billy and Copenhagen Go.
- The linear terminal continues to be relevant particularly at single runway airports with large scale examples at Kansai and Medina.
- The unit terminal has primarily been built in the USA, though ADPI developed this concept at Charles de Gaulle T2 and a number of international airports.
- New finger piers can be found at a number of largest new international airports such as Hong Kong, Singapore, Bangkok, Seoul Terminal 2 and Istanbul Grand.
- Small circular satellites have largely fallen out of fashion but a recent example is Tel Aviv, Ben Gurion.

- The larger linear satellite developed at Atlanta, has been repeated at Heathrow, and other locations where space is at a premium.
- The mid-field hub has become the norm for most international hub airports with two or more runways following the example of Washington Dulles.
- While several underground terminals have been proposed only Terminal 3 at Dubai has been constructed to address the extreme shortage of land.

There has been a progressive separation or specialisation of functions such as hangars, control towers and administration. Conversely, centralised terminals now dominate over decentralised ones due to security requirements and retail pressures to maximise footfall.

Dry boarding has been a preoccupation of designers since the pioneering days with drive through and cantilever concepts giving way to apron drive airbridges once the technology had evolved sufficiently. The only exception is that low cost carriers avoid their use in favour of steps to the front and rear aircraft doors to speed passenger boarding and alighting and as a result aircraft turnaround.

Commercial design initially focused on spectator events and catering as a means to subsidising operating costs. More recently the trend to privatisation has been accompanied by a radical growth in retail, which can now deliver enough revenue to cover all day to day airport operating costs. For the future it is expected that the growth of internet shopping will lead to refocusing retail towards experiences rather than direct sales. There will also be an increasing focus on leisure experiences such as the Changi Jewel as transfer hubs try to find new ways to compete.

There have been a variety of responses to the need to find an appropriate airport style including, Neo-Classical, Art Deco, International Style, High Tech, Contextual Design, Expressionism and Mega-Structuralism focussing on Aerial and Interior Architecture. No one style has prevailed, but architects have generally tried to reflect the modern era and capture the spirit of flight and the excitement of travel, most recently with the floating long span steel roof.

Some planning concepts and architectural styles have proven to be better able to withstand the challenges of growth and change. The finger pier and the indeterminate architecture facilitated by the International Style being the most amenable to incremental expansion by virtue of the use of orthogonal layouts and modular repetitive interchangeable components. This is perhaps why there has been a resurgence of this approach at the most recent European terminal designs at Berlin, Frankfurt, Schiphol and Marseilles.

Long span roof structures have also offered opportunities for internal reorganisation, at least at the upper level, which demonstrates one of the key benefits of the original concept for Stansted with departures and arrivals traffic in a side by side configuration at the main passenger level.

Commercial demands have often allowed the natural passenger circulation to be distorted with extended walking distances but the rise of internet shopping may in future provide a remedy as maximising commercial footfall may no longer be a priority.

7. Engineering design of the airfield, runways, taxiways and aprons

7.0 Introduction

The engineering design of the airfield is the subject of this chapter. It begins with the first civilian airfields, followed by the early development of design standards and the evolution of runway design and its impact on American airports in the 1930s. Wartime master plans mark a new beginning, after which post-war master plans of the 1950s, 1970s, and 1980s are considered. Finally it compares current and proposed master plans for the largest airports in the world.

7.1 The First Civilian Airfields

The first civilian airfields in Europe were all converted military bases, no longer needed after the finish of the First World War, such as Berlin Johannisthal, London Hounslow Heath, Paris Le Bourget and later Amsterdam Schiphol and London Croydon. They all employed grass landing and take-off fields, which remained the norm in Europe until the Second World War.

7.2 Early Development of Design Standards

The United States Army was influential in setting the first airport design standards. During the First World War the army had called on Albert Kahn, a Chicago architect who specialised in industrial buildings (he was later to design the Ford Dearborn complex and Ford Airport), to design an airfield at Langley. His design was based on a layout developed for the Canadian Royal Flying Corps (figure 7.01).

Figure 7.01 - An aerial view of Camp Leaside's facilities, near Toronto, Ontario, taken in 1918 from a Curtiss JN-4 "Canuck" – Source: Royal Canadian Air Force

Their standard two squadron plan was a mile square and could handle 100 aircraft. All the buildings were arranged in three rows: the first nearest the landing area housed the hangar buildings, the second repair and maintenance shops and the third administration and barracks.

After the war the Army Air Service decided to promote civilian airways and issued 'Specifications for Municipal landing Fields' in 1919. They proposed four overarching principles:

1. That the position of the field bears some reference to the main aerial routes
2. That it is unlikely to be shut in by future building operations
3. That it is capable of expansion
4. That it is situated close to transportation facilities and water supply, but necessarily within the city limits

They then went on to specify the size, shape, character of ground, approaches, marking and accommodation. The size of site identified was for 600 yards in every direction. A preference was expressed for square or rectangle but stated that an L shape would suffice. They advised that the ground should be firm under all weather conditions and well drained. A concrete cross 150ft by 50ft was recommended as a take-off and landing spot.

They advised that all landing fields should be free from surrounding obstacles such as high buildings, power lines and trees etc. A white circular marking 100ft in diameter and 3 feet wide was recommended, with the name of the airport marked in letters 15 feet long and 3 feet wide and wind cone at one corner of the field. The accommodation requirements were simply stated as: communication by telephone, transportation facilities, hangar space, wind indicator, gasoline, oil and sundry supplies.

Landing fields were then classified into four classes

1. Conforming in all respects
2. With reduced markings
3. Without permanent accommodation or supplies
4. Capable of emergency landing only

The following drawing appeared in 'Plans for Many landing Fields' Aircraft Journal No 4 (10th May 1919) and illustrates these classifications and also adds a size of field requirement that varies with altitude (figure 7.02).

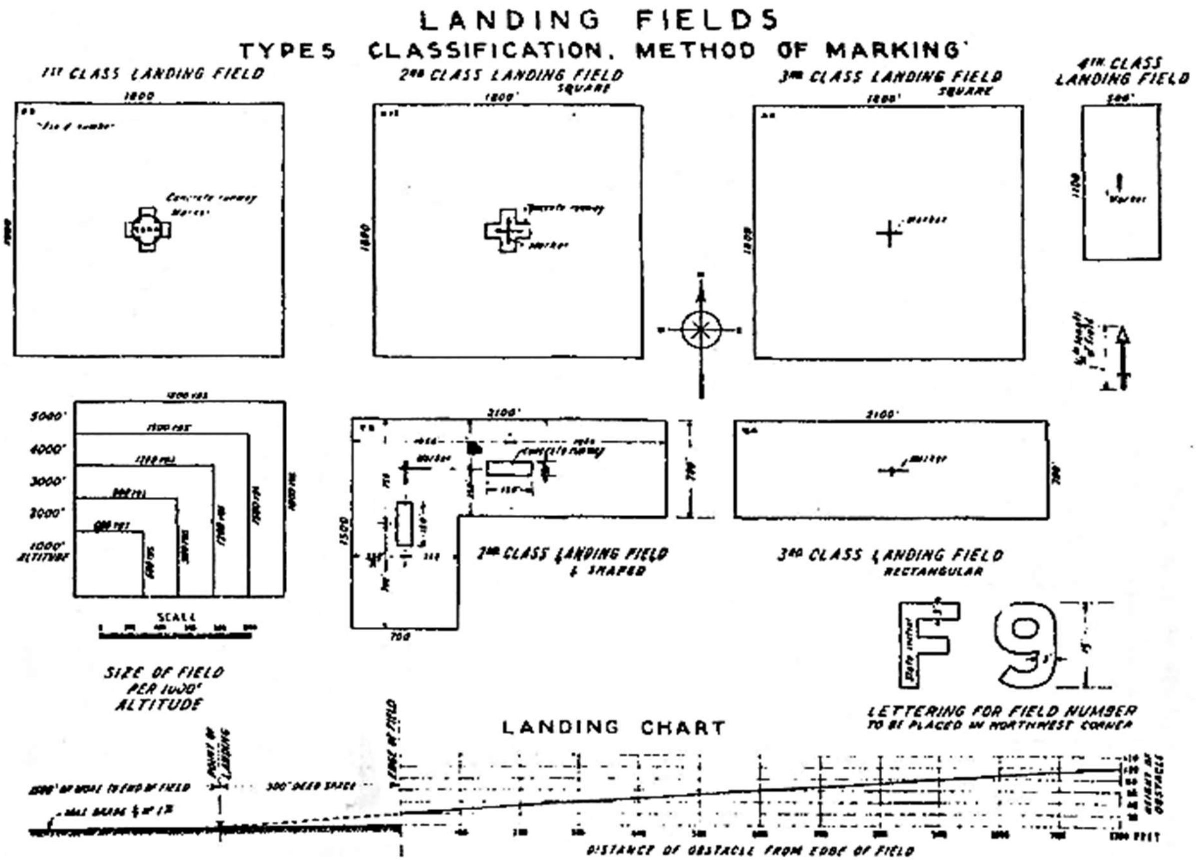


Figure 7.02 - Plans for Many landing Fields 1919 - Source: Aircraft Journal No 4

Shortly after this George Saey Wheat, a newspaperman and public relations specialist, assembled what is claimed to be the first textbook about Airport construction 'Municipal Landing Fields and Air Ports' in 1920.

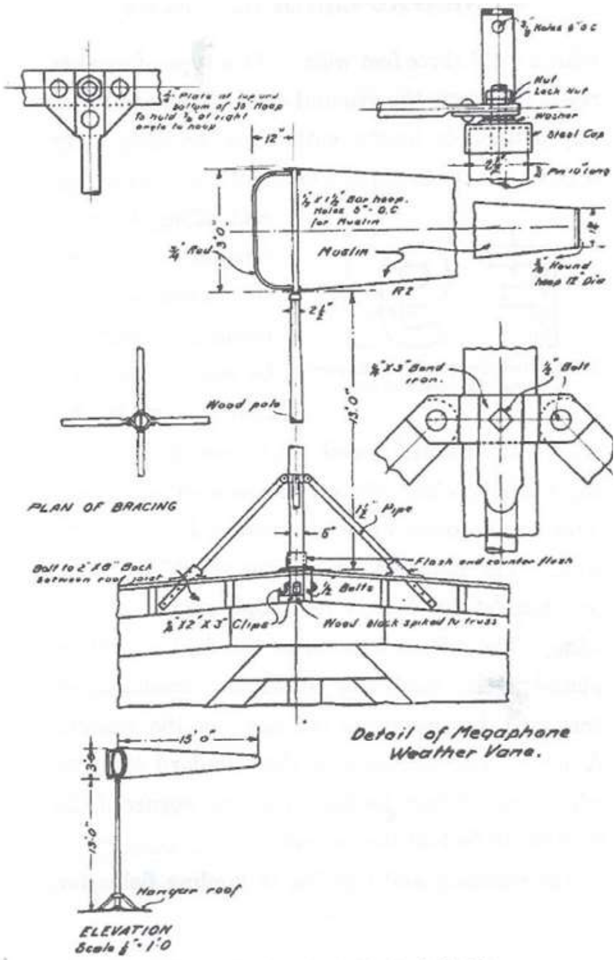
The book added very little guidance on design, excepting for a drawing of a standard wind cone, and an airship mast, but did coin the terms **runway**, **airport** and **terminal**, which have now passed into common currency, and identified that there were already over 100 municipal airports in existence in 1920.

The book included an introduction by Major General Charles T. Menoher, Chief of the Army Air Service who promoted the construction of landing fields in every city and town. A chapter by F.B. Rentschler, Vice president, Wright Aeronautical Corporation, introduced the issues of economic viability and safety, the preoccupation of all subsequent engineers, stating – '*The aeroplane has great potential …… but how about its economical use and its safety?'* (Wheat, 1920)

Lieutenant F.O. Carroll, Landing Field officer, Army Air Service wrote about constructing an airfield, recommending a 'runway' of at least 1000 yards in any direction from which the wind is likely to blow, and recommending 1:7 slope for any obstacle clearance (a criteria still employed for side clearances to this day), and that the best shape for a field was square or L shaped, with the centre marked with a concrete landing cross of 150 feet, and well drained.

He also advised that tall chimneys, wireless and observation platforms be erected away from the field, because they are dangerous when fog or low cloud obscure them, and that a wind cone (wind sock) should be placed at one corner of the field thirty feet off the ground (figure 7.03).

In addition he advised that the field should be floodlit and employ radio direction finding.



A Drawing for the Standard Aviation Wind Cone.

Figure 7.03 – Windsock 1920 - Source: Municipal Landing Fields and Air Ports

The next step of promoting hard surfaced runways can be found in a National advisory Committee for Aeronautics, Technical Memorandum 164 which was a reprint of Archibald Black's article 'How to layout and build an aeroplane landing field' that appeared in Engineering News-Record in November 1922 (Black, 1922)

He wrote:

> '*In general, a square plot is the most suitable for the terminal. Runways should be arranged so that airplanes can land or take off from them directly into the wind for the greatest possible time. For ordinary airplanes and for sea level altitudes, they should be about 2,500 to 3,000 feet long. Unless the soil drains particularly well, some attention should be given to artificial drainage, particularly around the runways. It is advisable to surface the most-used portions of the runways with gravel, cinders or other available material unless the soil drains particularly well.*

The ends should be kept clear of obstructions. All ditches should be filled up to the level of the field. The hangars, gasoline house, and all other buildings should be well spaced to reduce the fire hazard, and some suitable fire-extinguishing apparatus should be provided. The immediate requirements will usually be very modest. The important point is to obtain the site and prepare plans for its eventual development along comprehensive lines. In many cases, one hangar, some means of storing gasoline and oil, a wind indicator, telephone connection, and a location marker will be all that are necessary in the way of equipment' (figure 7.04) (Black, 1922).

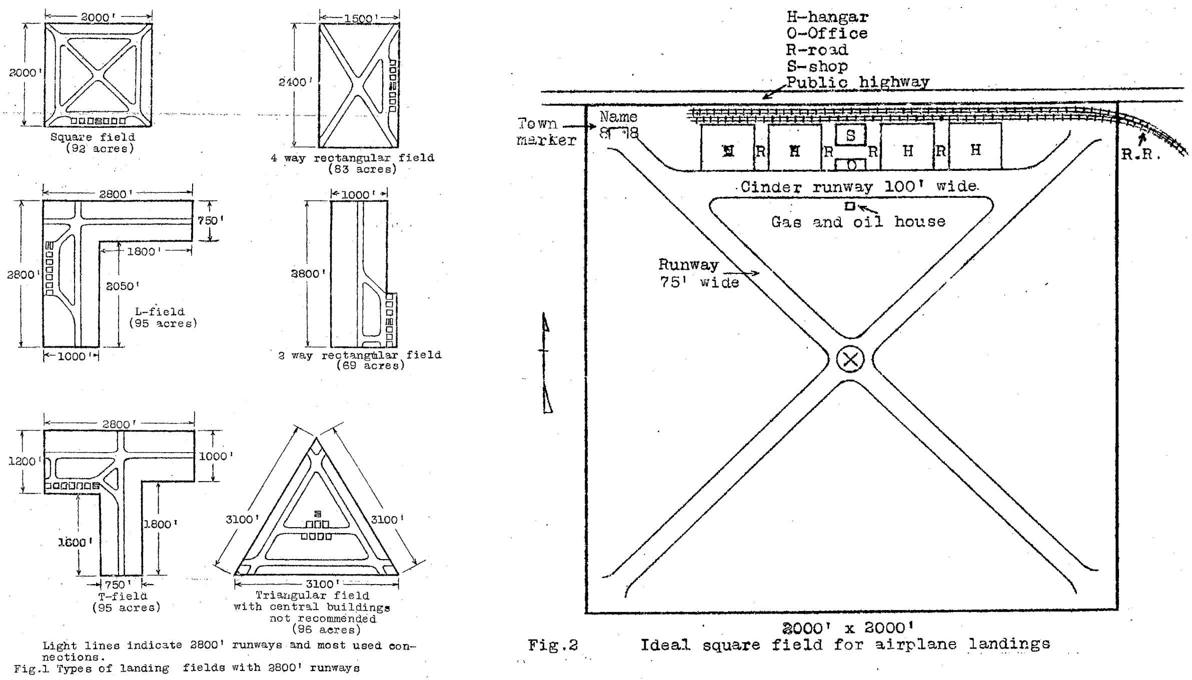


Figure 7.04 - How to layout and build an Airplane landing Field 1922 –
Source: National Advisory Committee for Aeronautics, Technical Memorandum 164

The Aeronautics Branch of the Department of Commerce, set up under the Air Commerce Act of 1926 to provide national standards for air safety and guidance to support the development of commercial aviation, published a number of bulletins and reports on airport design and operation. They devised an airport rating system covering:

- general Facilities and Equipment (A, B, C or D)
- effective Landing Area (A-D before 1930 then 1-4)
- lighting Equipment (A-E or X)

The highest rating was AAA, (or later after 1930 A1A), which required an airport to have:

- administration, cargo and passenger facilities together with fully equipped hangars, maintenance buildings and refuelling facilities

- an airfield with a landing area of 2,500 feet in all directions, with increased area if the airport was a high altitude
- a comprehensive lighting system of beacons, airfield floodlighting, boundary and obstruction lighting

These recommendations were first published in The American City in November 1927 and later updated as an Aeronautics Branch circular issued in 1929 (Eggebeen, 2007) (figure7.05).

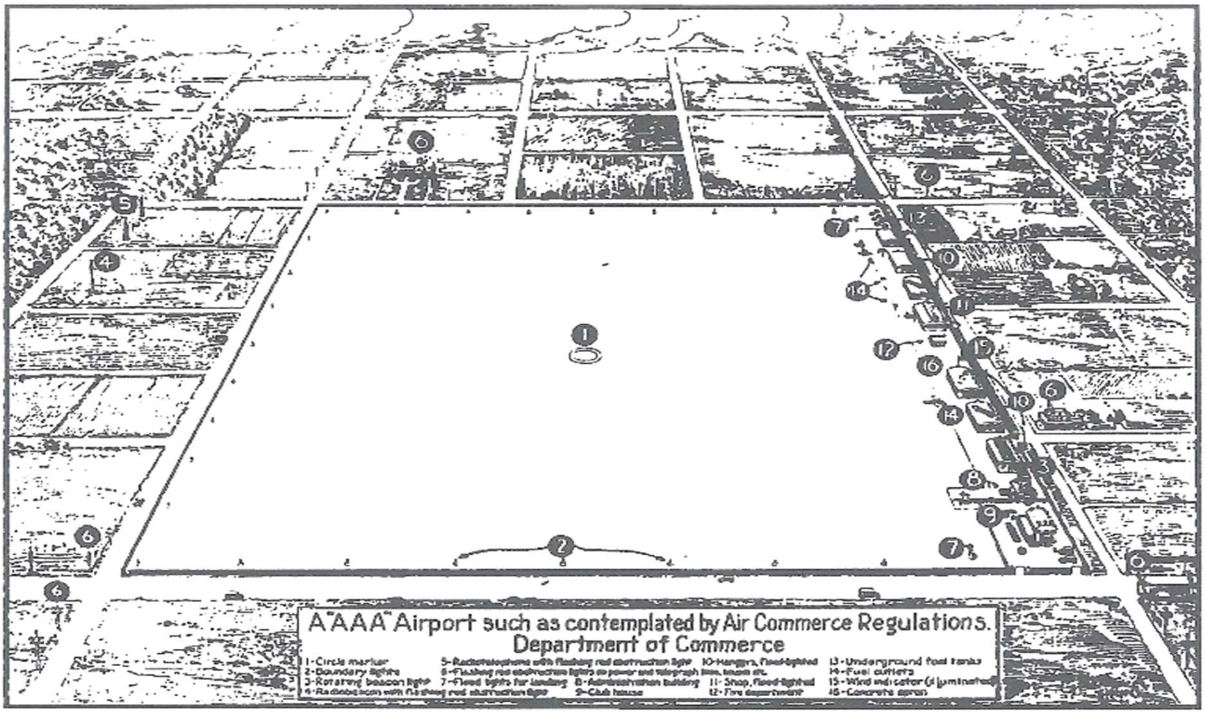


Figure 7.05 - An AAA Airport, U.S. Department of Commerce – Source: The American City 37 (November 1927, p642

This involved a voluntary inspection and certification process, and although no airports applied for federal inspection until 1930, Oakland Airport, California which opened in 1928 was designed to meet these standards, but did not submit an application for certification at that stage (figure 7.06).

Oakland airport was enlarged and improved with hard surfaced runways during the 1930s but John Walter Wood writing in 1940 said,

'*Along with so many other airports, less foresight has been shown in the planning and layout of the airport, which has had a sporadic and unplanned growth, the placement of buildings and other facilities of the earlier, smaller landing area bearing little relation to the present airport now in process of expansion'.* (Wood, 1940, pp. 125-130).

This showed just how fast requirements and design standards were evolving.

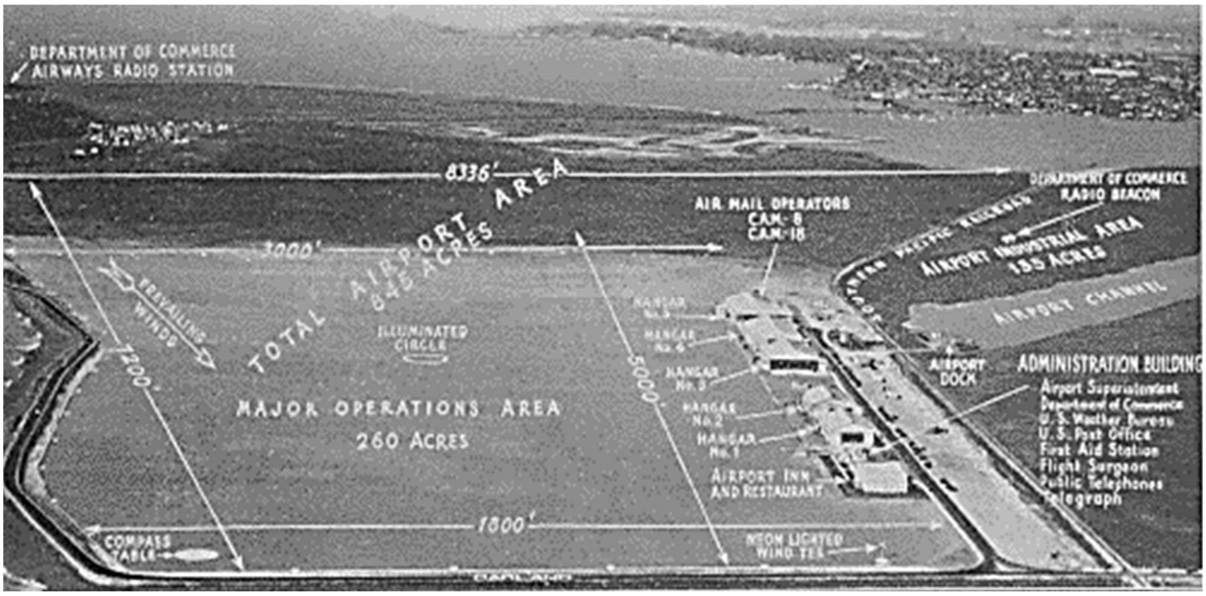


Figure 7.06 - Oakland, California 1930 – Source: Board of Port Commissioners, Port of Oakland, California

The first airport in the USA to receive official certification the Department of Commerce was Oakland/Pontiac Municipal Airport in 1930. It holds certificate no. 00001 (figure 7.07).

Figure 7.07 - Pontiac Municipal Airport 1930, (officially Oakland County International Airport) – Source: emotionreports.com

7.3 Runway Design

The move away from all direction grass fields to specific hard surfaced directional runways, was first put into practice at Boston Logan Airport which was constructed on a 189 acre site reclaimed from the sea and opened in 1923 and initially used by the military and the post office. Scheduled passenger services did not start until 1927 with the introduction of a regular service to New York. It had two 1500ft runways made of cinders (US Army Air Service, 1923) (figure 7.08).

Figure 7.08 - Boston Logan 1923 (originally Boston Commonwealth) – Source: Flickr – photographer US Army Air Service 1923

Henry Ford, the car maker, entered the aviation business by buying the Stout Metal Airplane Company and constructing his own airport at Dearborn, Michigan, the Ford manufacturing base. He pioneered a number of innovations in airport engineering design.

It opened in 1924 with two grass runways and floodlights for night landings and became the manufacturing base for the Ford Trimotor, an early all metal commercial airliner. The airport also constructed the only privately owned permanent dirigible mooring mast in 1925 (figure 7.09). A terminal building followed in 1926, and it pioneered the operation the world's 1st flight of a commercial airliner guided by radio. Also 1926 the first scheduled passenger service was launched between Ford airport and Grand Rapids. The airport was upgraded by building the first concrete runway in the world between 1928 and 1929 (Freeman, 2017) (figure 7.10 &.7.11). Henry Ford's interest in aviation waned in the early 1930s and the last flight of the Ford Air Transportation Service was in 1932.

The early concrete runways were built in a similar manner to highways in that many of them featured a thickened edge design. Typical designs included a cross section that went from 8 or 9 inches on the edges to 6 or 7 inches in the centre of each lane.

Figure 7.09 - The Army's RS-1 blimp, Ford Airport -1926 - Source: Abandoned and little known airfields

Figure 7.10 -Ford Airport airfield with concrete runways 1931– Source: Abandoned and little known airfields

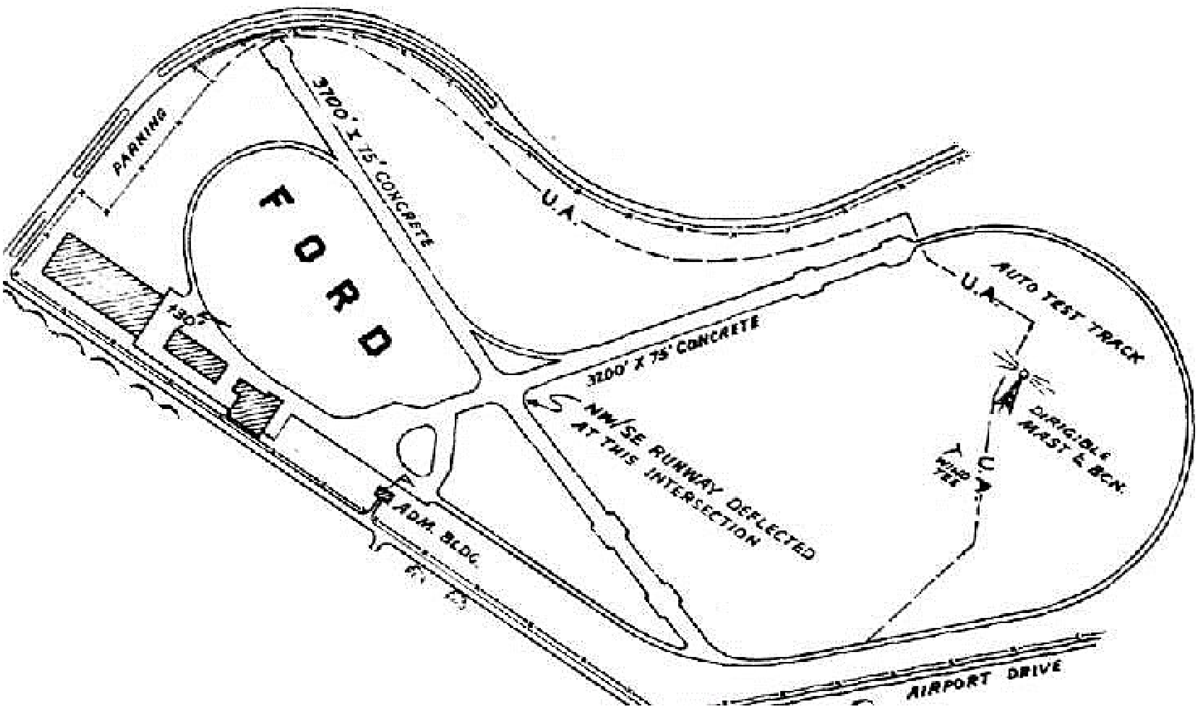


Figure 7.11 - Ford Airport - 1946 MI Airport Directory
Source: http://www.airfields-freeman.com

In the 1920s Archibald Black had sought to professionalise airport design in the United States and wrote a series of articles and books setting down proposed engineering and operating standards and good practice. This earned him expert status, and the invitation to commentate on the Lehigh Airport Competition. He advised that airport design should be undertaken in accordance with the 'Airport Rating Requirements', consider location in relation to the rest of the airways' network and meteorological conditions and to avoid seeking advice from former war pilots who may not have kept in touch with recent developments in aviation (Black, 1929, p. 16).

The Lehigh Portland Cement Company, seeing the marketing potential of concrete for runway construction, sponsored an airport competition in 1929 which became a major event in the airport world, attracting 257 entrants before the closing date of November 18th, 1929.

The competition was a blatant promotion for concrete as the brief required a minimum of four paved runways not less than 100ft (30 metres) wide, and orientated to provide for safe landing into the wind. Four design disciplines were represented on the programme committee: the architectural section, engineering section, aeronautics section and the civics and city planning section.

The aeronautical group drew attention to two important innovations that have since become standard at many airports particularly those in the United States. The first that was frequently suggested by competitors was that taxi strips be provided for aircraft to travel on between the passenger terminal and the runway to '*keep the runways free of planes taxiing into position*', and '*so that passengers were not jolted or inconvenienced while preparing for take-off or immediately after landing*.' (Black, 1929) The psychological importance of a smooth ride was emphasised by the jury.

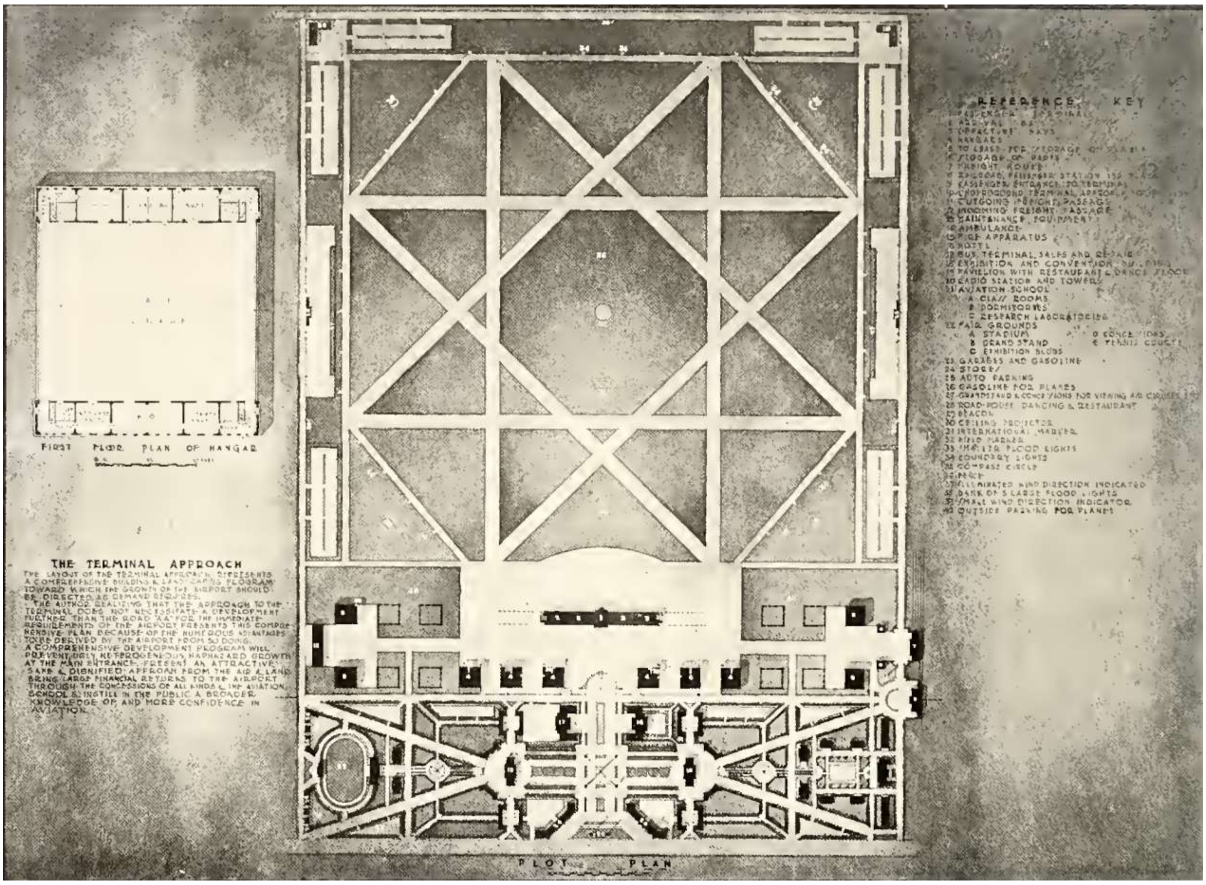
The second feature proposed by a number of competitors was the provision of double or parallel runways devoted exclusively to either take-off or landing. Again the safety benefit of this was stressed although there was evidently debate about whether a softer surfaced field was to be preferred for landing (Black, 1930). It cannot have been lost on the jury that these innovations would require even more concrete to be used.

The opportunities for introducing detailed engineering features were limited as the competition did not call for the design of lighting systems or drainage designs or for utility concepts to be developed. So the main innovations were to be seen in structural concepts, with proposals for underground structures, long span or cantilever roofs over hangars or passenger boarding points and sometimes the provision of underground rapid transit links to the city centre.

One of the best developed interchange concepts 'Rush City' by the internationally renowned architect Richard Neutra did not warrant even an honourable mention.

The competition results were widely published in the American press in 1930, and it is possible to see ideas that first appeared in the competition passing into common usage, such as the satellite and dry boarding concepts of the winning entry and the dual runway layouts of the third placed prize winner (figure 7.12).

It is worth directly comparing the airfield layout of the third placed prize winner from Odd Nansen and Latham C. Squire with the subsequent masterplan for Chicago Municipal (Midway) Airport in the 1930s.



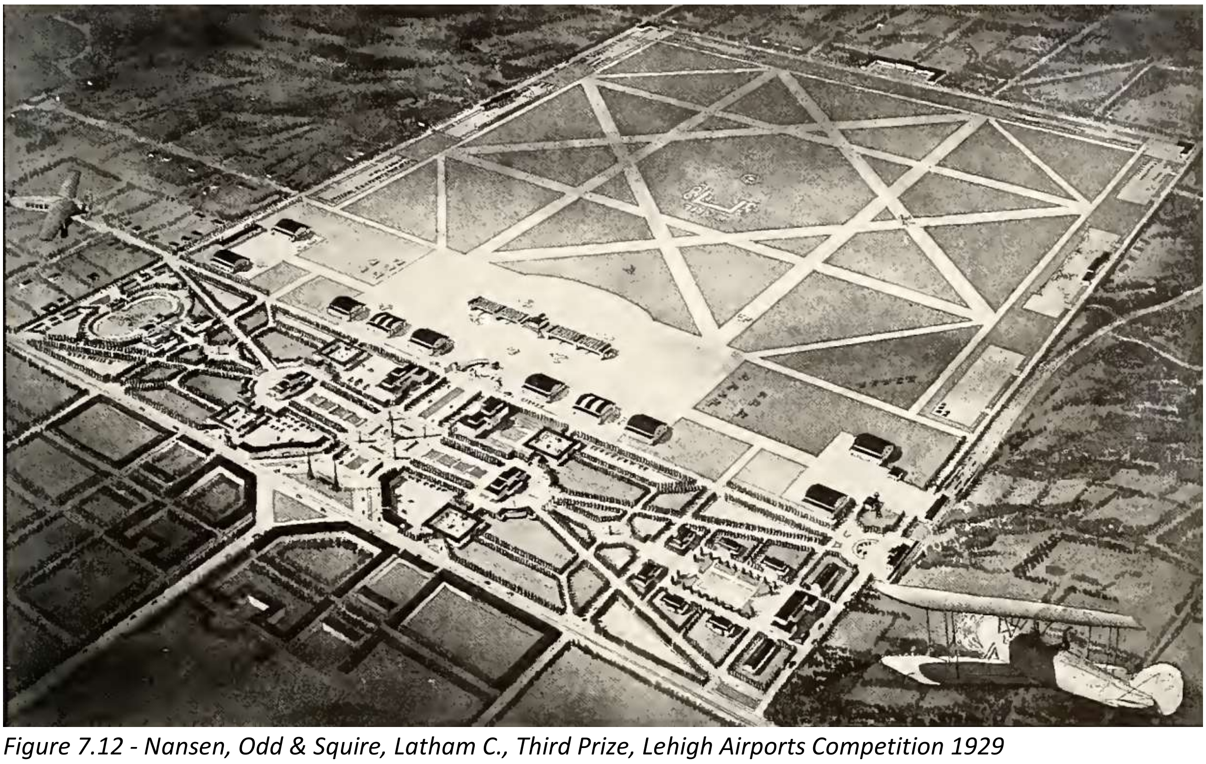


Figure 7.12 - Nansen, Odd & Squire, Latham C., Third Prize, Lehigh Airports Competition 1929
Source: American Airport Designs 1930

The Lehigh airport competition was influential on both the terminal design and the airport masterplan of Chicago Municipal Airport. The impact of the competition on the architectural design has been described earlier but the masterplan also shows the influence of the Lehigh competition on the Chicago Municipal (Midway) masterplan.

The last phase of the Chicago masterplan 1941 bears a remarkable resemblance in layout to the third prize winner with orthogonal and diagonal dual runways (figure 7.13 &7.14).

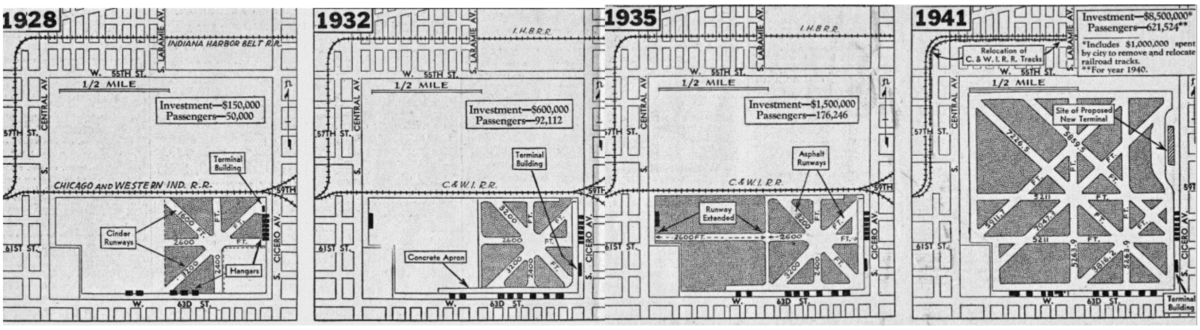


Figure 7.13 - Chicago Municipal Development Plan 1941 Source: Chicago Midway


Figure 7.14 - Chicago Municipal, Aerial photograph during construction and prior to rail line diversion (Note the photograph is at right angles to the plans above) c 1940 - Source: Chicago Tribune

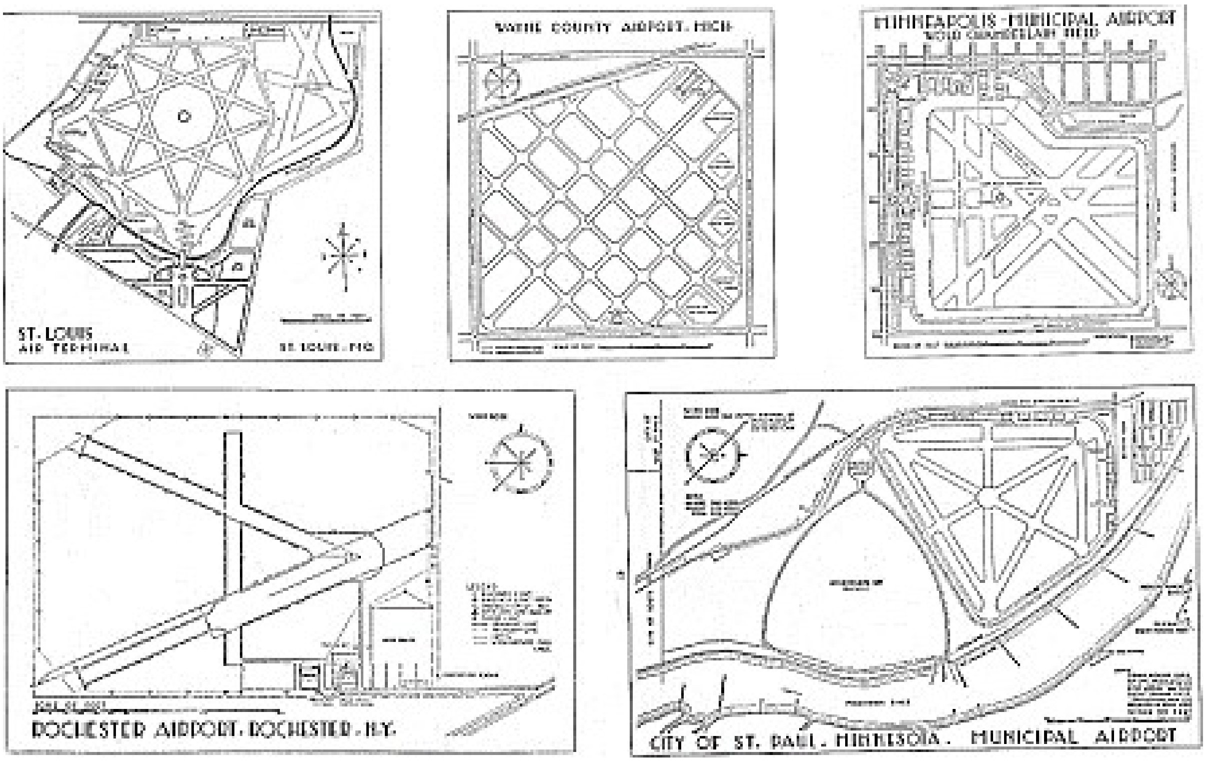


Figure 7.15 - American Airport masterplans 1930 – Source: Airports: Their Location, Administration and Legal Basis

American Airport master plans of 1930, above, show that hard surfaced runways were already the norm (figure 7.15), while European Airport master plans of 1932, right, show that airports were persevering with all direction grass fields (figure 7.16). Some commentators have suggested that this is a reflection of generally better ground conditions in Europe, while others suggest it was due to different views on safety at the time. The first European airport to be designed with concrete runways was Stockholm Bromma, in 1936 to respond to soft ground conditions. In Europe, it was followed by the conversion of Amsterdam Schiphol from an all direction grass field to concrete runways in 1939 again to respond to boggy ground conditions.

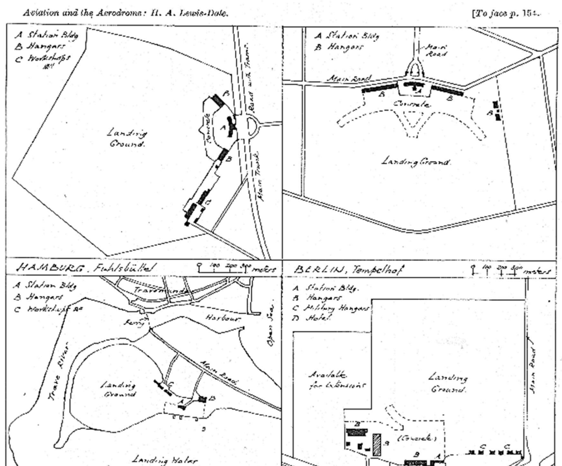


Figure 7.16 - European Airport Master Plans 1932 – Source: Aviation and the Aerodrome, H. Angley Lewis-Dale

Figure 7.17 - Stockholm Bromma 1936 – Source: Wikipedia

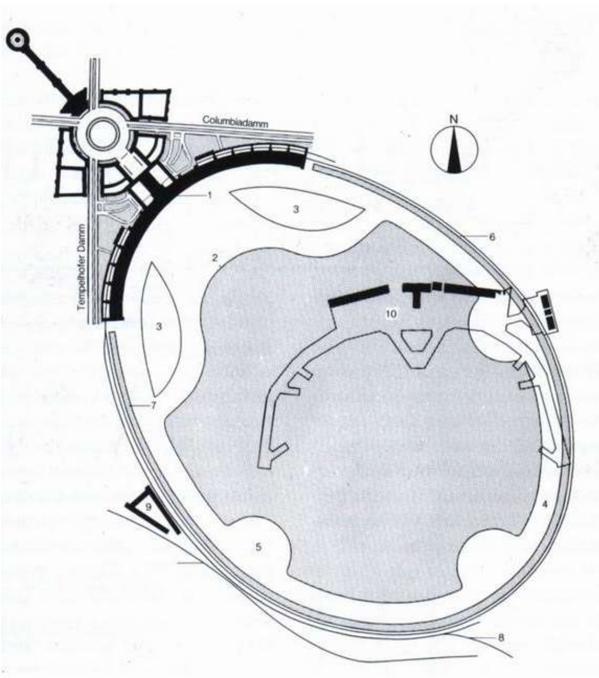


Figure 7.18 - Berlin Tempelhof 1939 – Source: Bezirksamt Tempelhof, 1998 p.81

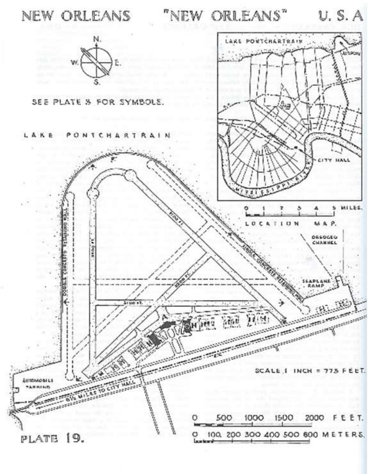
The last major airport to be constructed with an all direction grass field was Berlin Tempelhof in the late 1930s but even its airport director recognised it was obsolescent before it was completed. It is shown here superimposed over the earlier smaller airfield dating from the 1920s, (figure 7.18) which continued to operate scheduled services for most of the war, the last scheduled service being April 21st 1945.

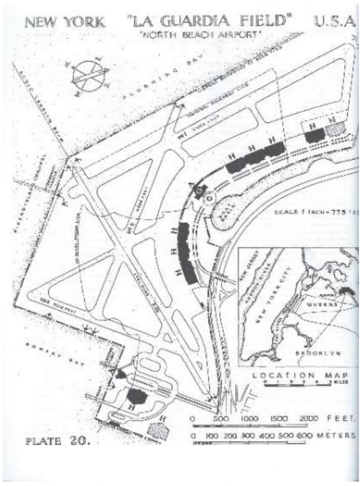
The new enlarged airfield did not become fully operational until after the Second World War when occupying American forces built concrete runways, in which form it served during the Berlin Airlift. It continued largely unchanged until its closure in 2007 as the noise impact near the centre of Berlin was no longer considered acceptable. It is now an urban park.

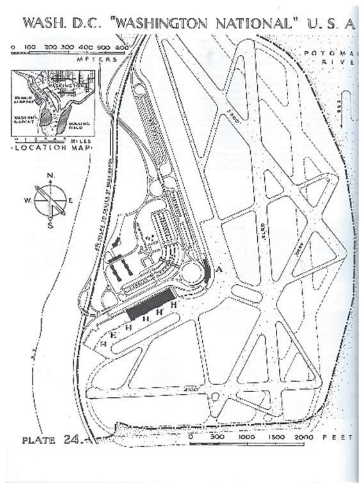
7.4 Evolution of American Airports in the 1930s

American airport plans of the 1930s such as New Orleans-Sushan, New York-La Guardia and Washington - National illustrate many of the planning innovations of the period (figure 7.19). They introduced multidirectional runways, often with separate parallel landing and take-off capability and progressively increasing runway length to suit the introduction of larger, heavier and faster aircraft. As a result airfields progressively became significantly larger. Terminals now began to project into the airfield instead of being restricted to the perimeter.

These three airports were also all built on reclaimed land, New Orleans, Sushan projecting into fresh-water Lake Pontchartrain, New York La Guardia projecting into East Rivers Bowery and Flushing Bays and Washington National on the west bank of the Potomac River.







New Orleans - Sushan 1934
Runways – 4 asphalt
3,700ft, 3,500ft, 3,200ft, 3,100ft 4,200ft
Site Area 301 acres

New York - La Guardia 1939
Runways - 4 asphalt
6,000ft, 5,000ft, 4,500ft, 3,525ft
Site Area 558 acres

Washington DC – National 1940
Runways – 4 asphalt
6,875ft, 5,300ft, 4,820ft,
Site Area 750 acres

Figure 7.19 - Source: Airports, Some Elements of Design and Future Development 1940, John Walter Wood

7.5 Comparison between American and European Airports in 1940

Overleaf is the summary of European and American Airport Master Plans as they appeared in John Walter Wood's seminal 1940 book – Airports, Some Elements of Design and Future Development (figure 7.20 & 7.21). It was a comprehensive survey of the most advanced airports of the period in Europe and North and South America. It reveals that while the great majority of American Airports incorporated hard surfaced runways by the end of the 1930s, most European airports retained omni-directional grass fields and those few that boasted hard surfaced runways did so only because the ground conditions were considered very unsatisfactory.

7.5.1 Comparison of American Airports 1940

The following airports' layouts have all been drawn to the same scale and were featured in John Walter Wood's 1940 book. It is notable that the vast majority of American airports had hard surfaced runways orientated to suit the main anticipated wind directions. A number followed a new trend, with terminals that projected into the airfield in the gap between runways, as seen at New Orleans, Sushan (12), New York, La Guardia (14) and Washington, National (19).

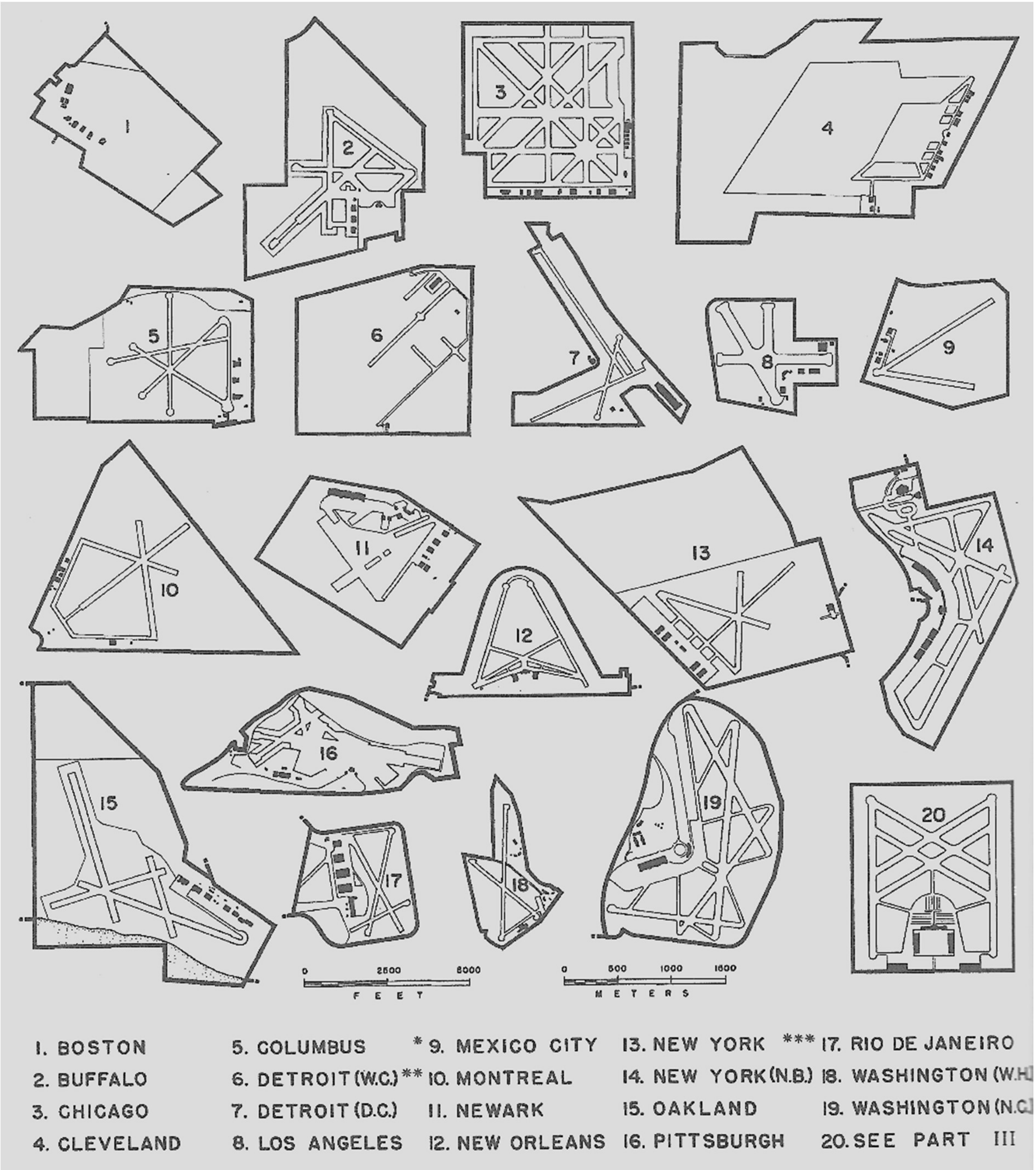


Figure 7.20 - Comparative American Airport Master Plans 1940 –
Source: Airports, Some Elements of Design and Future Development

7.5.2 Comparison of European Airports 1940

Like the preceding examples these layouts have all been drawn to the same scale and allow direct comparison with their American counterparts. The majority still maintain the all- direction grass field in preference to hard surfaced runways but these were about to become obsolete due to the ever increasing weight and performance of the newly introduced aircraft.

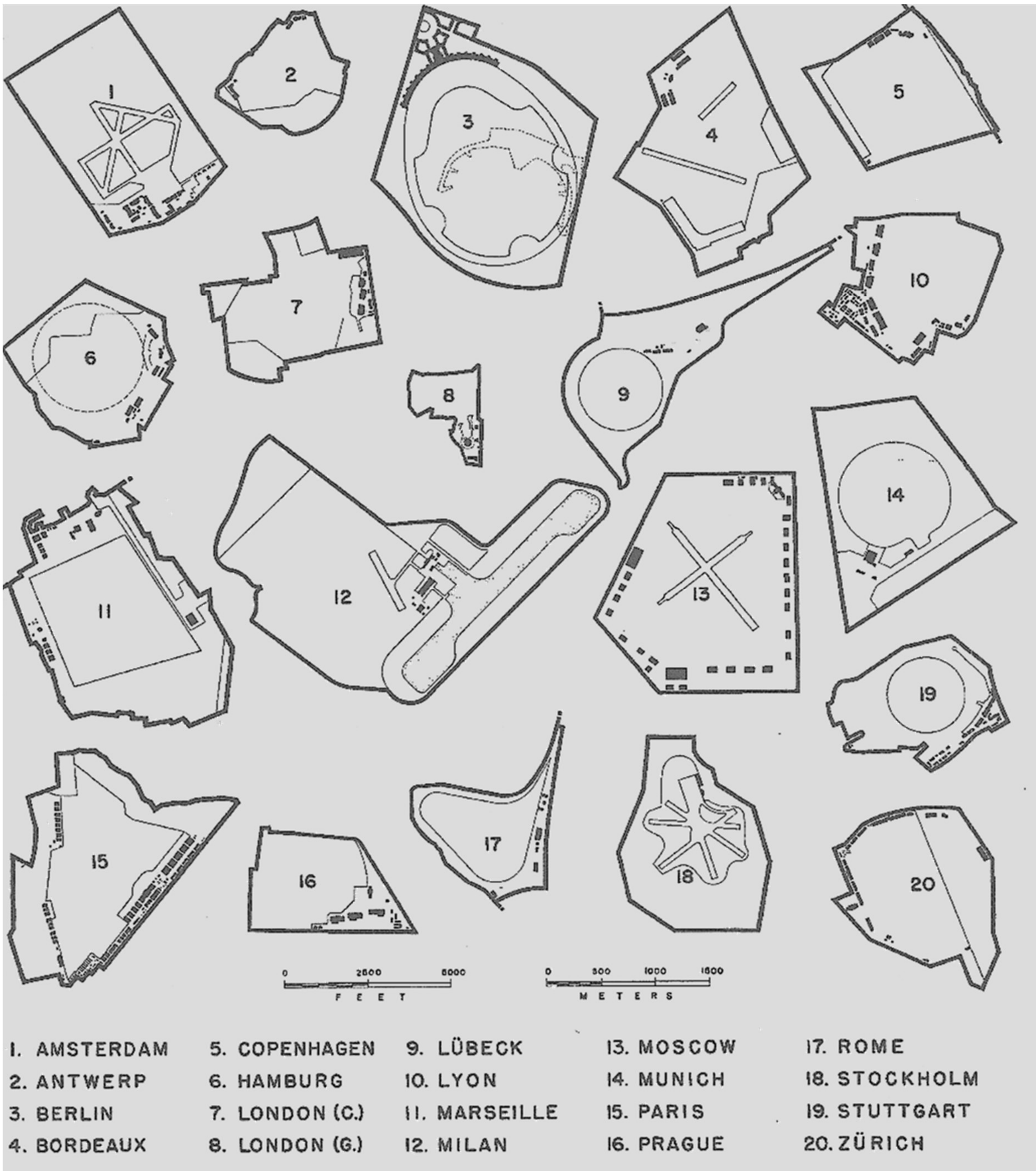


Figure 7.21 - Comparative European Airport Master Plans 1940 –
Source: Airports, Some Elements of design and Future Development

7.6 Wartime Airport Master Plans

During the Second World War a number of airport master plans were developed to be ready for peacetime and construction could start again. From this point onwards all new major airports incorporated hard surfaced runways, either concrete or asphalt to respond to the increasing weight and performance of aircraft.

Some featured an innovation, terminal zones at the centre of the airport rather than on the periphery, and surrounded by multi-directional runways. This idea later became commonplace for the largest international airports. This was the first time central terminal zones appeared on master plans of actual airports, although an earlier similar concept had been proposed in the entry to the Lehigh Airport Competition from H.L. Gogerty, which was relegated to an honourable mention on safety grounds as at that time safe operation was deemed incompatible with building in the centre of the airfield (Black, 1930).

Other master plans focused on integrating landplanes (short haul) and seaplanes (long haul), concepts. These became obsolete soon after the war as the range of land based aircraft could travel without refuelling expanded and seaplanes were progressively retired. A stillborn example of this approach can be seen in the Miles Aircraft Company proposals for a combined land and sea plane airport to serve London on the Isle of Grain in the Thames Estuary (figure 7.22), the site that was later reconsidered by the Mayor of London for a new Hub Airport for London in 2014. This was largely because it was one of the largest pieces of underdeveloped land to the east of London and would support regeneration of East London. The location was easily accessible for flights to the continent but still allowed routes to the USA to by-pass London and so minimising noise impact.

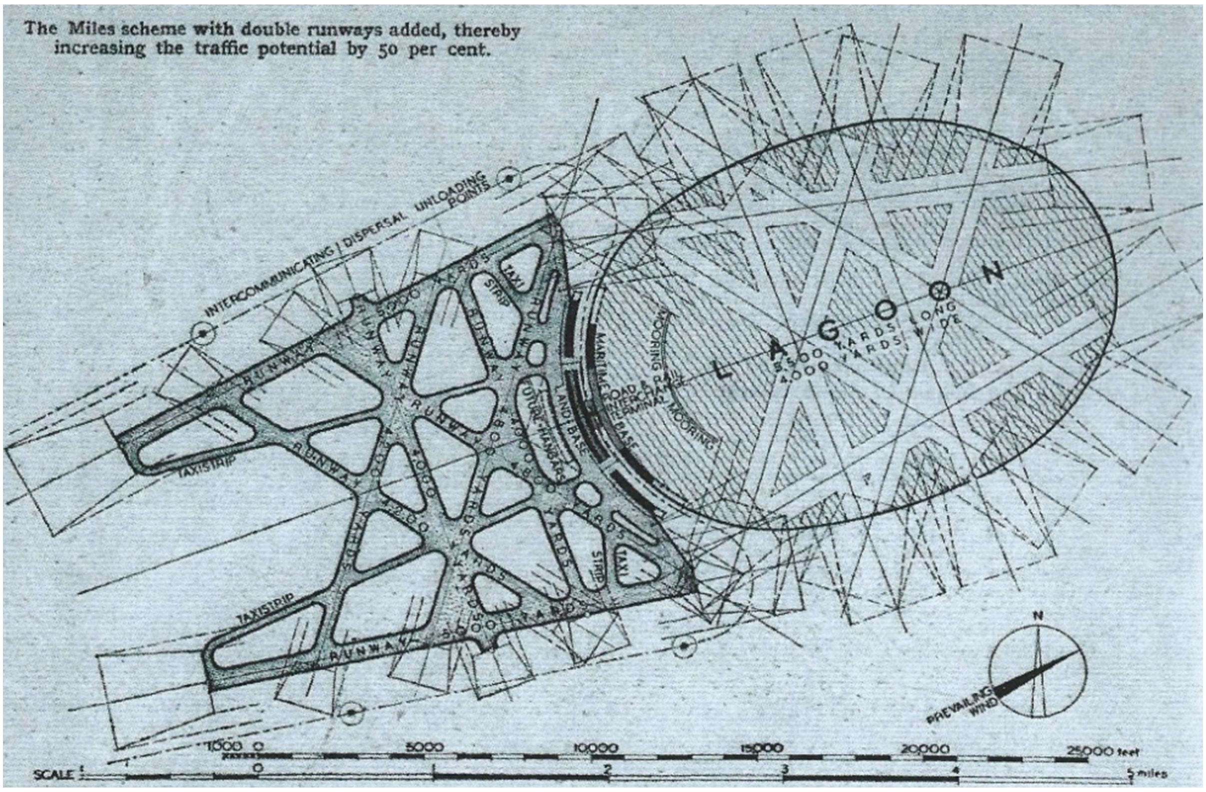


Figure 7.22 - London, Isle of Grain, 1943 Source: Flight

Meanwhile a proposal for a new airport at Heathrow was being developed under cover of the official secrets act, theoretically for long range bomber aircraft, but in practice to become London's Post War International airport to replace Croydon (figure 7.23).

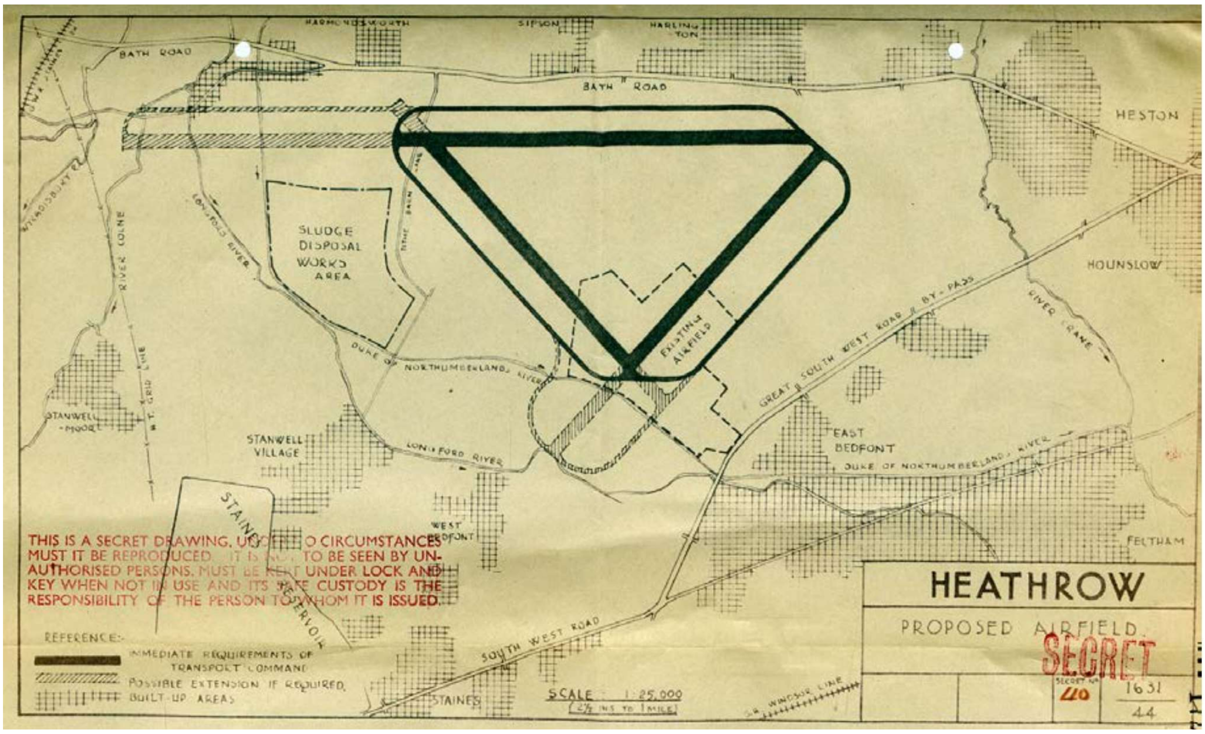


Figure 7.23 - London Heathrow Wartime Master Plan 1944 –
Source: House of Commons Briefing Paper 1136, 12th June 2017

By 1946 this had evolved into the Star of David layout doubling up the number of runways, and adding a further three runways to the north that were not developed at the time (figure 7.24 bottom right).

Master plans of the 1940s included New York Idlewild (JFK), Chicago O'Hare as well as London Heathrow using tangential runway forms analogous to a Catherine Wheel or in the case of Heathrow the 'Star of David'. The official story of Heathrow in 1955 recorded that 'The 1946 London Airport Layout Panel considered very seriously a tangential pattern of runways fanning out from the Central Area, but the runway plan decided upon concentrated on what was then described as a "parallel pattern" which was considered better suited operationally and to the topography of the site.' (Chandos, 1956) (figure 7.24).

Each of these airports also featured central terminal zones, typically reached by leaving a gap in the tangential runway system but London's Heathrow incorporated an underground road link to reach the central terminal zone.

This period also featured the first proposal for a new airport at London Gatwick, by Norman and Dawbarn, located on the existing Gatwick racecourse, where the Grand National had been held during the First World War. It featured a new integral purpose designed railway station on the mainline from London to Brighton (figure 7.25).

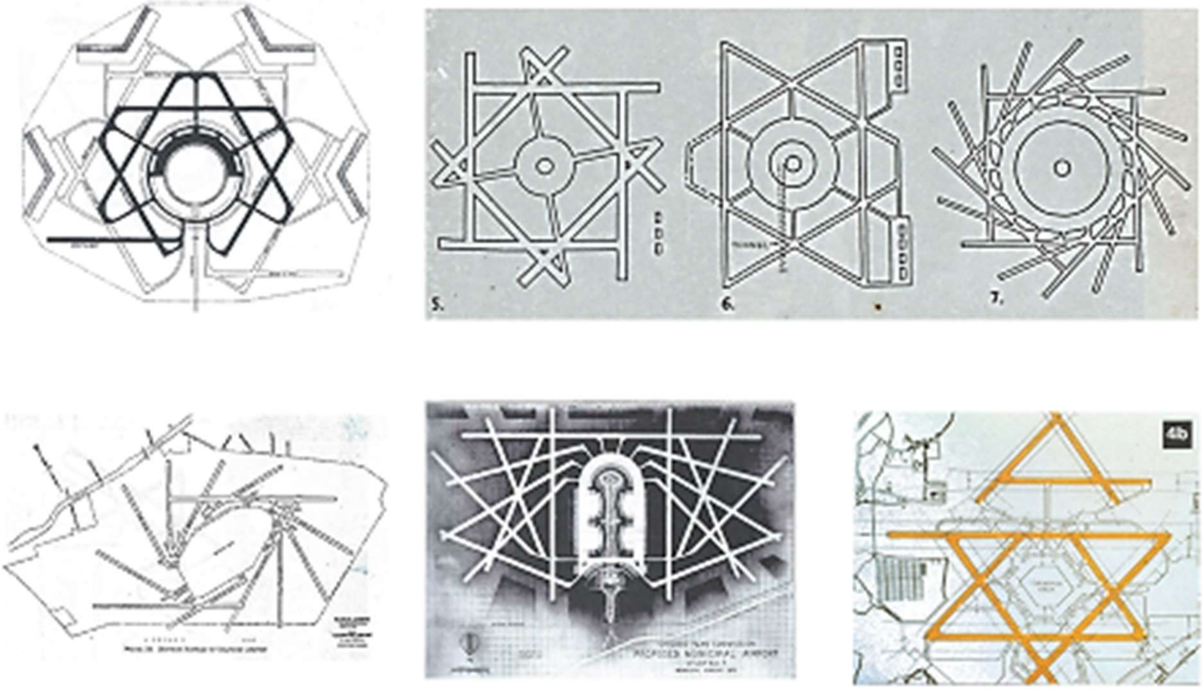


Figure 7.24 - Post WW2 Airport Master Plans –
Sources: Airport Planning, Charles Froesch & Walter Prokosch, 1946 British Airways (LHR)

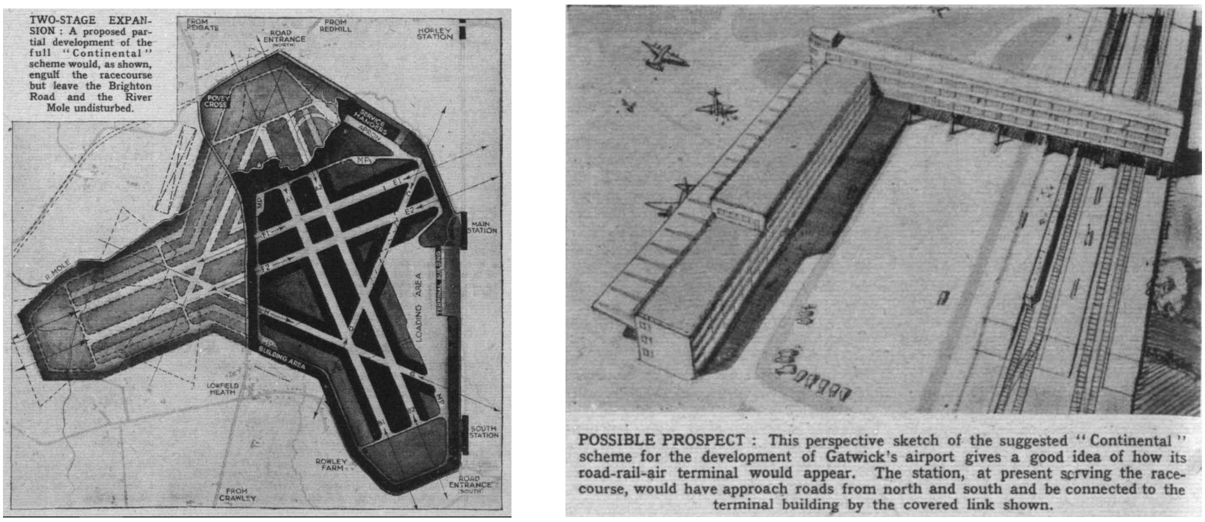


Figure 7.25 - Gatwick, Continental 1943 Master Plan, Norman and Dawbarn –
Source: Flight 25th November 1943, p 578 - 580

7.7 Airport Master Plans – 1954-56

Airport master plans of the 1950s followed the principles set down in the war time precedents but with some simplifications in runway layout as aircraft performance in cross winds improved (figure 7.26). For example, the New York Idlewild (JFK) plan was progressively simplified and the number of runways reduced as the 1950s advanced. The San Francisco plan of 1954 and Orly plan of 1955 only showed runways orientated in two directions, and single runway layouts were developed for London Gatwick (1958) and the expansion of San Diego Airport which was originally opened in 1928 as the Lindberg Field. They are respectively now the busiest single runway airports in the UK and the USA.

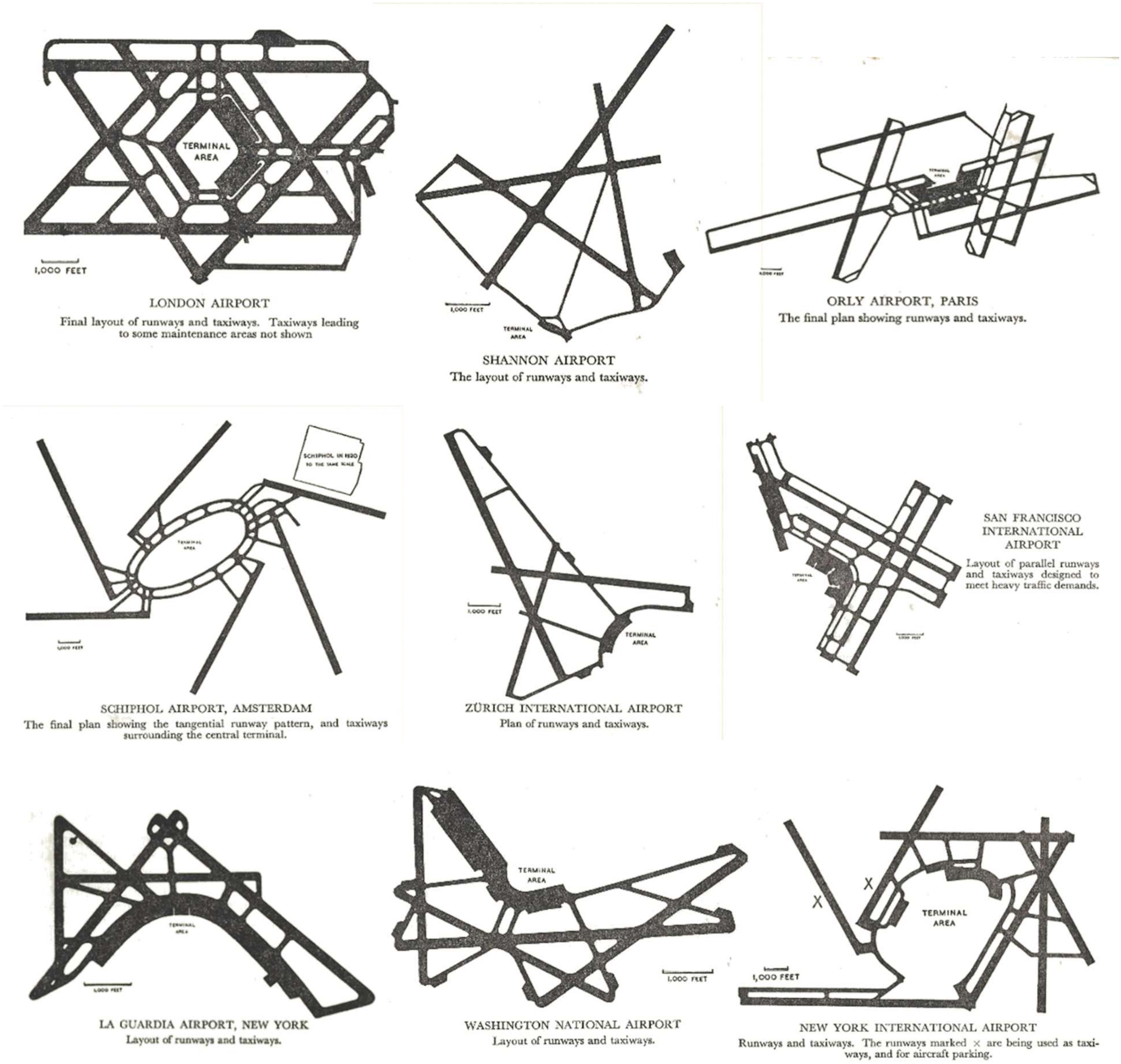


Figure 7.26 - Airport Master Plans 1954 – 56 – Source: Famous Airports of the World, John Stroud

Runway capability in terms of length and load bearing capacity improved radically in the post war period to respond to the introduction of larger, heavier and faster aircraft (Appendix C). The table below shows the runway lengths that were available at some of the major airports in the early 1950s. Runways were typically more than twice as long as those of the immediate pre-war period (figure 7.27).

Airport	Runway 1	Runway 2	Runway 3	Runway 4	Runway 5	Runway 6
London Heathrow	9,581 ft	9,316 ft	7,570 ft	7,735 ft	6,261 ft	5,823 ft
Shannon	NA	NA	NA	NA	-	-
Paris Orly	7,800 ft	6,100 ft	9,800 ft	9,800 ft	9,800 ft	8,000 ft
Amsterdam Schiphol	8,500 ft	7,050 ft	5,900 ft	5,750 ft	future	future
Zurich	8,520 ft	6,230 ft	5,100 ft	-	-	-
San Francisco	8,870 ft	7,750 ft	7,000 ft	6,500 ft	-	-
New York La Guardia	6,000 ft	5,000 ft	4,500 ft	-	-	-
Washington National	6,825 ft	NA	NA	NA	-	-
New York Idlewild	9,500 ft	8,200 ft	8,000 ft	8,000 ft	6,000 ft	-

Figure 7.27 -Airport Runway Lengths in descending order, 1954-56,
Source: Famous Airports of the World, John Stroud

7.8 Airport Masterplans 1973

Airport masterplans of the 1970s showed further simplification of the runway layouts as aircraft performance in cross wind conditions improved (figure 7.28).

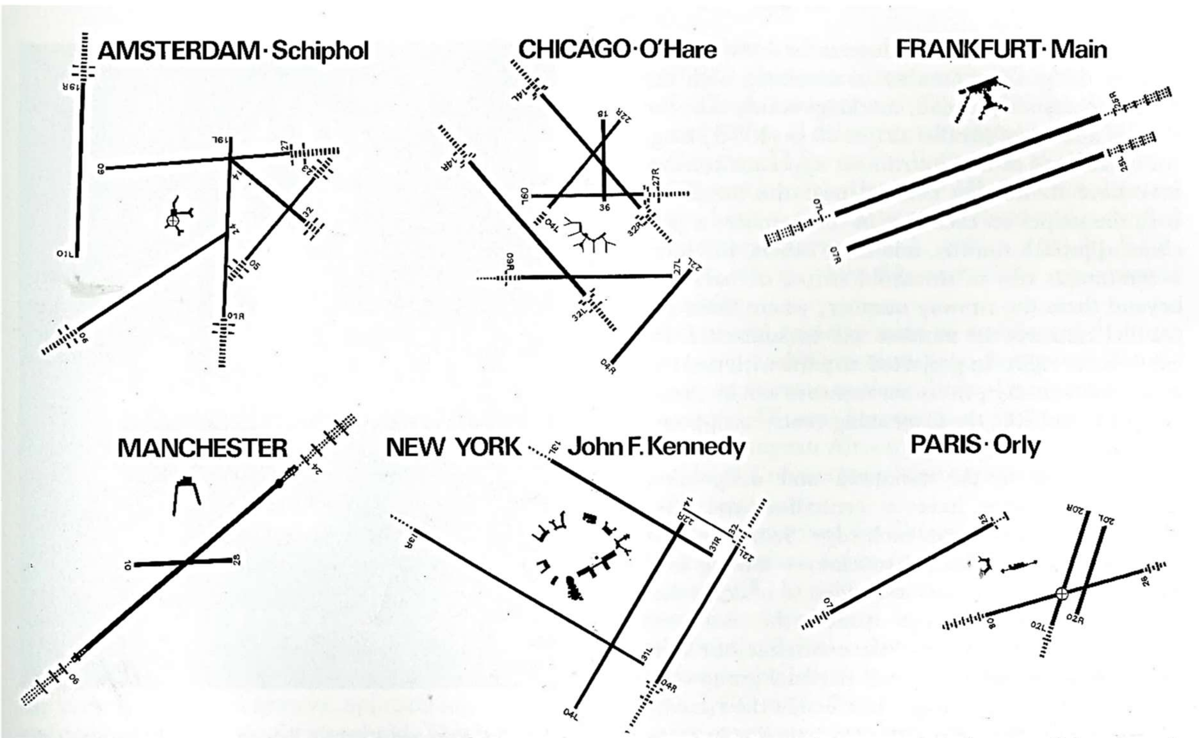
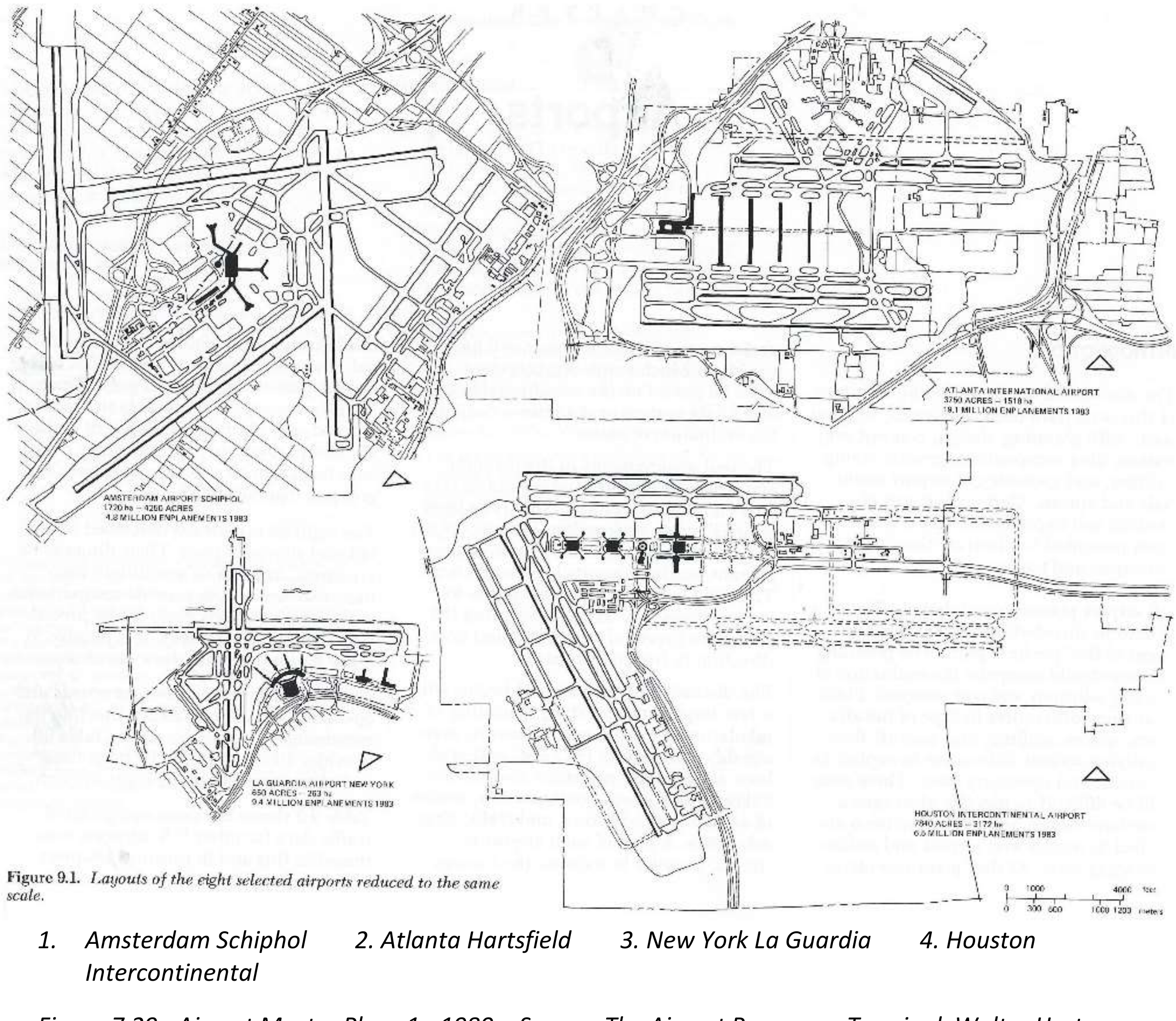


Figure 7.28 - Airport Master Plans 1973 – Source: The World's Airports, John Stroud

7.9 Airport Master Plans 1980

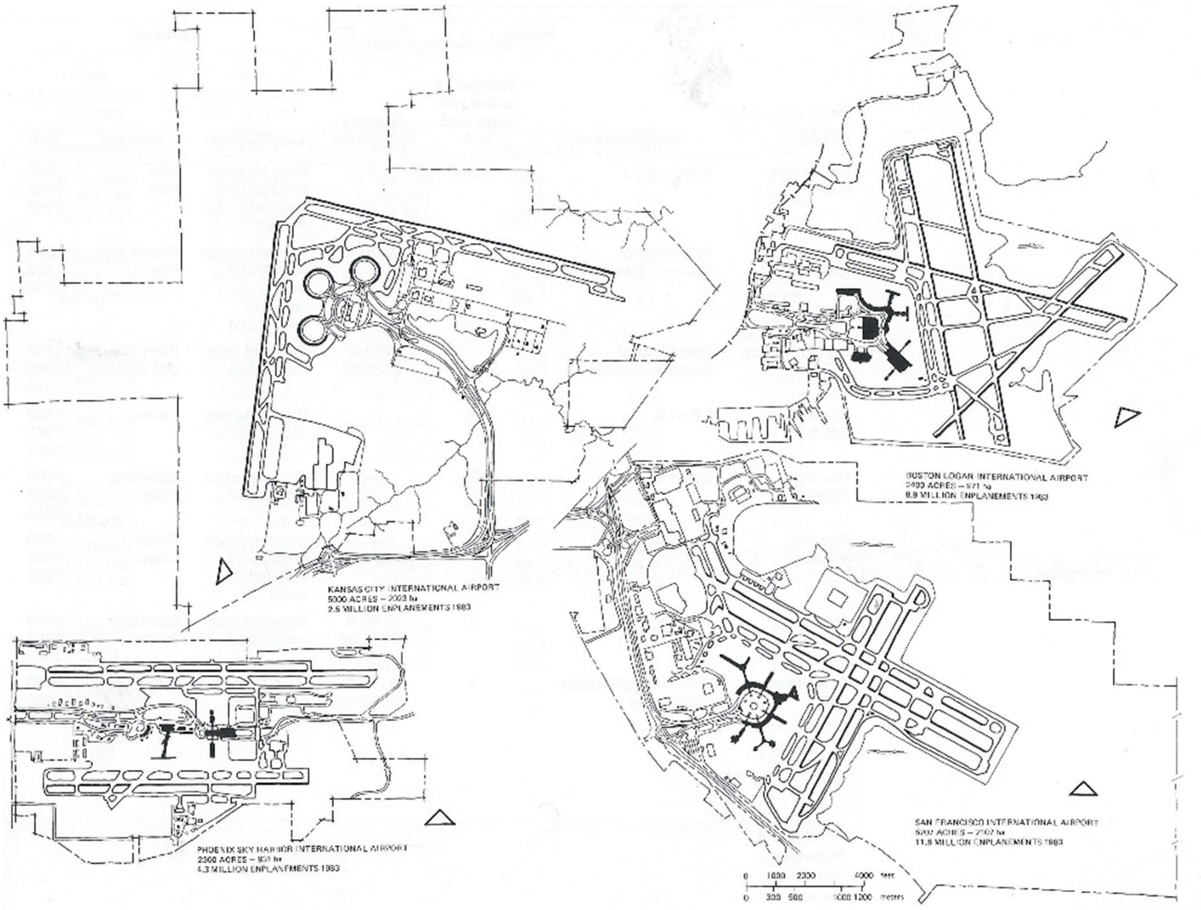
The selection of airports in the 1980 book The Airport Terminal by Walter Hart, some of which are illustrated below, included some unusual choices. Only Amsterdam Schiphol represented European airport design, but even that was based on the earlier Chicago O'Hare master plan. The book does however reflect that in the 50s, 60s and 70s as the innovations in airport master planning and construction of new airports were largely to be found in the USA as they built new airports and adapted existing airports to cope with the enormous increase in the volume of air travel, with larger airfields and the new concept of the transfer hub airport (figures 7.29 & 7.30).

Innovations to the airfield in the USA included the introduction of rapid exit taxiways to increase runway capacity, by reducing runway occupation time and delays. This was based on research and subsequent mathematical modelling to identify the ideal location of taxiway exits (Horonjeff, 1958). Early implementation rapid exit taxiways can be seen at New York JFK in 1959 coinciding with the widespread introduction of jet aircraft. Another innovation was the adoption of full length dual parallel taxiways, to allow efficient ground movement of aircraft and permit resequencing of departing aircraft, which can be seen in masterplans from the late 60s. Short Take Off and Landing Runways (STOL) also figured in masterplans of the 1960s & 1970s but have subsequently fallen out of favour.



1. Amsterdam Schiphol 2. Atlanta Hartsfield 3. New York La Guardia 4. Houston Intercontinental

Figure 7.29 - Airport Master Plans 1 - 1980 – Source: The Airport Passenger Terminal, Walter Hart



5. Kansas City 6. Boston Logan 7. Phoenix Sky Harbour 8. San Francisco

7.30 - Airport Master Plans 2 - 1980 – Source: The Airport Passenger Terminal, Walter Hart

However the book ignored an important new masterplan concept – a layout with a series of terminals organised around a landside spine to access a central zone set between parallel runways. This was first seen at Dallas Fort Worth (figures 7.31 & 7.32), and adopted for the stillborn 3rd London Airport at Maplin Sands (figure 7.33) and Paris Charles de Gaulle (figures 7.34 & 7.35) and still influences airport design today, particularly concepts from Airports de Paris (ADPI) as can be seen in the more recent design of Shanghai Pudong Airport and second phase of Kansai Airport. Its major limitation is it puts a landside area between the runways so the access road has to be lowered to allow taxiing aircraft to pass over the top.

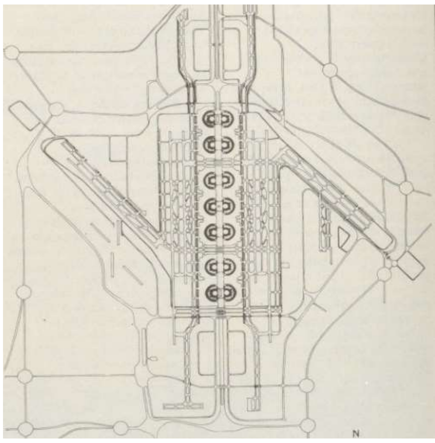


Figure 7.31 - Dallas - Fort Worth 1973 Master Plan Source: Architectural Design

Figure 7.32 - Dallas - Fort Worth Aerial View in 2007 Source: USDA Farm Service Agency

Figure 7.33 London, Maplin Artists Impression of proposals for a 3rd London Airport – c1972
Source: airporthistory.org

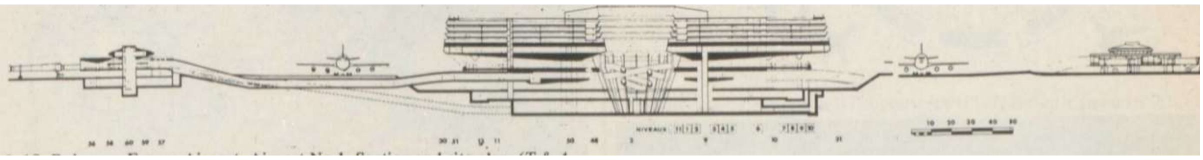


Figure 7.34 - Paris Charles de Gaulle, Section 1974, Source: Architectural Design

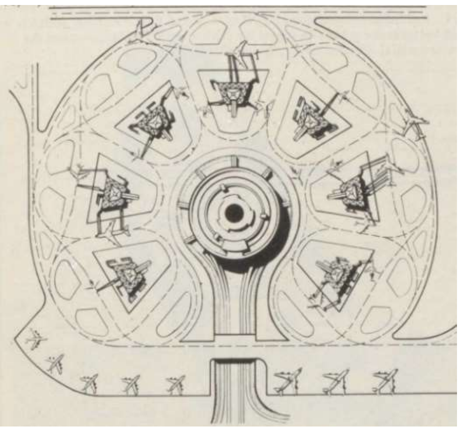



Figure 7.35 - Paris Charles de Gaulle, 1974, Source: Architectural Design & Google Earth

The table (figure 7.36) below shows that ever longer runways were being designed at these new airports in 1980 while runways at existing airports were being extended to cope with new heavier and faster jet aircraft such as the Boeing 747 and Concorde. Most major airports had runways of over 10,000ft, excepting La Guardia which was now restricted to handling smaller domestic flights as the site was too small for such an increase in runway length. The table also shows the transient popularity of short take-off and landing runways (STOL) for domestic feeder services.

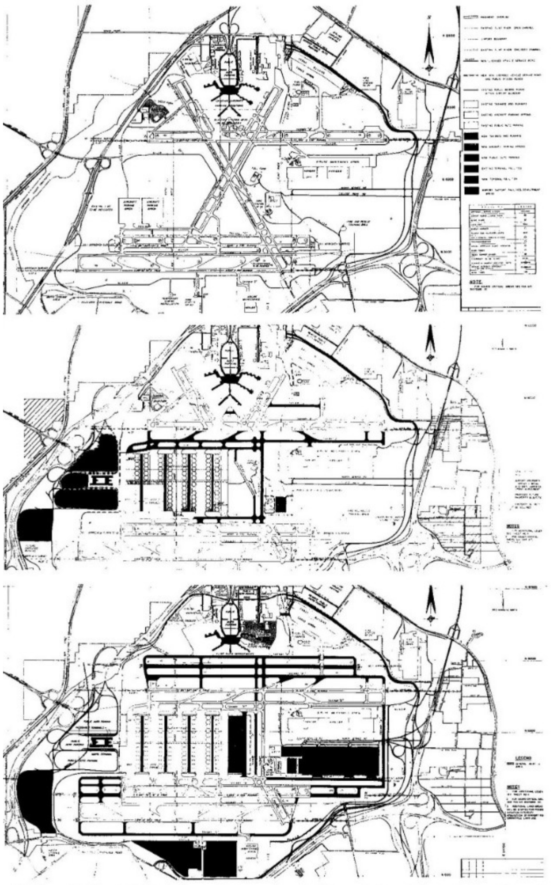
Airport	Runway 1	Runway 2	Runway 3	Runway 4	Runway 5	Runway 6
Amsterdam Schiphol	11,330ft	11,155ft	10,827ft	10,663ft	-	-
Atlanta Hartsfield	10,000ft	9,000ft	8,000ft	future	-	-
New York La Guardia	7,000ft	7,000ft	2,000ft*	-	-	-
Houston Intercontinental	12,000ft	9,400ft	2,000ft*	2,000ft*	-	-
Kansas City	10,800ft	9,500ft	-	-	-	-
Boston Logan	10,081ft	10,000ft	7,000ft	2,468ft	-	-
Phoenix Sky Harbor	10,300ft	8,753ft	-	-	-	-
San Francisco	11,870ft	10,600ft	9,500ft	7,000ft	-	-
Dallas Fort Worth	11,388ft	11,388ft	9,000ft	future	future	future
London Heathrow	12,802ft	12,000ft	7,734ft	-	-	-
New York JFK	14,572ft	11,352ft	10,000ft	8,400ft	2,560ft*	-
Paris Charles de Gaulle	11,811ft	9,400ft	future	future	-	-

Figure 7.36 - Airport Runway Lengths in descending order, 1980, Source: Airports of the World, John Stroud
**Short Take-off and Landing (STOL) runway*

The 1980s is the high point in designing ever longer runways as after this date new aircraft designs have improved take-off performance reducing the required runway length. While there are a few airports with longer runways they are in special hot and high locations, such as Denver, Colorado where the air is thinner, adversely affecting the lift characteristics of aircraft. For example, Heathrow is currently proposing to reduce the length of its longest runway currently 12,802ft or 3,902 metres to 3,500 metres as a part of its 3 runway master plan.

While runways were being progressively lengthened their declared capacity was conversely being reduced as airport planners became more realistic in their expectations. In 1946 it was claimed that a 6 runway airport could deliver 360 movements an hour or 60 an hour per runway. By 1980 the estimate of 4 runway capacity at Charles de Gaulle was 150 movements an hour or 37.5 an hour per runway, while currently their runways are rated at a maximum of 120 movements an hour or 30 movements per hour for each runway.

Some of this is as a result of better understanding of how wake vortex of a leading aircraft adversely affects the performance of a following aircraft. This is combined with the introduction of a new generation of larger and heavier aircraft, such as the Airbus A 380 and Boeing 748, which require more distance between them and a following smaller aircraft during flight to maintain a safe separation. The consequence is that runways are the ultimate constraint on airport capacity, hence the current trend to add runways in new master plans.



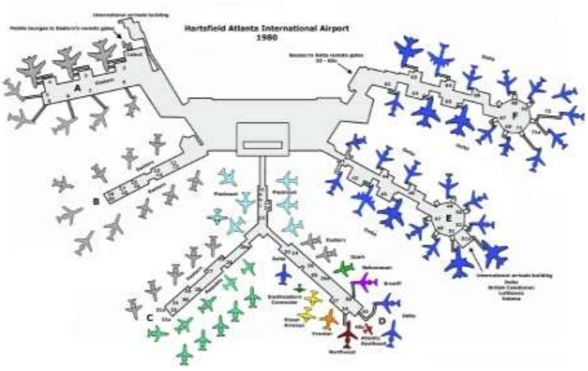


Figure 7.38 – Atlanta Hartsfield terminal layout, 1970s
Source: Sunshine Skies

Figure 7.37 Atlanta Hartsfield Master Plan Evolution
Source: Airports of the World, John Stroud 1980

Figure 7.39 Atlanta Hartsfield aerial view
Source: Google Earth c2010

Atlanta Hartsfield might be regarded as the original prototype hub airport with a number of aircraft landing close together at around midnight as early as 1939. The airport was progressively rebuilt after WW2 using a pier concept similar to Chicago O'Hare (figure 7.37, 7.38 & 7.39). A major change occurred when Delta Airways introduced the 'Hub and Spoke' concept in 1955, with aircraft converging simultaneously on the Atlanta Hub from a variety of regional airports, increasing the volume of traffic handled in a short period of time to new highs and requiring a new higher capacity masterplan.

The primary driver to the new layout was the efficient use of scarce runway capacity. The existing layout (top left) necessitated aircraft crossing the main East-West runway closest to the terminal to reach the further parallel runway raising safety concerns and greatly reducing runway capacity as gaps had to be left in the schedule to accommodate runway crossings.

The Atlanta master plan layout, of a mid-field terminal supported by a 'toast-rack' arrangement of parallel satellites, directly influenced the later concept at Denver and the ongoing updating of Heathrow and Washington, Dulles. The layout has been demonstrated to be both the most space effective master plan and the most efficient in aircraft circulation pattern for a large hub airport.

The same issue of capacity limitations caused by aircraft crossing runways re-emerged at Atlanta in the twenty first century as arriving aircraft on the outer runway had to cross the inner departing runway interrupting the flow of departures thus reducing ultimate capacity.

This was addressed by introducing the concept of taxiing around the end of the runway in 2008, based on a precedent at Frankfurt Airport. While the concept increased taxiing time it eliminated the time wasted waiting for a gap in the departures schedule and is regarded as inherently safer. The taxiway dips 30 feet (9.1 m) below the level of the adjacent runway before emerging at the gate area. The dip in the taxiway allows planes to keep taking off from the runway without any interruptions (figure 7.40).

FAA studies have predicted a 30 percent improvement in overall runway efficiency because of the new end-around taxiways. Airlines are hoping to save an estimated $26 to $30 million per year, because their airplanes would not be sitting on the runway as long waiting to take off or waiting to taxi. It also means less delays for travellers and a safer travelling experience. Taxiways around the end of runways eliminate the need for aircraft to cross active runways (GOMACO, 2008). This concept has subsequently been adopted by a number of airports, including Dallas Fort-Worth (figure 7.41), Hong Kong, Singapore, Heathrow, and the proposed new Dubai World Central.

Figure 7.40 -.Atlanta Hartsfield, End-Around Taxiway Source: GOMACO World 36.1 - January 2008 www.gomaco.com

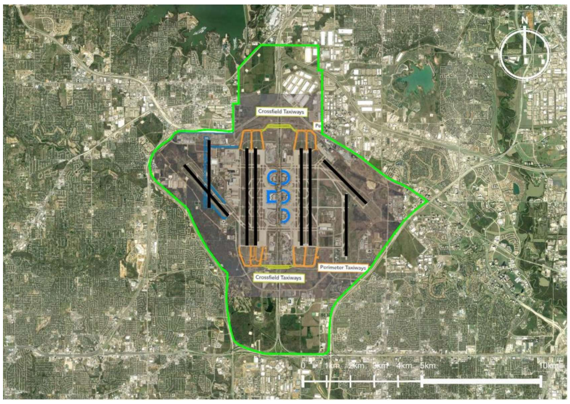


Figure 7.41 - Dallas Fort Worth, End–Around Taxiways (in orange) - Source: DFW Vision for the Future 2030 www.dfwairport.co

A more recent evolution of the mid-field terminal concept, can be seen at Hong Kong Chek Lap Kok Airport where the terminal and Y shaped pier is set centrally between two parallel runways. Opened in 1998, the master plan was used by IATA as an exemplar of a major airport layout. It was in 2004 envisaged to be capable of expansion to up to 100 million passengers a year.

In practice operational issues, and a conservative Civil Aviation Authority, have limited the runway capacity to lower levels than had originally been predicted lowering the annual runway movements for the three runway masterplan to 620,000 movements per annum and an estimated future throughput to around 120 million passengers a year despite having the largest average passenger numbers per aircraft of any airport in the world.

The original masterplan incorporated a Y shaped terminal which allowed more aircraft to be parked around a single building than was possible with the Atlanta toast rack layout. It was complemented by large mid field satellite. This had the advantage of simplifying any passenger movement and associated transit system, reducing the number of transfer security positions and increasing the footfall of passengers through the retail offer, thus reducing operating costs and increasing revenue generation opportunities compared with the Atlanta concept (figure 7.42).

Although this masterplan concept is inherently less efficient in land use than the Atlanta toast rack concept the benefits to the business case, from simplified passenger circulation and improved footfall past the commercial offer, mean that this is a much imitated layout. Derivations of this master plan concept can be found at Doha, Abu Dhabi, Jeddah, Singapore Terminal 5, Seoul Terminal 2 and Norman Foster's new proposal for Mexico City Airport.

Typically 2 runway airports with central terminal zones are now being expanded by adding a third widely spaced runway and second terminal zone as can be seen in the following master plans for Hong Kong (figure 7.43), Singapore Figure 7.44), Kuala Lumpur (figure 7.45) and Heathrow (7.46 & 7.47)). A similar splitting of Terminal zones into two has been followed in the larger new airports: Istanbul Grand (150MPPA) (figure 7.48), New Airport for London sited on the Isle of Grain in the Thames Estuary (180MPPA) (figure 7.49), and Dubai World Central (220MPPA) (figure 7.50 & 7.51), each featuring end-around taxiways.

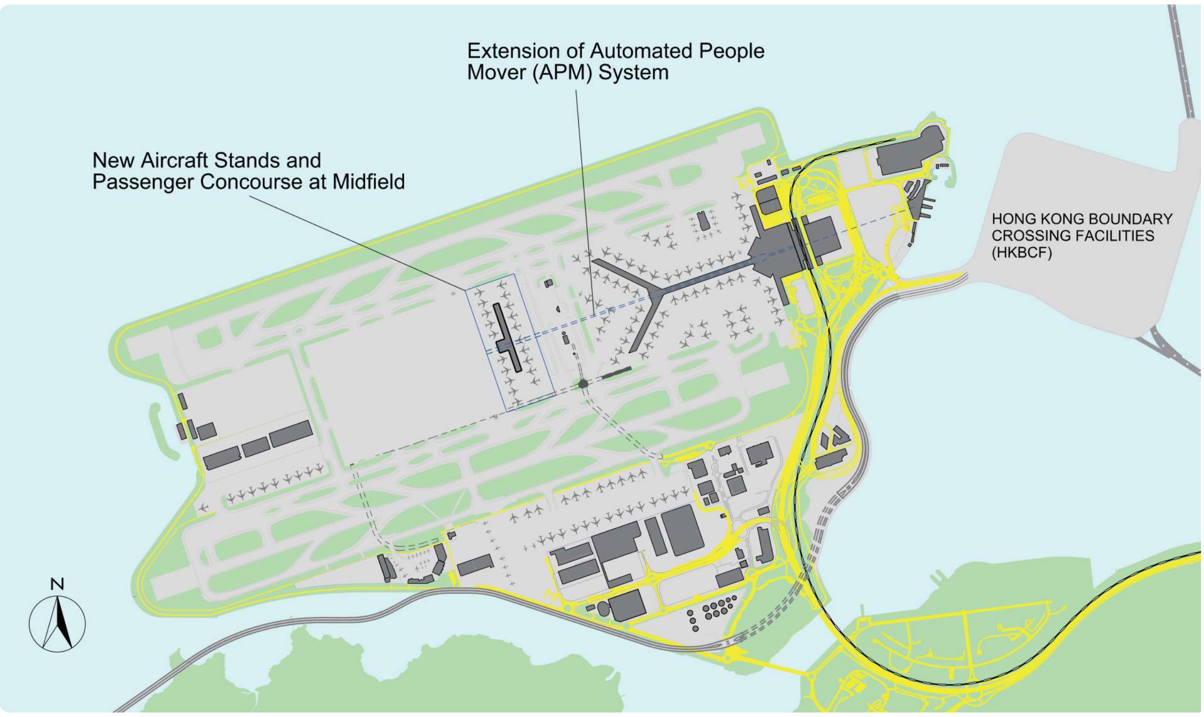


Figure 7.42 - Hong Kong International Airport, Two Runway Master Plan 2015 – Source: HKIA Master Plan 2030

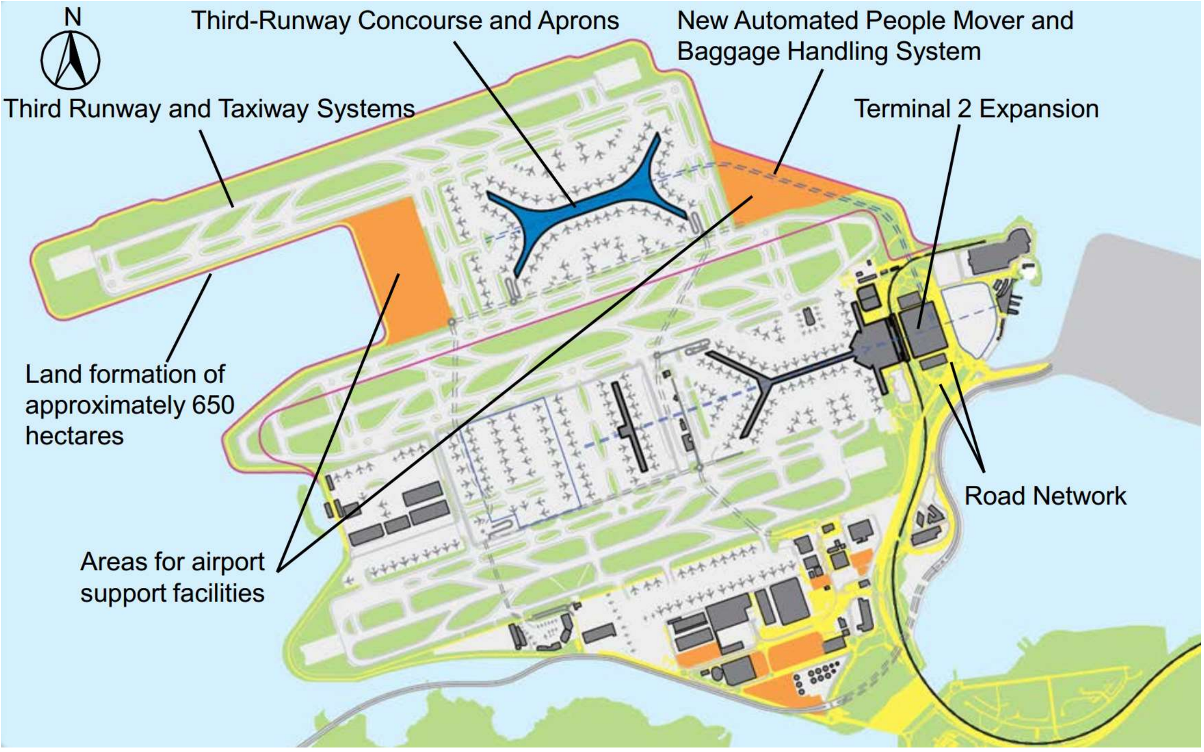


Figure 7.43 - Hong Kong International Airport, Three Runway Master Plan 2030 – Source: HKIA Information Pack 20.06.2014

Figure 7.44 - Singapore Changi Terminal 5 2036 Concept Plan – Source: Ministry of Transport, Singapore

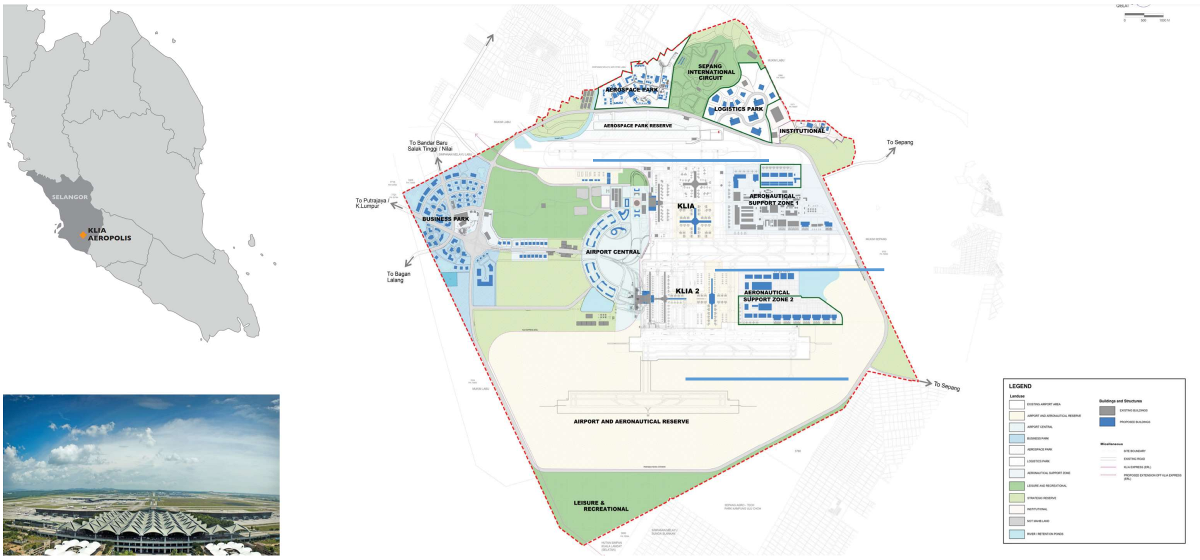


Figure 7.45 - Kuala Lumpur International 'Aeropolis' 2050 Masterplan – Source: klia.com.my

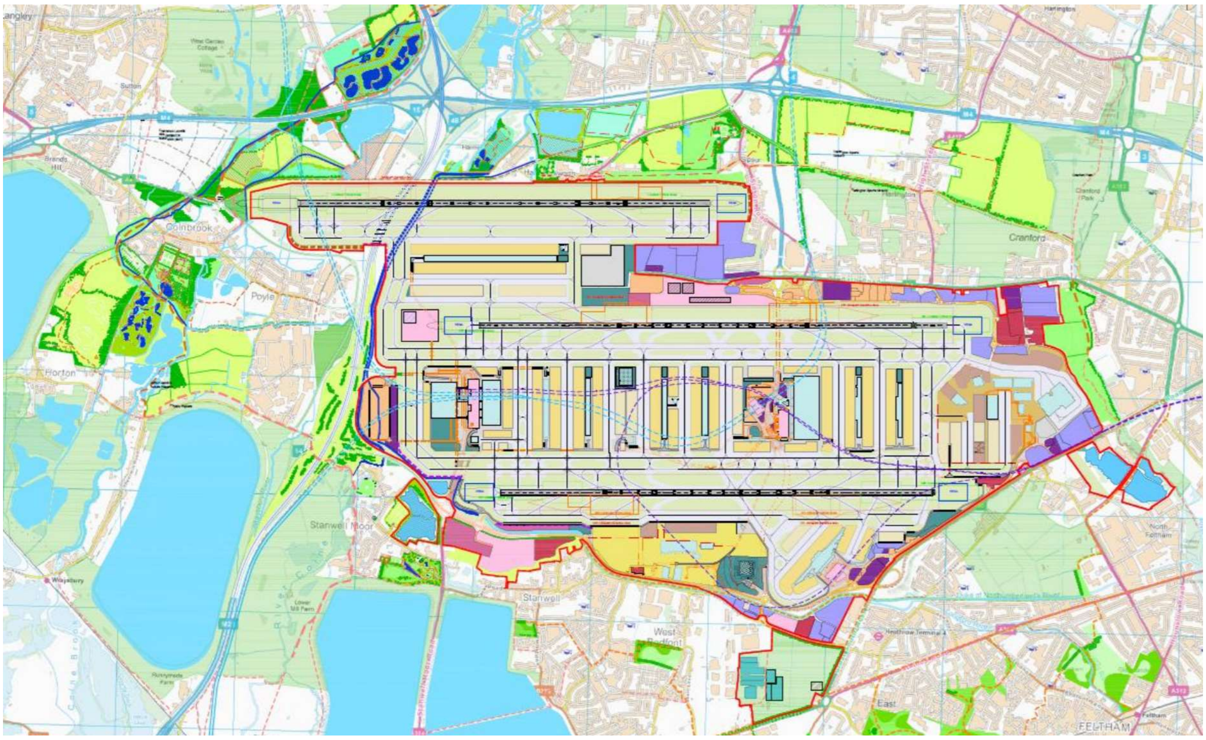


Figure 7.46 - Heathrow Expansion Programme – Source: LHR Planning Process & Environmental Assessment 07.03.2017

Figure 7.47 - Heathrow 3rd Runway Image c2040 – Source: Heathrow Airport Ltd

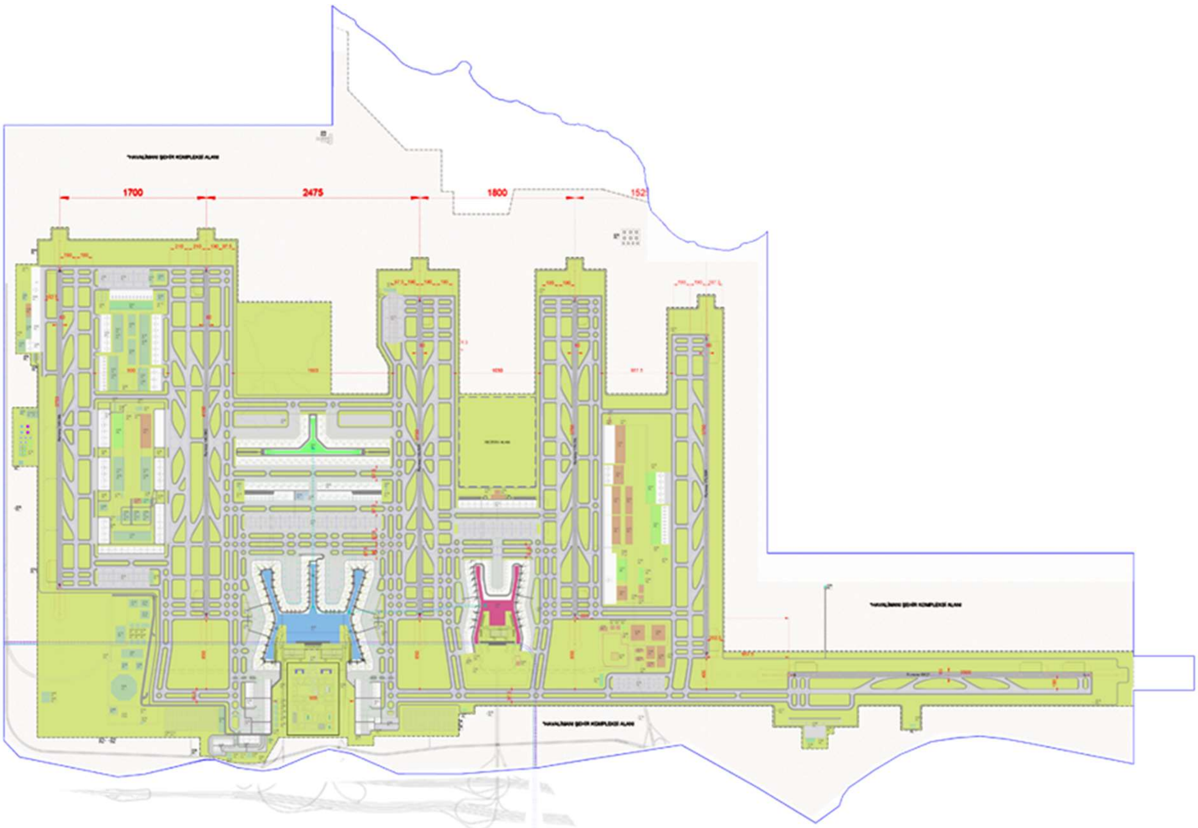


Figure 7.48 - Istanbul Grand Master Plan c2050 – Source: http://igairport.com

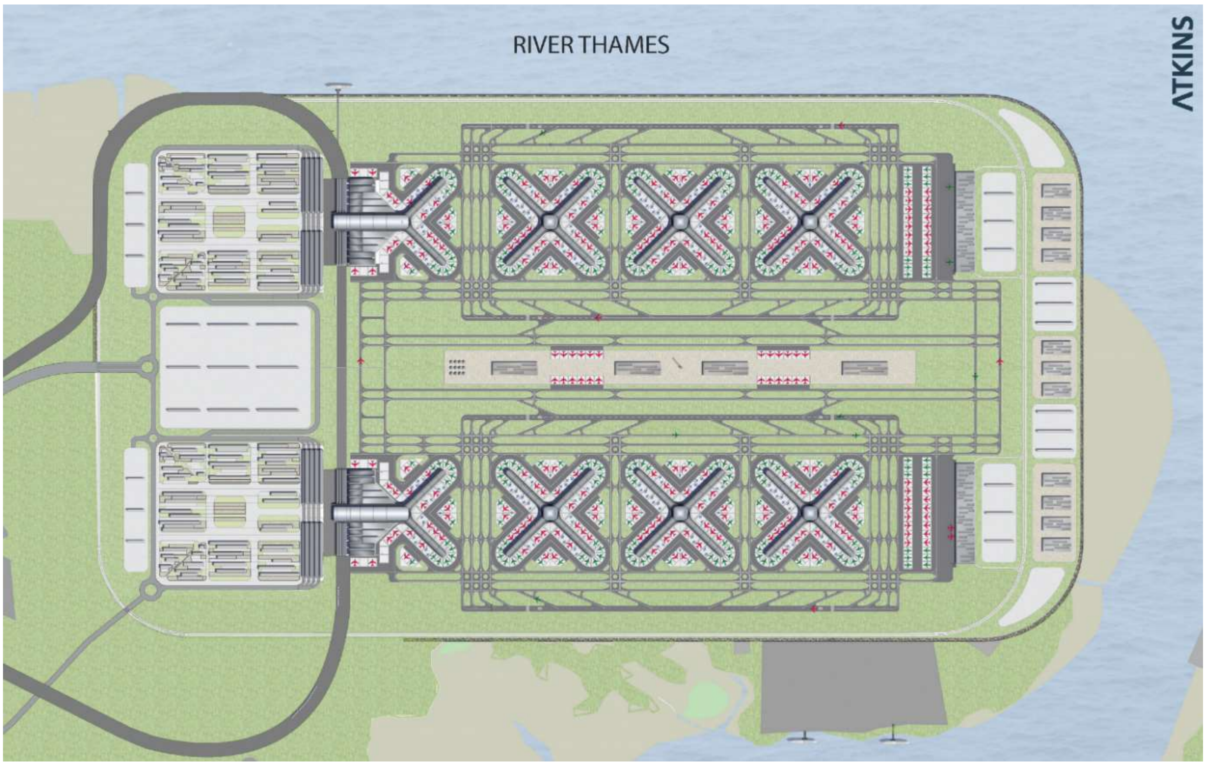


Figure 7.49 - New Airport for London, Isle of Grain c2050 – Source: Atkins


Figure 7.50 - Dubai World Central Model c2050 – Source Emirates Magazine

Figure 7.51 - Dubai World Central Master Plan c2050 – Source: Dubai Airport

7.11 Airport Master Plans 2016

Runway layouts of top 30 busiest airports in the United States and Europe are illustrated on the following pages (figures 7.52 & 7.53). This is followed by a world map (figure 7.54) showing the top 50 International Airports from which the master plans of the top twenty international airports worldwide in 2016, measured by volume of passengers handled, have been selected for illustration (figure 7.55). The international airports all have two or more runways, and the majority have mid-field terminals. The busiest Atlanta now handles over 100 million passengers per annum, a capacity also reached by Beijing Capital in 2019.

A benchmarking study undertaken in 2016 on the aircraft movement limitations of various runway configurations is included as appendix L.

7.12 Future Master Plans

Airports typically prepare master plans to respond to long range growth forecasts often for twenty to thirty years in the future. The following examples are for the largest planned airports. They all have mid field terminals, and all except London Gatwick have at least 3 runways (figure 7.56). The largest of these, Dubai World Central, is planned to handle over 200 million passengers.

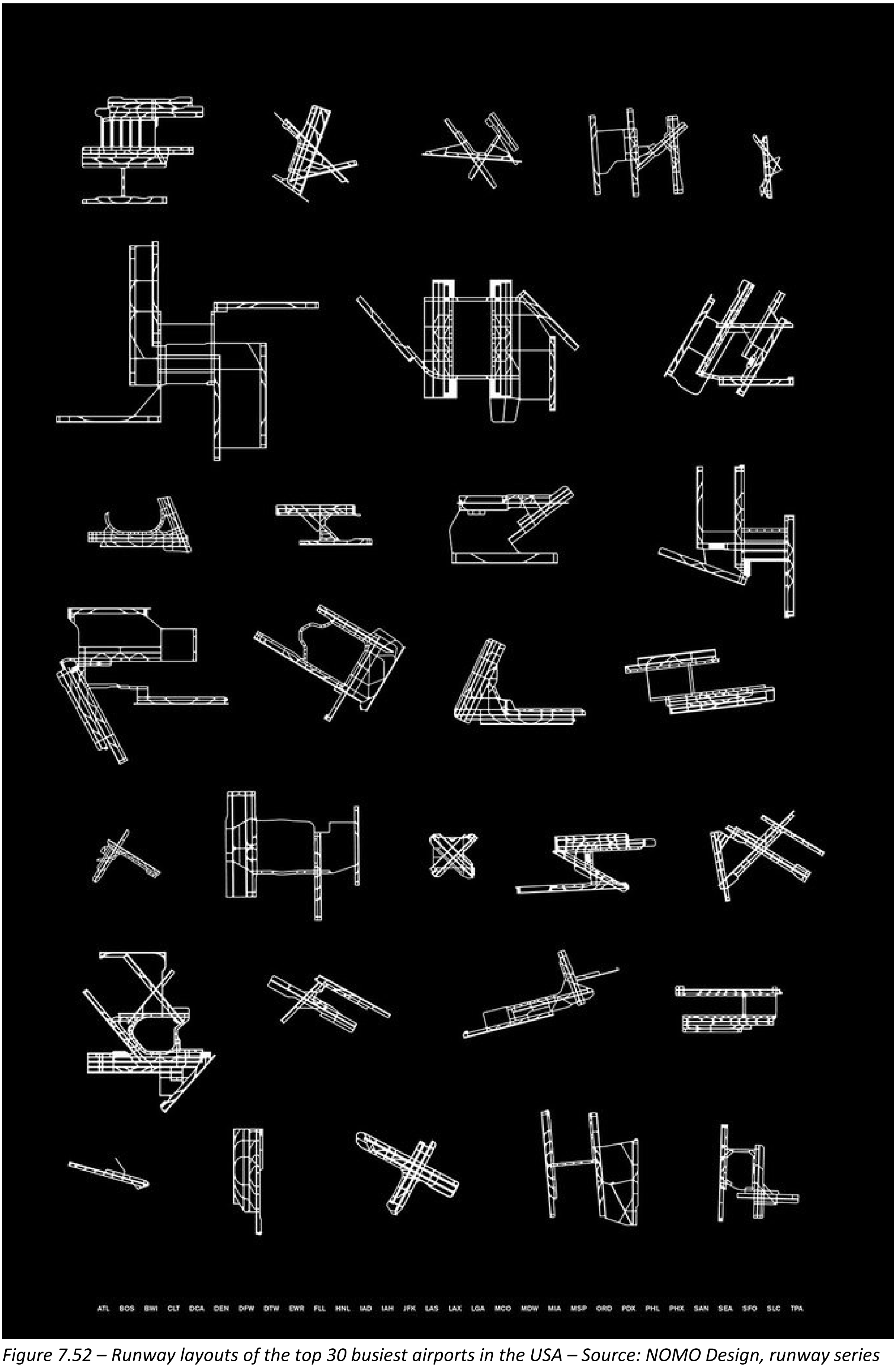


Figure 7.52 – Runway layouts of the top 30 busiest airports in the USA – Source: NOMO Design, runway series

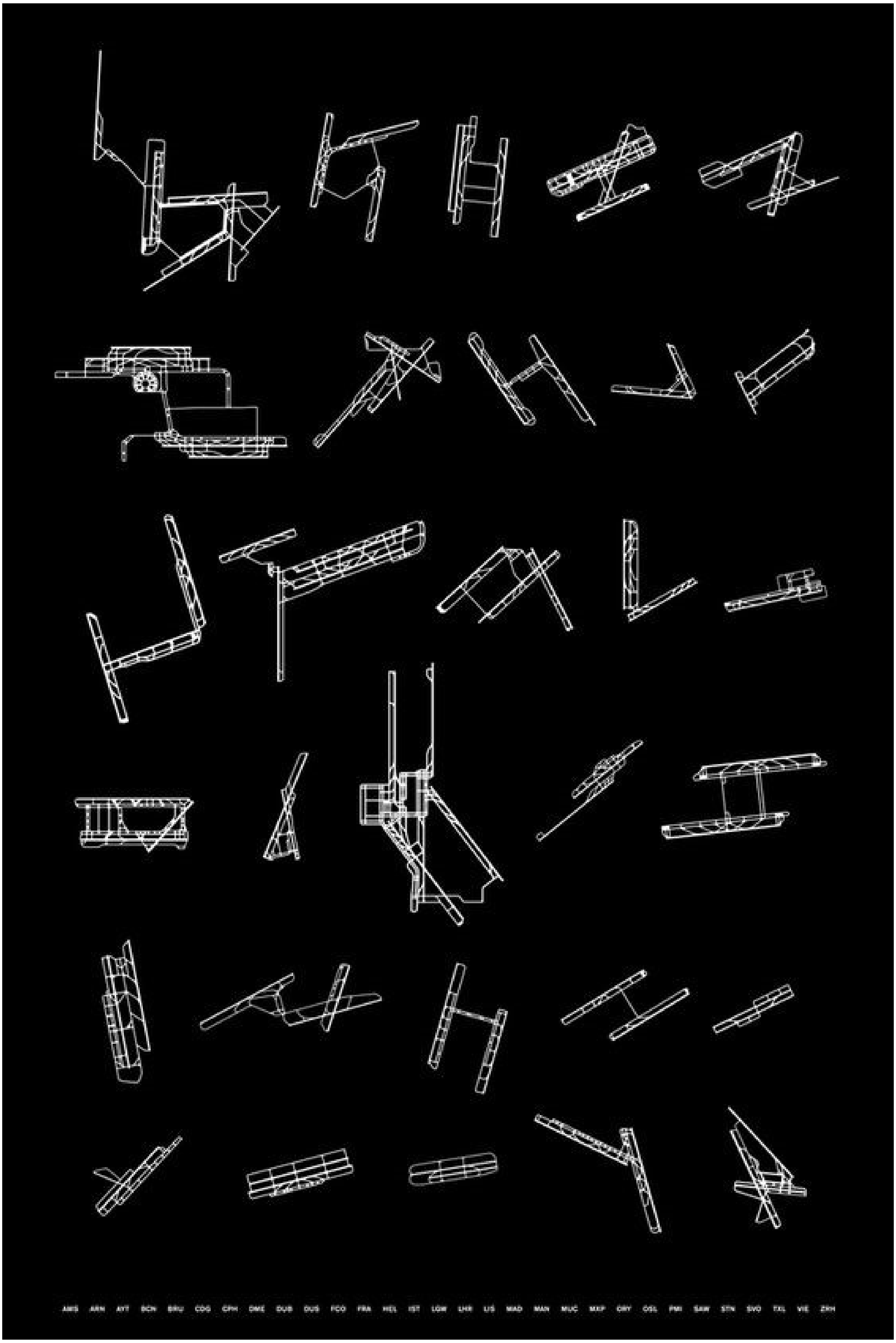


Figure 7.53 - Runway layouts of the Top 30 busiest airports in Europe – Source: NOMO Design, runway series

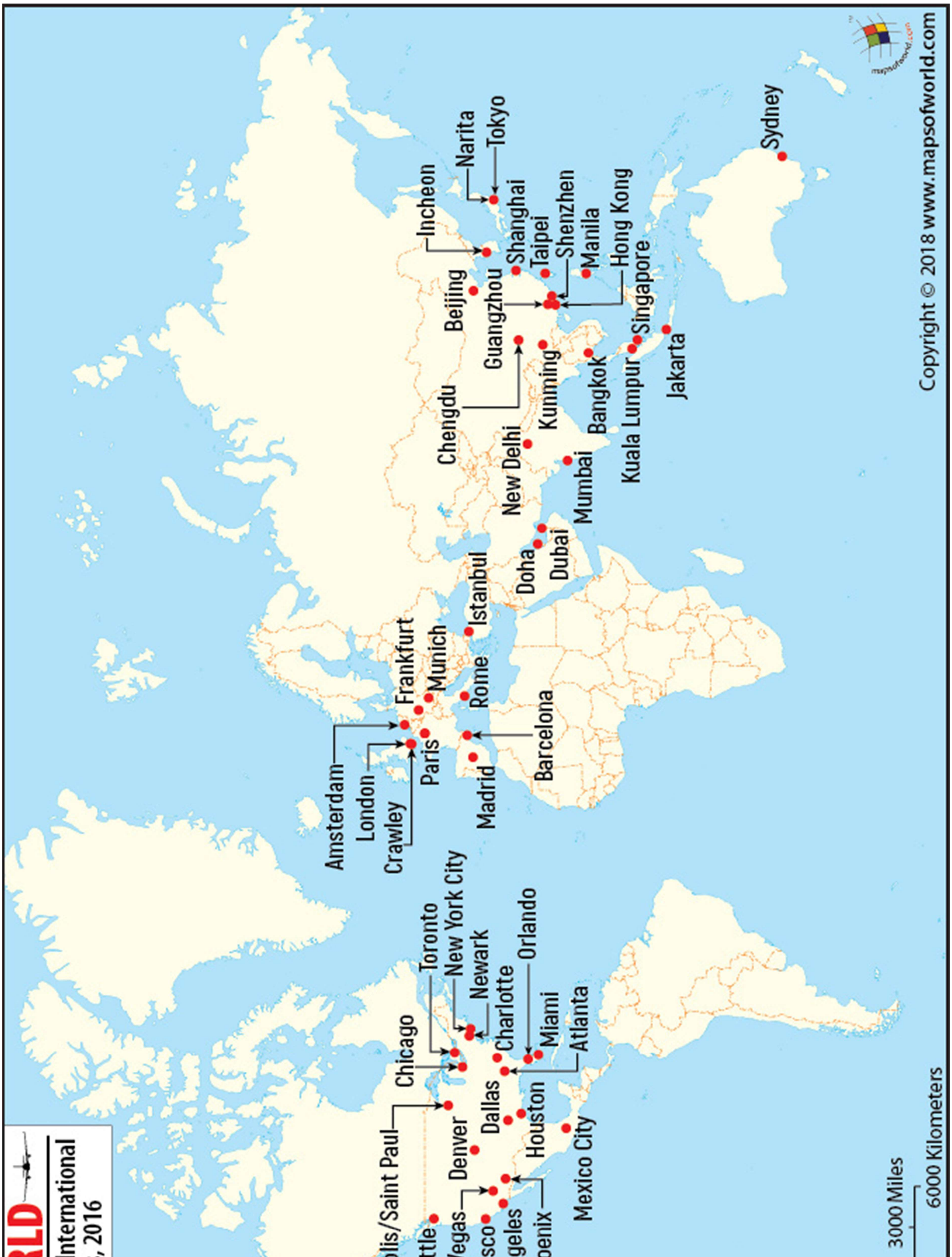


Figure 7.54 - Top Fifty Busiest International Airports, 2016 – Source: mapsoftheworld.com

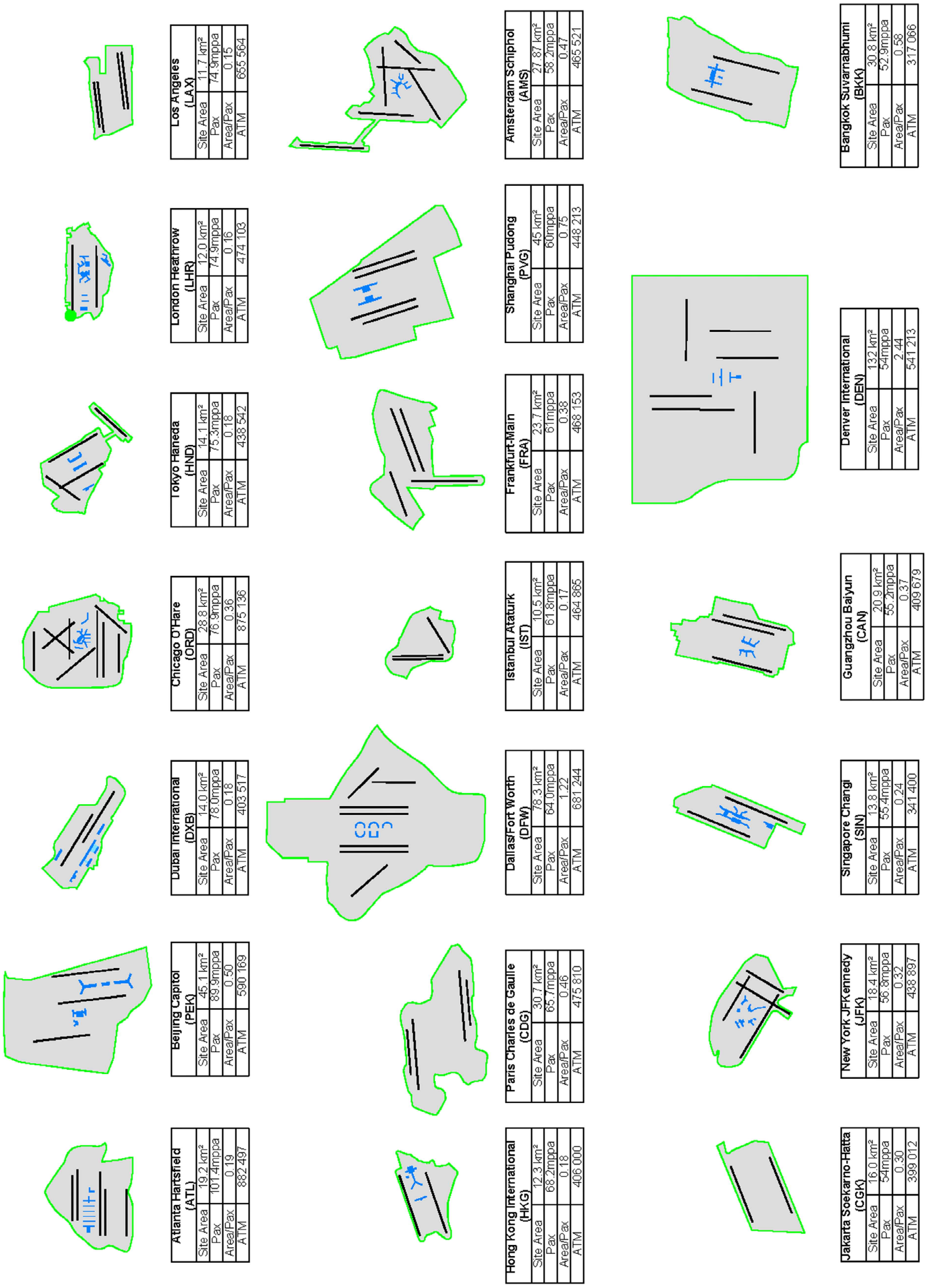


Figure 7.55 - Top Twenty Busiest Airports Master Plans 2016 – Source: Atkins Ltd

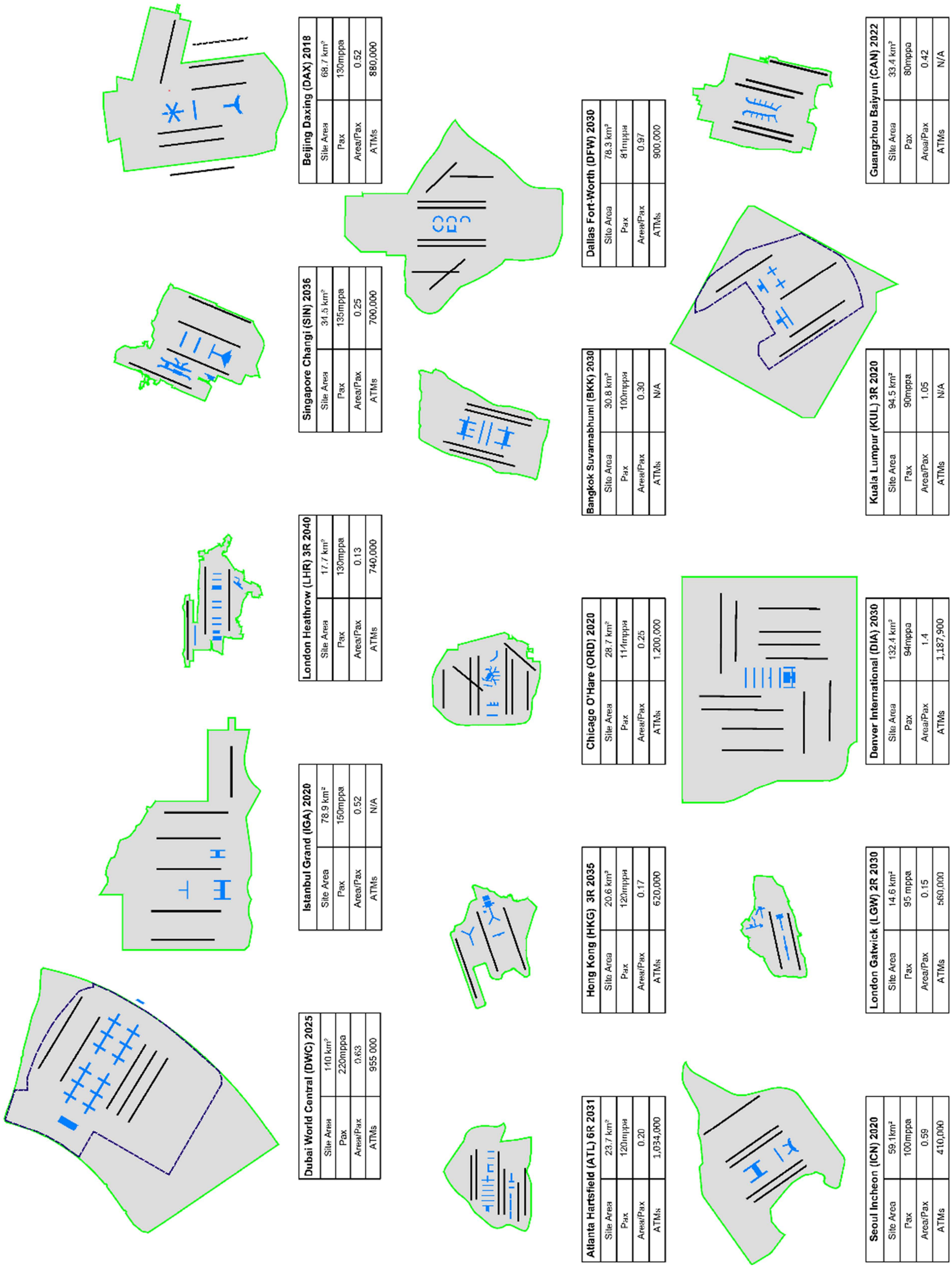


Figure 7.56 - Future Airport Master Plans – Source: Atkins Ltd

7.13 Conclusion

The engineering design of the airfield has from the start been influenced by the development of design and safety standards that evolved out of the experience gained in the First World War. These standards have been progressively codified by International organisations such as ICAN, its successor ICAO, the FAA in the USA, the CAA in the UK and more recently EASA for the European Union. These have been supplemented by IATA from an airline perspective.

The history of the airfield is driven by changing approaches to runway design from the first all directional grass fields, through the development of multi-directional runways to the simplified parallel runways that dominate today. Runway design has in turn had to respond to the evolution of aircraft design, which required longer, wider and stronger runways as aircraft grew larger, heavier and faster.

The USA led the way in the 1920s and 1930s in developing the runway design while European airports largely persevered with the obsolescent grass field. Airport masterplans developed during the Second World War envisaged the rapid growth in the number of flights and size of aircraft with multiple runways pointing to the dominant wind direction. With improving aircraft performance in the 1950s these masterplans were simplified with runways aligned to the dominant wind directions.

The widespread introduction of jets in the late 1950s allowed a further simplification in runway design, but these new aircraft demanded even longer runways. The introduction of the Boeing 747 and Concorde required the longest runways of all time. Since then aircraft take-off performance has improved and even the Airbus A380 requires shorter runways than the earlier generation of aircraft.

Washington Dulles airport is particularly significant in pioneering the mid field layout with all taxiways, apron, terminal and landside approach sited between two parallel runways. Most subsequent large hub airports including the largest at Atlanta have followed this philosophy.

The latest generation of hub airport master plans expand on the mid field layout by introducing additional widely spaced runways with new satellites and terminals between them. Examples of existing airports that are being expanded with multiple runways include Atlanta, Hong Kong, Singapore, and Heathrow all of which are planning to handle well over 100 mppa.

A new generation of airports are also being developed with multiple runways employing the midfield concept including Beijing Daxing, Mexico City and Istanbul Grand and the largest of all Dubai World Central which is planned for 220 mppa.

8. The airport as an interchange

8.0 Introduction

Air travel inherently involves transferring from one mode of transport to another so this chapter investigates the airport as an interchange starting with early visions and then considers the various types of connecting infrastructure: road to air, rail to air, sea to air, city centre air links, air to air transfers and the development of megahubs to respond to the needs of the global airline alliances. This is followed by considering the opportunities this offers for integrating journeys: road to air links, rail to air links and helicopter links. It concludes with consideration of the issues related to personalising the passenger journey, and the opportunities offered by the vision of the Vertiport and Vertistop aerial taxi.

8.1 Early Visions

The International Air Show (Internationale Luftschiffahrt Austellung) in Frankfurt between July and October 1909 was the venue where many of the elements of the modern airport interchange were anticipated**.** The exhibition was held in the newly opened Neo-Baroque Festhalle. The exhibition was mainly focussed on lighter-than-air flight, but there was also place for other forms of aviation (figures 8.01, 8.02, 8.03 & 8.04).

At the exhibition fourteen prizes of a total value of 200,000 Marks were given, for aeroplanes, aeroplane models, dirigibles, dirigible motors, dirigible hangars, dirigible cars, propellers, free balloons, rubber balloons, balloon photography, carrier pigeons, light metal, aeronautical astronomy and cinematographic views of the flight of birds. The exhibition concluded in October with a series of air races.

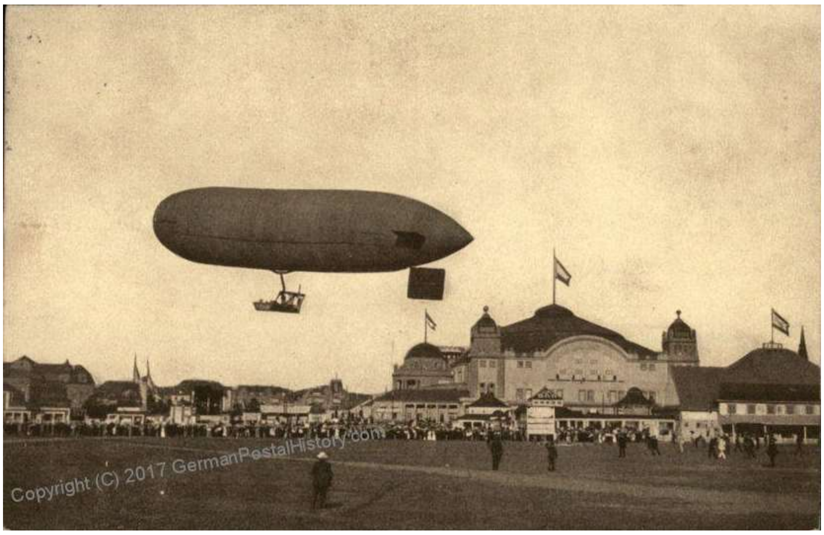


Figure 8.01 ILA Exhibition Poster 1909 Source: Smithsonian Institute

Figure 8.02 - Parseval Airship at ILA Exhibition 1909 Source: ILA Official Postcards – German Postal History

Figure 8.03 - Official postcard ILA (Internationale Luftschiffahrt Austellung) *Figure 8.04 - ILA Air Race Poster*
Sources: German Postal History and http://www.thefirstairraces.net/meetings/fr0910/events.php

Of particular interest for this study is the multi-modal surface access arrangement, by rail, road, tram, transit, and both airships and aircraft, as can be seen from figure 3.03 in chapter 3. The integration of surface and air access prefigured the modern airport interchange.

Donat-Alfred Agache provided an early vision of an airport from a planning perspective in his third place entry for the competition to plan the new capital city of Canberra, Australia in 1912. He laid out the city on Garden City principles overlaid with Beaux Arts symmetry like the other leading entrants. Uniquely he included an airport (highlighted) in the south east quadrant immediately adjacent to the main railway station (figure 8.05).

The Aerostatic Station (the name given to the airport), seen in his master plan contained all the elements of early airport design, a terminal building, hangars for aircraft and airships and a grandstand surrounding the four sides of an airfield (Agache, 1912).

From an operational viewpoint surrounding the airfield with buildings, and having no regard for the variable direction of the wind, would have severely limited its practicality but Agache was arguably the first to recognize that aviation had a practical use as public transportation and not merely as an aerial spectacle.

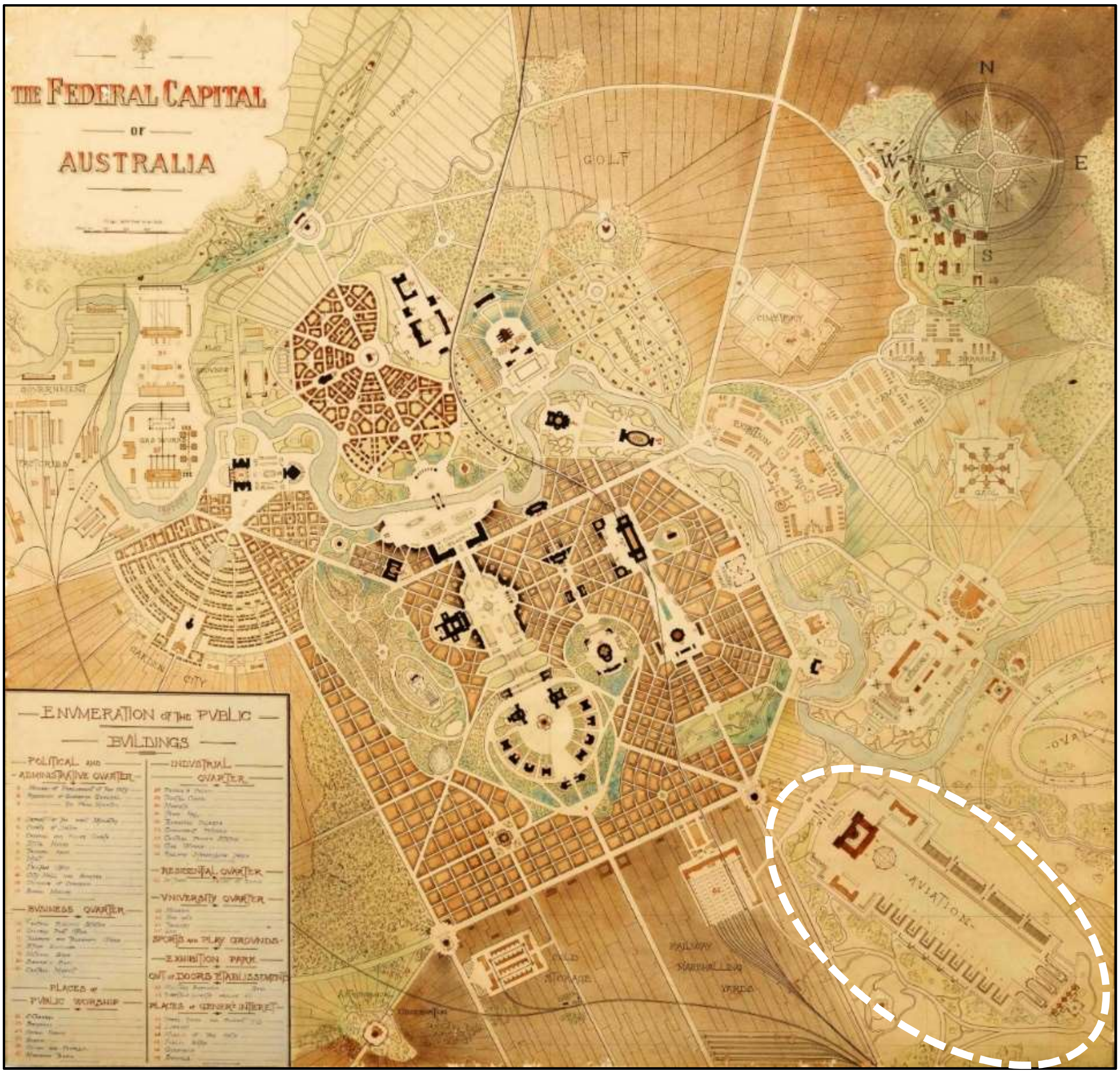


Figure 8.05 City of Canberra, Master Plan of 3rd placed competition entry by Donat-Alfred Agache showing the location of the proposed airport 1912 – Source: National Archives of Australia

Subsequent visions of urban integration included contributions from Sant'Elia (figure 8.06) and Le Corbusier (8.07) which integrated the airport with the fabric of the city. These concepts paid scant attention to safety, being surrounded with obstacles. From the size of aircraft portrayed, the images, which have colour added by the author, also show that neither architect saw the aeroplane as a source of mass transit but rather an expression of individual freedom.

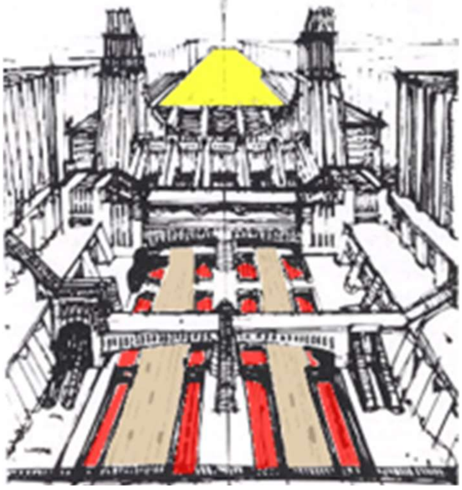


Figure 8.06 - Futurist Interchange 1912– Sant'Elia - Source: Author's collection

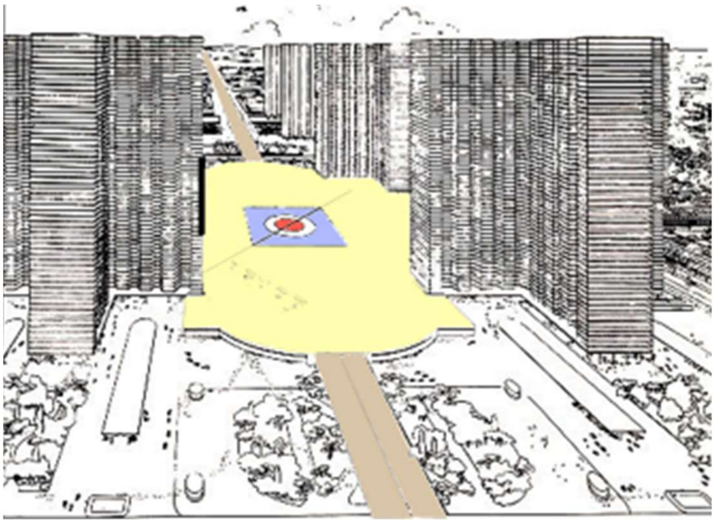


Figure 8.07 - Ville Contemporaine – Le Corbusier 1922 Source: - Author's collection

The entry to the Lehigh Airport Competition from H. Altvater showcased an alternative vision for a city centre airport in New York with radial runways accessed from a circular taxiway supported on the roofs of skyscrapers (figure 8.08). The judges commented as follows:

'*A visionary scheme published for its originality rather than any elements of practical design. Obviously, this plan would involve excessive danger in use*' (Black, 1930).

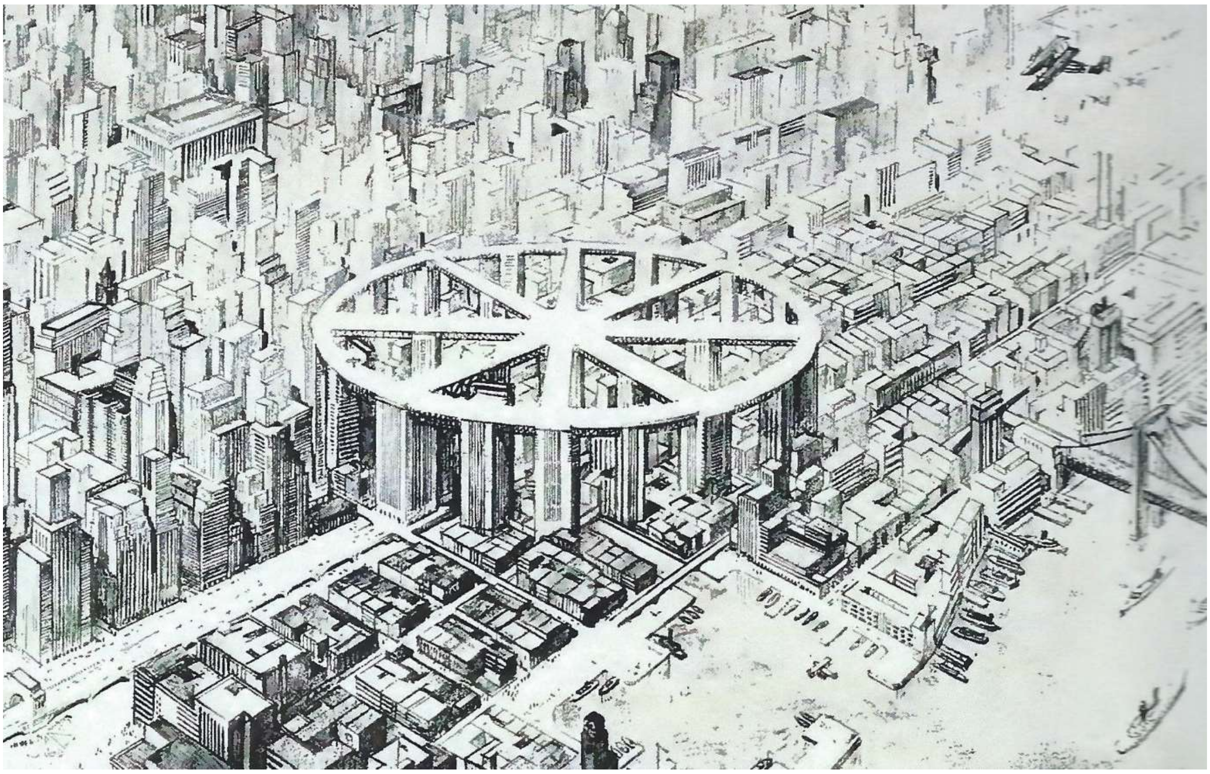


Figure 8.08 - Lehigh Airport Competition Honourable Mention Design – Source: American Airport Designs 1930

Another entry to the competition from Richard Neutra (figure 8.09) showed the airport as an interchange. Although he is now recognised as the most significant architect of the early modern movement to enter the competition his design was not even listed among the commended entries.

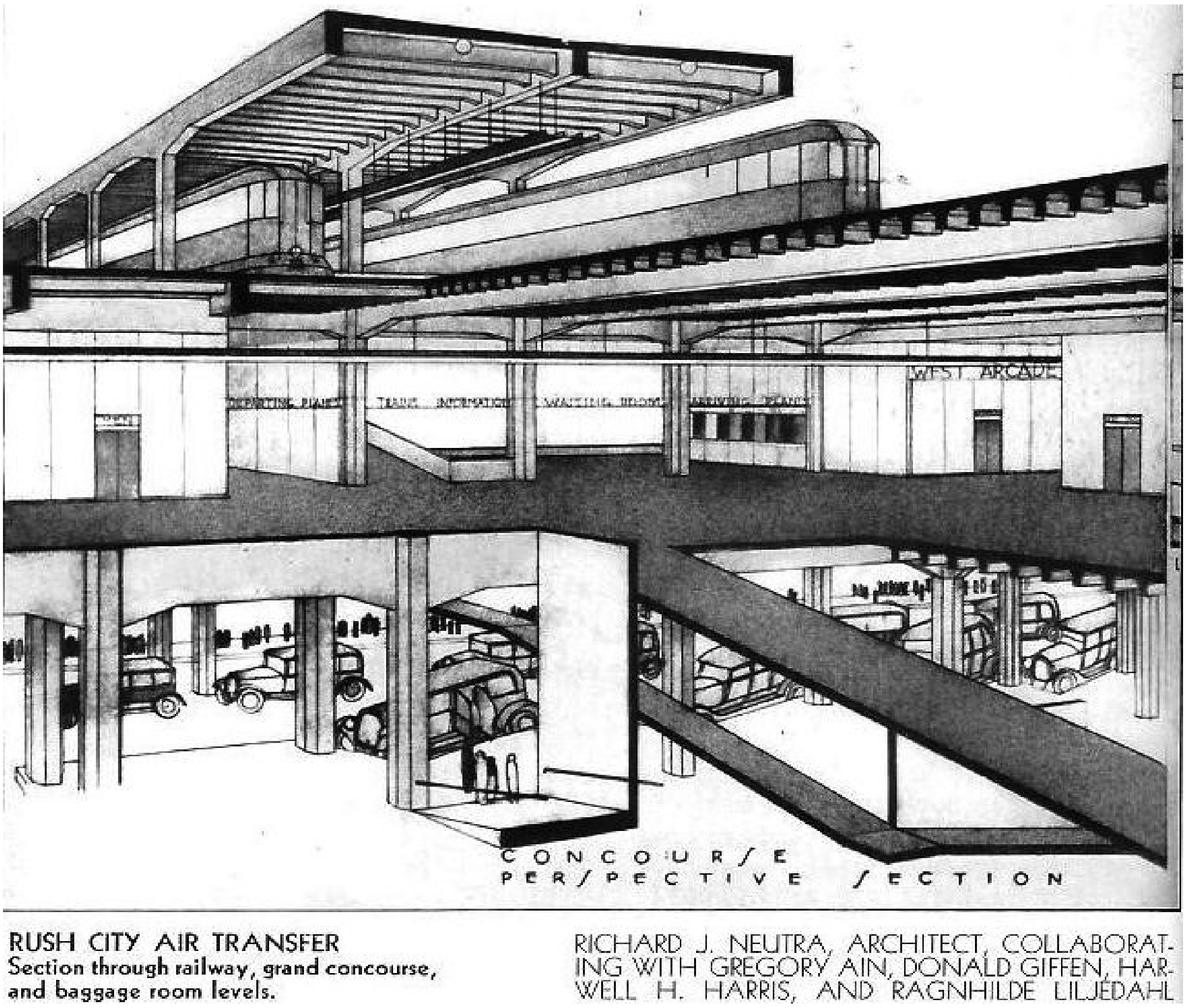


Figure 8.09 - Rush City entry from Richard Neutra to the Lehigh Airport competition – Source: Architectural Record August 1930

Ideas for bringing the airport into the city centre can also be seen in in Fritz Lang's 1927 film Metropolis (figure 8.10) and in proposals for an airport over Pennsylvania Station, New York (Wright, 1929)(figure 8.11), or the elevated airport over the Thames next to the Houses of Parliament (figure 8.12), London.

André Lurçat also made a proposal for an airport, known as Aeroparis, on an artificial island in the middle of the Seine to serve Paris. Ideas for city centre airports resurface from time to time but have so far always been rejected on various grounds, including cost disruption, impracticality, noise nuisance and safety.
(figures 8.13 & 8.14).

Figure 8.10 – Metropolis, Science Fiction Film, Fritz Lang, 1927 - Source: The-Philosophy.com

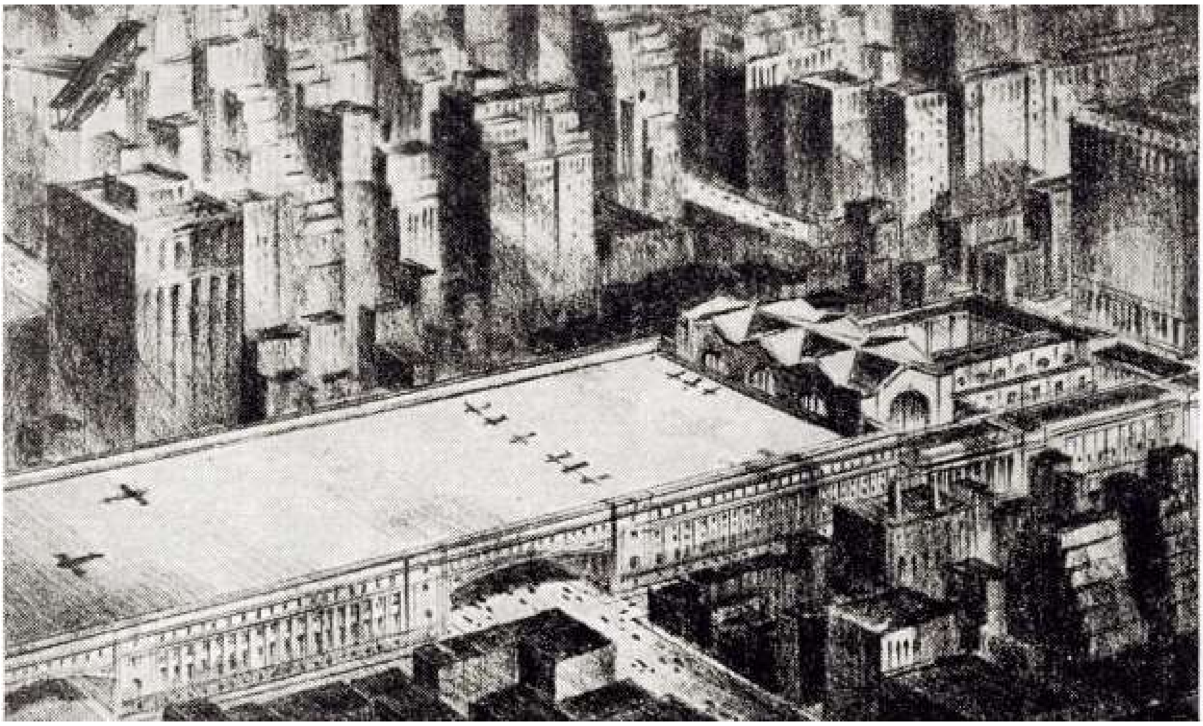


*Figure 8.11 - Proposed Landing Platform over Pennsylvania Station, New York 1929 –
Source: Popular Mechanics*

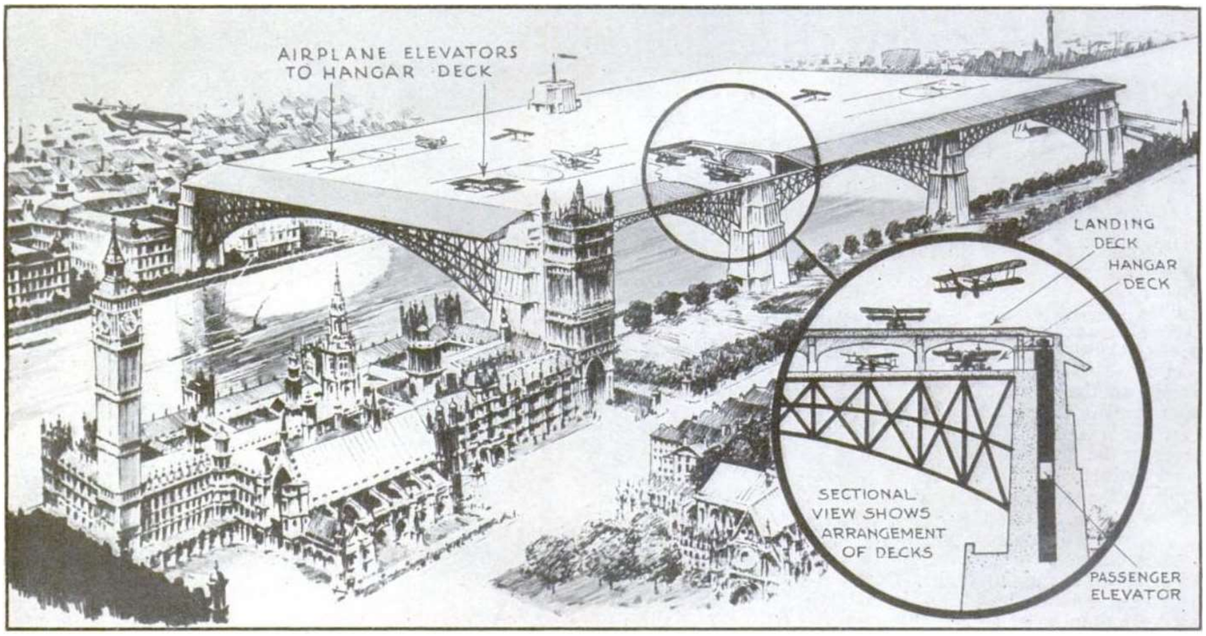


Figure 8.12 – Proposed Landing Platform, London, Westminster, c. 1930 – Source: Popular Mechanics

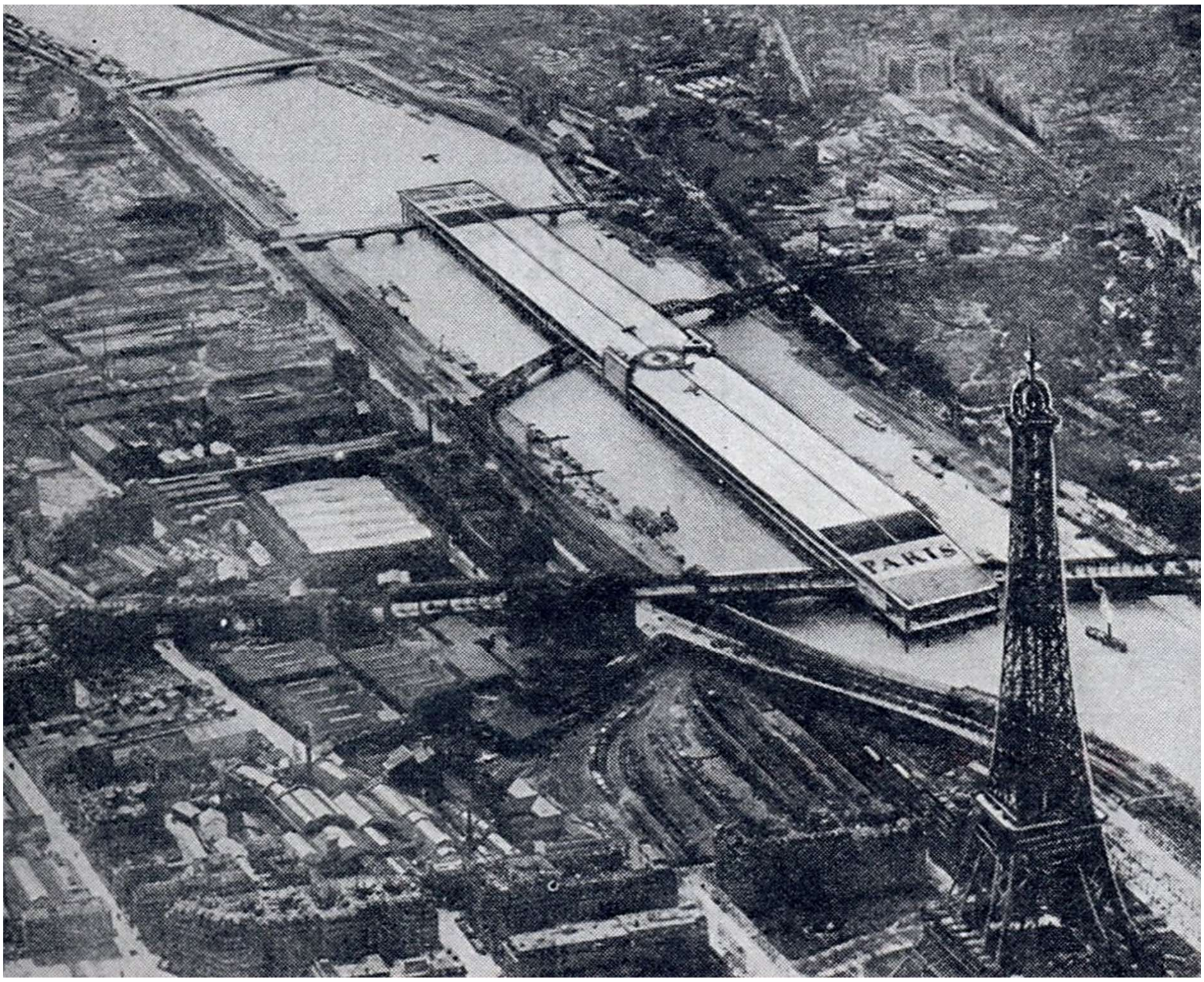


Figure 8.13 – Aeroparis, 1931 – Source: André Lurçat: CNAM SIAF ADAGP

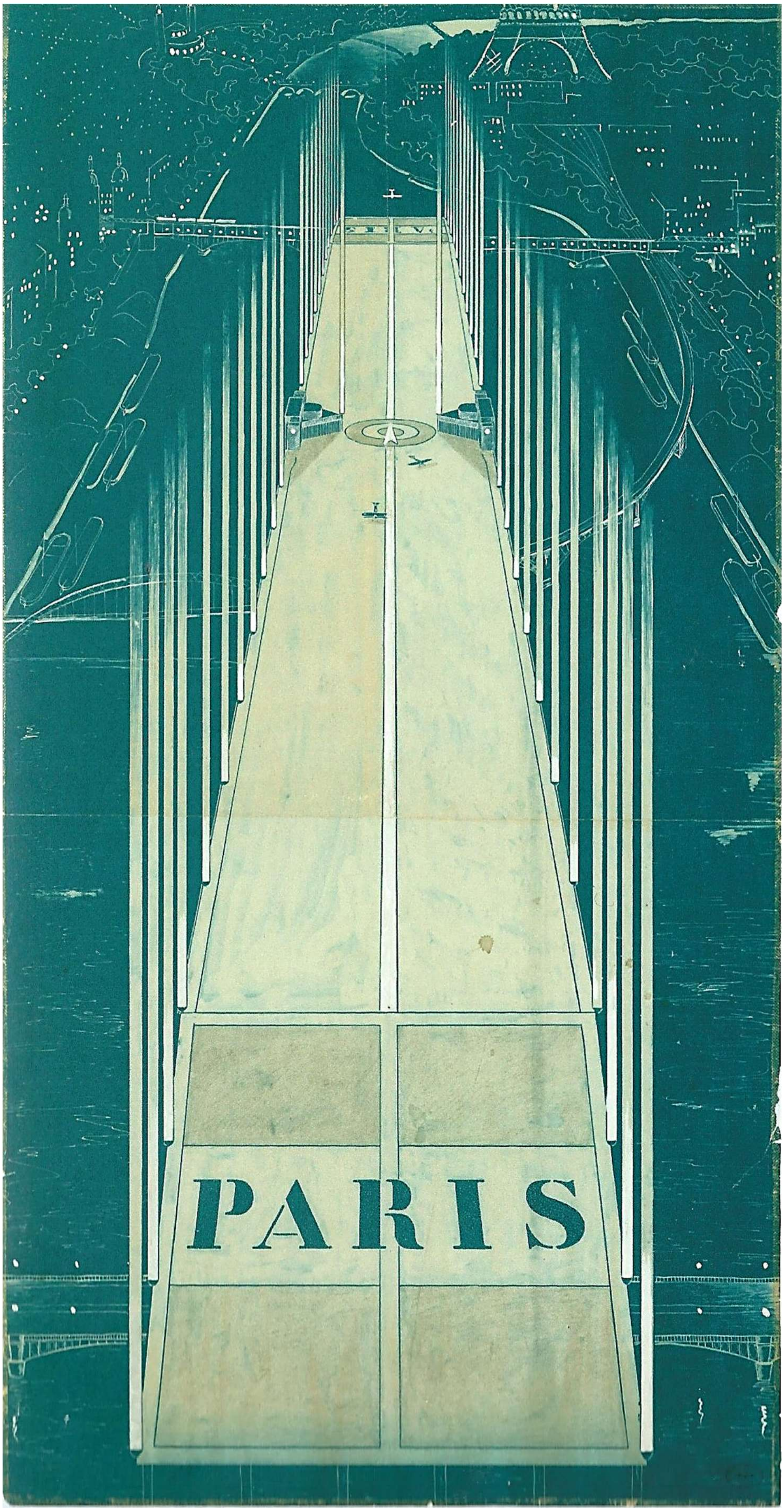


Figure 8.14 – Aeroparis, André Lurçat, 1931 – Source: 100 Years of Architectural Drawing

In his book Horizons, Norman Bel Geddes illustrated the Rotary Airport with numerous plans, sections, and diagrams showing how planes could clear skyscrapers and manage prevailing winds. In this way, Bel Geddes hoped to deflect criticism that building a floating airport in New York harbour was preposterous. Passengers went ashore by traveling an 800-foot-long moving walkway below the harbour (Geddes, 1932) (figures 8.15 & 8.16).

Figure 8.15 – New York, Manhattan, Rotary Airport, 1932 Norman Bel Geddes – Source: Harry Ransom Center, The University of Texas at Austin

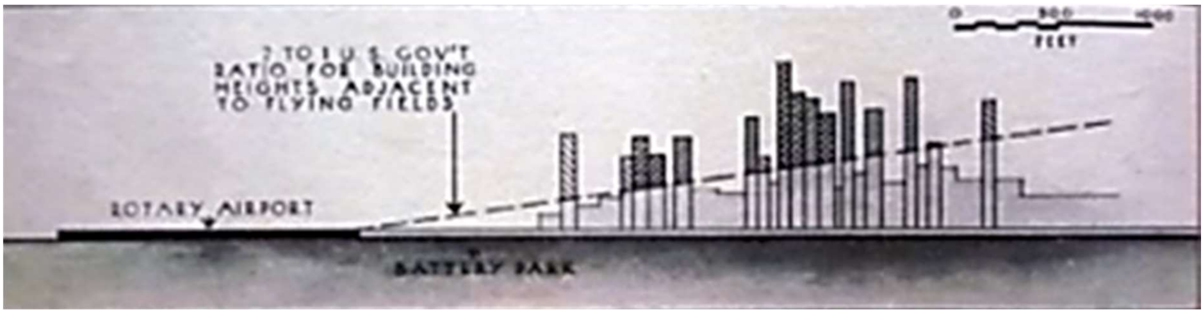


Figure 8.16 – New York, Manhattan, Rotary Airport 1932 _ Source: Tumblr

8.2 Road to Air Infrastructure

Early airports made use of existing road infrastructure to link the new airport to the city centre with, at the most, a short spur road as can be seen at Berlin Tempelhof, which opened in 1923, with the terminal completed in 1928. The new road Flughafenstraße linking the station with the terminal was designed to connect the airport to the main north-south avenue Berliner Straße (now known as Tempelhofer Damm) to the west and to Hermannstraße to the east.

There were other road transport links that could be used to reach the airport including the existing tramline 99 which ran along Berliner Straße, and a new tramline running from Berliner Straße along Flughafenstraße with its final stop in front of the terminal. Lufthansa also set up a free shuttle bus service between the city centre and the airport terminal (Heeb, 2007).

Some access to the airport remained much more traditional as can be seen from the aerial photograph which shows a surprising juxtaposition of a horse and cart stopped in front the terminal to make a delivery (figure 8.17).

Figure 8.17 – Berlin Tempelhof 1928 – Source: wordpress.com

The first major innovation can be seen at the new airport to serve Frankfurt Rhein-Main (FRA), which was opened on July 8, 1936 at its current location adjacent to the Frankfurt Kreuz autobahn intersection. This made it the first airport to be planned with direct access from a motorway network (Treibel, 1992, p. 170) (figures 8.18, 8.19, 8.20 & 8.21).

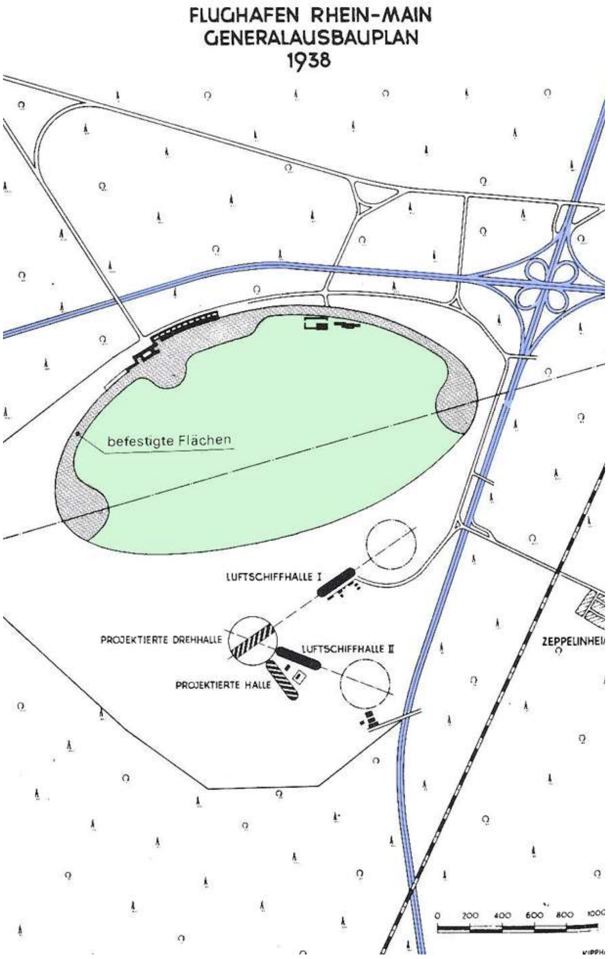


Figure 8.18 Frankfurt Rhein-Main site plan 1938 – Source: Die Deutschel Luftfart

Figure 8.20 – Postcard of Frankfurt Airport with the autobahn in the foreground, airship hangar in the background and photomontage of the Zeppelin LZ 27 – Source: motorbloeckchen.com

Figure 8.21 Frankfurt Interchange 1936 - Source: antik-falkensee.de

Figure 8.19 Frankfurt Rein Main, opening day 1936 Source: Fraport AG

Figure 8.22 Frankfurt Rhein-Main site plan 2018 – Interchange top right - Source: Fraport AG

Over time, Frankfurt Airport has become one of the world's most important air transportation hubs, thanks in part to its favourable location in the heart of Europe with direct access to an excellent highway network, and more recently the high speed rail system (figure 8.22).

An early example of a road network and airport being planned in concert can be found at New York, La Guardia, USA where the new airport was located on land reclaimed from Bowery Bay adjacent to the Grand Central Parkway which then was the under construction.

Grand Central Parkway was in turn linked to the Triborough Bridge, one of the New Deal's largest projects nationwide, connecting three of NYC's five boroughs, Queens, Manhattan, Bronx and serving more than a million vehicles daily (figure 8.23).

Figure 8.23 - La Guardia, New York 1939 showing the integrated planning concept with interchange between road, airplanes, large seaplanes, light seaplanes and yachts – Source: Macaulay Honors College

Robert Moses, the infamous New York planner and power broker, built 416 miles of Parkways, which were closed to all commercial traffic. This included the Grand Central Parkway which opened in 1936 linking Manhattan Island to Long Island and passing directly in front of La Guardia Airport the land for which was then being reclaimed. Parkways were conceived as 'ribbon parks' for 'pleasure driving'.
Moses went to great lengths to prevent the use of Parkways by public transport and wrote legislation prohibiting the use of Parkways by 'buses or other commercial vehicles', and to ensure a simple reversal of legislation couldn't undo his strategy built bridges over the parkway with only 11feet (3.3 metres) clearance. So while the photograph below shows a coach in the lower forecourt it would have been prevented from taking the direct parkway route to the airport (Caro, 2015, p. 952) (figure 8.24).

Figure 8.24 - New York, La Guardia 1939 showing the two level forecourt segregating arriving and departing traffic. Departures vehicles set down at the upper level and arrivals vehicles picked up at the lower level – Source: Bettmann Archive

The construction of the new airport, New York Municipal Airport, was supported by the Works Progress Administration (WPA) partly to create new jobs during the Depression and partly because it wanted to develop America's commercial transportation system.

Sadly the designers of the parkway system didn't have a vision of even a road based public transport network and went further in actively seeking to frustrate its introduction by limiting the headroom on the road to prevent its use by buses.

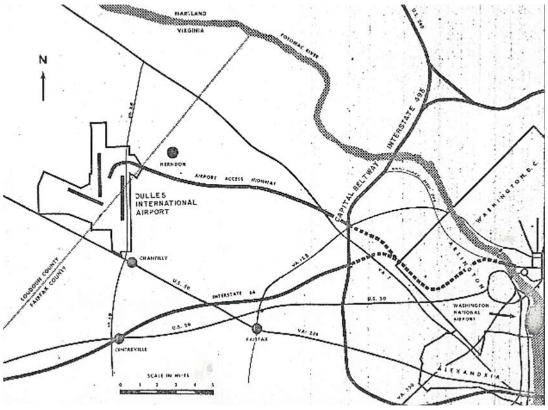
The close juxtaposition of the La Guardia Airport and Grand Central Parkway, can be seen in the bottom left hand corner of the following photograph, with the airport immediately to its north (figure 8.25).

Figure 8.25 Aerial view of La Guardia 1939 with forecourt and Grand Central parkway in the foreground
Source: Courtesy American Airlines. From the e-book "The Golden Days of Airline Travel" published by higgebooks.com

Washington Dulles took surface access design a step further by providing a dedicated airport access road, known as the Dulles Airport Access Road (DAAR), and covering initially about 12 miles and opening with the airport in 1962. It was subsequently extended to intersect Interstate 66 before leading into Washington passing close to Washington National Airport. This is a four-lane freeway for airport traffic only, and has no toll. There are sparse interchanges; on-ramps only inbound to Dulles, and off-ramps only outbound toward Washington, D.C. to prevent rat running. The road was built by the Federal Aviation Agency (FAA), and they obtained a wide enough right-of-way for parallel roadways to be eventually built on (Peck, 2005) each side (figure 8.26 &8.27).

Later the Dulles Toll Road (DTR) was built. It opened in 1984, with parallel roadways on either side of the DAAR. Cars, busses, and trucks use the road without restriction unlike La Guardia. The DTR has frequent full interchanges for commuter traffic. The DTR and DAAR essentially is a freeway in a dual-dual configuration, although they are two separate highways (Federal Aviation Administration, Department of Transportation, 1962).

The recirculating loop road layout at the entrance to the terminal and the segregation of arrivals and departures flows into two forecourt levels has become the model for highway access for all subsequent mid field airports (figure 8.28 & 8.29).



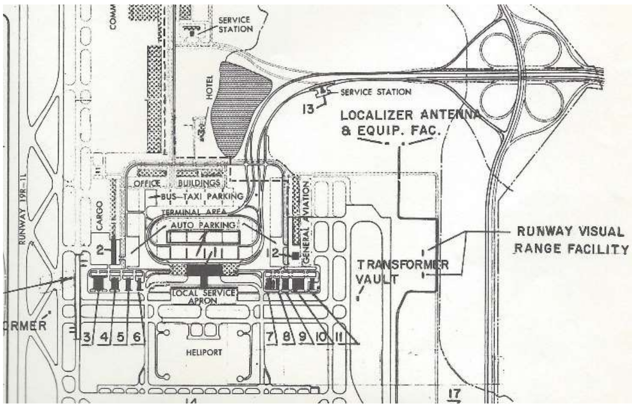


Figure 8.26 - Washington Dulles Airport Access Road (DAAR) 1962
Source: FAA Handbook of Information, Dulles International Airport

Figure 8.27 - Washington Dulles Airport Landside Zone and Forecourt 1962
Source: FAA Handbook of Information, Dulles International Airport

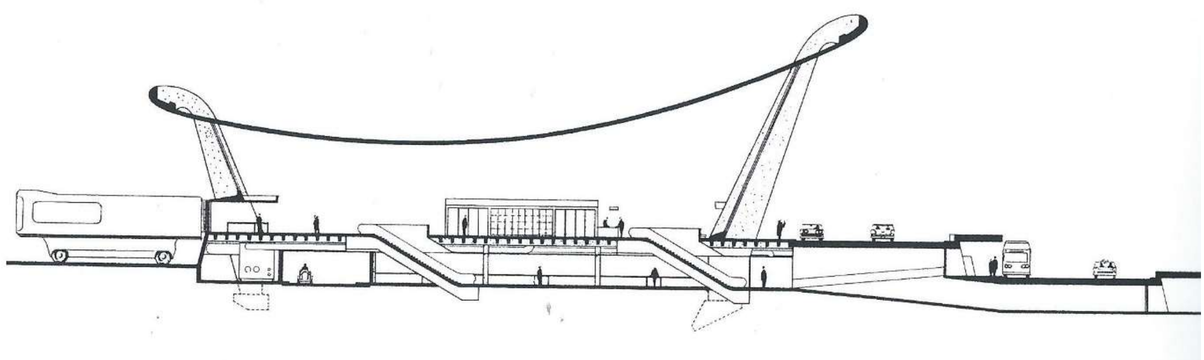


Figure 8.28 – Washington Dulles 1962 showing two level forecourt and pedestrian underpass in section
Source: Saarinen

Figure 8.29 - Washington Dulles 1962 model of terminal and forecourts seen from the car park
Source: Balthazar – Korba Architectural Models

8.3 Rail to Air Infrastructure

The very first purpose designed airport terminal at Konigsberg was connected to the city by a tram link in 1924 shortly after the airport's opening in 1922. Line 2 linked the rail station with the airport (figure 8.31 & 8.32).

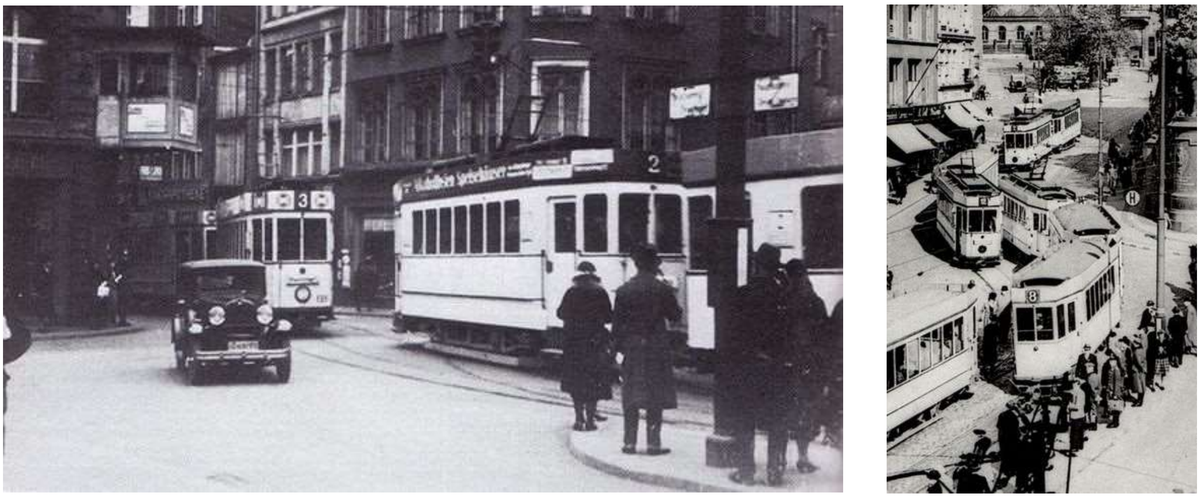


Figure 8.30 - Konigsberg Airport Tram Service, in foreground on the left and in the background on the right – Source: Pinterest 1931

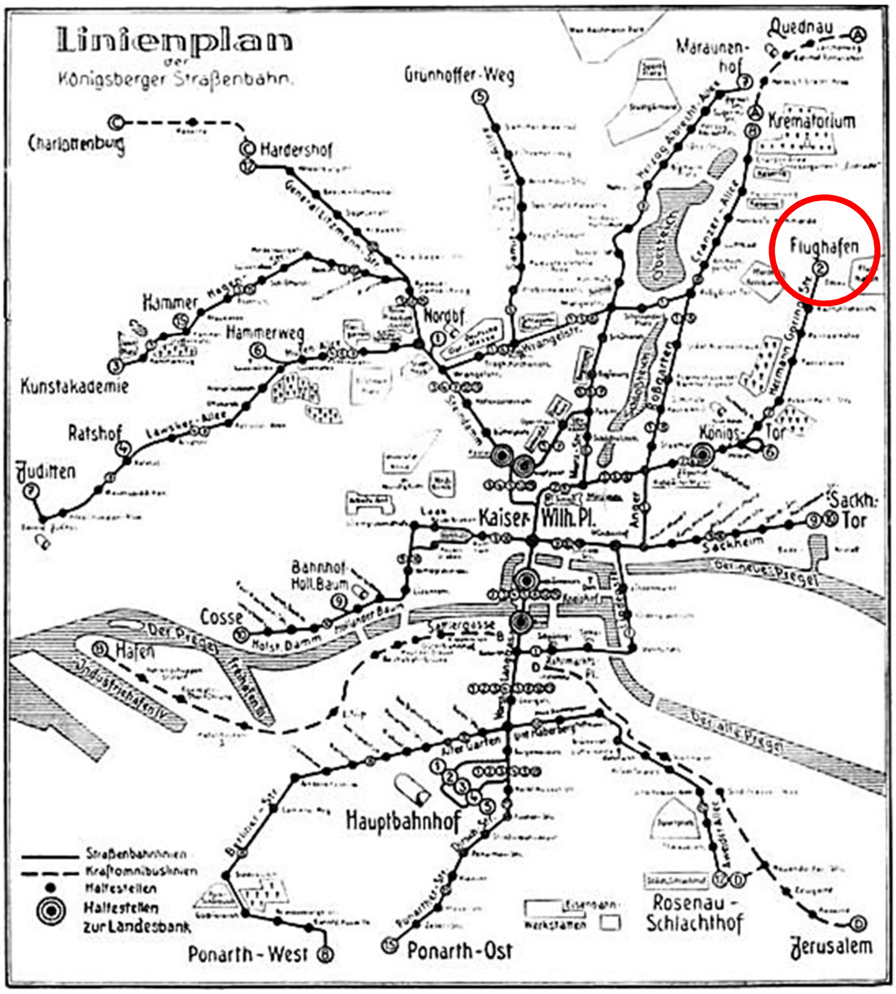


Figure 8.31 – Konigsberg Tram Network 1935 showing extension to the Airport – Source: Pinterest

At Frankfurt a new airfield was constructed in 1912, that built on the infrastructure that was created for the Internationale Luftschiffahrt Ausstellung (ILA, or in English: International Aviation Fair) which was held between 10 July until 17 October 1909 and is described at the beginning of this chapter (figures 8.01 to 8.04).

The layout of the ILA and adjacent airship field can be seen in Chapter 3 (figure 3.03). Initially the site was intended as only an airship port, but it soon became a true 'air'port when 'heavier-than-air' aircraft were allowed too.

After World War I the small airfield rapidly expanded, and from 1924 onwards an airline service was set up. It displays some unusual characteristics, for although it had a minor road access, it had a much larger rail station. It also exhibited a surprising juxtaposition of functions as the small terminal incorporated stables for horses (see figure 8.29) as well and handling passengers for flights (Treibel, 1992, p. 166) (figure 8.32 & 8.32).

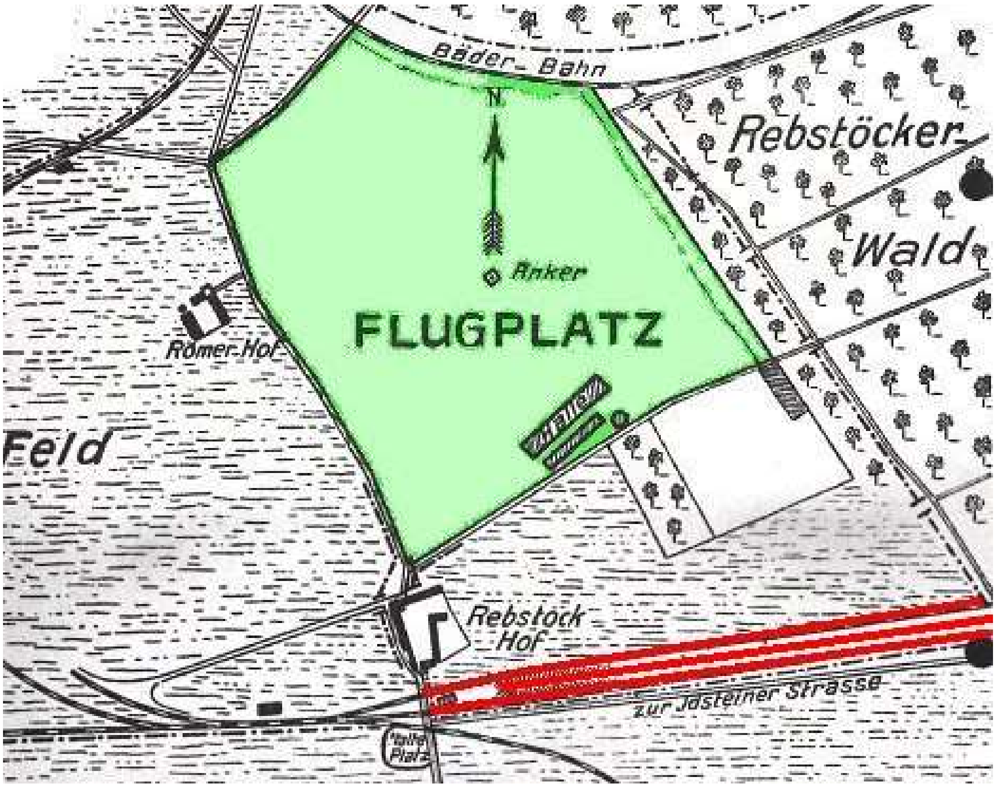


Figure 8.32 – Frankfurt, Rebstock Site Plan c1924 – Source: Die Deutschel Luftfart

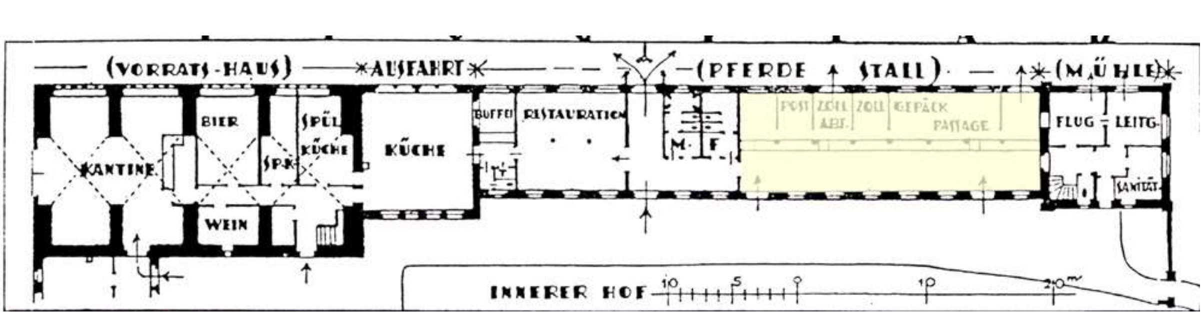


Figure 8.33 – Frankfurt, Rebstock Terminal c 1924 – Source: Die Deutschel Luftfart

It was the design of the much larger Berlin Tempelhof airport that was more important and influential. It included both a new road and an underground station. The new underground station known as 'Flughafen' (now renamed Paradestraße) was constructed to serve the underground railway that was extended to reach the new airport (figure 8.34).

The new station was designed by architect Alfred Grenander and was located at the intersection of the new Flughafenstraße and Berliner Straße about a kilometre from the new terminal building. A major function of this new interchange was to bring the very large number of spectators and visitors to the airport rather than transport the relatively few passengers. An underground tunnel was designed to link the station with the airport terminal but was never built (Heeb, 2007, pp. 18-19).

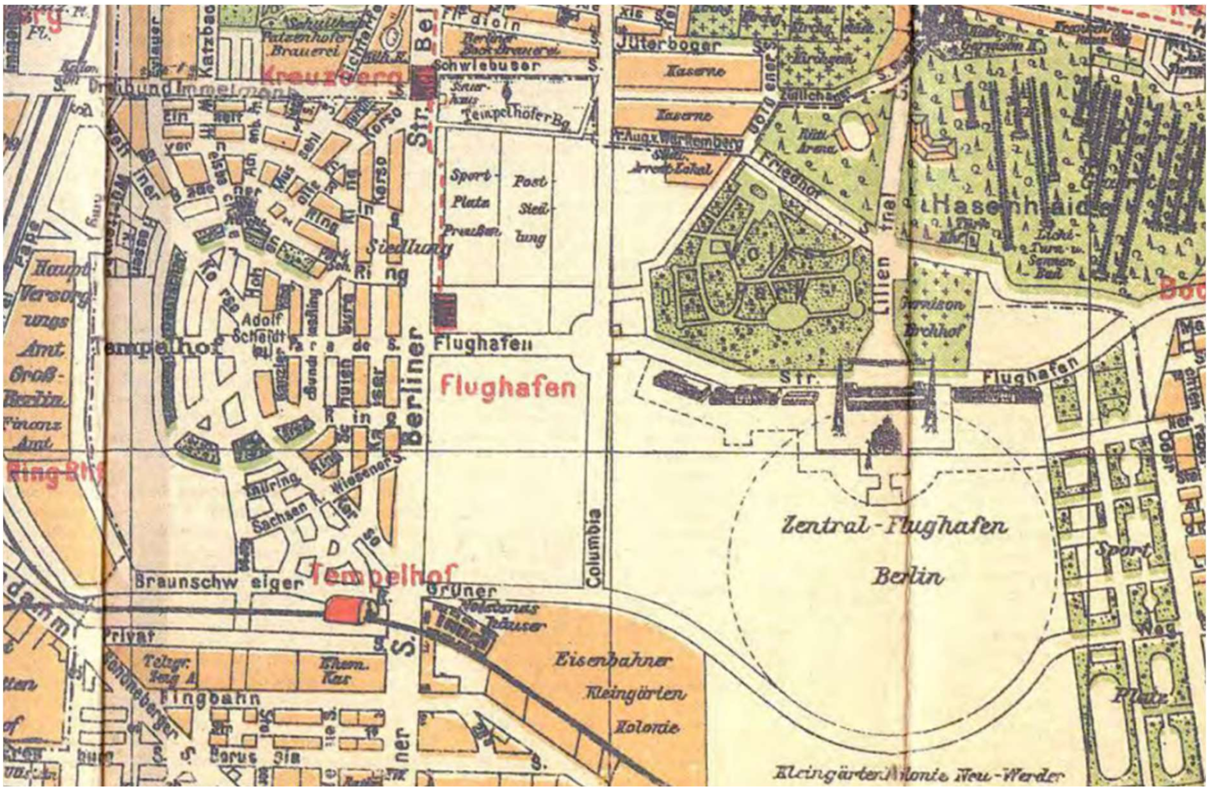


Figure 8.34 - Flughafen the underground station serving Berlin Tempelhof 1928 – Source: A multifaceted monument, the complex heritage of Tempelhof Central Airport

The second terminal at Tempelhof designed in the 1930s incorporated a much more far sighted and ambitious interchange concept while the airport still retained the obsolescent concept of a grass landing field. The terminal employed a number innovative features:

- Vertically segregated passenger and visitor movement was built on the concept first seen at Hamburg. Here passengers remain at a single level one floor above apron level where the aircraft parked, while visitors were led up to a gallery level where they could view departing passengers checking in below without interfering with their movement.
- The multiple aircraft boarding gates were strung out as curved arms from the central terminal allowed up to 20 aircraft to be handled simultaneously radically increasing capacity and allowing for passengers to transfer easily from one flight to another.

- The roof was designed as major spectator terrace for some 60,000 people for major air shows and the inevitable Nazi spectacular parades, as well as providing shelter to passengers boarding and alighting aircraft. The airfield could also accommodate another million people on the apron and grass verges for events such as the Reichsflugtage, the Third Reich's air shows. Access to the spectator gallery was provided by a series of staircases around the perimeter of the building in the manner of stadia (figure 8.35).

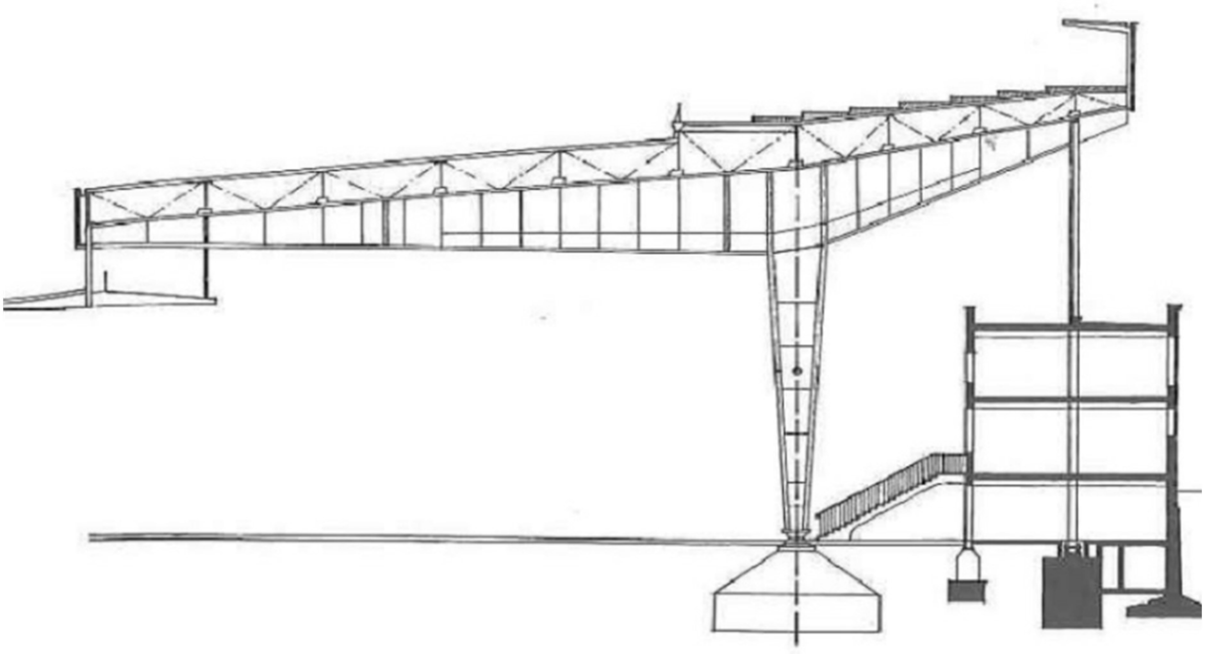


Figure 8.35 - Section though 40-metre overhang of the canopy by A. Schleusner showing the roof canopy over the passenger boarding area and spectator terrace 1939 – Source: Hecker 2000, p. 96)

- A baggage sortation hall was located immediately below the check in hall. Mechanical movement of baggage was by lifts, a first for any airport. A new station was built to integrate the existing underground railway, which ran along Berliner Straße, with the terminal.
- A new rail track was integrated into the terminal at a basement level to transport freight and post to the terminal. The postal facility was linked to the landside road network on Berliner Straße, while the freight facility was linked to Columbiadamm (figure 8.36).
- A separate VIP entrance was designed to allow Hitler, his high ranking entourage and official state guests, to by-pass the main terminal and gain access directly to the gate area via a special ramp (the Fuherrampe) linking the luggage level with the freight courtyard that vehicles could pass through to reach the aircraft parking area.

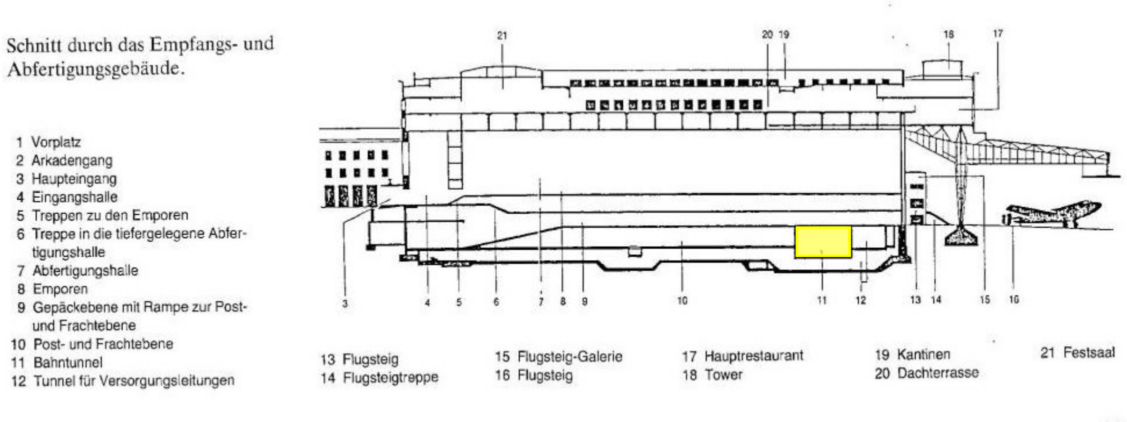


Figure 8.36 – Section through terminal with rail track highlighted in yellow 1939 – Source: Die Deutsche Luftfarht, Geschichte der Deutschen Verkehrsflughafen

Tempelhof is also uniquely sited just 2.5 km from the centre of Berlin, a feature that was originally considered to be advantageous by providing unrivalled connectivity, but was subsequently to be its downfall, as the noise nuisance from jets was no longer considered acceptable in a heavily populated urban area. This ultimately led to the airport's closure in 2007.

The town planning concept integrated the airport into the fabric of the city in a way that no other airport has ever achieved. A 'Courtyard of Honour' forms a symmetric approach to the main entrance of the terminal. Only the eastern part of the plaza (today's Platz der Luftbrucke) was built and so formed a semicircle rather that the originally intended circle.

The new terminal was located at the eastern extremity of the east west axis that crossed the north-south axis of Albert Speer's unrealised master plan of 1937 for the centre of Berlin, 'Welthauptstadt Germania' which translates as World Capital Germania.
(figures 8.37, 8.38 and 8.39).

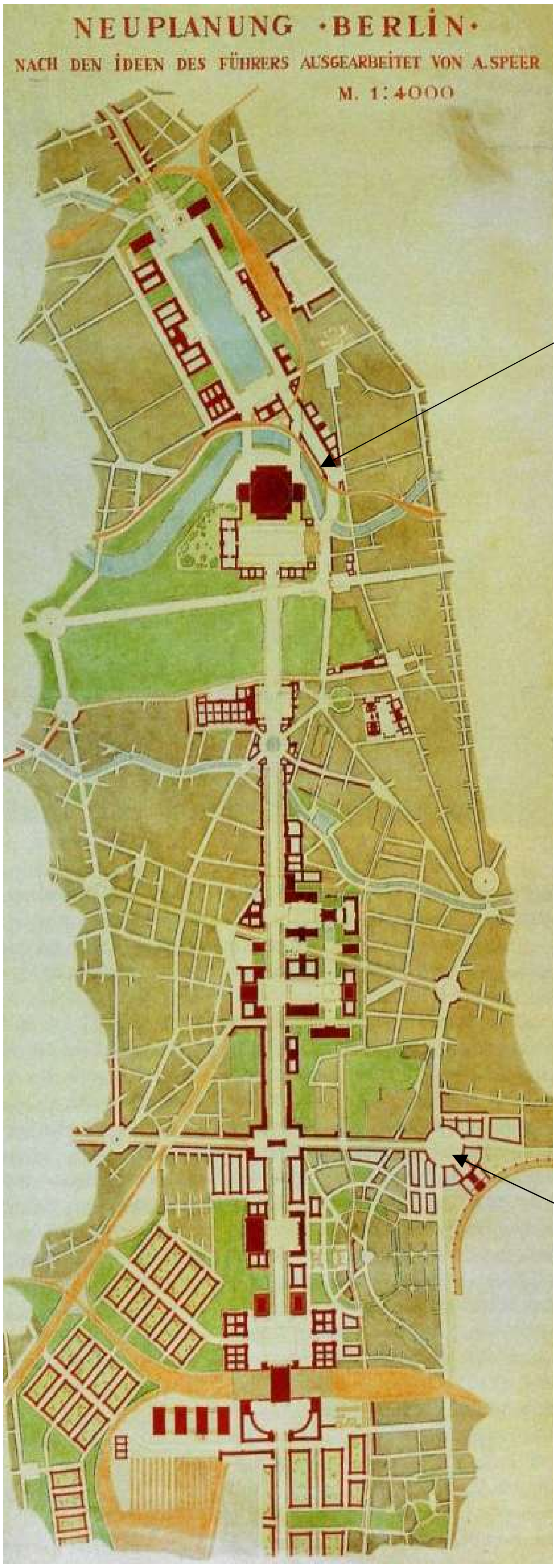


Figure 8.37 - Germania Master Plan 1937
Architect: Albert Speer
Source: Landesarchiv, Berlin

Figure 8.38 -Volkshalle/Große Halle, Berlin Model 1937 - Architect: Albert Speer - Source: Britlink

The proposal for the second terminal at Tempelhof was developed in parallel with Albert Speer's concept for Berlin, but its neo-classical diagonal symmetry was readily assimilated into the master plan. This vision of integrating an airport with the community has not been reproduced since but the sophistication of the design concept that integrated passenger, spectator, baggage, freight, mail and VIP circulation suggests that it was indeed a precursor to the modern interchange terminal. As Norman Foster has observed Tempelhof was the *'Mother of all modern airports'* (Airport Technology, 2017)

Figure 8.39 - Tempelhof Airport New Terminal model showing original concept for a circus at the entrance 1937 - Architect: Ernst Sagebiel – Source: Alibaba.com

Gatwick Airport of 1936 was a pioneer for its terminal design, not just for its circular form that has informed subsequent satellite designs, but for its connectivity to the mainline railway network and for the underground link from the station to the centre of the terminal both of which were world firsts.

Gatwick was located next to the main Southern Railway line that linked London with Brighton and the South Coast. The railway line acted as one of the main navigation features that pilots followed after crossing the coast when flying from France to Croydon Airport. Before becoming designated as an airport the racecourse at Gatwick had served as an emergency landing ground for aircraft that couldn't reach Croydon. Although originally considered by the Air Ministry to be too far from Croydon to act as a diversionary airport on a permanent basis the Air Ministry eventually relented. Imperial Airways also saw the advantages of Gatwick as a diversionary airport outside the fog band that affected London.

Southern Railways also saw the potential of an airport directly linked to the railway to limit the loss of rail traffic to air travel that they feared was inevitable when air travel had developed sufficiently. This was codified in a report by aeronautical consultants Norman, Muntz and Dawbarn to the board in March 1934 which proposed they should use their 1929 air powers to become involved in civil aviation. A new station was designed on the main London to Brighton rail line, which was being electrified at the same time, about a mile south of the existing station serving Gatwick Racecourse. It was originally known as Tinsley Green, and opened on 30th September 1935, shortly before the new airport started services in 1936. The station was later renamed Gatwick and was served by 30 rail services a day from London to Brighton and 36 on the return journey to London (figures 8.40 & 8.41).

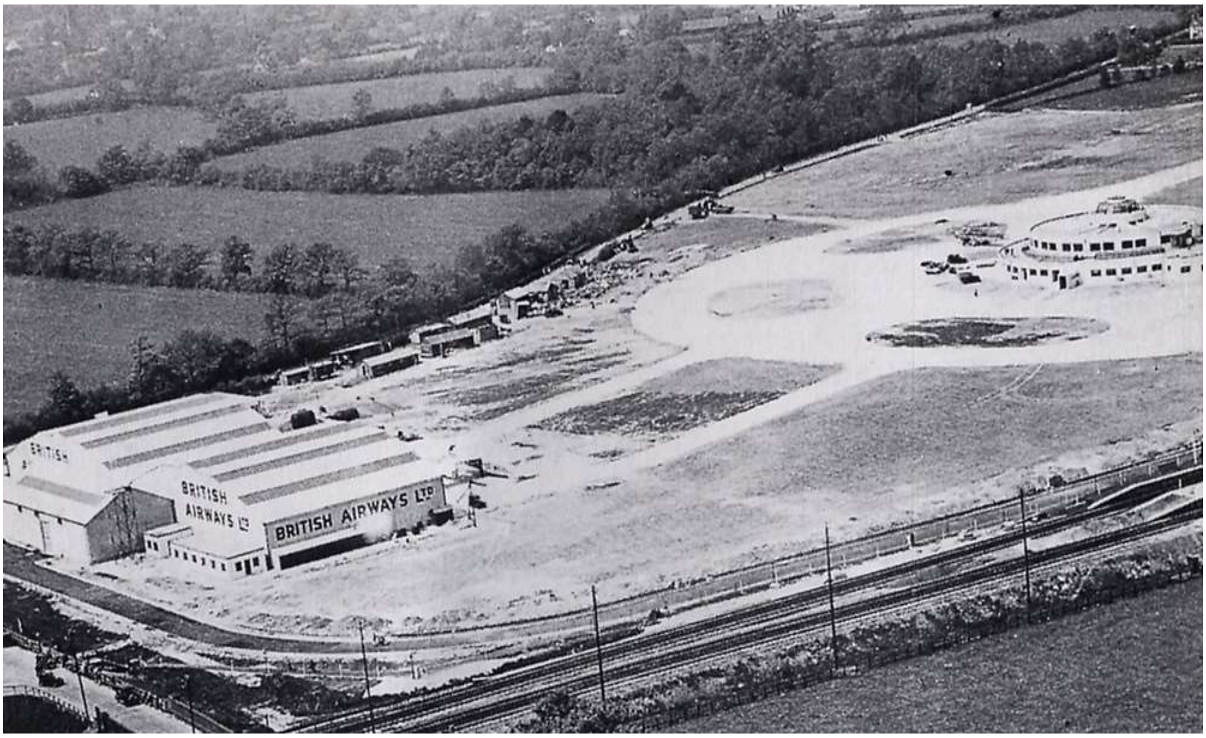


Figure 8.40 – Aerial view of Gatwick, 1936, with the railway and station in the foreground – Source: YRM Library (reproduced with permission from RMJM)

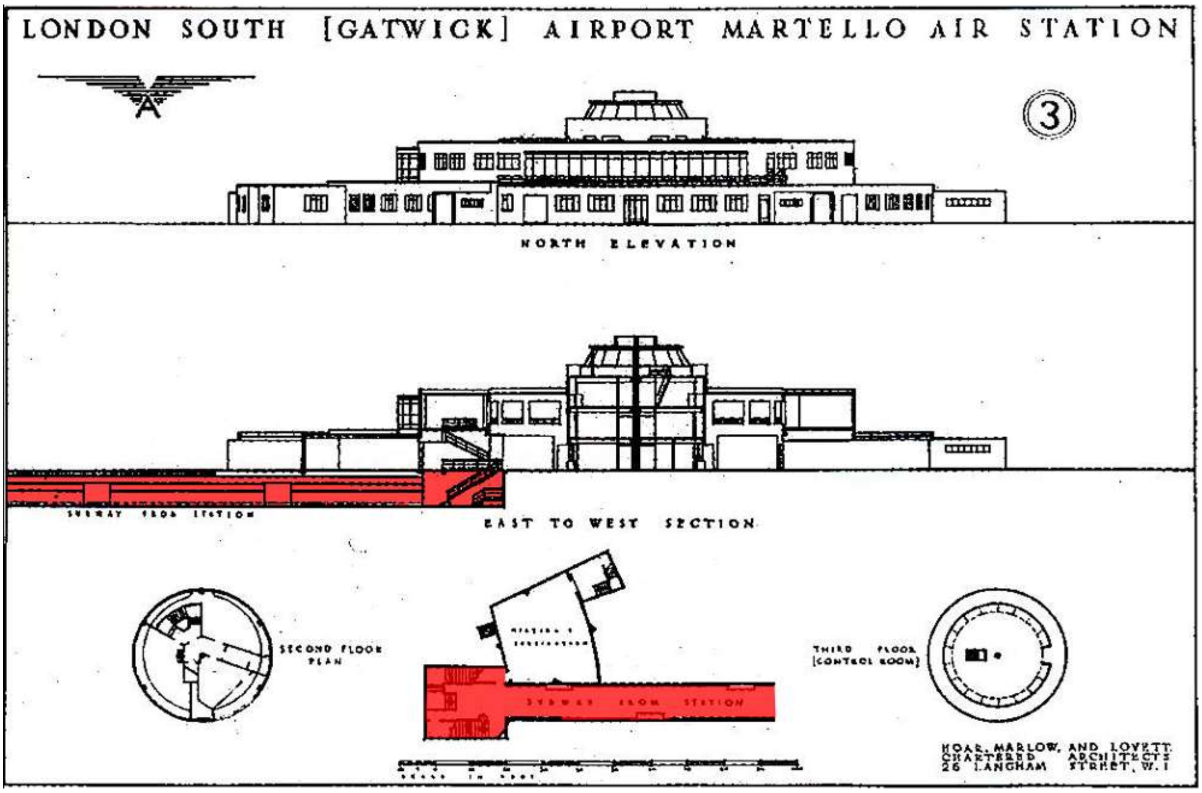


Figure 8.41 – Gatwick 1936 terminal with underground link to station highlighted in red – Source: RIBA Library

Heathrow, originally conceived under cover of war time secrecy, was announced to the public in 1946. It featured the first terminal area to be developed in the middle of the airfield. Unlike contemporary airport master plans for New York and Chicago, its unique 'Star of David' configuration required all the connecting surface access infrastructure to be routed underground to reach the central terminal area (figure 8.42).

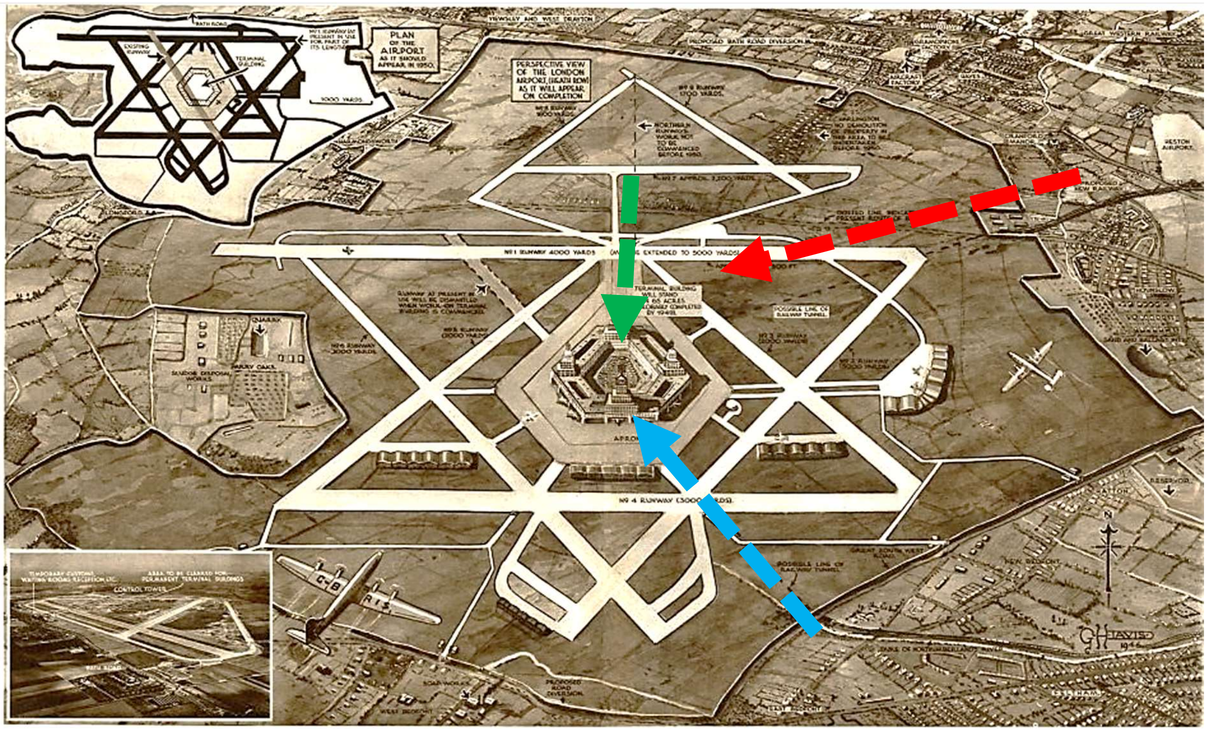


Figure 8.42 - Heathrow master plan 1946 - Source: Illustrated London News, Saturday 25 May 1946

The green arrow shows the underground road link from the A4, the red arrow the underground rail link (built later as the Heathrow Express, and due to form part of the Elizabeth Line) and the blue arrow an extension to the Piccadilly underground line. While the underground road link was built at the outset for the opening of the first permanent terminal in 1955 it took until 1977 before the Piccadilly line extension to the Central Terminal Area was completed and 1998 before the Heathrow Express rail link opened. While it took a very long time to realise the concept this was the first airport concept to envisage integrating both rail and underground metro links into the airport master plan.

Gatwick Airport and its original 'Beehive' terminal were closed in the mid-fifties to make way for a new much more ambitious airport that was originally primarily aimed at handling diversionary traffic from Heathrow, but soon became a fast expanding base for the burgeoning inclusive tour charter traffic. It was located just to the north of the original airport on the site of the horse racecourse that had hosted the Grand National for several years during the First World War.

The terminal was dramatically located directly over and spanning the diverted A23 and integrated with a new railway station. It was the first airport to have a railway station integrated under one roof. As a result Gatwick has always had a high percentage of passengers arriving by rail, in 2017 it was 34% of all passengers, against 36% arriving by car (figure8.43 & 8.44).

Figure 8.43 - London, Gatwick 1958 – Source: British Caledonian

Figure 8.44 - Gatwick with Rail Station, Interchange and Transit Link to the North Terminal in the foreground - c2000 Source: BAA

Amsterdam, Schiphol was one of the first airports to open a main line railway station that linked two major cities, the capital The Hague, and the commercial centre, Amsterdam. As Schiphol has persevered with a single terminal operation the railway station could be ideally located underground to serve both arriving and departing passengers. It later developed as a transfer hub to support KLM, investing heavily in a sophisticated baggage system to deliver excellent minimum connection times for transferring passengers that were vital to the airline's business model. Schiphol is now a highly regarded international transfer hub. It has even promoted itself as London's 3rd airport (figure 8.45) as it serves more UK regional airports than either Heathrow or Gatwick making it an important transfer hub.

Figure 8.45 - Amsterdam, Schiphol Interchange– Source: Schiphol Airport

London City Airport has one of the highest percentage of passengers using rail access of any airport at 62%. This is because the Docklands Light Railway, which was extended to the airport in 2005, connects the airport directly with the City, Canary Wharf and other key locations in East London making it the fastest and most convenient way of reaching the airport. The airport is committed to increasing DLR mode share for passengers to more than 70% by 2025. The airport's location in the Royal Albert Dock and connection to the River Thames enables the potential for river transport to be a real possibility for access by passengers and staff. Historically a river service was operated between The City and the airport with passengers being dropped at City Pier, close to Royal Albert Dock's western end, and then transported by bus for the remainder of the journey to the terminal building. However, this service has not operated since 1993 and today there is no real offer for airport passengers and staff to travel by river. With the ever increasing and much needed development of sites along the River Thames there could be a viable opportunity to introduce a dedicated stop for the airport providing connections both east and west along the River Thames, and particularly to areas that are not otherwise accessible by DLR, London Underground or overland rail services (LCY, 2017).

Zurich Airport also offers, in conjunction with Swiss Railways, an integrated service to pick up and deliver baggage to selected railway stations in Switzerland.

Paris, Charles de Gaulle also has excellent road and rail connections and promotes itself as an international transfer hub to support Air France. At the heart of the Terminal 2 complex an international rail station (1994) links the airport with the TGV network and Eurostar services. The airport is also directly linked to the Paris Metro network and RER regional network (figure 8.46).

Figure 8.46 - Paris, Charles de Gaulle, TGV Station 1994 – Source: Aeroport de Paris

Seoul Incheon International Airport is unique in having a direct high speed rail link to Seoul Gimpo Domestic Airport to facilitate transfer traffic before continuing to the City Centre (figures 8.47, 8.48, 8.49 & 8.50).

Figure 8.47 – Seoul Incheon to Seoul Gimpo AREX rail link - Source: The Global AirRail Alliance

Figure 8.48 – Seoul Incheon rail network – Source: The Nation


Figure 8.49 – High speed rail link from Seoul Incheon to Pyeongchang - Source: 2018 Winter Olympic Games

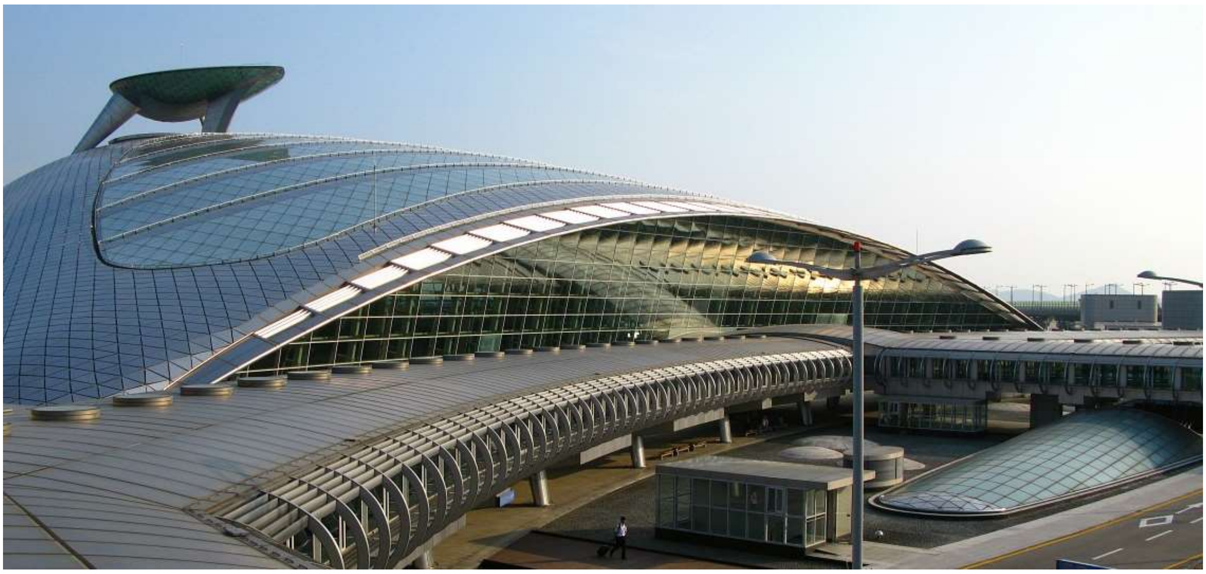


Figure 8.50 - Seoul Incheon Airport Terminal 1 Interchange 2001 – Source: Thousand Wonders

8.4 Sea to Air Infrastructure

It may not be immediately obvious why seaplane bases form part of this story, but a number of innovations were first seen there, added to which some of the vocabulary used in aviation originates there including (air)port, pier and jetty.

The Pan American Airways seaplane base (1930) at Miami was the first airport developed by an airline. Airline designed and financed terminals have subsequently formed the model for many airports in the USA but the approach has rarely been employed in other countries, although in some cases such as Munich Terminal 2 and Birmingham Eurohub (now terminal 2) development cost have been shared by the airport and airline.

Miami was also one of the earliest airports to employ covered walkways and jetties, an idea that later evolved into the passenger boarding bridges we use today (figure 8.51).

Figure 8.51 - Miami, Dinner Key 1930 – Pan American Airways Seaplane Base and Terminal – Source: Wikimedia.org

The airport was known as the “Air Gateway between the Americas,” as the Pan American Seaplane Base and Terminal Building at Dinner Key linked the United States and Latin America. At the time of its construction in the midst of the Great Depression, the Art Deco style building was the largest and most modern marine air terminal in the USA. The famous Pan Am “Clipper” Flying Boats opened major trade and passenger routes, and made Miami a centre of international air transportation.

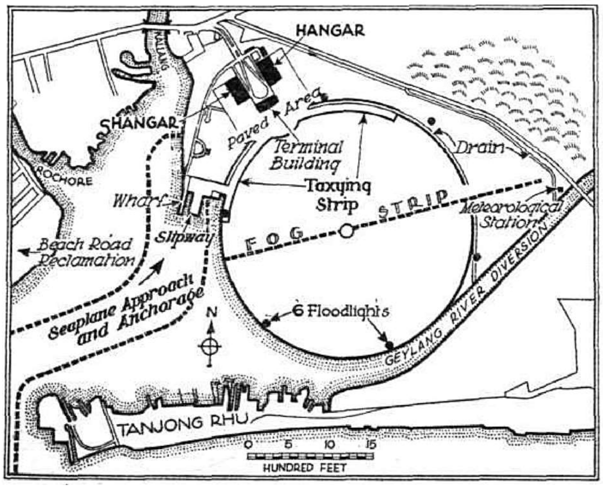


Figure 8.52 - Singapore Kallang 'Land/Sea' Airport
Source: Flight Global 26.08.1937

The design concept for Singapore, Kallang was well publicised in the British press in the late 1930s both for its modern Art Deco imagery and innovations that included a circular control tower, and retractable boarding canopies but also for the idea that it should handle both short haul land planes and long haul sea planes and so became an early example of an airport conceived of as an interchange (figures 8.52, 8.53 & 8.54).

Figure 8.53 - Singapore, Kallang, terminal landside in the early 1950s and airside after closure and restoration - Sources: Courtesy of Mr Koh Kim Chay & Singapore National Library Board

Figure 8.54 - Singapore, Kallang Aerial Photographs 1945 - Combined Landplane & Seaplane Airport, showing airfield and sea plane approach - Sources: Pinterest & Collection Database, Australian War Memorial, ID 119757 Photographer: Lieutenant R.J. Buchanan

La Guardia took this one step further in 1939 and introduced for the first time the idea that there could be more than one terminal at an airport, specialising in a particular segment of traffic, in this case one terminal to serve domestic/short haul landplane services and another to serve international/long haul seaplane services (Figure 8.55 & 8.56).

Figure 8.55 - New York, La Guardia 1940, Seaplane Terminal – Source: Smithsonian Institution Photo Hans Groenhoff

Figure 8.56 - New York, La Guardia, summer 1940 – A Pan Am B314 at anchor in Bowery Bay. At upper right is Rikers Island Channel, take-off and landing area for the Boeing Clippers – Source: www.flightwisdom.com

Seaplanes became obsolete soon after the war as the range and performance of landplanes increased, but seaplane bases still continue to serve small specialised and mainly leisure markets, in coastal cities as can be seen at Sydney (figures 8.57 & 8.58).

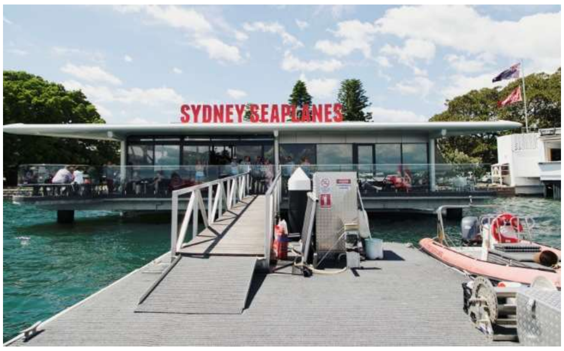


Figure 8.57 - Sydney Seaplanes
Photo- Parker Blain - Source: Broadsheet Sydney

Figure 8.58 – Sydney Seaplanes
Source: Alquemie.com.au

As well as serving the leisure market, with a sophisticated Interchange that links cruise ships with small seaplanes accessed via multiple piers, the Vancouver Seaplane Terminal serves numerous isolated and inaccessible coastal communities (figures 8.59 & 8.60).

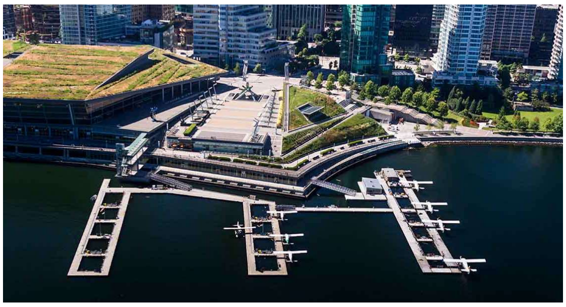


Figure 8.59 – Vancouver Seaplane Terminal
Source: Vancouver Harbour Flight Centre

Figure 8.60 - Vancouver Seaplane and Cruise Terminal
Source: Vancouver Harbour Flight Centre

An example of an interchange that links long haul and short haul flights today can be found at Male in the Maldives but in this case the precedent set by La Guardia is reversed with the long haul flights by landplanes while the short haul services that link the many islands are flown by seaplanes (figure 8.61).

Figure 8.61 - Male, Maldives – Transfer between long haul land based airplanes and island hopper seaplanes
Sources: http://www.transmaldivian.com/services/and blog.holidaysplease.co.uk

There have been many dreams of integrating seaports with airports and railways as can be seen in the early proposal by the Austin Company in 1928 (figure 8.62).

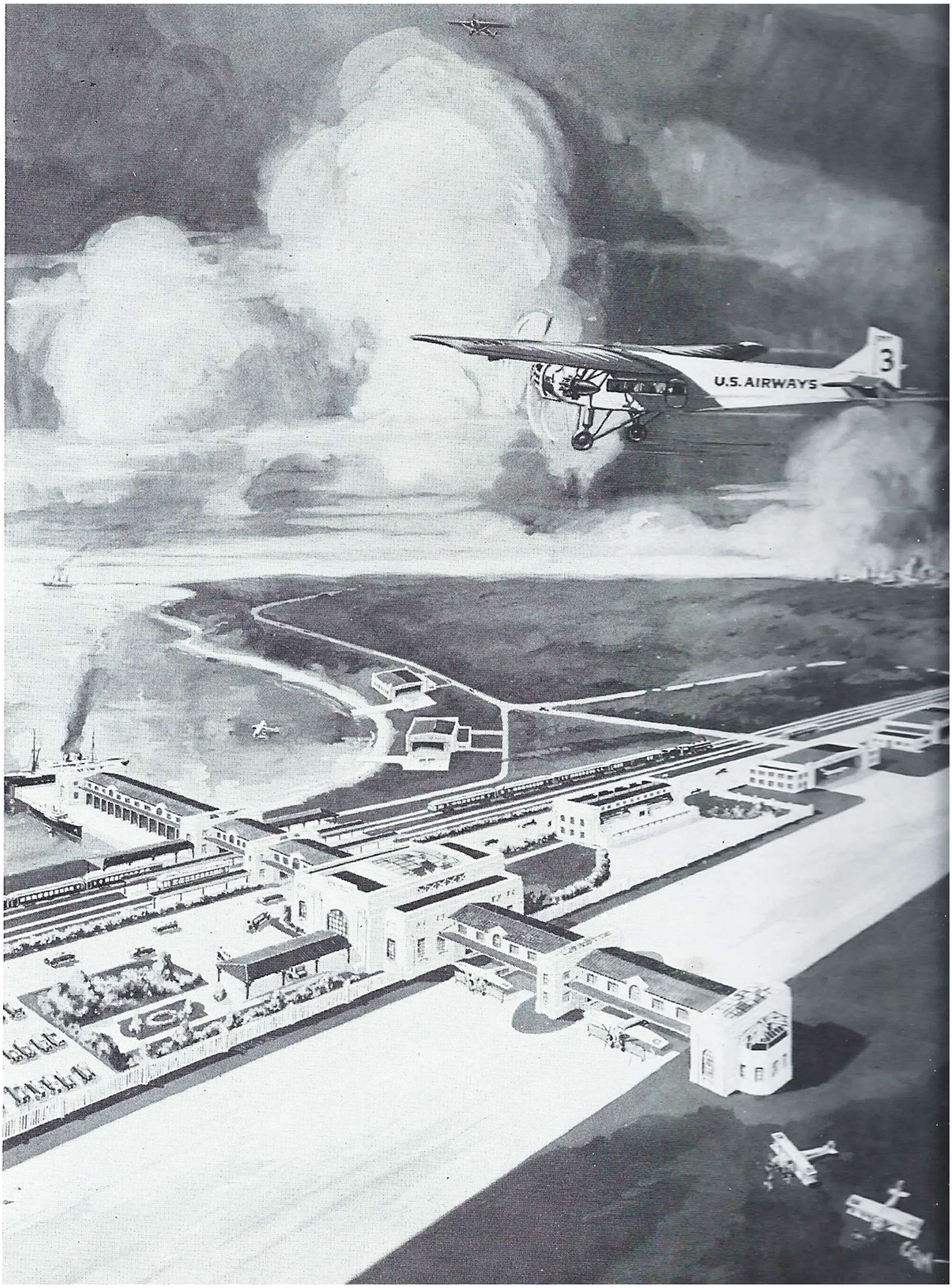
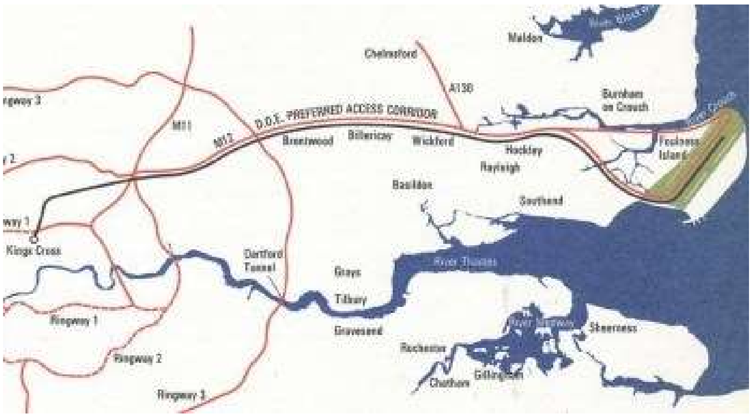


Figure 8.62 – Terminal for ocean liners, trains, airplanes and seaplanes 1928 – The Austin Company
Source: The Airport Book, Martin Greif

The reality is that sea and air travel serve very different markets, one based on bulk movement and the other speed, so there is very little synergy. As a result there is typically very little demand to change from one mode of transport to another, with only a few very notable exceptions. However there have been some proposals to co-locate air and sea ports on adjacent sites to share the costs of providing road and rail links to the cities they serve. One such example was the British Airport's 1973 proposal for London's Third Airport at Foulness on the Maplin Sands, alongside the Port of London Authority's proposals for a deep seaport on an adjacent site.

After reclaiming the land at Foulness, an airport would be built starting with a single runway at its opening. By 1986, it would be able to serve 32 million passengers. By the late 1990s, the airport would have four runways and ten terminals and would serve up to 120 million people per year at a cost of approximately £1 billion Access would be by a non-stop rail service from Kings Cross, taking just 40 minutes. There would be a motorway link from the planned London Ringway (subsequently abandoned but parts would become the M25) and both the road and the railway would enter the spine of the airport from the south and later continue from the north end of the site. The airport would handle 32m passengers annually by 1986 and 120m when completed in the late 1990s (figure 8.63).

The Port of London Authority had identified the potential of Maplin a decade earlier and had extended its area of responsibility to include the site. It had seen the need for a major deep-water container port and a terminal for super-tankers and was eager to start construction. The reclaiming of 30 square miles at Maplin was just part of its broad plans to reclaim some 300 square miles along the Thames estuary (Hurst, 2012).



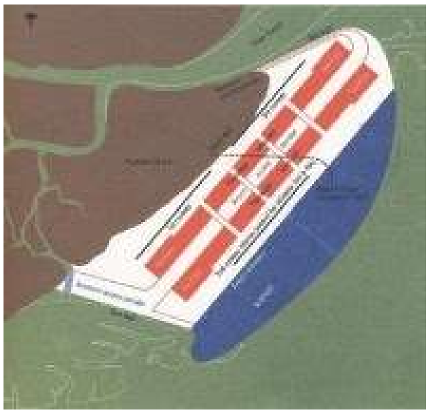


Figure 8.63 - Proposed Third London Airport, Foulness, Thames Estuary c1973 - Source: UK Progressive

Other airports that make a virtue of linking water and air travel include London City Airport and Venice, Marco Polo. A river bus service from central London served London City Airport, until the opening of the Docklands Light Railway rendered it obsolete (figure 8.64).

A public water bus (vaporetto) service runs from the airport dock to Venice and the outlying main islands (Murano, Burano, Lido).Within the passenger terminal at Venice Airport is a separate area for the water services with a large electronic departures and arrivals board just like for the aircraft. There are 5 services in total serving all the main islands. The beauty of this service is that there will be a stop quite close to your accommodation in Venice, which is highly unlikely if using the airport bus service (figure 8.65 & 8.66).

Figure 8.64 - River boat to London City 1988   Source: London City Airport


Figure 8.65 - Marco Polo, Venice, Master Plan 2030 – Source: One Works

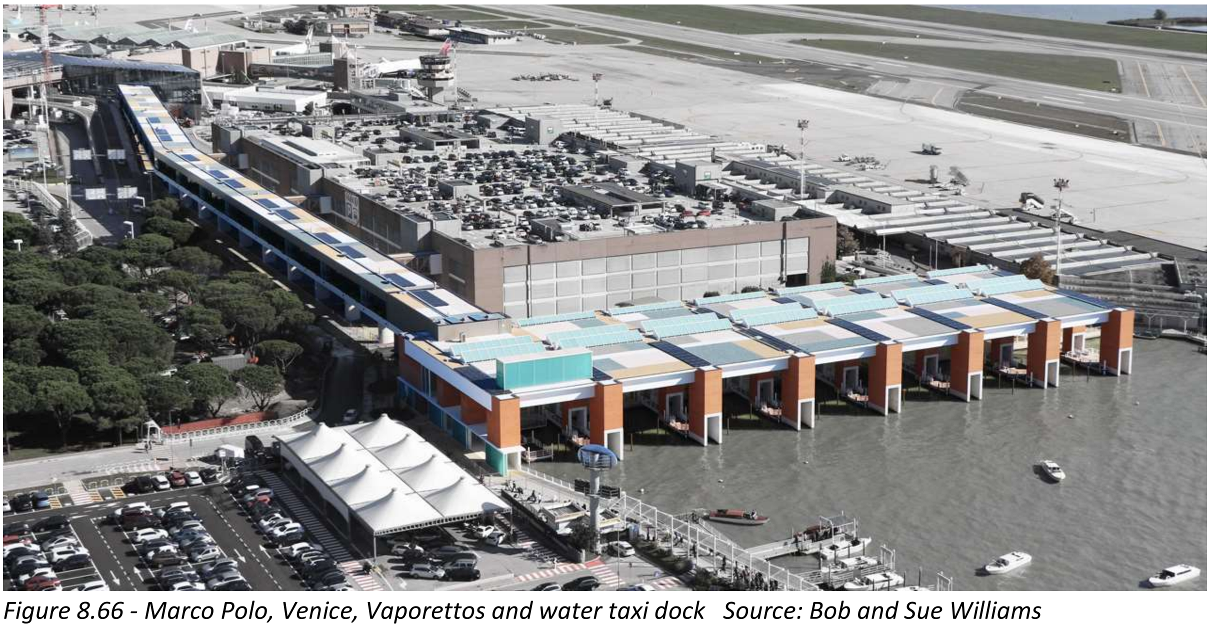


Figure 8.66 - Marco Polo, Venice, Vaporettos and water taxi dock   Source: Bob and Sue Williams

Kansai Airport 1994 Ferry Terminal includes an unusual Air to Sea to Air connection with a high speed ferry that links it to Kobe Airport and provides a more direct route to the city of Kobe than travelling by road. The route is shown in red on the map below (figure 8.67).

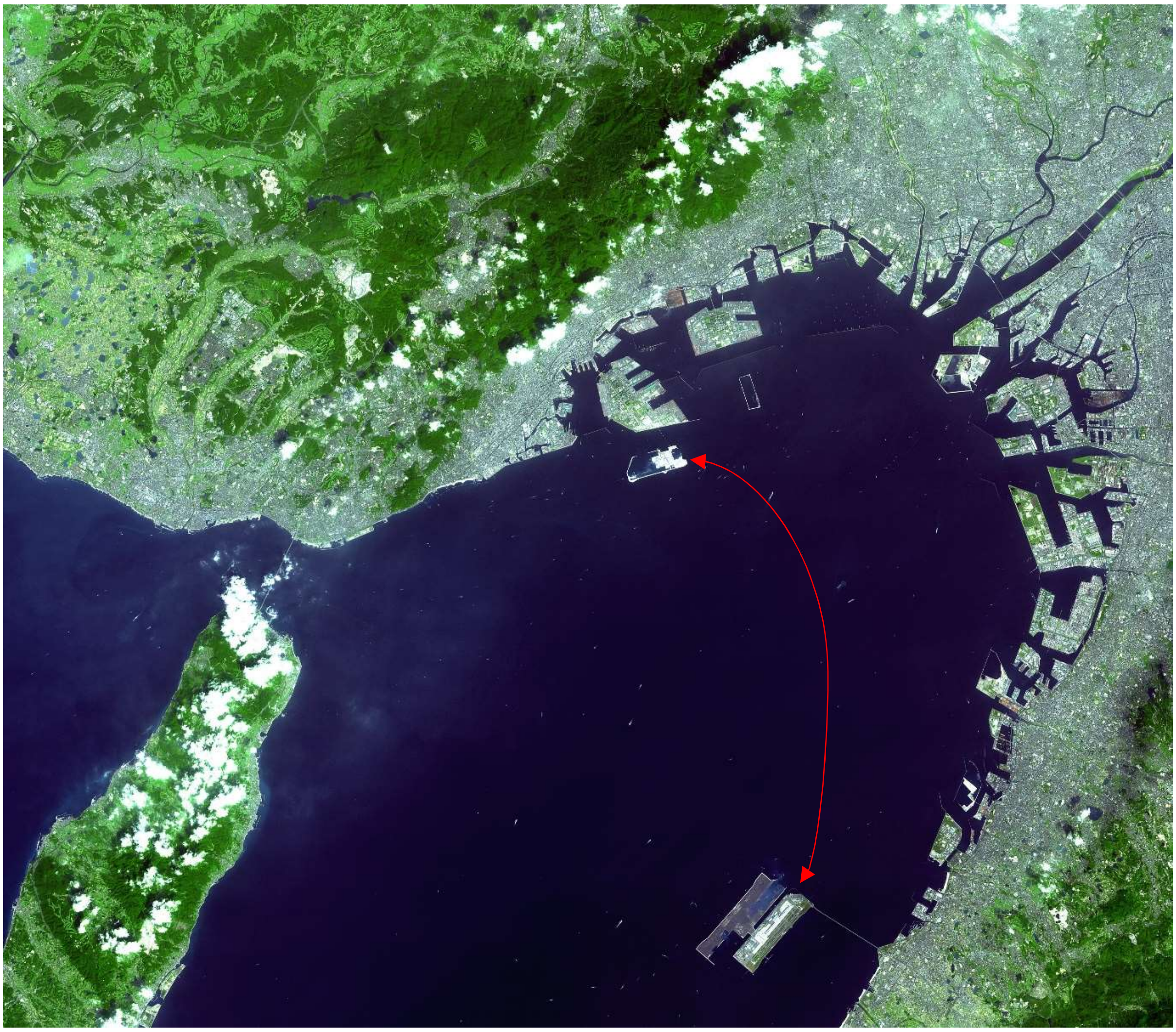


Figure 8.67 - Osaka Kansai 1994 to Kobe Sea Transfer - Source: Wikimedia http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16451

Hong Kong Airport includes a unique air-sea transfer facility known as SkyPier (2003) which supports very a successful sea route to nine ports in the Pearl River Delta of mainland China and Macau. Passengers arriving by ferry from China are routed through a dedicated transfer processing facility that includes check in and security check to allow passenger to access the terminal airside via a dedicated transit system. SkyPier has eight berths and is designed to handle up to 8 million passengers a year. It currently has over 110 scheduled sailings a day (figure 8.68, 8.69 & 8.70).

The Marine Cargo Terminal (MCT) is a component of aviation logistics services at Hong Kong International Airport (HKIA) offering one-stop air-sea inter-modal transportation services connecting HKIA with 18 ports in the Pearl River Delta (PRD) region. The role of the MCT is to facilitate cargo distribution and provide an alternative mode of transportation between the PRD region and HKIA ((figure 8.71).

Figure 8.68 - Ferry Routes to HKIA from the PRD
Source: HKIA Masterplan 2030

Figure 8.69 – HKIA Land, Sea Air Transfer
Source: Airport Authority Hong Kong

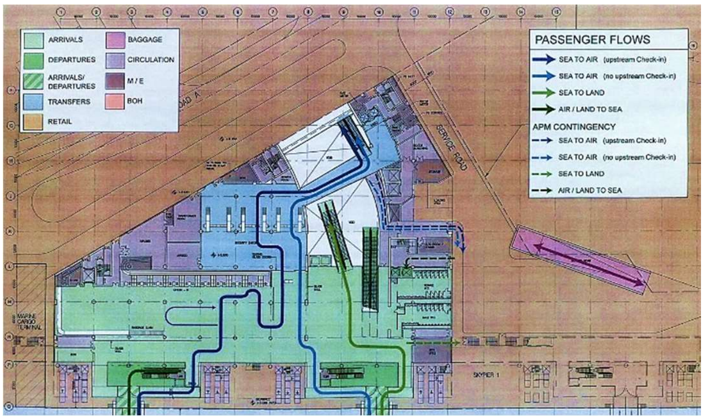


Figure 8.70 – HKIA SkyPier 2003 Passenger Flow Layout
Source: Airport Authority Hong Kong

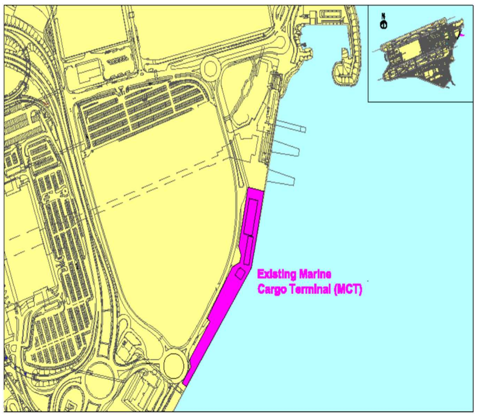


Figure 8.71 - HKIA Marine Cargo Terminal
Source: HKIA Masterplan 2030

An artificial island constructed off the coast of the Gaza Strip was proposed by Israel's intelligence and transport minister in 2017. It is arguably political propaganda rather than a serious design proposal but if constructed the projected island would include cargo and passenger ports, a marina, gas and electricity terminals, a desalination plant and space for an airport in the future (figure 8.72).

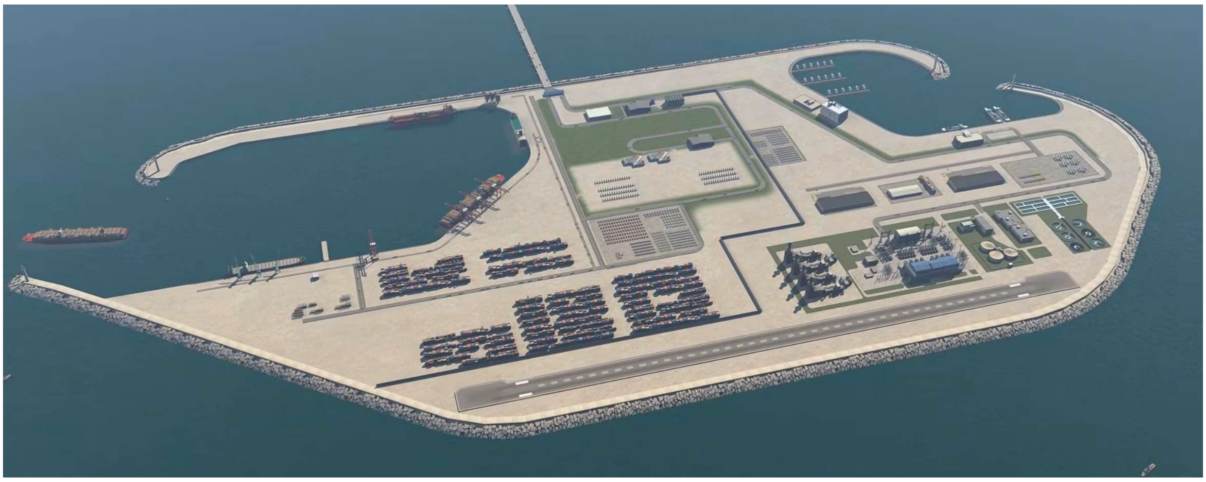


Figure 8.72 - Gaza Airport and Seaport 2017 - Source: ET Magazine (Engineering and Technology)

Israel envisaged retaining control of security in the sea around the island and carrying out inspections at the port, and proposed that an international policing force would be responsible for security on the island and at checkpoints on the bridge. It envisaged an international consortium building the 525-hectare island five kilometres offshore and connecting it to the mainland via a causeway, which would have a bridge in the middle that could be raised, cutting off access.

Dubai Al Maktoum Aerotropolis includes Al Maktoum International Airport and is planned as Dubai's airport of the future and will connect the airport with the Jebel Ali Seaport. The first phase of the airport opened with cargo operations in 2010 followed by passenger services in 2013. Upon completion, the airport will become the world's largest airport with an ultimate capacity of 160 – 220 million passengers and 12 million tonnes of cargo per annum (figure 8.73).

Dubai World Central (DWC), which claims to be the world's first purpose-built Aerotropolis, is a strategic initiative of the government of Dubai to enhance the emirate as a leading international trade centre. It comprises several key components in a 140 km^2 multiphase development of six clustered zones - the Al Maktoum International Airport (AMIA) forms the heart of a greater project, which includes Dubai Logistics City (DLC), Aviation District, Business Park, Commercial District, Residential District, Golf District, Exhibition District and Humanitarian District - which collectively serve as a strategic platform for the expansion and growth of aviation, logistics, light industry and ancillary service businesses.

DWC is located near Jebel Ali Port and Free Zone and will make air-sea connectivity achievable in four hours, with a dedicated road linking the airport and seaport that allows enterprises in the Free Zone direct access to both the Airport and Seaport directly. DWC offers 100% tax free operations and 0% corporate taxation combined with 100% foreign ownership (figure 8.74).

Figure 8.73 - DWC Location plan - Source: AEC Online

Figure 8.74 - DWC Sea-Air logistics Corridor Source: Pinterest

In a report by IATA for Hong Kong International Airport and included in the HKIA Master Plan 2030 they stated that over the past 15 years, the correlation between air cargo demand and world trade has been declining steadily and advised there were two primary reasons for this decline in the following illustration (figure 8.75):

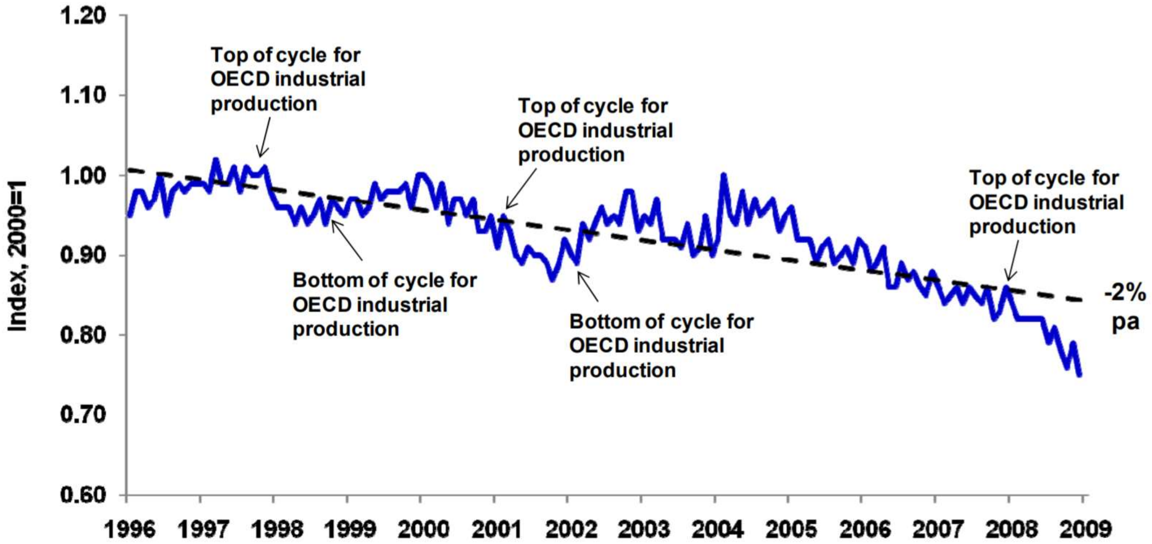


Figure 8.75 - Extract from HKIA 2030 masterplan 2030 – Air Freight as a ratio to world trade – 1996 -2009 Source: IATA

The first comes from increased competition from containerised shipping due to technology advances, increased speed, improved reliability and lower costs of sea transportation.

While the other is due to variations in product life cycles can be seen in the following examples:

- As products mature and demand is stable or declining, a shift from air to sea transportation can be seen in order to keep costs down.
- As a new generation replaces ageing products, air shipment is preferred to get the new product to market quickly.
- As new generations of products become lighter and lighter, growth of air freight tonnage carried slows.

So even where administered together such as the New York Port Authority, or Amsterdam Airport and Seaport, there have been a limited number of attempts to integrate air and sea freight, and the decline in airfreight envisaged by IATA means it is increasingly unlikely that air and sea cargo operations will be integrated.

The exceptions include Hong Kong because the special geography of the Pearl River Delta makes it faster to link some mainline Chinese cities with Hong Kong by sea than by road, and Dubai where the Freezone makes it possible for businesses to link with both the seaport and the airport within a tax free zone.

8.5 City Centre Air Links

Instead of taking people from the city to an airport in the country there were plans to bring airships to the centre of the city of New York and be moored at the top of the Empire State Building (Figure 8.76) when it opened in 1931.

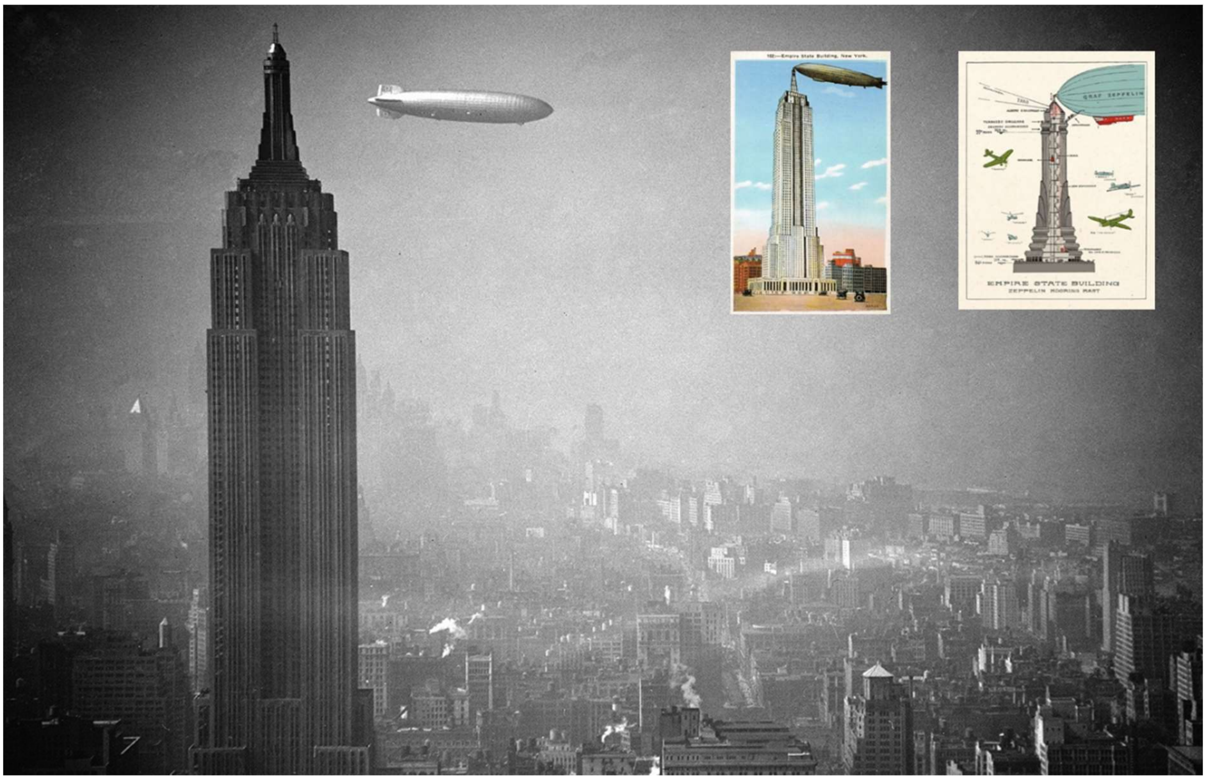


Figure 8.76 – Empire State Building, New York with Hindenburg passing in 1936, with inset details of the mooring mast - Source: wordpress.com

The building's distinctive Art Deco spire was originally designed to be a mooring mast and depot for dirigibles. The 102nd floor was originally a landing platform with a dirigible gangplank. A special elevator, travelling between the 86th and 102nd floors, was supposed to transport passengers after they checked in at the observation deck on the 86th floor.

However, the idea proved to be impractical and dangerous, and after a few attempts with airships at other skyscrapers the idea was abandoned. This was due to the powerful updrafts caused by the size of the building itself, as well as the lack of mooring lines tying the other end of the craft to the ground. Dr Eckener, the commander of the Graf Zeppelin had previously advised that the project was impractical.

Many Heliports have been proposed within city limits, such as the Bell Textron heliport, but few have been built and even fewer still operate because of safety and noise issues (figure 8.77). Only a sprinkling of short take-off and Landing Airports (STOLports) have been constructed within rather than beyond the city fabric. A notable exception is London City Airport which relies heavily on the Canary Wharf business district for its unique urban catchment (figure 8.78).

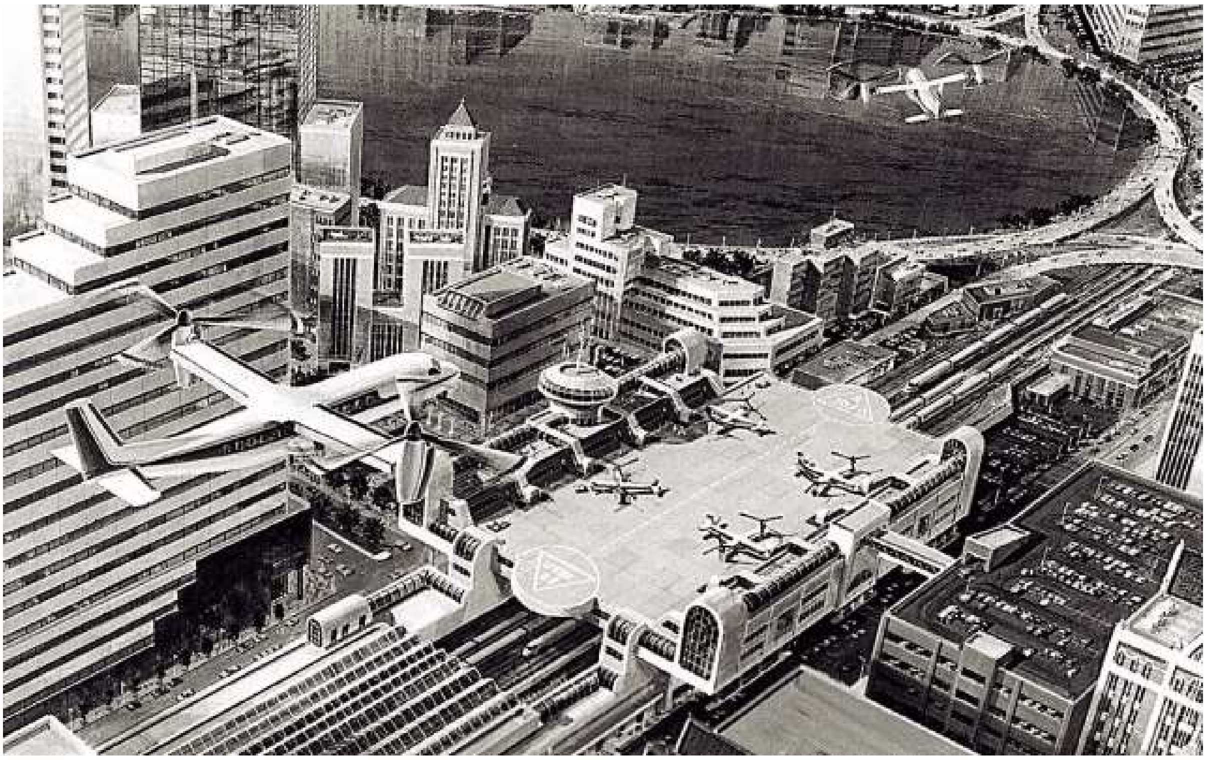


Figure 8.77 - Bell Textron – Concept for Inner City Airport 1994 – Source: Bell Helicopter Textron

Figure 8.78 - London City STOLport c2000 – Source: London City Airport

8.6 Air to Air Infrastructure

The invention of the Automated People Mover (APM), was vital to the large hub airport to transport passengers over ever increasing distances. It was first employed on a relatively modest scale at Tampa Airport in 1971 (figure 8.79).

Figure 8.79 – Tampa automated people mover linking the terminal with remote satellites 1971 – Source: Westinghouse (later Bombardier and now Adtrans)

The Airport Train at the Dallas Fort Worth International Airport, which opened for service in 1974, is unique for a number of reasons. First, it was the first network APM system built. To date, it is the only network system ever built with individual trains following different routes direct to individual terminal stations (figure 8.80).

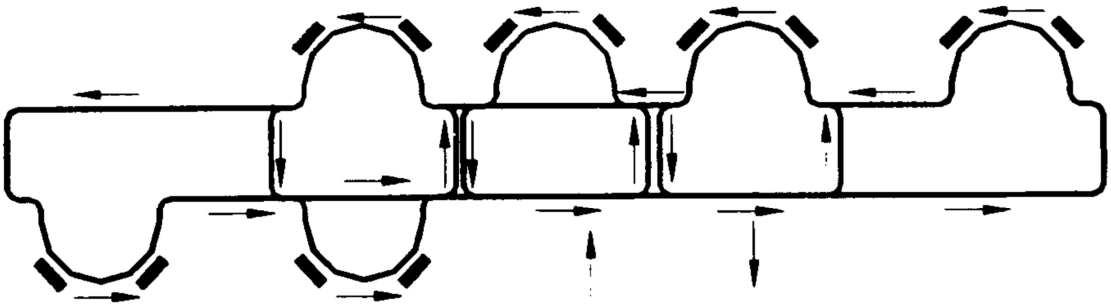


Figure: 8.80 - Dallas Fort Worth 1974 – Network APM system – Source: Journal of Advanced Transportation, Vol. 33, No.1, p.35-50

Secondly, the Airport Train is the largest APM system ever built, with over 13 miles of operating guideway, 68 vehicles, and over 50 stations. Third, it was the first APM to incorporate operational switching.

The DFW Airport Train represented an audacious attempt by its designers, Vought Aeronautics Corporation, to combine both passenger and goods transportation into one, integrated system (figure 8.81). When it opened, the Airport Train transported transfer passengers and baggage, staff, airmail, goods and waste (Elliott, 2010).

Since opening the use of the transit for baggage, goods and waste has been abandoned but the passenger system has been updated and expanded to serve a new international terminal. It continues to support very effectively passenger transfer from one terminal to another. The elevated airside route provides panoramic views of the airport for the passenger when transferring between terminals.

Figure 8.81 - Dallas Fort Worth 1974 – Vought Airtrans Automated People and Goods Mover System – Source: Wikipedia https://creativecommons.org/licenses/by-sa/2.0

The underground APM System at Atlanta Hartsfield International Airport links the terminal with a series of satellites using a pinched loop APM configuration which allowed the transit to turn around at the end of the route and so increase capacity beyond that of a simple shuttle system (figure 8.82).

Figure 8.82 - Atlanta Hartsfield underground APM system 1980 - Sources: Atlanta Hartsfield and Westinghouse

While operational switching had been utilized previously at Dallas Fort Worth, the Atlanta system was the first to utilize switching with the coordinated reversing movements at end stations to allow two parallel linear guideways to accommodate a loop mode of operation and offer unprecedented capacity. In case of failure it is backed up by a tunnel walkway that incorporates passenger conveyors.

Heathrow Terminal 5 was developed following the Atlanta model using a pinched loop APM configuration, supported by back-up tunnel incorporating passenger conveyors, which helps to make it one of the most competitive transfer hubs in Europe delivering minimum connection times of 45 - 60 minutes (figure 8.83).

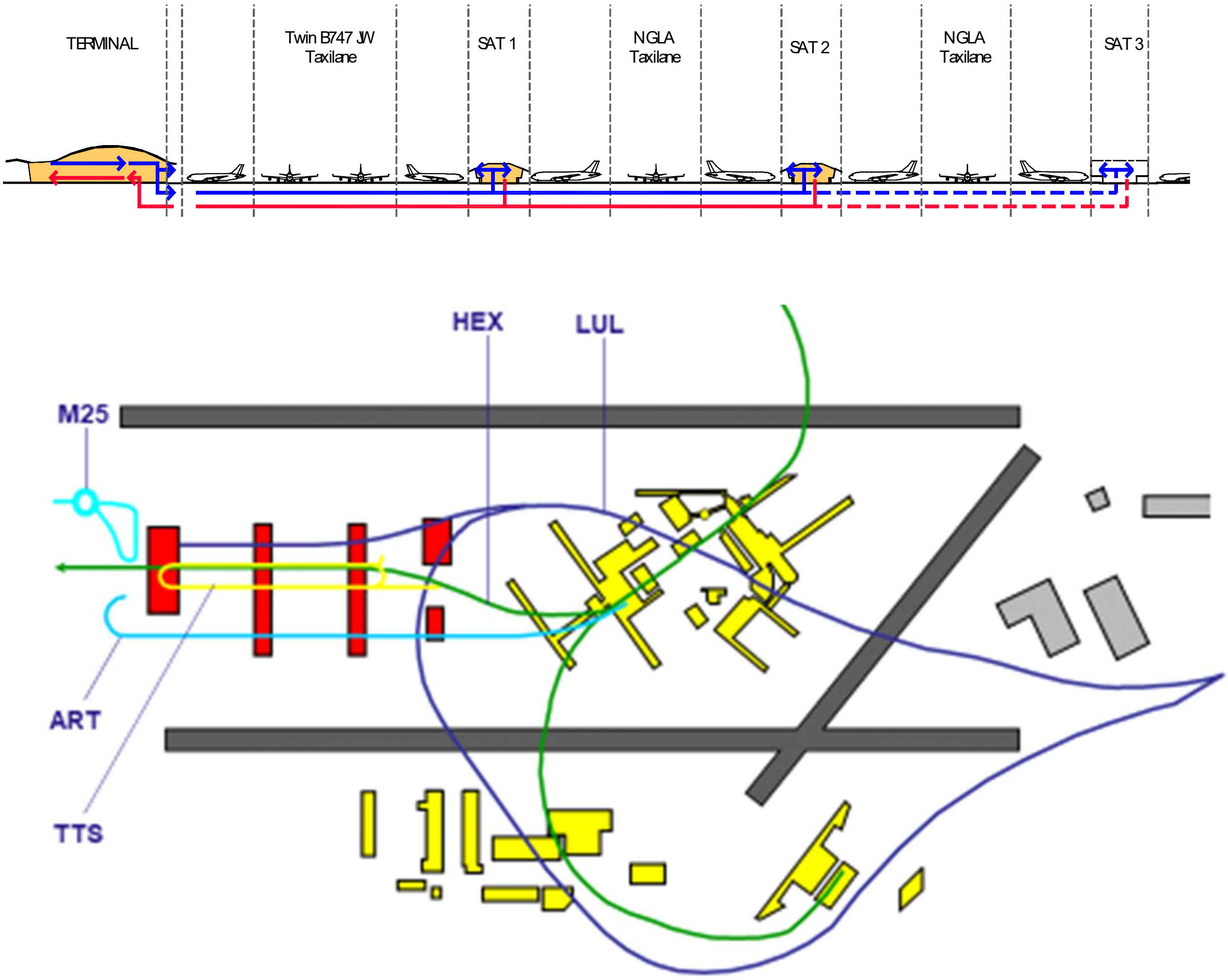


Figure 8.83 - Section and site plan showing the tracked transit system (TTS) or APM 2008 – Source: YRM (reproduced with permission from RMJM)

Key: *TTS – tracked transit system or automated people mover*
ART – airside road tunnel linking Terminal 5 with Terminals 1, 2 and 3
HEX – Heathrow Express high speed rail link to London
LUL – London Underground Ltd Piccadilly line
M25 – London orbital motorway

8.7 Mega Hubs

Mega Hubs exist primarily to allow Airline Global Alliances to serve the transfer market to supplement direct point to point traffic. Alliances started in the late 1980s when Northwest Airlines and KLM began code sharing. There are now three major Alliances: One World, Star Alliance and Sky Team that were established either side of the millennium. They typically comprise full service or legacy airlines that rely on a high proportion of interlining transfer traffic to make their business model work. This has led to a new generation of Mega Hub airports and the updating of existing airports to serve this new market.

The focus of these Mega Hubs is to make the transfer process as smooth and fast as possible but sheer size is also a vital component. Most Mega Hubs are designed to handle over 50 and some over 100 million passengers per annum (MPPA).

Dubai World Central, the largest currently being designed, is being planned to handle over 200 MPPA to serve Emirates Airline and its code share partners. The model for these Mega Hub airports originated in the domestic market in the USA at airports such as Atlanta, Chicago O'Hare and Dallas - Fort Worth.

American airports, however, only handle domestic transfers, and any international transfer passengers have to land, passing through immigration and customs processes before checking-in for a new flight. USA domestic transfer passengers do not have to be re-security screened, and arriving and departing passengers can mix freely when transferring making the transfer process for domestic traffic very simple.

By contrast with American practice modern international airports have more complex process requirements as transfer passengers and their baggage on international flights are typically security screened between their arriving and departing flights.

Megahubs serving the Global Alliances relying on transfer traffic include:

- Europe: London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, Frankfurt and Madrid Barajas
- Middle East: Dubai International, Dubai World Central, Doha and Abu Dhabi
- Asia: Hong Kong Chek Lap Kok, Singapore Changi, Seoul Incheon and Bangkok
- USA: Atlanta, Chicago O'Hare, Dallas Fort Worth and Denver.

Two models are commonly found:

1. Arriving passengers and departing passengers are allowed to mix freely in circulation areas. Departing passengers are then security screened at their departure gate and held in a secure boarding area before enplaning. The main advantage of this option is that common arriving and departing circulation simplifies the terminal layout reducing capital cost, and facilitating the fastest possible transfer times typically known as minimum connection times (MCTs) but at the expense of considerable operating cost.

2. Arriving passengers are segregated from departing passengers and security screened at centralised points in the terminal after which they can mix freely with departing passengers. This option is inherently safer because it prevents exchange of materials between arriving and departing passengers, and is more economical to operate but extends transfer times and increases capital cost.

Both models can be found in major international airports. The complexity of passenger movement in a modern international airport is illustrated in the following, diagram of arriving, departing and transfer passenger flow at Heathrow Airport (figure 8.84) which segregates arriving from departing passengers,. Domestic passenger flows are shown in red and international passenger flows are shown in blue.

In the cross section (figure 8.85) departing passenger flows are shown in blue arriving passenger flows in red and transfer passenger flows are shown in green.

A complementary baggage flow diagram is shown in the next section drawing (figure 8.86).

An exploded isometric of the multi-level Heathrow Terminal 5 shows the complexity of the underground linkages between the terminal and the satellites (figure 8 .87).

Finally an aerial computer generated image of Terminal 5 shows its relationship with the M25 and western perimeter road in the foreground, the northern and southern runways either side, and Terminal 3 in the background (figure 8.88).

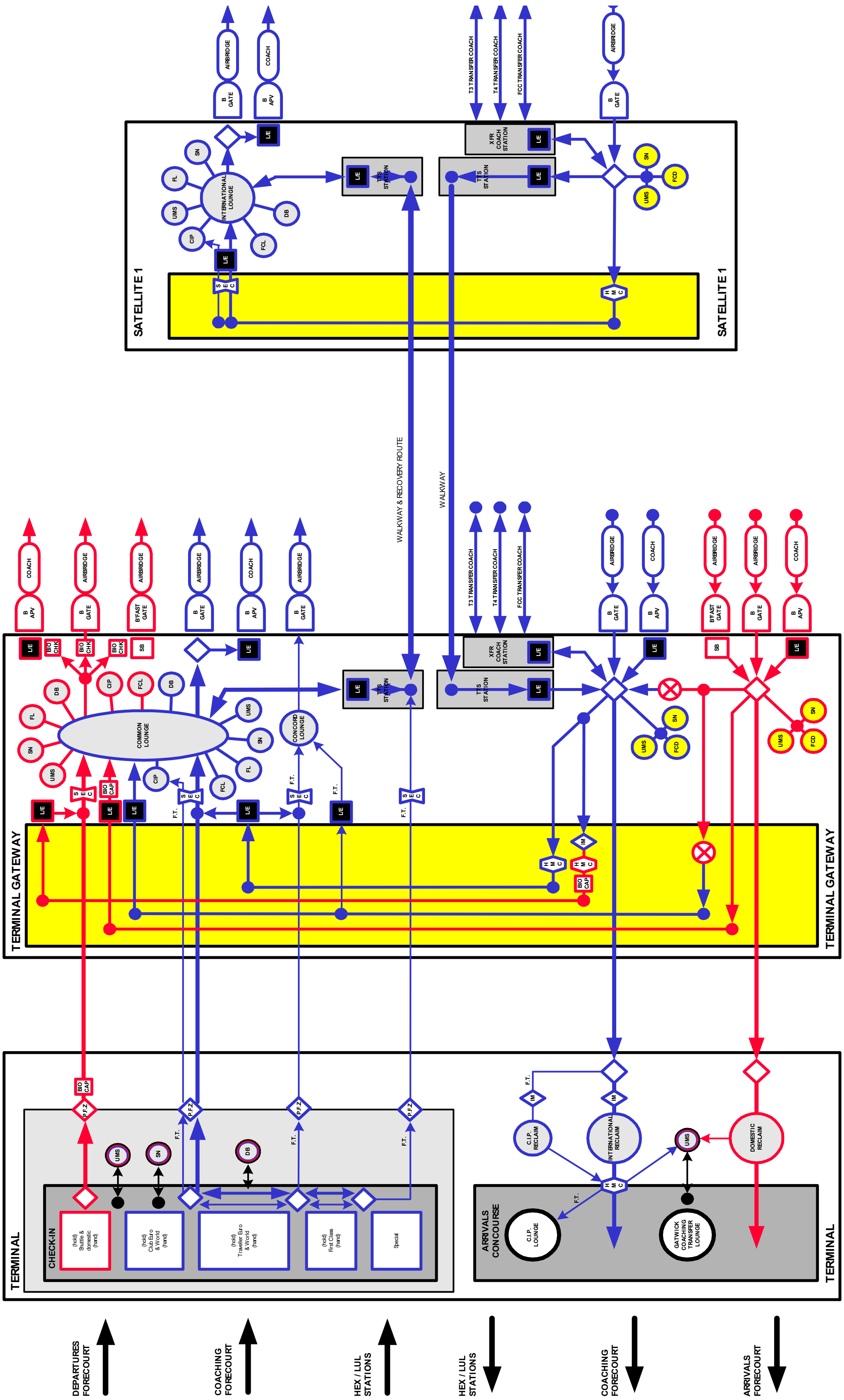


Figure 8.84 Heathrow Terminal 5 2008 - Passenger flow logic showing the complexity associated with centralising transfer security – Source: YRM (reproduced with permission from RMJM)

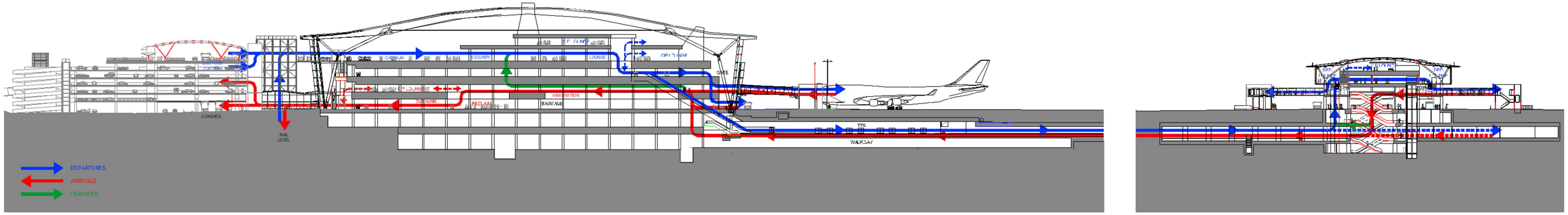


Figure 8.85 - Heathrow Terminal 5 cross section showing passenger flow through terminal and satellite – Source: YRM - (reproduced with permission from RMJM)

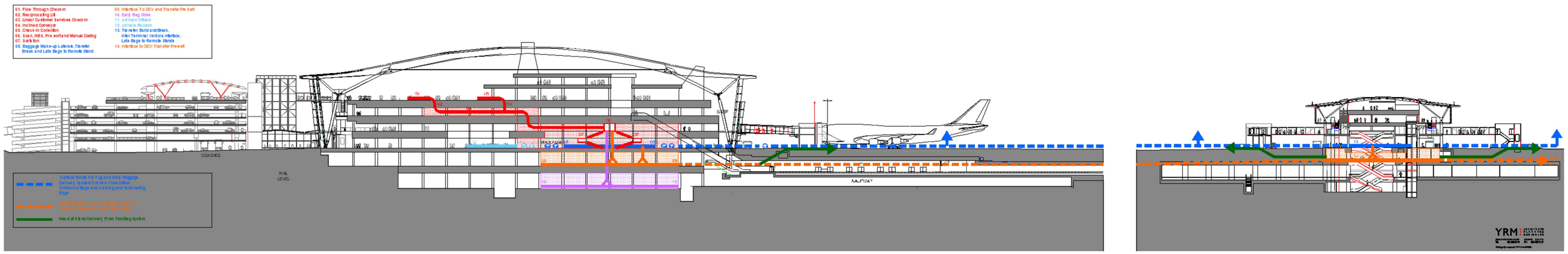


Figure 8.86 - Heathrow Terminal 5 cross section showing baggage flow through terminal and satellite – Source: YRM (reproduced with permission from RMJM)

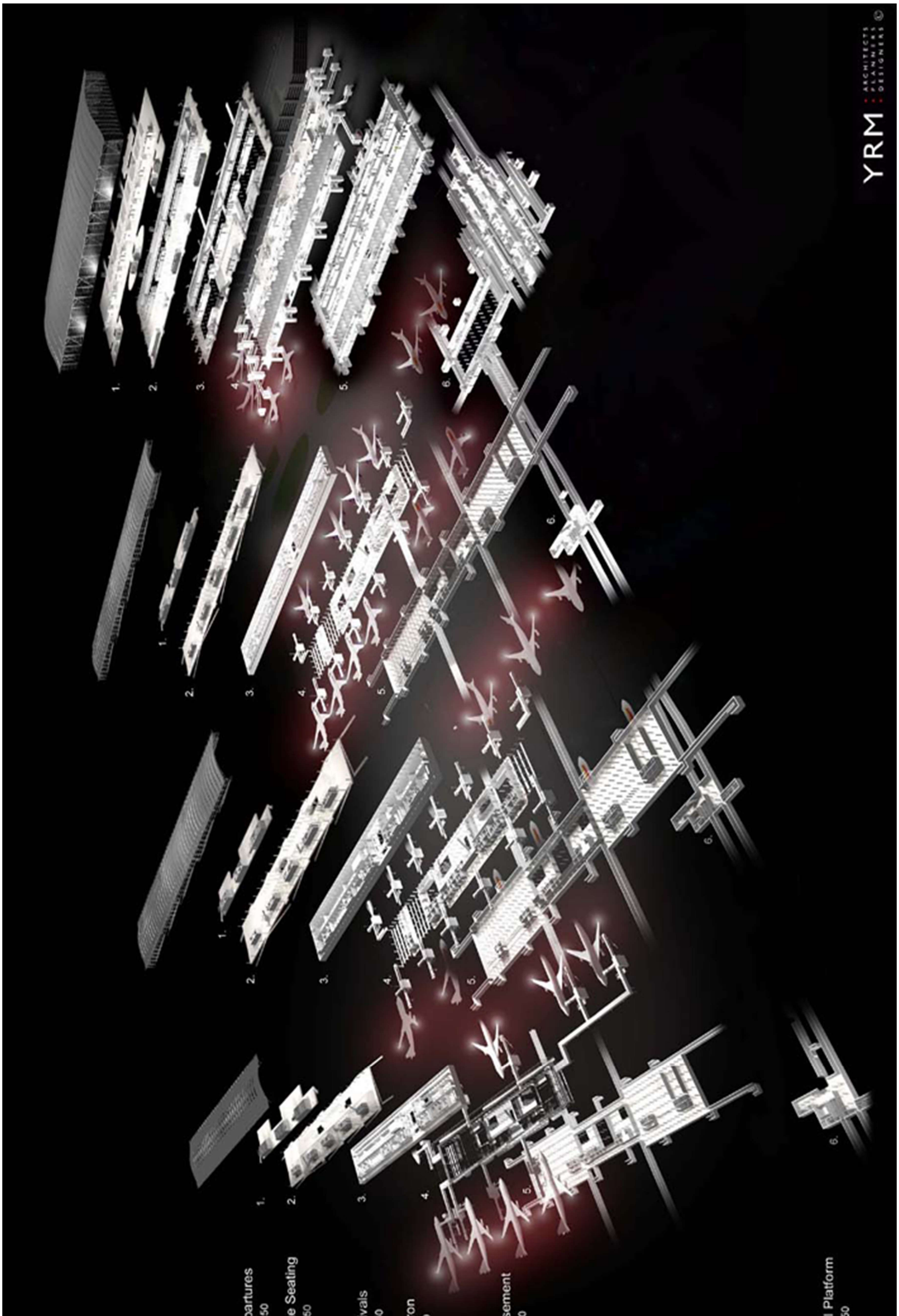


Figure 8.87 – Heathrow Terminal 5 2008 – Exploded axonometric of the Hub Infrastructure – Source: YRM (reproduced with permission from RMJM)

Figure 8.88 – Heathrow Aerial Perspective of Terminal 5 Complex 2008 – Source: YRM (reproduced with permission from RMJM)

The introduction of electric autonomous vehicles at Heathrow (POD) saw the beginning of a new personalised rapid transport system (PRT) (figures 8.89 & 8.90). An upgraded version of the system using larger minibus sized vehicles is being considered as a group rapid transit (GRT) for the 3rd runway expansion project.

Figure 8.89 – Heathrow Ultra Personal rapid Transit (POD) 2010 – Source: Heathrow Airport

Figure 8.90 – Ultra Personal Rapid Transit 2010 – Source: Ultra

Arguably the most developed transfer Mega Hub is Hong Kong International Airport as it has the most ways of integrating journeys of any airport, including car, taxi, bus, rail, and air and unusually major sea links to mainline China (figures 8.91 & 8.92).

Figure 8.91 Hong Kong International Airport 1998 – Air, Road, Rail and Sea Interchange – Source: HKIA

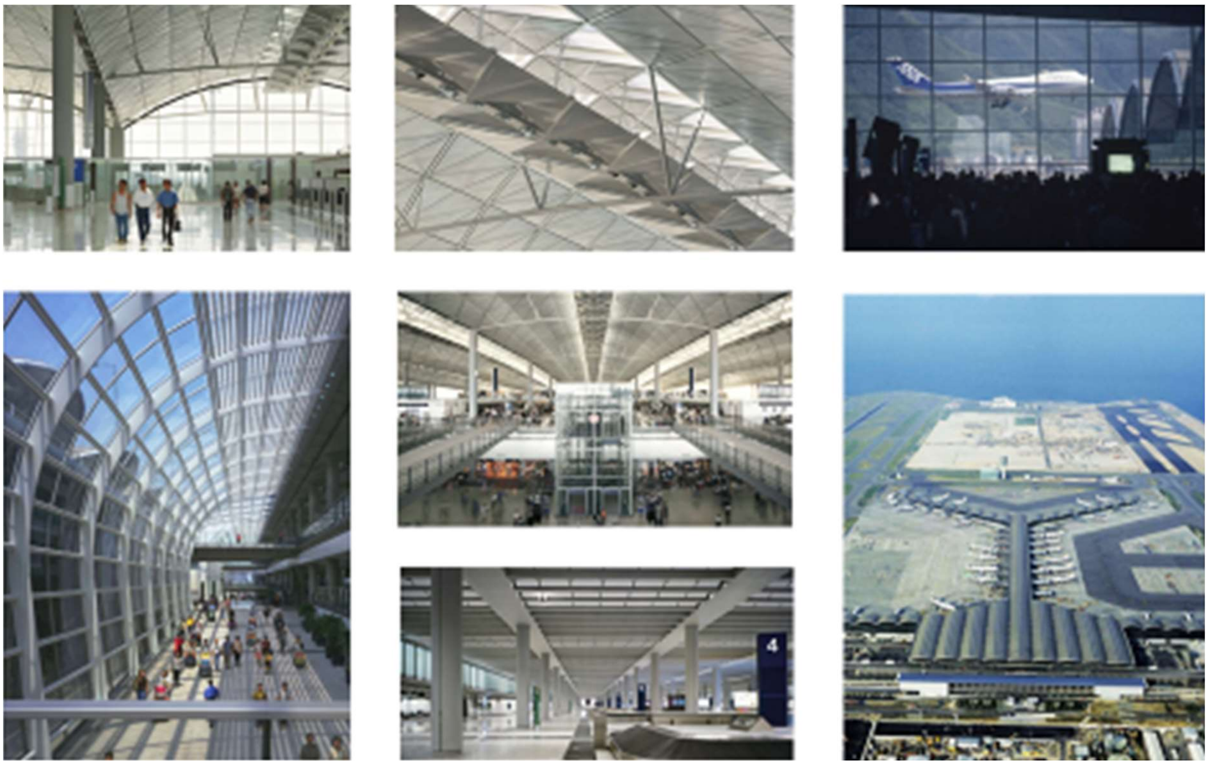


Figure 8.92 - Hong Kong International Airport 2008 – Asian Megahub – Source: HKIA

8.8 Integrating Journeys

It is not sufficient to provide infrastructure to allow people to transfer from land or sea based travel to air travel. It is also necessary to have an operator who is prepared to integrate the journey. For this the airlines rather than airports have driven the evolution of integrated surface and air travel. The following section explores the airline initiatives that have encouraged transfer to air travel.

8.9 Road to Air Journeys

For the very first flights from Berlin Johannisthal in 1919 it is interesting to note that the airline provided flying kit and motor transport to and from the aerodrome as an inclusive part of the fare. Luggage was also carried free of charge, but the total weight of the passenger and baggage could not exceed a certain weight. Transferable serial tickets could also be purchased.

Imperial Airways provided a coach service from London Victoria Hotel near Trafalgar Square to Croydon Airport from as early as 1924 (figure 8.93).

Figure 8.93 - Imperial Airways and Air France coaches arriving at Croydon Airport in 1928 – Source: Historic Croydon Airport Trust

Imperial Airways built their town terminal at London, Victoria in 1939 in Art Deco style providing a covered set down for taxis and private cars and direct access to the railway platform where passengers could board a train for Waddon station, which served Croydon Airport for short haul flights, or a train that went to Southampton to board a flying boat that served the long haul Empire routes. Luggage would be checked in at the town terminal, or delivered there on return, and a direct train from Victoria Station next door provided the link to the airport or the docks (figure 8.94).

The flying boat service ended in 1950 and Croydon Airport closed in 1959. The terminal lived on for a time as a check-in facility for Gatwick Airport and as a coach arrival and departure point to other airports closing, finally, when the airline business model could no longer sustain the additional cost of town check-in.

Figure 8.94 – Imperial Airways head office 1939 with town check-In, direct platform access and covered forecourt Source: RIBA Architecture Image Library Nos: 72869, 72872 and 72871- Photographer: Charles Borup

The design for the five-story Airlines Terminal at New York's 42nd street by Architect John B. Peterkin's (1886 – 1969) took the idea of a town terminal a stage further by consolidating the reservations, ticketing and baggage handling for the five major American airlines (American, Eastern, TWA, United and Pam Am) (figures 8.95, 8.96 & 8.97). Originally designed to occupy a single level it was expanded during construction to segregate arriving and departing passengers on two levels eventually opening in 1941. It continued in operation until 1978. It included a number of technical innovations not previously seen in airport terminals including escalators, car lifts and welded steel frame construction.

Figure 8.95 – Airlines Terminal 42nd Street New York, Postcard 1941 - Source: www.6sqft.com

Figure 8.96 --Airlines Terminal, New York 42nd Street, 1941 Interior – Source: LaGuardia Airport

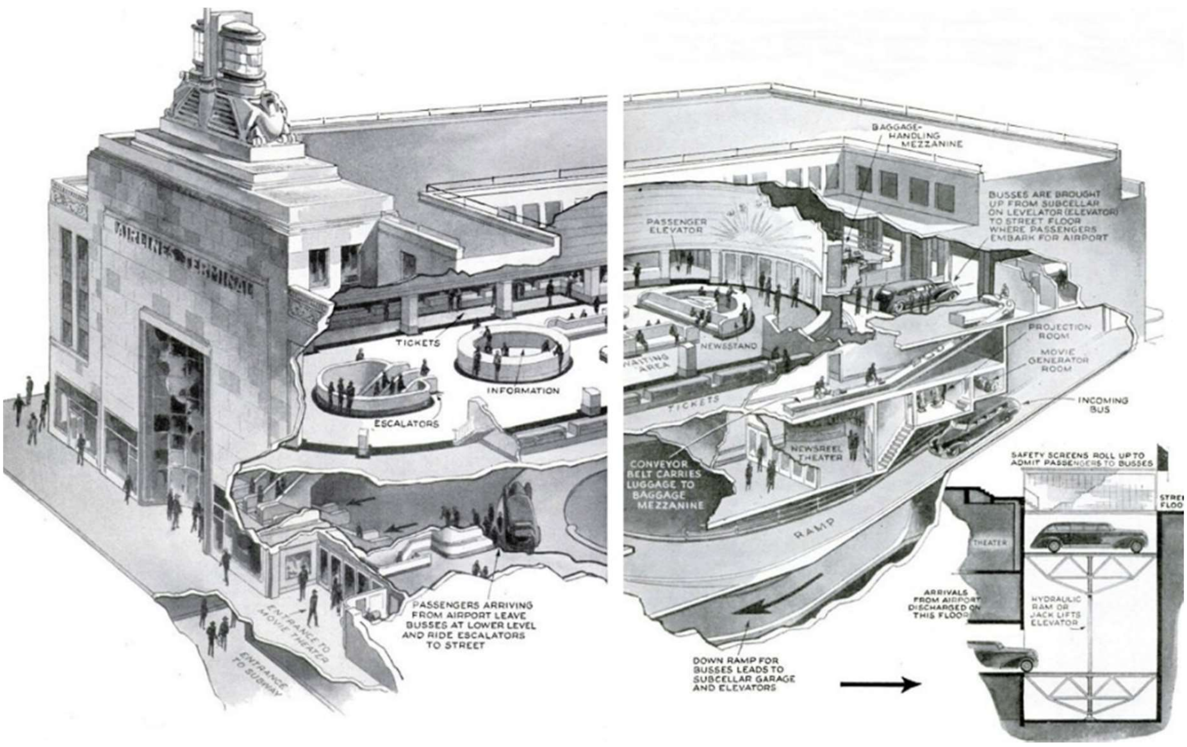


Figure 8.97 - Airlines Terminal, New York 42nd Street 1941 Sectional Perspective – Source: LaGuardia Airport

A limousine and bus service linked the Airlines Terminal with La Guardia, Newark and later Idlewild (JFK) Airports, from the basement of the terminal (figure 8.98).

Figure 8.98 - Airport Limousine Service 1941
Source: La Guardia Airport

British European Airways (BEA), now the short haul part of British Airways, built the West London Air Terminal in 1957 to provide town check-in facilities in London's West End. From there passengers were transported to Heathrow by specially designed buses with a separate compartment for checked in baggage (figure 8.99). This was replaced by a new building in 1963 built over Gloucester Road Tube Station and included a head office for BEA. It continued in use until 1973 when the check-in facilities were closed but the coach service continued. The demise of the coach service was confirmed, following the extension of the Piccadilly Underground line to Heathrow Central in 1977 finally ceasing operation at the end of 1978.

Figure 8.99 – BEA West London Air Terminal 1957 & 1963 – Source: The Library Time Machine

A final Town Check-in facility was built at Paddington Station in the UK with 27 check-in desks to complement the Heathrow Express rail service opening in 1999, and operated by British Airways and the Star Alliance. It was short lived closing after a few years when the airlines concluded it was too expensive to operate after the 9.11 terrorist attack on the World Trade Centre prompted economy measures from the airlines, ending seamless rail-air travel in the UK.

Town centre check-in has found a new lease of life in Asian Airports including Hong Kong, Kuala Lumpur and Seoul at their rail stations. Dubai airport also intends to provide town check-in facilities to support the move of airlines to Dubai World Central airport, initially by coach but later by metro and high speed rail link.

Hong Kong Airport Express is the fastest way of travelling between Hong Kong airport and downtown, it only take about 24 minutes from Hong Kong airport to Hong Kong Central.

If you take Airport Express to Hong Kong airport, you could also enjoy free In-Town Check-In Service at Hong Kong or Kowloon stations as late as 90 minutes before the departing flight or as early as the previous day (figures 8.100 & 8.101).

Figure 8.100 - Airport Express Check-in Hong Kong
Source: Hong Kong Extras.com

Figure 8.101 Hong Kong Airport transfer
Source: hongkong-airport-transfer.com

Coach and bus operators have taken advantage of the volume of custom that airports generate to develop coach stations at airports that serve not only passengers flying from airports but also passengers who never leave the ground and are simply transferring from one coach service to another. Heathrow houses one of the busiest bus stations in the UK second only to Victoria (figure 8.102). Major airport bus stations can be found at other large airports such as Frankfurt (figure 8.103) acting as interchanges for those needing to change from one service to another as well as serving the airport. Hong Kong Airport also provides a cross border coach service to main land China serving the whole of the Pearl River Delta (figure 8.104).

Figure 8.102 - Heathrow Central Bus Station – Source: Heathrow Airport Ltd

Figure 8.103 – Frankfurt Airport Bus Station -
Source: Frankfurt Airport

Figure 8.104 Hong Kong, Coach Interchange
Source: Wikizie.co

8.10 Rail to Air Journeys

USA Transcontinental Air Transport Inc (TAT) introduced Air-Rail link Day-Night services on July 7, 1929 when their transcontinental trips began. They initially offered a 2 day train/plane trip with the first leg on the Pennsylvania Railroad overnight from New York City to Columbus, Ohio, where passengers boarded a Ford Trimotor aircraft at Port Columbus International Airport that stopped in Indianapolis, St. Louis, Kansas City, Wichita, and finally Waynoka, Oklahoma. There, passengers caught the Santa Fe Railway for an overnight trip to Clovis, New Mexico, where they would take a second Ford Trimotor flight to Albuquerque, Winslow, Az., Los Angeles, or San Francisco (figure 8.105 & 8.106). Its slogan was 'Harnessing the Plane and the Iron Horse' (figure 8.107). The one-way fare from New York to Los Angeles (including a lower berth each night on the train) was $338. Cynics were to deride its TAT abbreviation as "Take a Train."

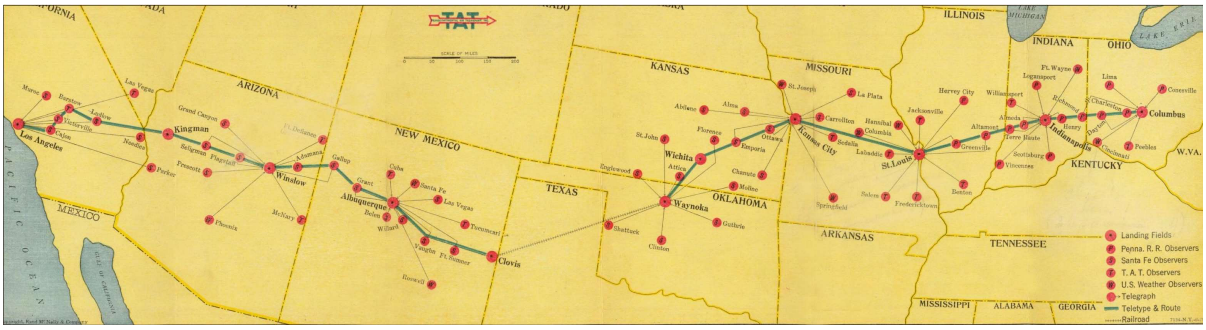


Figure 8.105 – TAT Day-Night Rail-Air Service 1929 - Source: http://oldtrailsmuseum.org

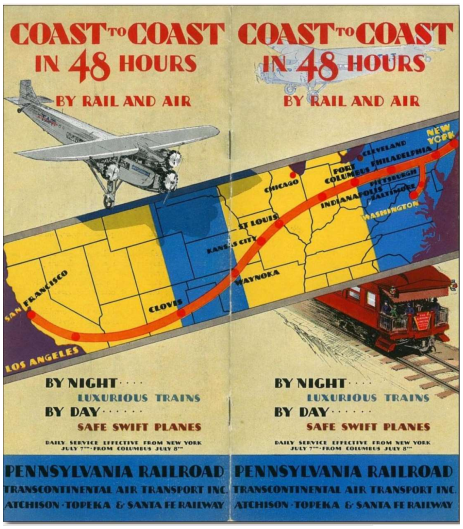


Figure 8.106 – TAT Advertisement
Source: http://oldtrailsmuseum.org

Figure 8.107 - Paperweight marking the start of TAT rail-air service
Source: Wikipedia

British Airways offered an integrated rail/air ticket from London to Paris in 1936. Passengers could board a first class carriage at London Victoria Station at 9.28 for the forty minute rail journey to catch the 10.25 flight from Gatwick which was scheduled to land at Paris-Le Bourget at 12.00 (figure 8.108). It now possible to make an equivalent journey today in two and a half hours from London to Paris by the high speed rail link Eurostar, but the equivalent journey by air would take longer because of modern security and increase in scale of the airport operation.

Figure 8.108 – British Airways Advertisement - Source: Flight 12.11.1936

Figure 8.109 – ICE integrated rail/air service at Frankfurt Source: Lufthansa

More recently Lufthansa have introduced integrated rail and air services on the high speed ICE rail network. It is possible to check in for the train as well as the flight, online or by mobile phone, from 23 hours before the train's departure time. It is also possible check baggage through to the destination at the AIRail Centre in Frankfurt Airport's mainline station (figure 8.109).

The stillborn proposal for a new airport for London in the Thames Estuary shows the complexity of the road and rail network needed to serve a large hub airport (figure 8.110). The rail network included a high speed rail link to central London (red), extensions to both the northern and southern arms of Crossrail (blue) and links to the local network both to the north and south of the Thames (grey). Complementary links to the M25 orbital road network are shown in green. The interchange was also designed to allow cruise ships .to dock and passengers to transfer to the airport and rail network to allow speedy access to central London.

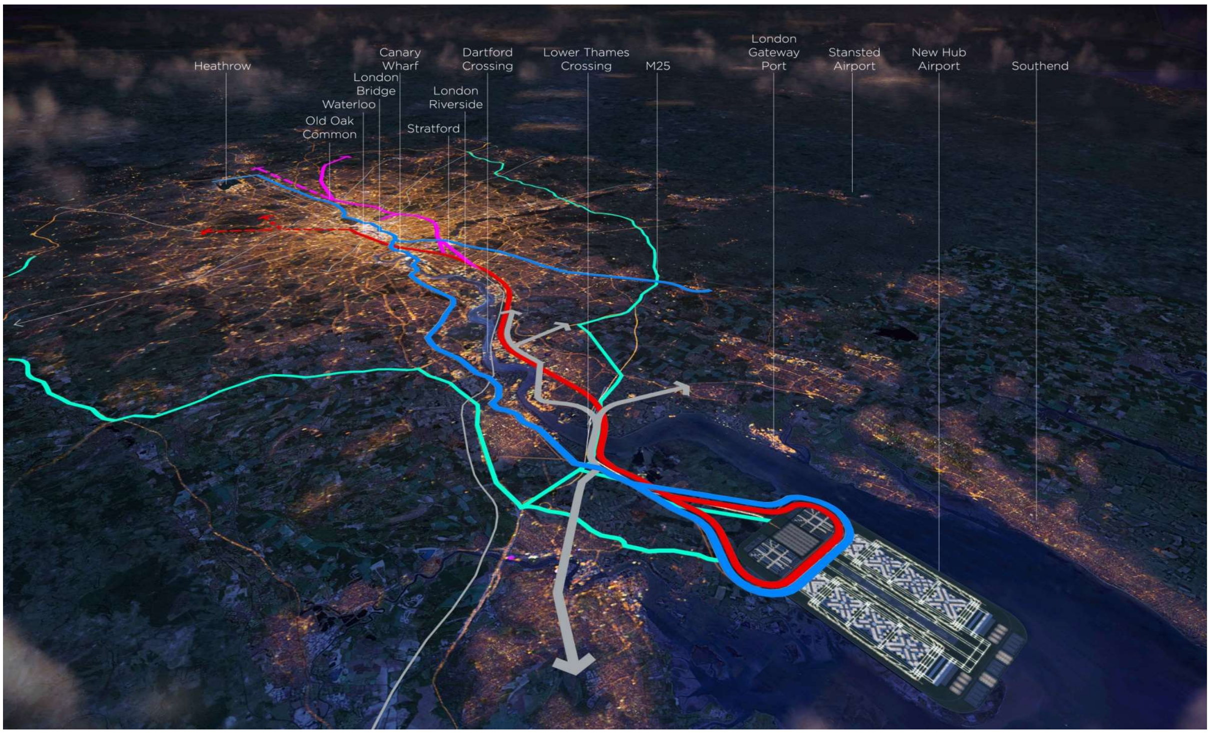


Figure 8.110 – A New Airport for London, Isle of Grain, Proposed Rail Network 2013 – Source: Atkins

8.11 Air to Air Transfers

By the late 1930s airline networks were sufficiently developed to allow passengers to plan a multiple sequence of flights though often with an overnight stop. The drawing below shows not just the Lufthansa flight network from Berlin but also the frequency and times of services. As can be seen Berlin was the centre of a major network by 1939 (figure 8.111).

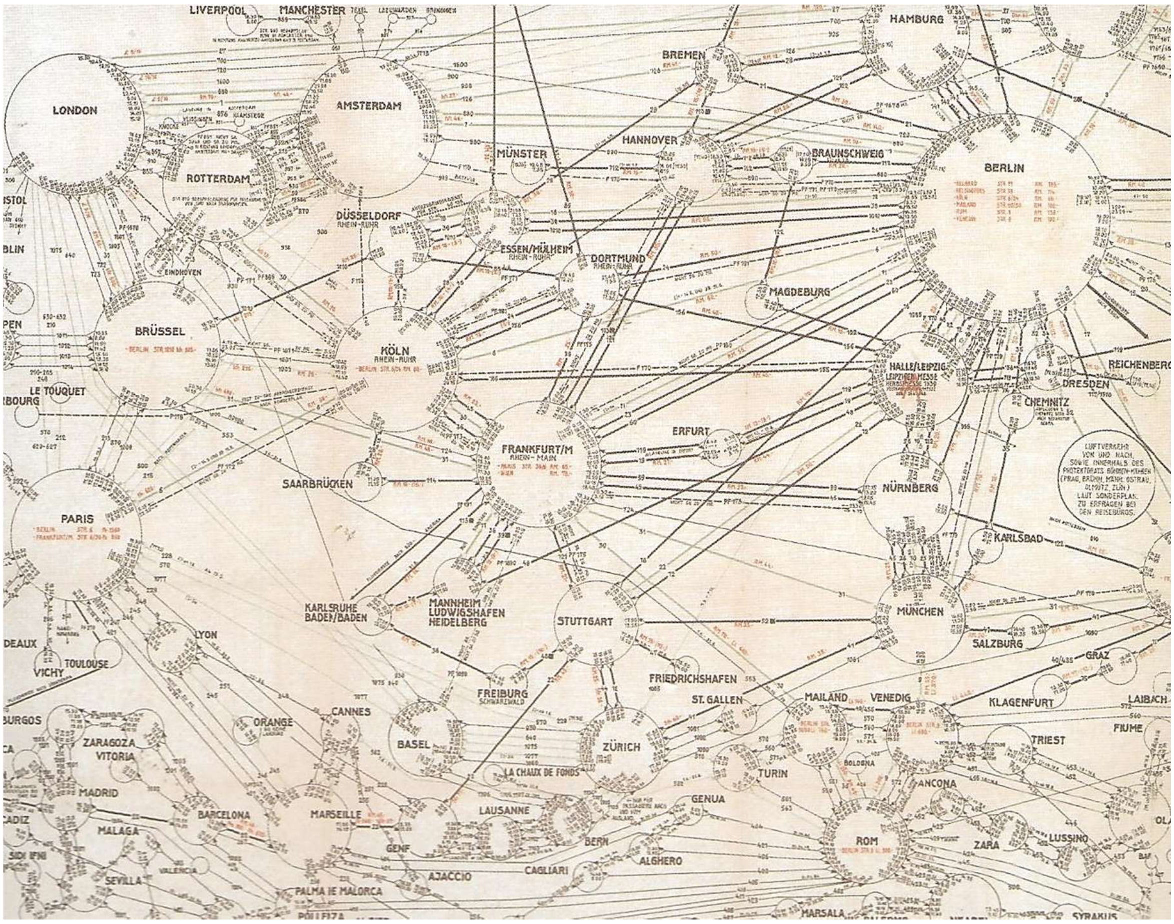


Figure 8.111 - Lufthansa Timetable 1939 – Source: Historic Airports (courtesy of John King)

Atlanta airport saw the beginnings of the hub concept in 1939. In the hour between 11.45pm and 12.40am eleven of Atlanta's thirty daily flights were handled, in an operation that was known as the 'Midnight Merry-Go-Round' (Braden, 1989) (figure 8.112).

Figure 8.112 – Atlanta, Georgia, 'Midnight Merry-Go-Round' – 'Hubbing' at Atlanta 1939 – Source: A Dream Takes Flight (courtesy of Jack Gray and H.W. Tofflemire)

Eastern and Delta Airlines introduced the modern airline hubbing concept in the USA. Both claimed to be the first to invent the concept in the 1950s, and both elected to use Atlanta Hartsfield as a key hub airport. Their concept was to schedule a number of flights to converge on their chosen hub, Atlanta, at closely spaced times and then leave closely together an hour or so later (Braden, 1989). This move opened the opportunity for secondary cities to be linked to one another when otherwise the volume of traffic could not justify a direct route.
Heathrow illustrated the hub concept in the diagram below in its submission to the Airports' Commission, showing graphically the increased connectivity potential of a hub airport (figure 8.113).

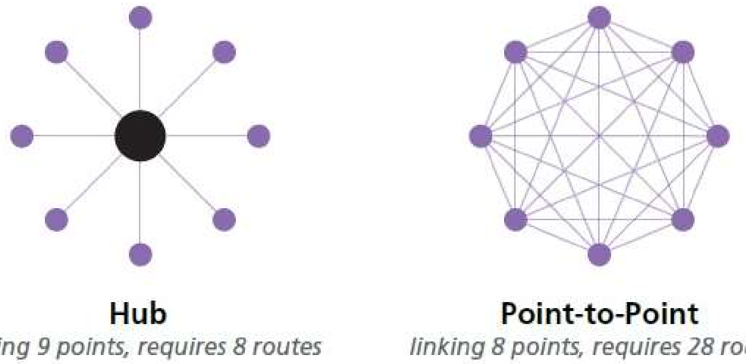


Figure: 8.113 - The Hub Concept: The most efficient way of connecting many points – Source: Heathrow

The hub-and-spoke system became the norm for most major airlines after the U.S. federal government deregulated the airlines in 1978. Under the direct-route, or point-to-point, system used prior to deregulation, airlines were forced by the federal government to fly directly between two small markets. This resulted in many flights that were routinely half empty, which resulted in airlines losing money.

Today, most airlines have at least one central airport that their flights have to go through. From that hub, the spoke flights take passengers to select destinations. This concept was initially adopted in the USA for domestic traffic, but following the establishment of the Global Alliances, now underpins most large international airports. The best connected airports to long haul destinations in 2014 are illustrated in the diagram below (figure 8.114).

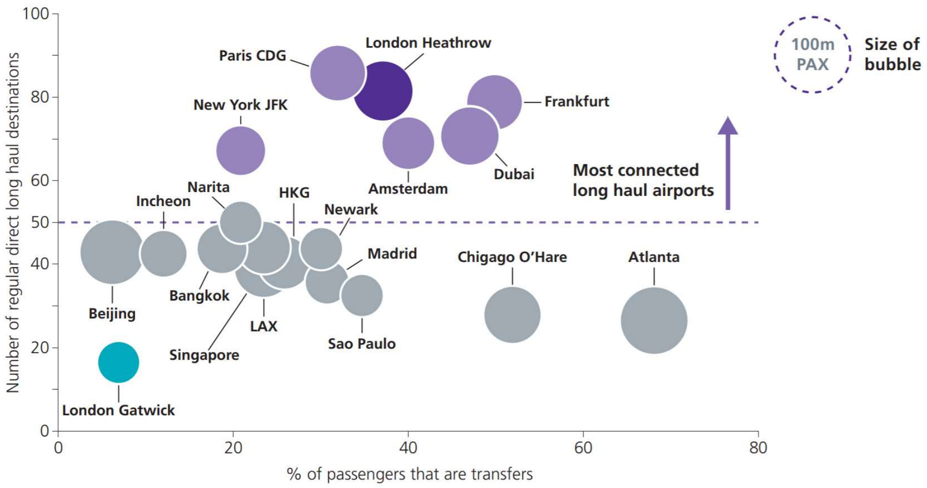


Figure: 8.114 - Best Connected Long Haul Airports, 2014 - Source: Heathrow- Taking Britain further (p49)

Layouts of the largest hub airports can be found at the end of chapter 7. The airports are typically characterised by the wave pattern of their flight schedules with 4 to 5 waves or peaks a day to provide the maximum connection opportunities within a short time span. This leads to a peak with many aircraft on the ground at one time followed by a trough when they all fly out again.

Hub airports are specifically designed to facilitate the speedy transfer of passengers form one flight to another with multiple passengers boarding bridges, moving walkways, automated people movers and fast track security lanes all contributing to the speed of transfer.

A hub airport demands ease of aircraft movement, speedy turnaround of aircraft and excellent minimum connection times for passengers. This led Atlanta Hartsfield to develop an entirely new airport planning concept with a mid-field terminal building linked to multiple satellites by an underground people mover that has been christened the ‘toast rack’ concept (figure 8.115).

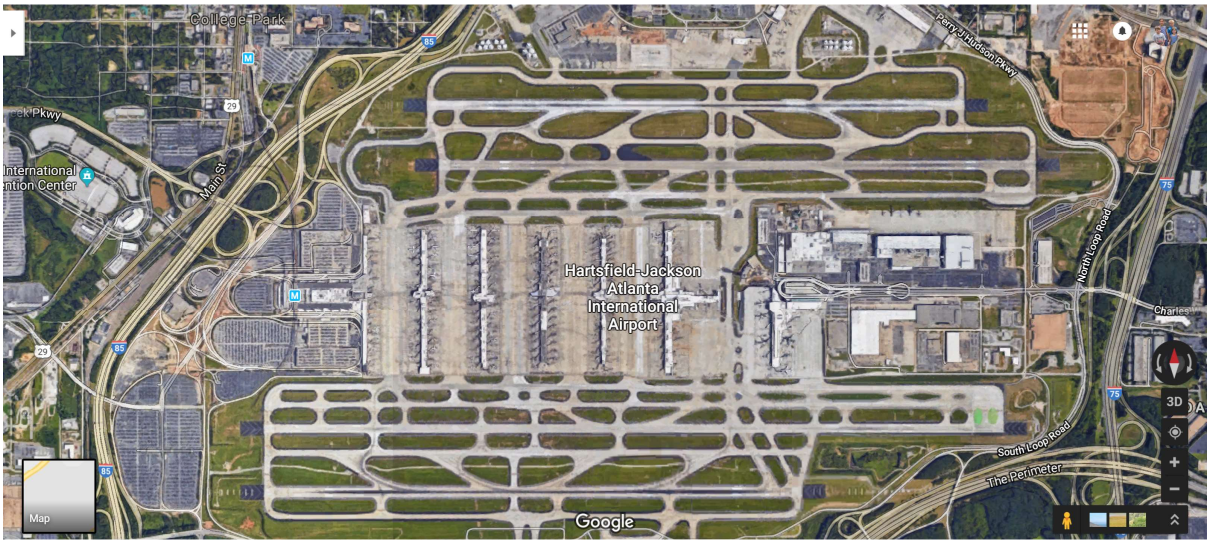


Figure: 8.115 - Atlanta Hartsfield ‘toast rack’ planning concept 2019 – Source: Google Earth

Atlanta is currently the largest hub airport in the world handling over 100 million passenger per annum, primarily domestic transfer traffic, while Dubai has reached 90 million passengers per annum handling only international traffic with the proportion of transfer traffic now nearing 80%.

Low cost carriers have more recently bucked the trend, led by Southwest Airlines, by making use of older under utilised secondary airports such as Chicago Midway to provide point to point services that compete with the Global Alliances at a lower cost. While this has led to innovations in airport processes to speed aircraft turnaround and eke out capacity constraints there has been little innovation in airport design. The few purpose designed terminals for low cost carriers, developed to supplement existing terminals used by legacy carriers, such as Bordeaux Billy and Copenhagen Go have concentrated on reducing costs by reducing space standards, using lower quality finishes and foregoing the use of airbridges.

8.12 Helicopter Transfers

Helicopter links to the city centre have often been short lived. The Waterloo Air Terminal on the South Bank was converted from the Waterloo entrance building to the 1951 Festival of Britain. There was a test flight between the heliport and Paris sponsored by the Evening Standard in 1953 but this was never put into service.
Helicopters flew to London Airport Central (Heathrow) after BEA moved their services there from their post war base at Northolt. The service opened on 25.07.1955 and lasted just ten months closing on 31.05.1956 possibly because the helicopters could hold just five people and so were uneconomical as well as being very noisy (Flight Global, 1956, p. 193) (figures 8.116 & 8.117).

Figure 8.116 - Waterloo Air Terminal 1955 – Source: Tim Dunn on Twitter

Figure 8.117 - Waterloo Air Terminal and Heliport 1955 – Source: Pinterest

A scheduled helicopter service, known as Airlink, flew between Heathrow and Gatwick from 1978 to 1986, but when the M25 opened the Government cancelled the licence. It was a fully commercial operation by British Caledonian Airways supported by the British Airports Authority. Both these organisations had a vested interest in introducing a high speed connection between Gatwick and Heathrow airports. Since neither had helicopter expertise, they turned to another company resident at Gatwick, British Airways Helicopters (BAH), who could provide the expertise necessary for the CAA to issue an Air Operators Certificate for the service. With ten flights a day each way it achieved an annual capacity of 50 to 60,000 people (figure 8.118).

Figure 8.118 – Airlink helicopter over Gatwick c1980 Source: ashpole.org.uk

The Martin Aircraft Company proposed a car, rail, bus and helicopter interchange known as Metroport next to Union Station in down town Los Angeles in 1965. Helicabs were intended to become the aerial version of a taxi, while the larger Sky Lounge which combined a bus and helicopter to fly passengers to Los Angeles Airport (figure 8.119).

Figure 8.119 – 'Metroport' 1965 – Source: The Guardian

Perhaps the best known, and the most dramatic helicopter route was operated by Pan American Airways. It linked New York JFK airport with Central Manhattan with the landing platform located on the roof of the Pan Am Headquarters which was in turn located directly above Grand Central Station, surely the ultimate interchange. The Pan Am building was designed by Walter Gropius and his practice The Architects' Collaborative or TAC. It is the only aviation related building designed by one of the founders of the modern architectural movement to have been realised in practice, and demonstrates his preoccupation with the aerial view a concept he introduced to architectural theory (Gropius, 1935). (Figures 8.120. 8.121, 8.122 & 8.123) that was discussed in section 3.5, page 32.

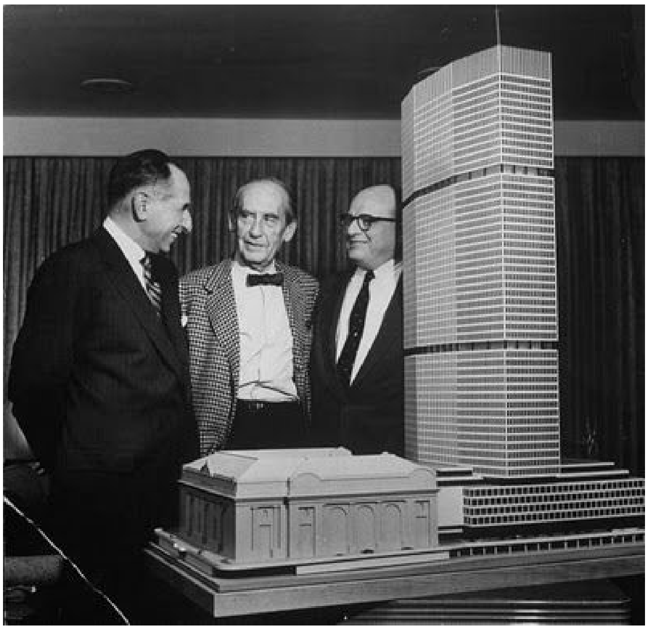


Figure 8.120 - Walter Gropius (centre) with a model of the Pan Am Building, showing its juxtaposition with Grand Central Station – Source: OTRO

Figure 8.121 - Aerial view of the Pan Am building with a NY Airways helicopter in the foreground Source: Pan Am Historical Foundation

This service operated between 1965 -1968, briefly resuming in 1977 but was terminated in May after a fatal accident when a rotor blade broke after the landing gear failed and killed five people. All three of New York's heliports are now located at the river edge rather than on building roofs.

Figure 8.122 - Grand Central Terminal 1954 Source: rarehistoricalphotos.com

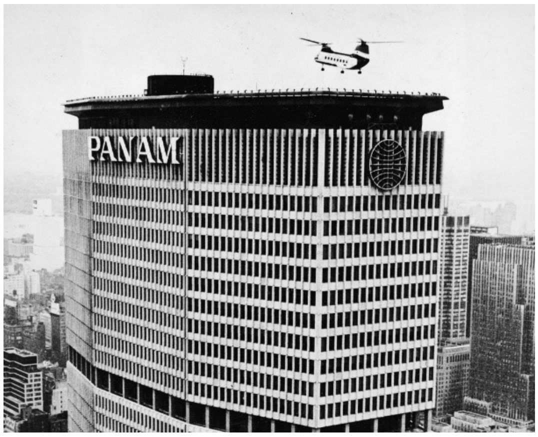


Figure 8.123 - Pan Am heliport 1965 -1968 Source: 6sqft.com

8.13 Personalising Passenger Experience

There has always been a desire to personalise the journey and individualise the experience. While most people rely on the private car for this there have been several attempts to develop personal flying machines as illustrated by Frank Lloyd Wright in Broadacre City (figure 8.124). His concept envisaged a decentralised way of living with airports spread out across the countryside, well removed from urban centres. In 1958 he wrote:

> *'As flight develops air-rotor or helicopter depots will be connected with the cross-country rights-of-way on which once were laid the hard rails'* (Wright, 1958).

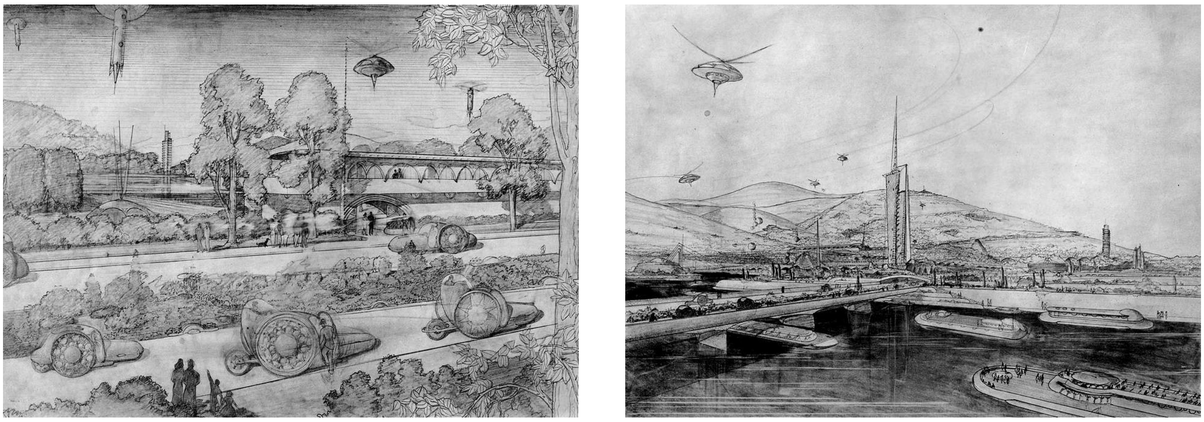


Figure 8.124 'Broadacre City' – 1957 – Source: Wikimedia

Figure 8.125 – 'Broadacre City' 1958 and helicopter concept– Source: Frank Lloyd Wright

His plans for Broadacre City showed the airport located away from the urban centre adjacent to a golf course. He imagined that for shorter journeys and to access the airport residents would use personalised helicopters that resembled flying saucers which he christened 'aerotors' (figure 8.125). Writing in Architectural Record Wright had proposed:

> *'In the affair of air transport Broadacre rejects the present and substitutes the self-contained mechanical unit that is sure to come: an aerator capable of rising straight up and by reversible rotors able to travel in any given direction under radio control at a maximum speed of, say, 200 miles an hour and able to descend safely into the hexacomb from which it arose or anywhere else. By a doorstep if desired '* (Wright, 1935).

Wright's ideas have never been put into practice.

8.14 Flying Communities

The closest to the Broadacre ideal that has been realised in practice can be found at the fly-in community or airpark at Spruce Creek, Datona Beach, Florida (figure 8.126 & 8.127)). The development was created from a former military airbase. The main runway of 4000ft (1300m) and one cross wind runway were retained while the rest of the site was developed into 1500 individual houses, many of which featured aircraft hangars or tie down facilities. Unlike Broadacre City, however, this community is for the very rich, but an even more extreme and exclusive version of personalised flying can be seen at actor John Travolta's house which boasts its own runway and parking spaces for jet aircraft (Figure 8.128).

Figure 8.126 Spruce Creek, Datona Beach, Florida – Source: livingwithyourplane.com

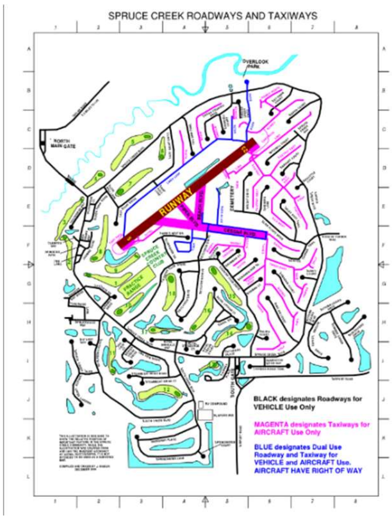


Figure 8.127 Spruce Creek Fly-in,
Source: sprucecreekproperties.com

Figure 8.128 John Travolta's House,
Source: community.infiniteflight.com

8.15 Vertiport and Vertistop Development

More recently Uber Elevate has been developing a personalised air taxi concept which could link city centre landing pads with major airports using Vertical take-off and landing (VTOL) aircraft (figure 8.129). Dubai, Dallas and San Francisco airports are currently vying to be the first to introduce the concept. The goal is to operate demonstrator flights starting in 2020 and begin commercial operations in 2023 from bases known as Vertiports and Vertistops (figure 8.130).

Figure 8.129 - UberAir - Air Taxi – Source: Uber.com

The following is an extract from an Uber Elevate Publication predicting the future of air taxis. – Fast-Forwarding to a Future of On-Demand Urban Air Transportation - October 27th, 2016

'In the U.S. there are 5,664 helipads with all but 66 for private use developed for use by the property owner without public assistance. Most of this infrastructure is essentially unused. After years without use, many helipads have been declared inactive and for emergency use only. Many of these are located in highly desirable downtown locations that could provide rapid access into urban areas. Los Angeles alone has over 40 high-rise helipads in the immediate downtown. Cities such as San Francisco also have many high rise building helipads, however none has permitted use due to local ordinances that are highly restrictive due primarily to noise concerns.

Over the past two years NASA has studied the idea of VTOL air-taxis operating in dense urban areas. Specifically, they chose San Francisco as one metropolitan area to provide detailed geographic, land use, infrastructure, weather, and operational constraint considerations to bring real world issues into their study. This permitted NASA to develop a *detailed Concept of Operations (CONOPs) for how the vehicles would be used and where the required supporting infrastructure could be placed. This NASA study provides a number of insights that help better understand the feasibility of conducting very dense operations (far more than any existing city experiences with helicopters today).*

A VTOL fleet will likely be supported in a city through a mixture of both vertiports and vertistops. Vertiports would be large multi-landing locations that have support facilities (i.e., rechargers, support personnel, etc.) for multiple VTOLs and passengers. Following the heliport examples used in New York City and other locations, vertiports would be limited to a maximum capacity of around 12 VTOLs at any given time to achieve a compact infrastructure size while enabling capacity for multiple simultaneous VTOL takeoff and landings to maximize trip throughput. Vertistops, on the other hand, would be single vehicle landing locations where no support facilities are provided, but where VTOLs can quickly drop off and pick up passengers without parking for an extended time. An example of a vertistop includes small helipads that are atop high-rise downtown buildings today'.

Figure 8.130 – Illustration of a floating barge Vertiport at San Francisco Bay – Source: Uber Elevate

Airbus, Groupe ADP and the RATP Group, along with the Paris Ile-de-France region and the French Civil Aviation Authority (DGAC), have announced the launch of a feasibility study to demonstrate an urban system of vertical take-off and landing (VTOL) vehicles for the 2024 Olympic Games in Paris (Figures 8.131 & 8.132).

It is claimed that this collaboration, encompassing all components of land and air mobility, marks the creation of a team of recognised experts to develop not only French technology, but also a model for urban mobility, associated services and export potential. The goal is to integrate the entire value chain: design and production; maintenance; flight operations; low-altitude air traffic management; urban integration and planning; infrastructure, both physical and digital; and passenger interfaces.

Like helicopter travel it is anticipated that this will always be a premium low volume service limited by safety considerations and the available airspace.

Figure 8.131 – Airport de Paris Vertiport Model – Source: Groupe ADP

Figure 8.132 – Vertiport for the Paris Olympics 2024 - Source: Airbus / Artist Impression: MVRDV

8.16 Conclusion

While multi-modal surface/air transport can be seen as early as 1909 at the Frankfurt air show it took many years before airports were designed with integrated surface transport. Germany led the way at Berlin, Hamburg and Konigsberg which were planned with rail, bus and tram links from the city centre, but this public transport was almost certainly aimed at staff and spectators who vastly outnumbered the numbers of passengers in the 20s and 30s.

There were many unrealised dreams of multi modal interchanges from Donat-Alfred Agache, Sant'Elia, Le Corbusier, Richard Neutra, André Leurçat and Norman Bel Geddes among others during the inter war years, and more recently many designers have continued to propose complex and expensive interchanges that have remained unrealised because insufficient thought has been given to the anticipated demand and operational economics.

Integrated road to air infrastructure can first be seen at Frankfurt Airport which was designed to link to the new autobahn network. Later the main initiatives such as dedicated access routes and grade separated forecourts can be found in the USA where the private car has always been pre-eminent.

Gatwick was unique in having a purpose built dedicated new main line railway station and with it the opportunity for travellers to buy an integrated rail/air ticket. The new Gatwick has built on those benefits and has always enjoyed a high proportion of travellers arriving by rail. More recently airports such as Amsterdam Schiphol, Paris Charles de Gaulle and Frankfurt have been linked to the European high speed rail network and most major international hub airports now have direct rail links to the city centre.

There has been limited success for sea to air transfers, because of the very different speed of operation between the two modes of travel, with the notable exception of Hong Kong where sea links through the Pearl River Delta have opened up a large untapped market in mainland China.

The main drive for the rise of airports as air to air interchanges has come from the airlines. Although air to air transfers were seen at Atlanta in the late 30s, Delta and Eastern were the first to introduce the hub and spoke concept in the 1950s for the United States domestic market. This was given a further push internationally with the development of the Global Alliances, either side of the Millennium, resulting in mega hubs around the world.

There is another strand of interchange development that has focused on more personalised travel to the airport such as Frank Lloyds Wright's 'Aerotor' and numerous attempts to introduce helicopter links to the city centre but none have so far been lasted long due to safety, noise and economic concerns. However, Uber is still aiming to overcome these difficulties and introduce air taxis.

This chapter has also shown that while many of the early visions for infrastructure to link road, rail, sea and air travel have been realised it also requires airlines and other transport operators to offer connecting services to make proper use of these interchanges. The demand for interchange between both land, sea and air always originates from the airlines and airports can only aspire to satisfy that demand but not induce or create it.

9. Airport City and Aerotropolis

9.0 Introduction

The chapter opens by discussing the origins of the terms and the early use of the expression Airport City followed by consideration of examples of airport city developments. It then explores the term Aerotropolis which was given new meaning by John Kasarda, and follows with examples of airport master plans that follow that philosophy.

9.1 Origins

The terms ‘Airport City’ and ‘Aerotropolis’ describe a smaller or larger hinterland around an airport that relies on the power of an airport as an interchange to act as a magnet to attract commercial and other developments. It is the airport equivalent of a metropolis in encouraging suburban satellite development.

The meaning of both words has changed radically since they were coined. The term Aerotropolis was first used by Nicholas De Santis in 1939 in an article in the magazine Popular Science to describe his imaginary concept for a city centre megastructure much taller than the Empire State Building that sported an airport and airship mooring on the roof of the building (figure 9.01).

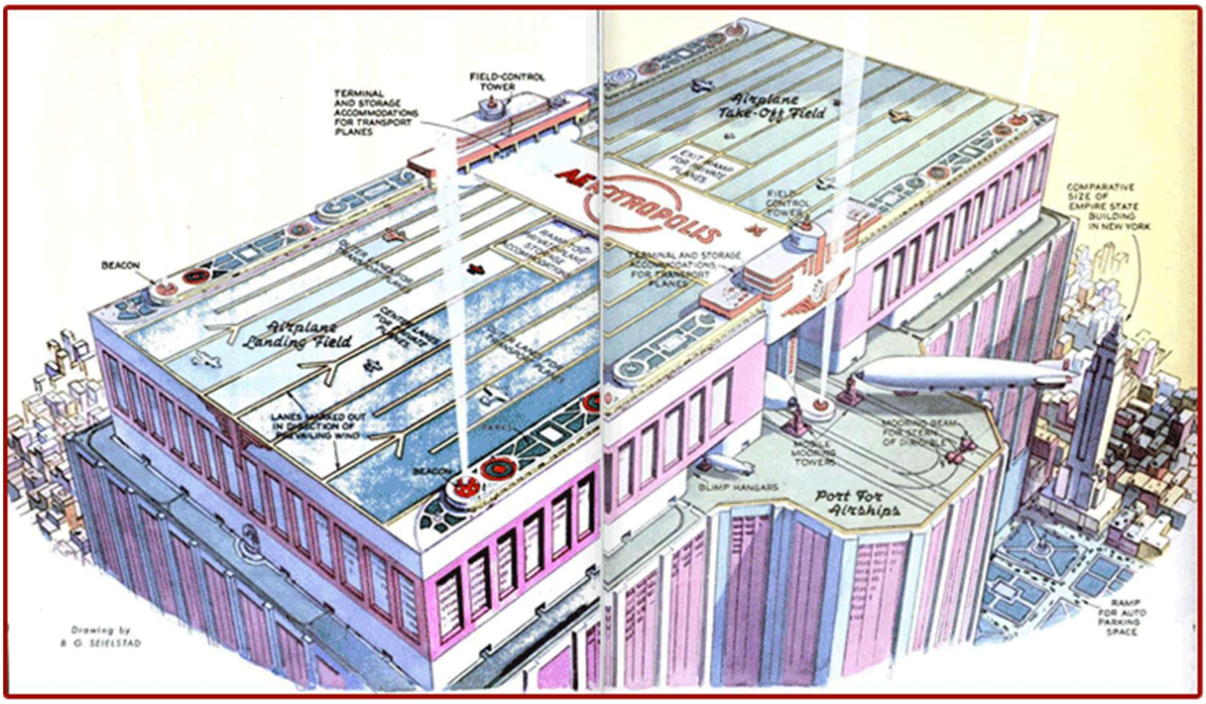


Figure 9.01 Aerotropolis – Source: Popular Science November 1939

9.2 Airport City

By contrast the term Airport City was developed to put a positive spin on the concept of multiple devolved terminal buildings at New York’s Idlewild airport when the original centralized scheme with a single large terminal had proved unaffordable.

The concept for the original Idlewild masterplan, with its two mile long peripheral gate area, can be traced back to the ideas for a decentralised/centralised terminal presented in Charles

Froesch's and Walther Prokosch's concept for a large terminal in their influential and far-sighted book 'Airport Planning' that was published in 1946. They argued that the traffic through the central terminal became sufficient to allow for the inclusion of extensive concession areas in a central terminal area. (Froesch, 1946, p. 170) (figure 9.02)

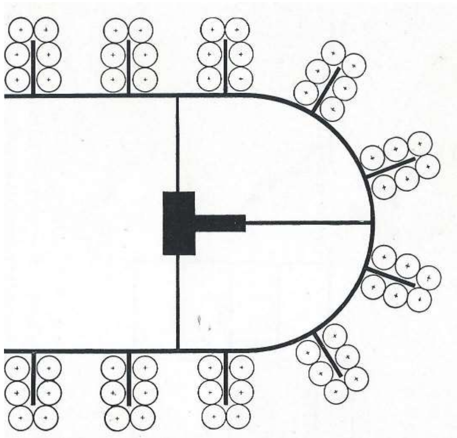
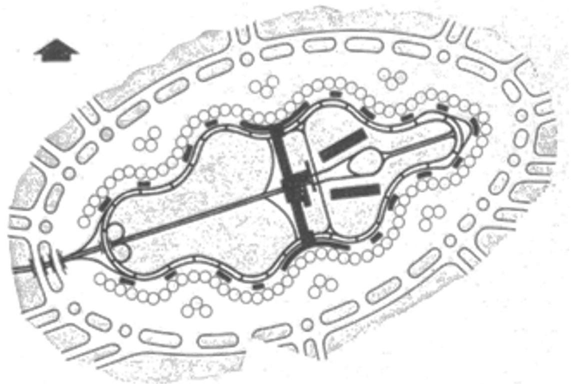


Figure 9.02 -Terminal Concept – Source: Airport Planning 1946

However the Idlewild decentralised 'Airport City' concept, born of financial expediency, transferred the responsibility for developing the terminal from the airport authority to individual airlines and set the trend for future terminal development in the USA, for many years (figure 9.03). Much later the requirement for central security search in combination with the retail imperative to maximize footfall, has eventually made the concept obsolescent.



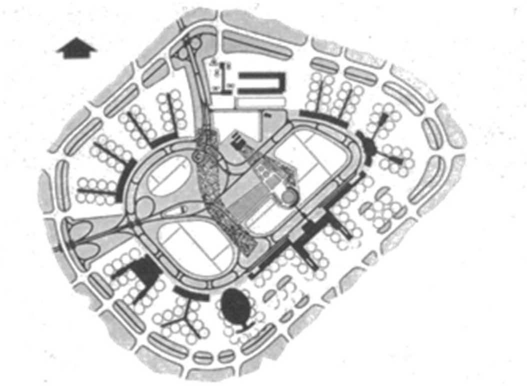


Figure 9.03 – New York, Idlewild Original Concept and Airport City Revision – Source: Architectural Record 1962

More recently the terms 'Airport City' and 'Aerotropolis' have been used to promote airport related commercial development that would benefit from proximity to the airport in providing speedy delivery of goods and services worldwide. Airports are also major employers typically employing 1000 people for every million passengers that pass through the airport. For example Heathrow employed 73,000 staff in 2016 when it handled 76 million passengers. This puts the working population at the airport itself on a city scale, which induces further indirect employment in the hinterland around.The trend for the airport to move from city centre to the periphery, has induced new commercial development to follow suit. This phenomenon can be seen at number of major airports such as Dallas Fort Worth where in time residential development followed commercial development in surrounding an airport and ultimately throttling its development as environmental concerns such as noise and air quality took a higher priority.

9.3 European Airport Cities

Major Hub Airports, such as Heathrow, then can become victims of their own success, where unforeseen and unplanned for growth places an enormous strain on the supporting infrastructure, ultimately restricting growth and leaving demand unsatisfied however some European Airports have consciously planned for Airport City development

9.3.1 Amsterdam, Schiphol

The Schiphol Group sees its own airport as an 'AirportCity':

> '*A dynamic environment integrating and enhancing people and businesses, logistics and shopping, information and entertainment. This efficient, multi-modal hub for air, rail and road transport is a seamless link in the travel process that provides visitors a unique experience*'

The Schiphol Group consists of four business areas; Aviation, Consumers, Real Estate and Alliances and Participation. They benefit from the synergy that is created by the 'AirportCity' concept. Schiphol is described as a 'Mainport' by the Dutch government with two closely related functions:

1. As an airport with a hub function, a junction where many national, European and intercontinental air links come together.
2. As a metropolitan area with high quality housing, living and business climate where many companies operate competitively in international production and consumption networks and where many people live, work and spend their free time.

Schiphol also characterises itself as a Megastructure, in that it cannot be fully understood from ground level. Schiphol Airport has pursued the airport city concept for many years, but it did not come together overnight; but it has developed in a planned rather than totally free market environment. Schiphol was built on land reclaimed from the Haarlemermeer Lake and is some four metres below sea level, so has required extensive pumped drainage infrastructure to keep it functioning, so planned intervention is ingrained in the DNA of the airport. It was, for example, only the second airport in Europe to have a paved runway.

The development of the 'AirportCity' concept relied on the prior development of a rail network that progressively linked the airport with south Amsterdam, and later the city centre, finally forming a complete rail link between Amsterdam, Leiden, Schiphol, The Hague and Rotterdam. The rail station as the focus of Schiphol was reinforced by the creation of Schiphol Plaza, a landside interchange integrating the terminal with the rail station via a retail shopping mall. In 2009 the HSL high-speed rail link was inaugurated linking the airport with Antwerp, Brussels and Paris, significantly increasing its catchment area and appeal as a business development zone (figures 9.04 & 9.05).

Hubert-Jan Henket, supervisor of architecture and urban design, Schiphol 1996-2008 has observed, *'The average traveller these days is much less elite than the passenger almost half a century ago. They have become consumers looking for amusement and the airport responds by providing plenty of facilities. With the provision of an increasing number of facilities that could also be found in the city, the airport began to look more like an airport city. Shortly after I was appointed, this realisation became so strong that Schiphol even positioned itself as an AirportCity. And when this caught on, we began to market the concept.'* (Henket, 2013, pp. 78- 79)

Figure 9.04 - Schiphol Airport City - Source: www.kcap.eu

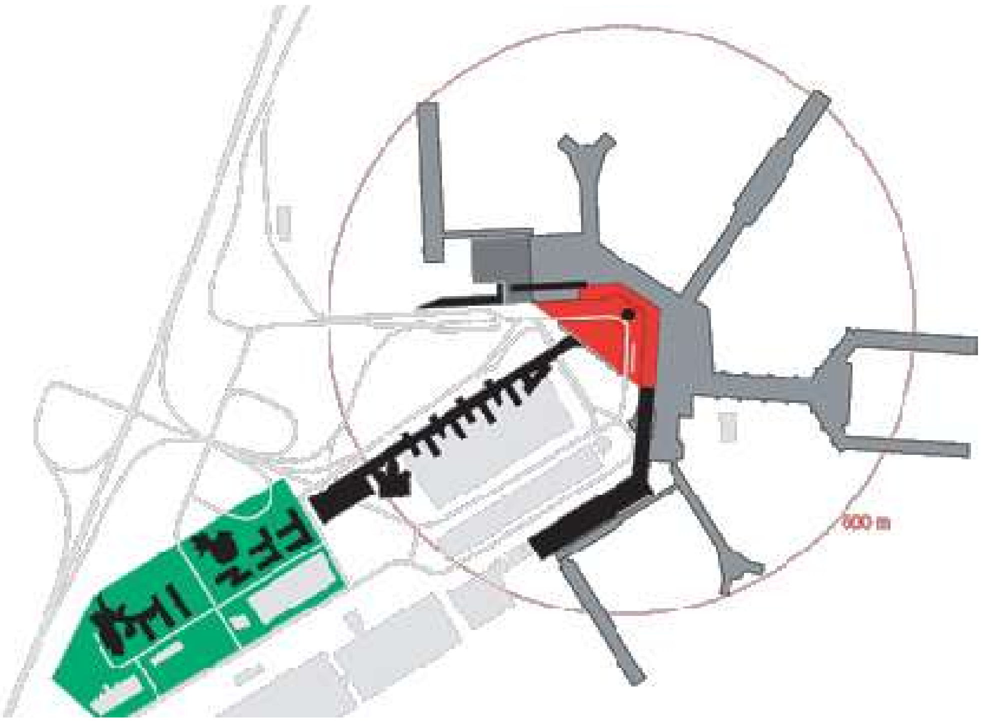


Figure 9.05 Schiphol Airport master plan   Source: http://www.ggau.net

9.3.2 Frankfurt, The Squaire and Munich, Airport City

The Schiphol concept of the airport city has been much copied in Europe as can be seen at Frankfurt (figure 9.06) and Munich Airports (figure 9.07) which both consist of commercial facilities developed adjacent to the rail/airport interchange.

Figure 9.06 - The Squaire, Frankfurt - Source: Amoma.com

Figure 9.07 - Munich Airport City – Source: Skytrax

9.4 Aerotropolis

The term 'Aerotropolis' was popularised by John Kasarda, and is now used to describe city scale, planned, commercial, residential and leisure developments made possible by the catalyst of airport development (figure 9.08). The benefits of associating development with an airport were already well known as can be seen in the juxtaposition of Crawley New Town (established in 1947) with the later development of Gatwick Airport (1958). Crawley, unlike most new towns, boasts exceptional economic performance as the result of its association with the airport. The Crawley Observer reported that the Centre for Cities 2017 Report found that Crawley:

- has the highest employment rate in the UK at 84.9 per cent in 2016, 10.1 per cent higher than in 2015
- sees workers earning the third highest average wage in the UK of £634 per week, behind only London and Reading which both benefit from being close to Heathrow Airport
- has the seventh highest number of patents granted per 100,000 people
- is the eighth most productive city, with an average gross value added (GVA) of £59,500 per worker. GVA measures the contribution to the economy of each individual
- has the highest proportion of private sector jobs in the UK (75,029 private sector jobs, only 10,444 public sector). This is a ratio of 7.2 and the UK average is 2.8
- generates £10,910 of services sold abroad per job in the town – the sixth highest in the UK
- is one of only 13 towns or cities with above average exports per job and productivity
- saw an increase in business start-ups of 29 per cent – the third highest in the UK and 20 per cent above the average **(Centre for Cities, 2017)**

The Aerotropolis concept, which seeks to realise the economic benefits experienced at Crawley, but on a city wide scale, has been particularly seized on by Asian and Middle Eastern airports such as Hong Kong International, Seoul Incheon, Beijing Daxing and Dubai World Central. However the concept diagrams John Kasarda uses to promote his ideas represent economic models and not spatial models (figure 9.08).

The concept that Kasarda presents might be regarded at first sight to be very naïve and simplistic because it fails to recognise the local context or safety and environmental constraints that are inherent to airport development, and offers no vision of the public transport network that is an essential complement to a Global Hub and needed to allow an 'Airport City' or 'Aerotropolis' to grow up around it. However, regarded solely as marketing collateral for an economic vision the diagram makes more sense.

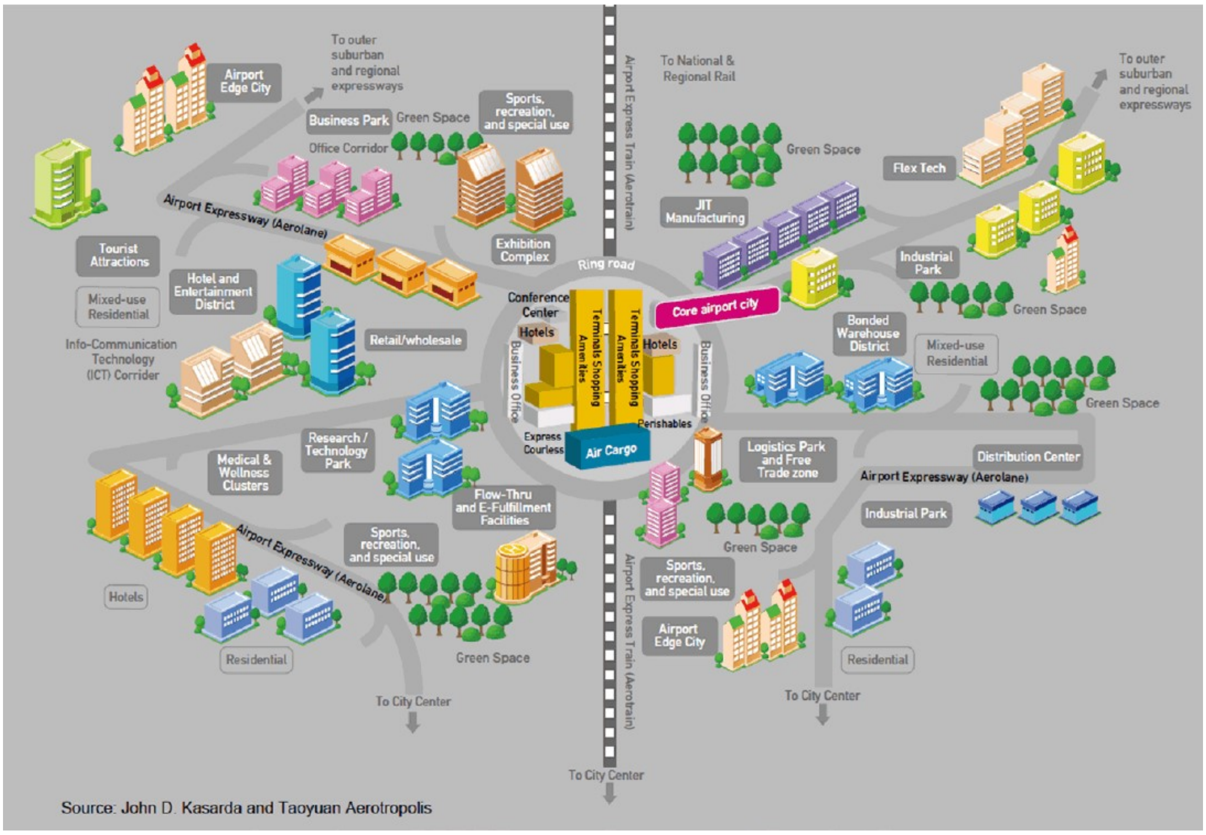


Figure 9.08 - Aerotropolis – Source: John D. Kasarda and Taoyuan Aerotropolis

The following airports are examples of regional development that have been realised with an understanding of the catalytic benefits airports can have on the surrounding hinterland.

9.5 Hong Kong

Although it was designed before John Kasarda popularised the term, Hong Kong Chek Lap Kok exhibits many of the characteristics of an aerotropolis but with an added element of rationality, practicality and contextual and environmental sensitivity. The airport campus itself contains:

- A 30 hectare South Commercial District focuses on logistics, including:
  - Tradeport Hong Kong Limited
  - HACTL the world's largest stand-alone air freight and express cargo facility
  - Asia Air Freight Terminal
  - Mixed Use freight forwarding centre
  - DHL air express hub
- A 10 hectare East Commercial District with an office park development of 300,000 metres^{2}including Cathay Pacific's head office and training facility
- A 57 hectare North Commercial District known as SkyCity adjacent to the airport terminal and served directly by an extension to the airport express train (figure 9.09) containing:

- o SkyPlaza, a multi-purpose commercial complex
- o IMAX 3D theatre
- o International exhibition and trade centre
- o Hotels and entertainment facilities
- o Sky Pier Ferry terminal providing a cross border interchange between the airport and the Chinese mainland

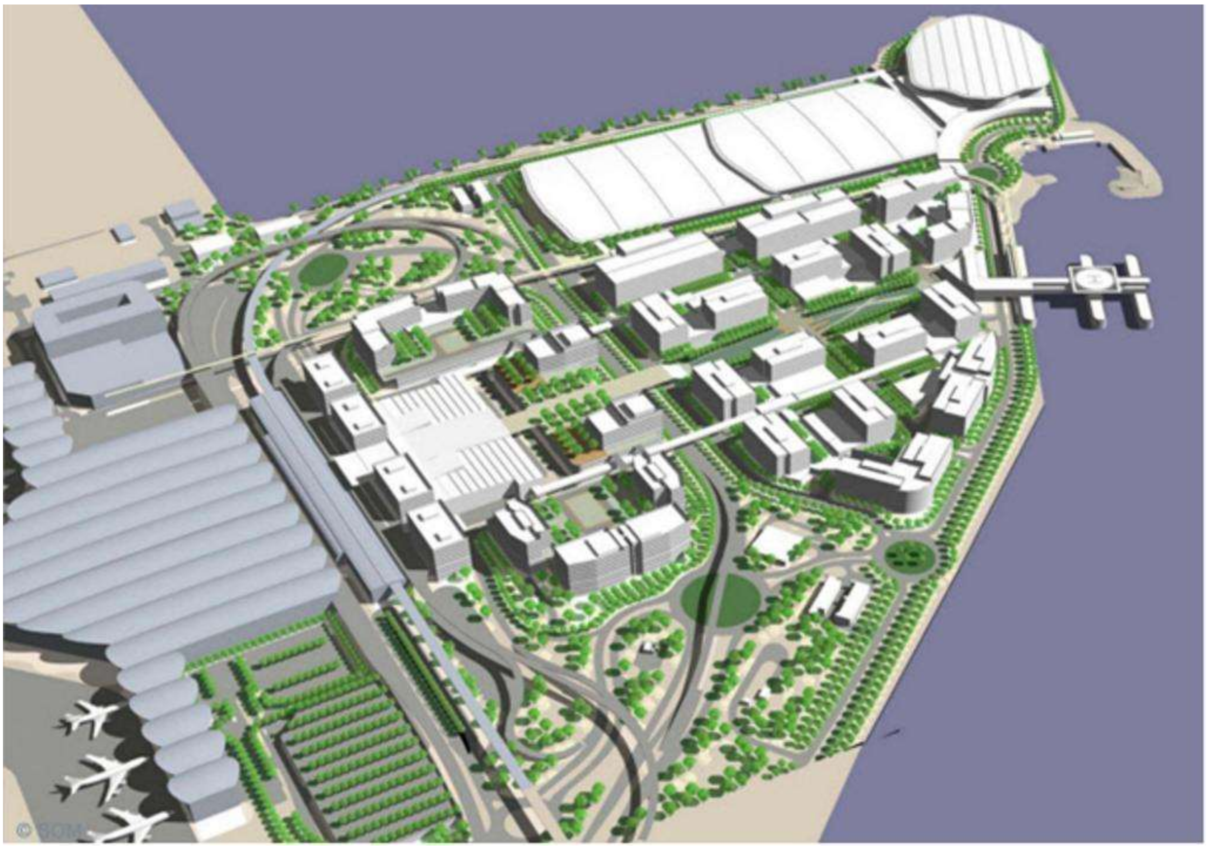


Figure 9.09 - Hong Kong International Airport Aerial View of SkyCity and SkyPier Ferry Terminal
Source: 720 Collaborative Strategic Master Planning Consultancy

Hong Kong already has the expansion of the airport under way with the addition of a third runway being reclaimed from the sea. Many of these features can be found in major international airport cities but what makes Hong Kong different are the adjacent facilities on Lantau Island that have been developed as a part of an integrated regional master plan to create an Aerotropolis:

- The new town of Tung Chung currently houses 80,000 people but is planned to expand to 250,000 people many of whom work at the airport (figure 9 10). It has been carefully sited to the side of the airport so that the noise from take-off and landing aircraft will not intrude.
- A separate cross border high speed ferry terminal links Hong Kong with the Chinese Cities of the Pearl River Delta adjacent to but by-passing the airport.
- A Disney Theme Park.

Figure 9.10. Hong Kong Tung Chung 1998- Source: Wikipedia

Further, the airport is the focus of major investment in new transport infrastructure with a bridge link under construction that will link Hong Kong with Macau. What is just as important is that all this development just occupies a thin northern strip of Lantau Island preserving over 90% of the island as a tropical rain forest (figure 9.11).

Figure 9.11 - Hong Kong Chek Lap Kok and Tung Chung and Lantau Island 1998- Source: Wikipedia

9.6 Seoul Incheon

Incheon International Airport functions as one of the main hub airports of northeast Asia. Incheon airport has been globally ranked number 1 for 10 consecutive years for airport services, and ranked number 2 for international cargo transportation.

Geographically, Incheon Airport is within reach of 61 foreign cities, each with over 1 million people, and can be reached within 3.5 hours flying time. It is claimed it is possible to make a day trip from the airport and reach a population of 2.5 billion people in Asia.

The airport was created by linking two islands, Yeongjong to the east, and Yongyu to the west (figure 9.12). Dams were formed to keep the sea at bay and allow the construction of the airport on the former seabed. It was planned from the outset as an Aerotropolis, and is supported by three development zones within an overall Free Economic Zone (IFEZ). An express railway links Incheon with the domestic airport Gimpo and capital city Seoul some 61 Km and 43 minutes away.

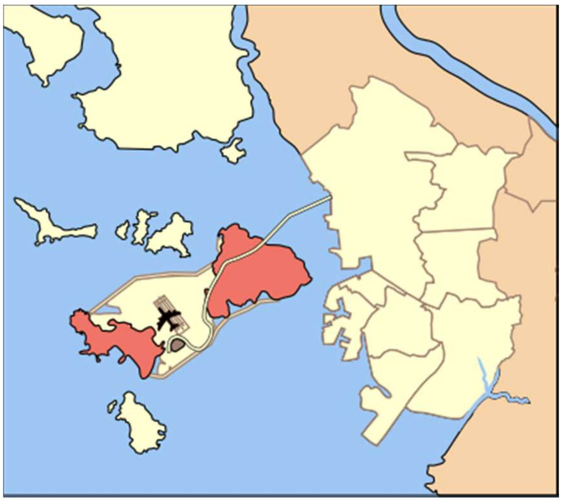


Figure 9.12 - .Seoul, Incheon – Source: Wikipedia

The three zones of the IFEZ comprise (figure 9.13):

- Yeongjong, which forms a continuum to the east of the airport, focuses on airport support facilities and logistics, tourism and leisure.
- Cheongna, further to the east on the mainland, concentrates on international finance, high-tech industry, and distribution. It will have a future planned population of 90,000 people.
- Songdo international city is located to the southeast of the airport on 600 hectares of reclaimed land and is connected to the airport by a 12 kilometre bridge. It is characterised as a 'smart city'. Songdo is home to international business relating to Information Technology, Bio Technology and Research and Development. Songdo is still under development, and has a current population of 100,000 people and a planned future population of 300,000 people.

Also, Incheon Harbour which consists of cutting-edge harbour infrastructure is located at a 20-minute car distance from the IFEZ. On top of this impressive connectivity, the area lies only an hour away from Seoul, Korea's metropolitan area.

The master plan shows how the rail and road network linking to the capital and the aerotropolis cities is incorporated into the airport (figures 9.14 & 9.15). Aerial views of Songdo City show a very high level of ambition for the development of the aerotropolis. They also show the purpose designed road and rail networks that link the city directly to the airport via a giant causeway/bridge (figures 9.16 & 9.17).

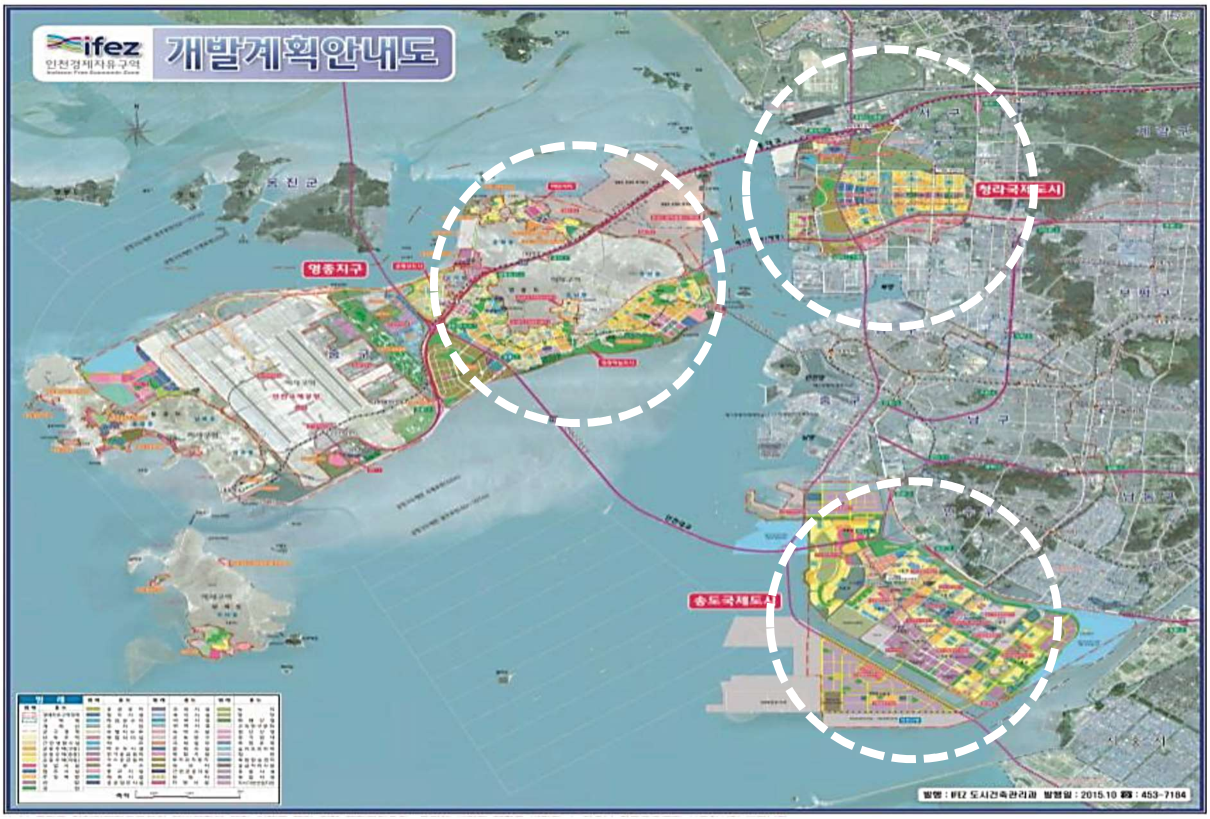


Figure 9.13 - Seoul Incheon, Yeongjong, Cheongna and Songdo - Source:Songdo

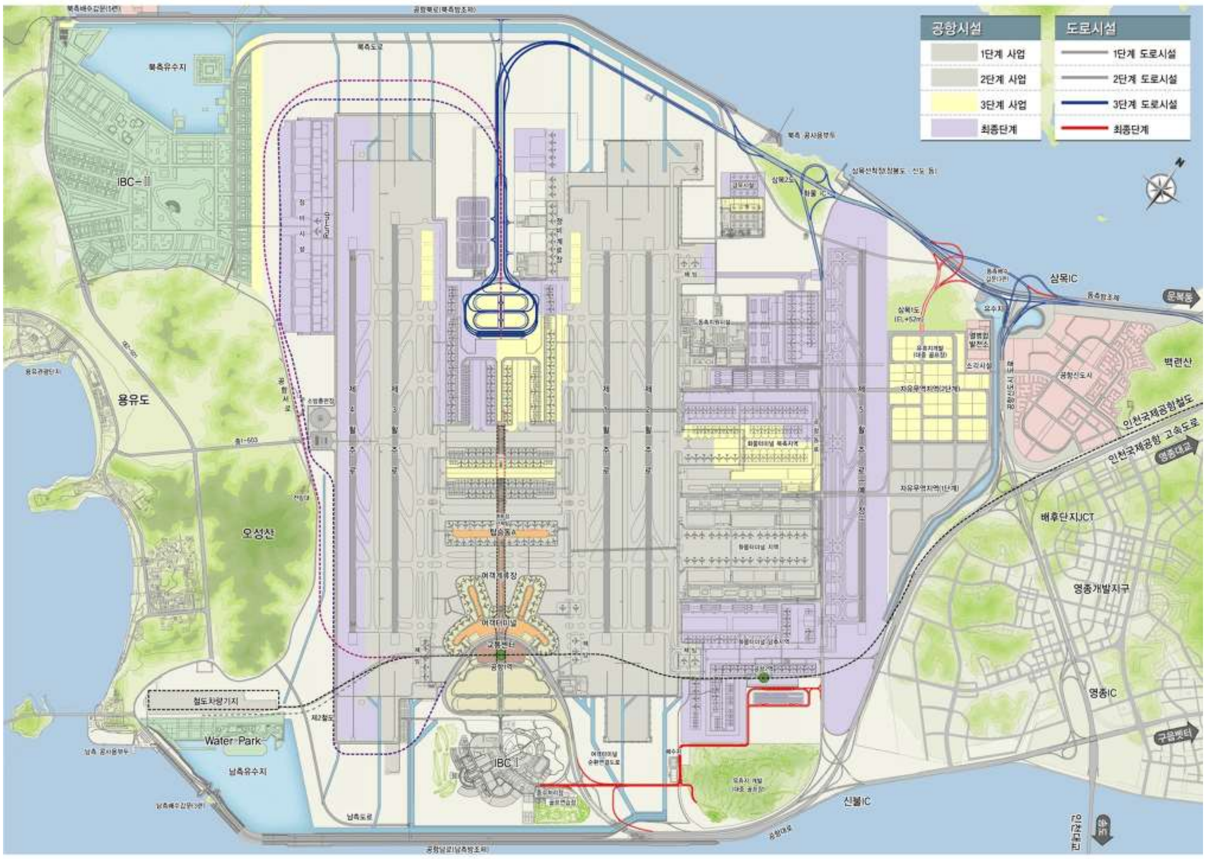


Figure 9.14. – Seoul Incheon master plan, with five runways and two terminals – Source: Seoul, Incheon

Figure 9.15 – Seoul Incheon connectivity -Source: About Airport Planning

Figure 9.16 Songdo Landmark City Master Plan - Source: John Portman and Associates

Figure 9.17 – Songdo City showing link to Incheon airport - Source: http://www.mooyoung.com

9.7 Beijing Daxing

The airport's master plan was prepared by NACO, the Dutch airport consultant, and features a major passenger terminal interchange providing the airport with public transportation links; high-speed rail, metro, expressways, Beijing Airport Bus routes, local buses and inter-airport transportation system. The terminal design was undertaken by Zaha Hadid in association with ADPI.

The first phase of the airport project is designed up to handle up 72 million passengers, 20 million tons of cargo and mail, and 620,000 aircraft movements in 2025, with future plans to handle 100 million passengers in the long term.

A new high-speed railway service, the Beijing–Xiong'an intercity railway, is under construction and will start from Beijing West railway station. It will connect the urban area of Beijing, Daxing District of Beijing, the new airport, Bazhou and Xiong'an. The section between the airport and Beijing will operate at speeds of 250 km/hour and the section between the airport and Xiong'an will operate at speeds of 350 km/hour, cutting the end-to-end journey time between the two cities to about 30 minutes and Beijing to the airport in about 11 minutes (figure 9.18).

The master plan incorporates two terminals, each supported by a major airport city type of development on the approach to the terminal. The runways are widely enough spaced to allow ancillary facilities, such as cargo and logistics to be located between them, while peripheral areas are reserved for aircraft maintenance, repair and overhaul (MRO) and other airport supporting facilities (figure 9.19).

Figure 9.18 - Beijing Daxing Location Plan
Source: Australian Business Traveller

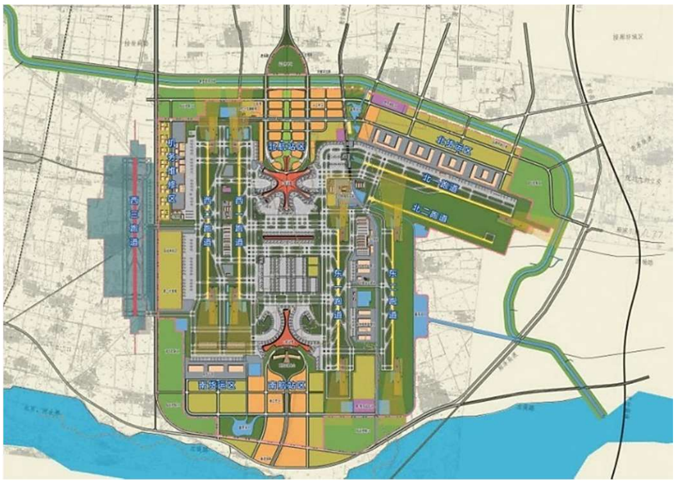


Figure 9.19 - Beijing Daxing Master Plan
Source: http://www.bjbna.com

Aerial photographs show there are many undeveloped sites around the airport, so that with its exceptionally good connectivity the surrounding area it is a natural candidate to become an aerotropolis. Some of the close-in development that will form part of the aerotropolis are shown on the original masterplan by NACO (figure 9.20) and early ADP masterplan which was developed prior to their collaboration with Zaha Hadid (figure 9.21).

Figure 9.20 – Beijing Daxing – Original Masterplan - Source: NACO

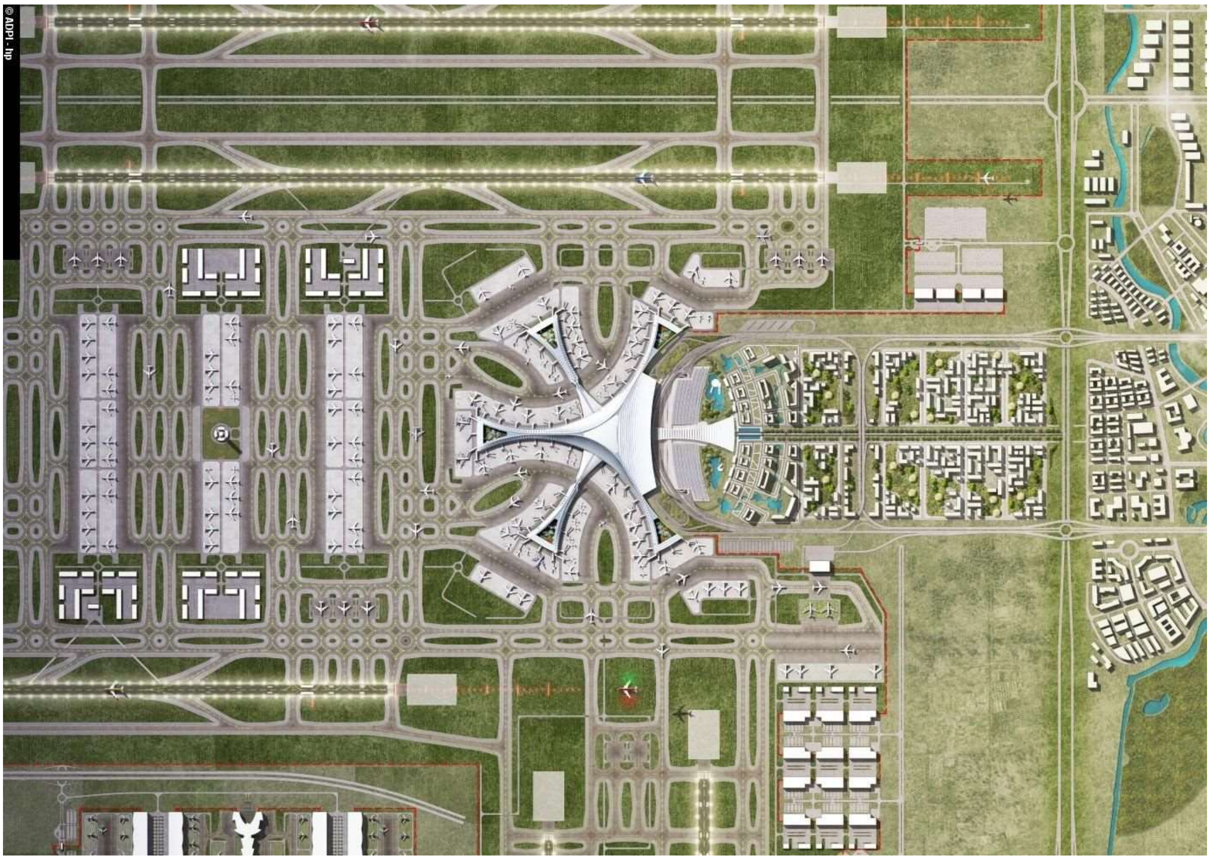


Figure 9.21 - Beijing Daxing Terminal Area – Source: ADPI

9.8 Istanbul Grand International

Istanbul Grand Airport is to supersede Ataturk as Istanbul's main hub airport and opened in 2019. It is located some 30 kilometres north of Istanbul (figure 9.22). It has been planned on a grand scale to handle up to 150 million passengers a year through 2 terminals, on 6 runways, four parallel and two cross wind, with 500 aircraft parking stands of which 165 are planned to have airbridge connection to the terminal (figure 9.23 & 9.24). It also has three separate aircraft maintenance areas and multiple cargo zones and parking for 70,000 cars.

Figure 9.22 - Istanbul Grand – Source: Daily Mail

Figure 9.23- Istanbul Grand Aerial Image – Source: Airport Technology

Figure 9.24 -Istanbul Grand, Aerial view – Source: Nordic-Office of Architecture, Grimshaw Architects, Haptic Architects

IGA Airport City which supports the airport comprises:

- 420,000m^2 of commercial development adjacent to the main terminal
- 315,000m^2 of commercial development adjacent to the future second terminal
- 4,500,000m^2 Free trade zone and logistics entre
- 775,000m^2 East development zone
- a city park

The anticipated employment created by the Istanbul New Airport is expected to reach 225 thousand employees by 2025. Source: www.igairport.com

Figure 9.25 - Istanbul Grand Simulation Model with airport city in the foreground – Source: Eurocontrol

The airport is supported by an extensive range of airport city projects, but as it is currently promoted the airport city does not have the same level of ambition nor is it on the same scale as Hong Kong, Incheon or Dubai World Central (figure 9.24, 9.25 & 9.26).

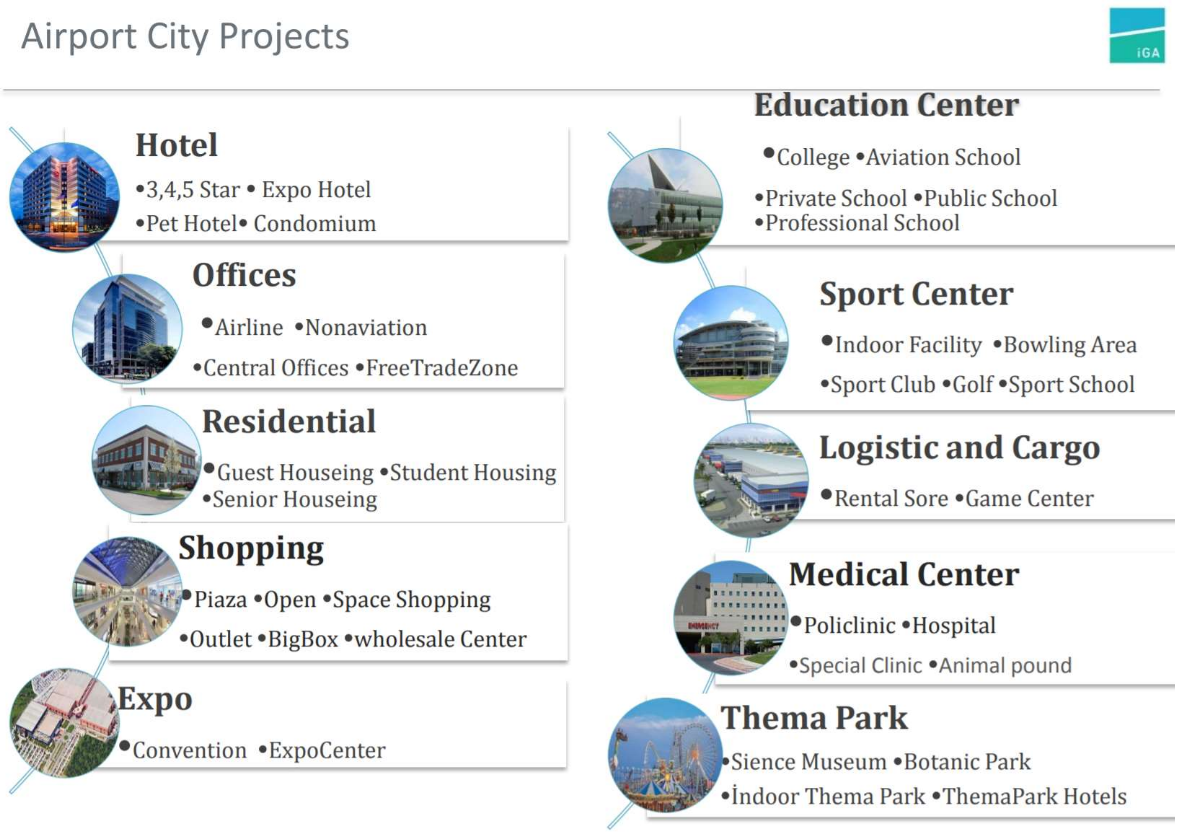


Figure 9.26 - Istanbul Grand Airport City Scope - Source: IGA

9.9 Dubai World Central

Dubai World Central is the most ambitious Aerotropolis to date. It is focused on Al Maktoum Airport which is planned to grow to 220 million passengers a year, and ultimately supersede the existing Dubai International Airport as Dubai's main hub airport (figure 9.27). It contains several zones over an area of 145km^2 that combine to form the Aerotropolis: Commercial, Golf, Business Park, Logistics, Aviation, Exhibition and Residential Districts (figure 9.28). The exhibition area was planned to host the delayed Expo 2020.

Figure 9.27 -. Dubai World Central Aerotropolis - Source: emirates247.com

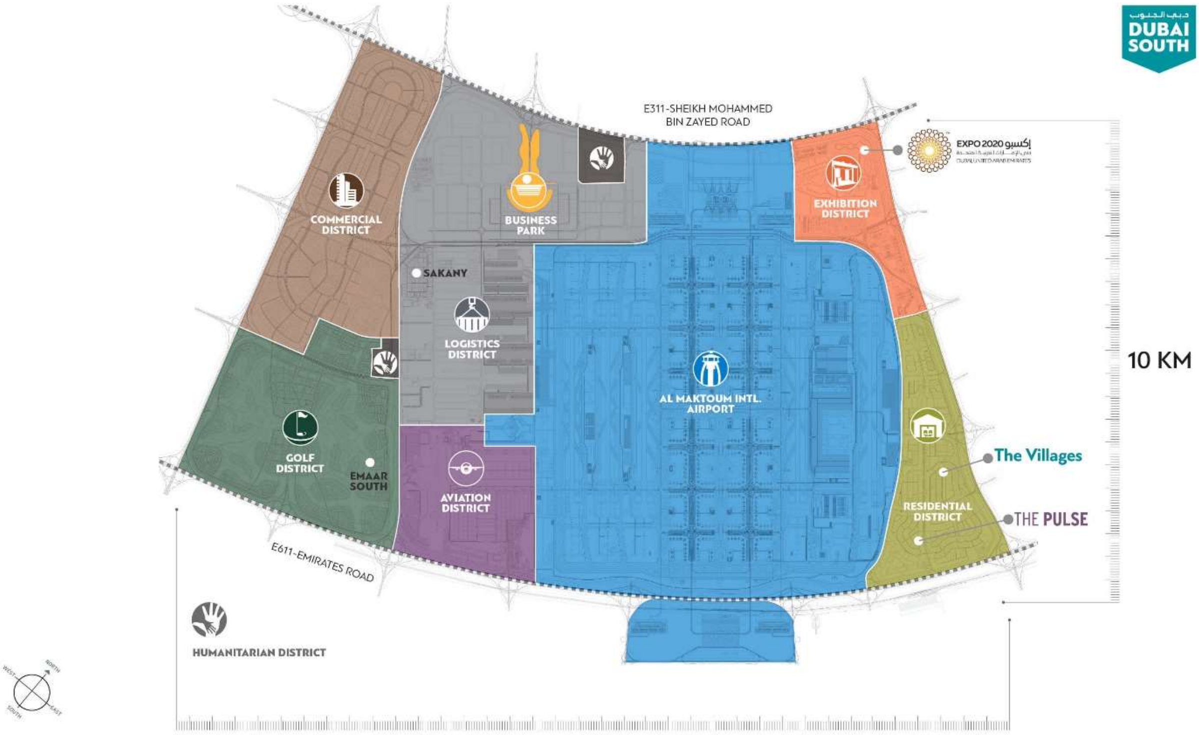


Figure 9.28 -. Dubai World Central Master Plan – Source: Dubai South

These ambitious plans are complemented by equally far reaching schemes for investment in infrastructure projects including extensions of two metro lines to the airport, and the proposed high speed rail system, designed to link the various Emirates especially Dubai and Abu Dhabi via the new airport (figure 9.29).

Figure 9.29 - Dubai Metro 2030 – Source: Wikipedia

The airport is linked to the Jebel Ali Port with a dedicated road link, around which a Free Zone has been formed which allows businesses to operate without being taxed (figure 9.30). An initial phase of the airport currently handling 7 million passengers a year is being expanded to 15 million passengers a year. Meanwhile there are currently doubts about the financing of the project that is slowing down progress. This has resulted in the existing Dubai International airport to publish plans to handle more traffic increasing the existing capacity from 90 million passengers a year to 118 million passengers a year in 2023 primarily through process improvement rather than further investment in infrastructure.

Figure 9.30 -. Dubai Jebel Ali Port – Source: Megaconstrucciones.net

9.10 Conclusion

Planners have long recognised that airports can be generators of growth in the local and wider community. At first at major airport such as Atlanta, Dallas- Worth, Heathrow and Gatwick this was an unplanned consequence of airport development, but later planners recognised the benefits of designing the hinterland around the airport first as an airport city, as at Amsterdam Schiphol and Frankfurt and then later more ambitiously as an aerotropolis at Hong Kong, Seoul Incheon, Beijing Daxing, Istanbul Grand and Dubai World Central.

While some of the claims for the aerotropolis are more polemic than reality Hong Kong in particular has shown the advantage of considering development around the airport to the wider benefit of the metropolis. The key to success there was that development was not just limited to commercial exploitation but included residential and leisure areas, that were integrated with the wider transport network, to generate a real sense of community.

10. The challenges of environmental sustainability

10.0 Introduction

This chapter considers the impact of environmental sustainability on airport design, from two points of view. Firstly the impact of protest and secondly the development of scientific environmental assessment. It addresses the major sources of nuisance in turn: noise, air quality and emissions, climate change, ecology and biodiversity, water and waste management. It concludes by discussing the future of airport environmental assessment.

10.1 Environmental Sustainability

While civil aviation may have started in 1919, it took some 40 years before the airport community recognised the environmental consequences of flying. Although socio/environmental issues such as noise, air quality, safety and property values had been identified as early as 1930 in a study by Harvard University (Hubbard, 1930), the impacts were largely either ignored or belittled. The new concern was largely provoked by the introduction of noisy jet aircraft in the 1960s and the associated rapid growth of air travel.

There are now three strands to the story of the evolution of airport environmental sustainability, firstly the influence of environmental protest groups in frustrating airport development and secondly the development of environmental assessment as a recognised science. Both had their origins in the New York region. The third strand, which is still in its infancy, is the identification of measures required to address extreme weather events at airports resulting from climate change.

10.2 The Impact of Protest

An early protest movement was provoked by the Port Authority of New York and New Jersey (PANYNJ) proposal in 1959 to build a major regional airport at a swampy location in Morris County, New Jersey to supplement Newark Airport. The development was opposed by two organisations, the Jersey Jetport Site Association and the North American Wildlife Foundation. In less than a year, they purchased, assembled, and donated to the federal government enough property in the core of the swamp to qualify for perpetual protection as a National Wildlife Refuge. This led to the establishment of the Great Swamp National Wildlife Refuge by an Act of Congress on the 3rd November, 1960, and the demise of the airport project.

Not long afterwards in 1966 in Japan, a group of local residents combined with student activists and left-wing political parties formed a popular resistance group to oppose the development of Narita airport on farm land. They started protest activity called the 'Sanrizuka Struggle' with the aim of stopping the airport development. Their protests often figured in the international news and resulted in a much delayed and reduced development. Local farmers still stake their claim to some of the land on the airport's grounds, which means that it is technically still not complete.

Other protest groups such as HACAN, Plane Stupid and the Frankfurt protesters have sought to prevent airport developments. In general protest groups have been able to delay or reduce the scale of developments or gain operational restrictions rather than stop them, but in Japan protest provoked a complete change in government policy.

The conflicts at Narita were a major factor in the later decision to build Kansai International Airport in Osaka (1994) followed by Chubu Centrair (2005), Kobe (2006) and Kitakyushu (2006), off-shore on reclaimed artificial islands, instead of again trying to expropriate land in heavily populated areas(figures 10.01, 10.02, 10.03 & 10.04).

Figure 10.01 Osaka Kansai – Source: Pinterest

Figure 10.02 - Chubu Centrair – Source: Pinterest

Figure 10.03 - Kobe - Source: Pinterest

Figure 10.04 - Kyushu – Source: Pinterest

Other successful Asian airport schemes on reclaimed land include Hong Kong Chek Lap Kok (figure 10.05) and Seoul Incheon (figure 10.06). The former involved creating land for the airport by demolishing part of a mountain and pushing the spoil into the sea to create the airport platform, while the latter was created by linking a small island with the mainland by building a dyke and draining the area behind to form the airport. In both cases aircraft take off over water limiting the noise footprint over nearby communities.

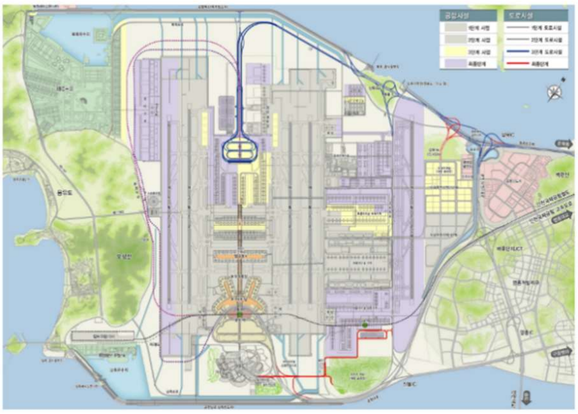


Figure 10.05 - Hong Kong Intl Source: AECOM *Figure 10.06 Seoul Incheon – Source; Incheon Master Plan*

Attempts to reclaim land to build airports on reclaimed land with the objective of reducing noise nuisance have had less success in the United Kingdom. An early scheme to build a new large airport for London on the Isle of Grain was developed in 1943 by Frederick George Miles of the Miles Aircraft Company and architect Guy Morgan but it was rejected primarily because the site was considered too remote from London (figure 10.07). In the meantime proposals for Heathrow had been developed in secret under wartime provisions, thus avoiding public scrutiny.

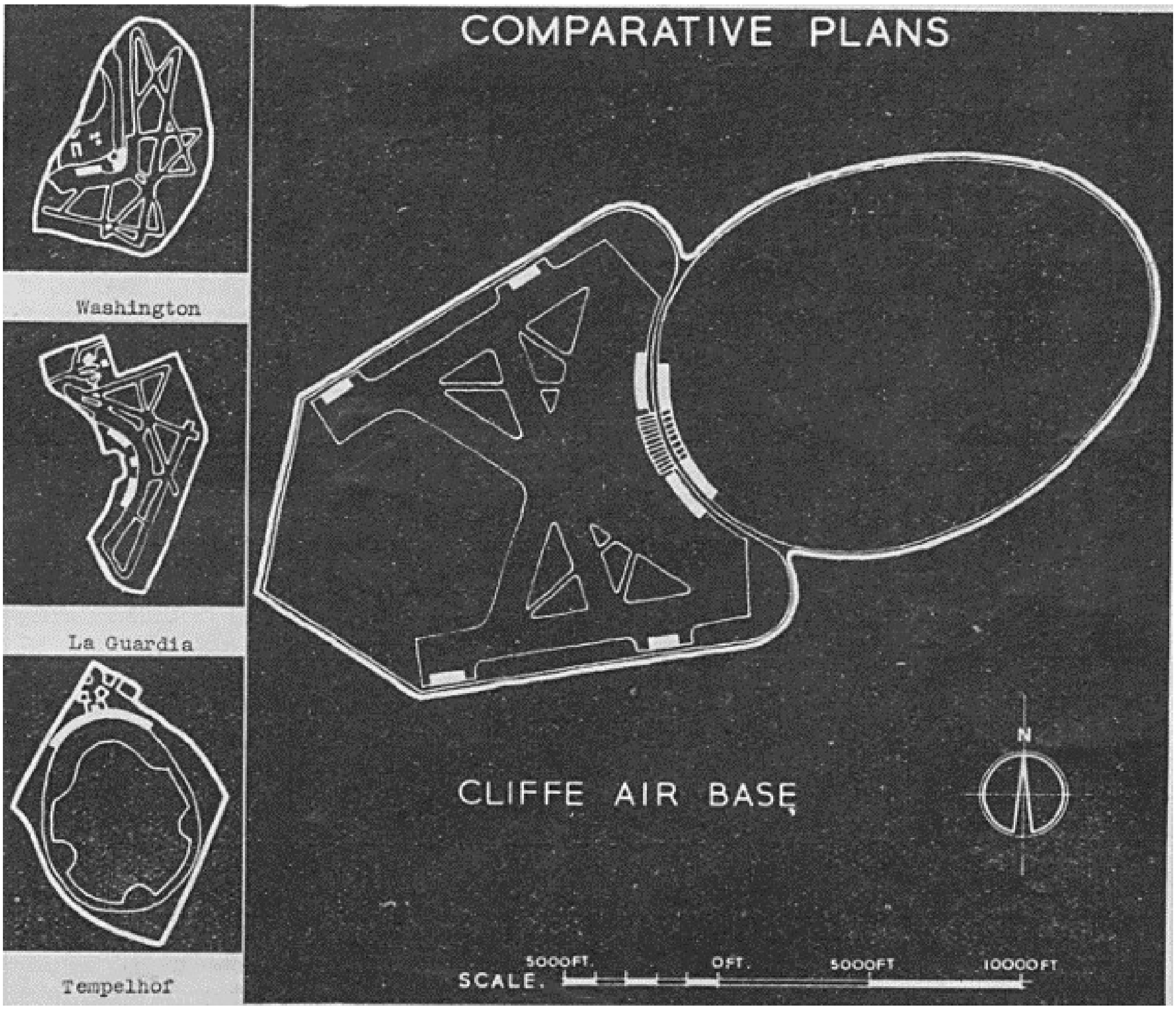


Figure 10.07 - London, Isle of Grain – showing comparative size with contemporary airports – Source: Flight

A one man environmental protest by Sir Peter Hall, who was at one time the President of the Town and Country Planning Association, in the form of a dissenting minority report to the Roskill Commission temporarily saw the UK Government support the development of a new airport at Maplin Sands (Foulness) (figure 10.08) on the South Essex coast in preference to the majority view that supported development at Cublington in the heart of rural England. However, a change of government saw the project cancelled, preferring instead to expand the existing airport at Stansted.

Figure 10.08 - London 3rd Airport Proposal on reclaimed land at Maplin Sands c1972– Source: British Airports Authority

The idea of a coastal airport was revived on several occasions in subsequent decades, the most recent being the Mayor of London's 2013 proposal for a new hub airport to replace Heathrow on the Isle of Grain in North Kent (figure 10.09). Despite demonstrating that less than 4,000 people would come within the $55dBA_{Ldn}$ noise contour (the EU measure of noise nuisance) compared with over 1,000,000 people using the same measure at Heathrow, the proposal was rejected again primarily on grounds of cost and additional risk.

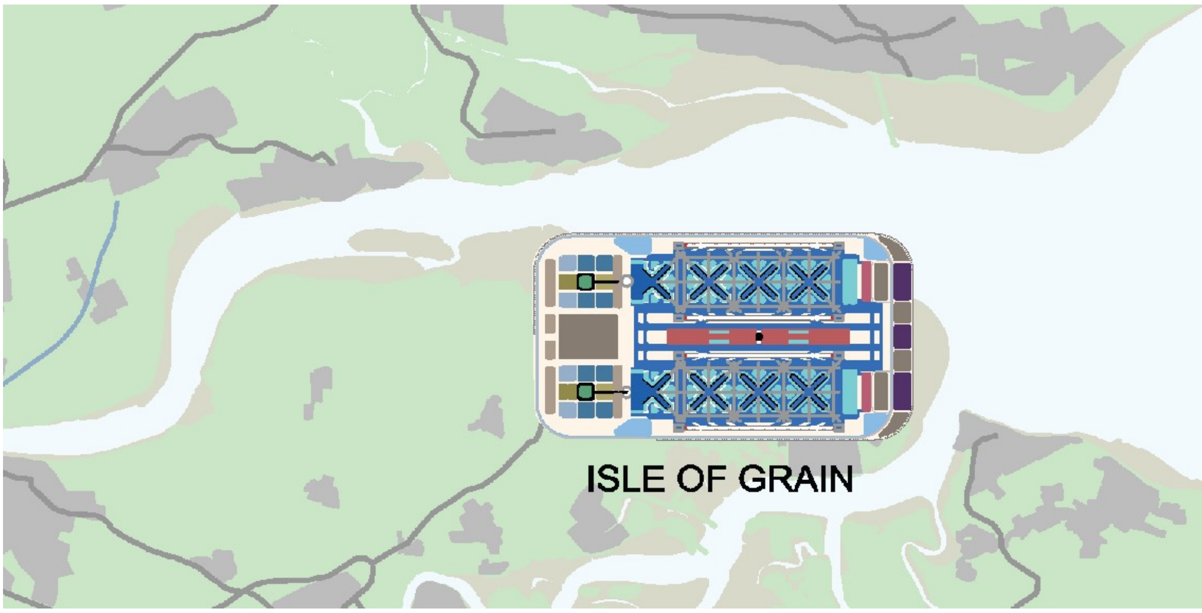


Figure 10.09 - A new airport for London, Isle of Grain, master plan 2013 – Source: Atkins

10.3 Environmental Assessment of Airports

The application of a formal scientific approach to environmental assessment can first be seen in the publication of the 'Jamaica Bay and Kennedy Airport, a multidisciplinary environmental study' in 1971 (National Research Council (US) Environmental Studies Board, 1971) (figure 10.10). The scope of the study included considering the impact of proposed airport improvements such as lengthening runways, site reclamation, air traffic control innovations and advances in technology including projected aircraft engine developments. The following issues were considered in the report:

- Noise including the impact on housing developments, and ineffectual noise monitoring
- Water Quality, reduction in tidal volume, sewage disposal and water pollution
- Air pollution from aviation and automobiles
- Implications of historic and proposed landfill, and spoil disposal
- Marine and marsh ecosystems and wildlife
- Bird-strike hazards
- Popular attitudes to Jamaica Bay particularly as a leisure resource

In identifying attitudes to Jamaica Bay they included a survey on recreational habits. The results, which might seem surprising when seen from today's perspective, were:-

- Driving for pleasure 20.73%, walking for pleasure 17.93%, playing outdoor sports or games 12.71%, swimming 6.47%, sightseeing 5.91%, bicycling 5.15%, fishing 4.19%, attending sports events 3.75%, picnicking 3.53%, nature walks 2.70%, boating 1.95%, hunting 1.86%, horse riding 1.25%, camping 0.86%.

Figure 10.10 - New York, JFK showing its proximity to Jamaica Bay and Metropolitan New York
Key: 1. Brooklyn - 2: Canarsie - 3: Howard Beach - 4: JFK Airport - 5: Inwood – 6: Broad Channel – 7: Rockaways – 8: Breezy Point Park -. 9: Floyd Bennet Field (former New York Airport)
Source: Jamaica Bay and JFK Environmental Assessment 1971

Politicians began to recognise the importance of environmental issues, at least in their rhetoric, as exemplified by President Nixon who said:

> '*The 1970s absolutely must be the years when the United States pays its debt to the past by reclaiming the purity of its air, its waters and our living environment. It is absolutely now or never*.'

The following topics appear to be the primary focus for environmental management at airports:

- Noise
- Air quality
- Climate change
- Ecology/Biodiversity
- Water
- Waste management

These issues are discussed in turn with selected examples. Appendix A explores the policy and technical issues involved in environmental sustainability and sets down further examples.

10.4 Noise (unwanted sound)

The noise problem, has historically always been the most important and controversial environmental issue. It begins with a letter of complaint to the Times in 1924 about the noise from low flying aircraft at Croydon Airport (Cluett, 1977). The opening of the new Croydon Terminal in 1928 provoked the publication of the following quotation from Ezekiel xxvii. 28 in the press: *'The suburbs shall shake at the sound of the cry of thy pilots*' (Cluett, 1980). Noise nuisance was greatly exacerbated by the introduction of jet aircraft in the 1950s (figure 10.11).

Figure 10.11 – Aircraft Noise – Source: Eurocontrol

The Anti-Noise League was formed in London in 1933. As reported in the British Medical Journal (BMJ) their concerns included motor cars and their hooters, pneumatic drills, clattering lorries, banging doors, aeroplane engines and wireless loudspeakers. In 1935 the Science Museum organised an exhibition about noise abatement. (The Science Museum UK, 2015) (figure 10.12).

The centre piece of the exhibition from the sonic perspective was, however, the demonstration house erected in the buildings section to showcase advances in architectural acoustics, building materials and quiet domestic technology. This was a full-size, two-storey house, on the scale and design of a typical suburban semi-detached dwelling. It was built especially for the exhibition by C W Glover, of consulting engineers C W Glover & Partners. Glover was a member of the Council of the Anti-Noise League. In complete contradiction he had earlier made a name for himself by proposing to build an elevated airport in central London near King's Cross Station, possibly the noisiest airport concept ever proposed (figure 10.13).

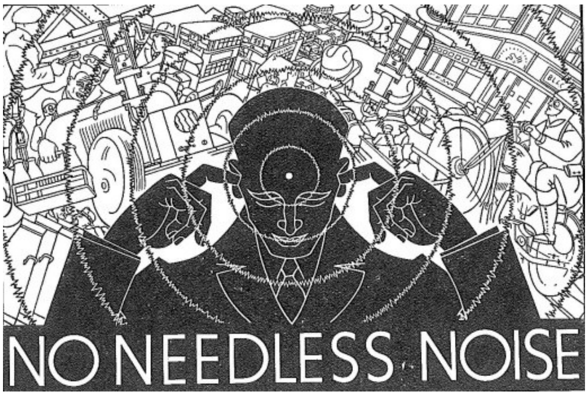


Figure 10.12 - Logo of the Anti-Noise League, The pressure group behind the 1935 exhibition -. Source: Science Museum

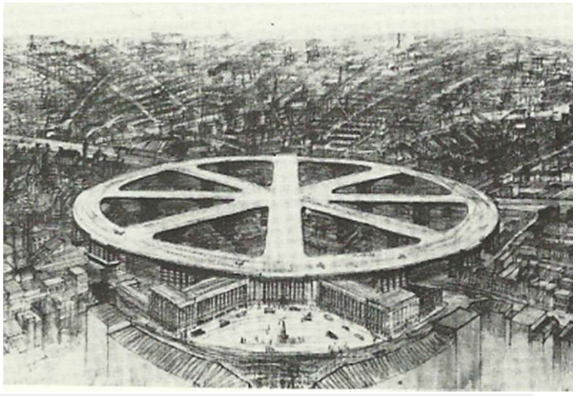


Figure 10.13 -Kings Cross Airport, Charles Glover Source: Illustrated London News 1931

In 1936 the anti-noise league raised the matter of the suffering caused to those on the ground through the noise of the passage overhead of aeroplanes flying at low altitudes with the Air Ministry."The Low Flying Nuisance: The Anti-Noise League's Complaint and the Air Ministry's Reply" (Aircraft Engineering and Aerospace Technology, 1936).

Airport Conferences in the 1960s focused on the introduction of jet aircraft including Concorde and the stillborn Boeing SST and on the introduction of helicopters to link major airports with the city centre and the anticipated noise nuisance. The first issue was how to measure noise nuisance, a debate that is still continuing today, with varying definitions adopted by the FAA (USA), CAA (UK), EASA (EU) and other national regulatory bodies. All measure noise in terms of sound pressure dBA, but use different adjustments to establish a noise footprint that reflects perceived annoyance. See appendix A for further detail.

10.5 Reduction of Noise at Source

Manufacturers' new technologies have produced significant noise reductions over time as illustrated in the graphs in appendix A. The earliest passenger jet aircraft the Boeing 707 and De Havilland Comet used jet engines designed for military use without regard to noise, so there was plenty of scope for noise reduction as jet engine design developed for civilian use. This has allowed airports to claim improvements in noise levels over time without having to change any design features.

10.6 Land Use Planning and Management

The following planning techniques have been adopted by airports to mitigate against noise pollution.

- Planning, easements and zoning
- Airport Location away from urban centres - Boston, Schiphol, Sydney, New York
- Coastal Locations, Reclaimed Land, Artificial Islands: Kansai, Centrair, Seoul
- Closure of city centre airports- Tempelhof, Kai Tak and most Heliports
- Ground noise mitigation, control at source: walls, bunds (artificial landscaped hills), ‘ground-scaping’ (contoured landscaping), Ground Run Pens (GRPs) (walls enclosing parked aircraft on three sides) and hush houses (fully enclosed hangar like structures) – London Heathrow and Gatwick, Amsterdam and Frankfurt
- Runway design - Displaced thresholds, Long Runways – London Heathrow, New Delhi and New York

10.7 Noise Abatement Operational Procedures

There are many initiatives being employed at airports around the world in order to mitigate against noise pollution. Examples include:

10.7.1 Noise preference routes:

Using defined, or 'noise preferential' routes (NPRs) is one way of minimising exposure to noise for people living near airports by minimising overflight of highly populated or sensitive areas. However, focusing routes into a narrow band has some disadvantages as while a large number of people benefit, a smaller number have increased disturbance which has given rise to protests where this has been implemented.

10.7.2 Continuous descent:

This involves a number of techniques (figure 10.14):

- keeping the aircraft high for as long as possible, (increasing the distance from the aircraft noise sources to the ground by following the green line in the following figure rather than the conventional red line reduces the number of people exposed to engine noise) (figure 10.14),
- keeping the aircraft at low engine power for as long as possible,
- keeping the aircraft in a clean aerodynamic configuration for as long as possible (by not deploying flaps and so reducing airframe noise).

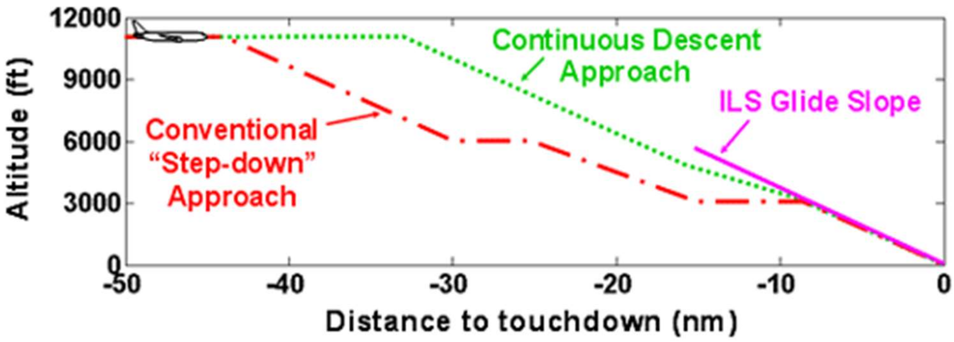


Figure 10.14 - Comparison of conventional 'step-down' and continuous descent approach Source: http://silentaircraft.org/approaches (Cambridge MIT)

While continuous decent profiles for landing aircraft arguably are primarily being used to save fuel they have the added benefit of reducing noise generated by aircraft on approach.

10.7.3 Steeper approach angles (figure 10.15):

Steeper approach angles (3.2˚ instead of 3.0˚) are also being investigated with the objective of reducing the noise footprint

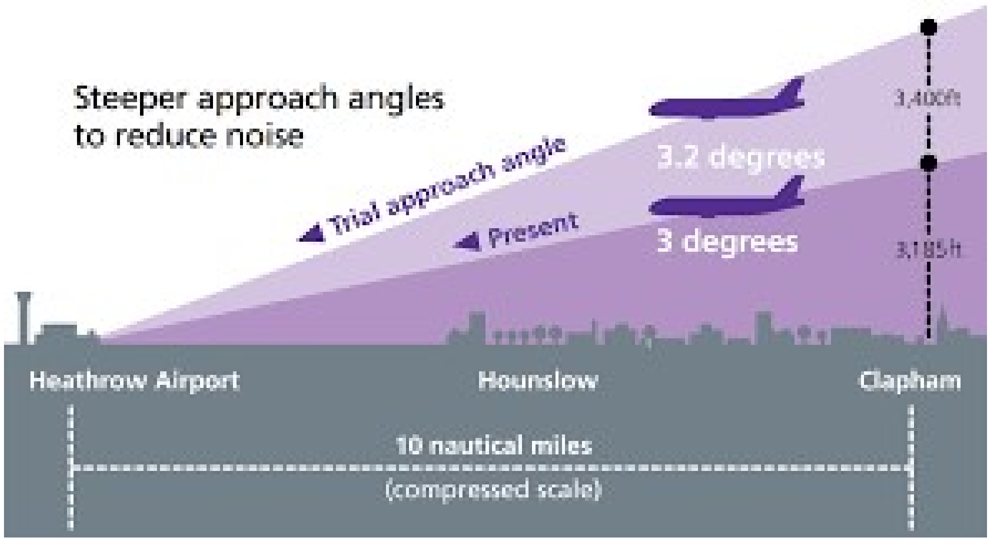


Figure 10.15 – Noise impact of steeper approach angles - Source: yourheathrow.com

Even steeper angles of approach have been implemented at selected airports such as London City (4.6˚) but these require additional certification of the aircraft type. Relatively few of the smaller aircraft types have been certified in this way, the largest being the Airbus A318 which British Airways operates between London City and New York JFK in an all business class format.

10.7.4 Displaced thresholds (figure 10.16):

Displaced thresholds move the landing point on a runway away from the end to keep aircraft flying higher for longer as aircraft require less distance to stop than they do to accelerate and take off.

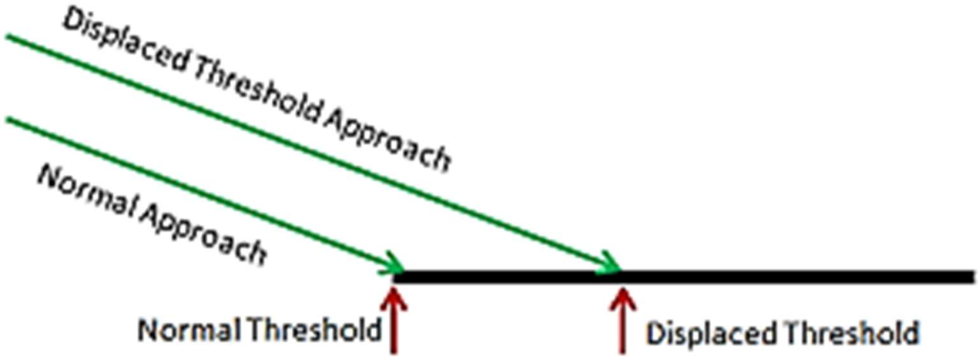


Figure 10.16 – Impact of displaced thresholds – Source: Smart Aircraft Training

Examples of displaced thresholds to minimize environmental impact of approaching aircraft can be found at a number of airports, including Narita and Delhi airports. The benefits of displaced thresholds are currently being investigated as a noise mitigation measure for Heathrow Airport, an initiative to make the proposed 3rd runway project more acceptable.

10.7.5 Engine ground running restrictions:

Most modern aircraft have small jet engines, known as auxiliary power units (APUs), in the tail of the aircraft to power their ancillary systems during turn-around. To mitigate against the need for aircraft to run these engines, during turn-around and when parked on the stands, experimental fixed electrical ground power (FEGP) and pre-conditioning air (PCA) systems were installed as long ago as 1942 at Washington National Airport.

This was intended to be a showcase for advanced American technology, but the development and take up of technology has been slow primarily due to the high cost, which has to be borne by the airport rather than the airline. (Froesch, 1946, pp. 212-226) (figure 10.17). The adoption of FEGP and airport provided PCA obviates the need for aircraft to run the auxiliary power unit (APU), a small jet engine in the tail of the aircraft, to power their ancillary systems and reduces both noise and emissions. It has now become standard practice at larger modern airports.

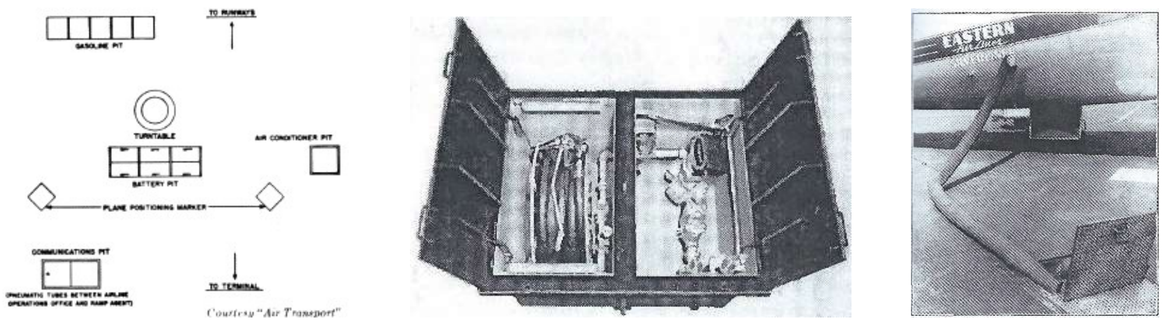


Figure 10. 17 - Illustration of the fixed ground service equipment at Washington National Airport 1942 – Left –diagrammatic stand equipment layout, Centre – FEGP, Right – Aircraft Air Conditioning (PCA) Source: Airport Planning, Charles Froesch

10.7.6 Start up and taxiing

Ground noise is produced by low frequency vibrations. The deep rumble is caused by aircraft running their engines on the ground. Ground noise is particularly noticeable when aircraft are starting up and when engines are under test which requires the use of full power. To mitigate against engine test noise Ground Run Pens (GRPs) and hangar like enclosures (hush houses) can be employed but much engine testing is still carried out on open unprotected stands.

Noise generated while aircraft taxi between the stand and end of the runway is a further source of annoyance to local communities. There are operational mitigation techniques that are sometimes employed such as towing aircraft to the end of the runway before starting their engines. Physical mitigation techniques include provision of landscaped noise bunds as at London Gatwick or concrete fences such as at London Heathrow where space is more limited.

A recent innovation is 'Ground-scaping' which involves complex profiling of the ground to prevent any direct sound paths. Characterised by large wavelengths, ground noise therefore easily 'rolls' over obstacles. In addition, it is scarcely absorbed by air or soil, and houses have low insulation factors for this low frequency noise. The ground ridges are wedge-shaped hills that deflect the sound waves upwards thanks to their sloping surfaces. The ridges are 3 metres tall (1.5 metres above ground level and 1.5 metres below) as can be seen below at Amsterdam Schiphol -The Buitenschot Land Art Park (figure 10.18).

Figure 10.18 - Amsterdam Schiphol -The Buitenschot Land Art Park – Source: land8.com - Photograph Captain Luchtfotografie

A similar 'Ground-scaping' technique was investigated for Runway 3 at Heathrow but there was insufficient space to implement the idea, but where the site area is generous this is a technique that could have further application. It should be noted that these techniques are only suitable to alleviate ground noise as they have no effect on airborne aircraft during take-off and landing.

10.8 Operating restrictions at airports

Operating restrictions include night curfews, runway alternation, noise directives local agreements and noise insulation grants are typically regarded as the last resort when design options to mitigate noise have been exhausted. They are set down in in appendix A.

10.9 Noise Exposure at Airports

The following noise contour map (figure10.19) shows graphically the advantages of locating Hong Kong airport so that aircraft take off and land over water, with the result that very few residential properties are adversely affected by noise. Other examples of noise contours can be found in appendix A.

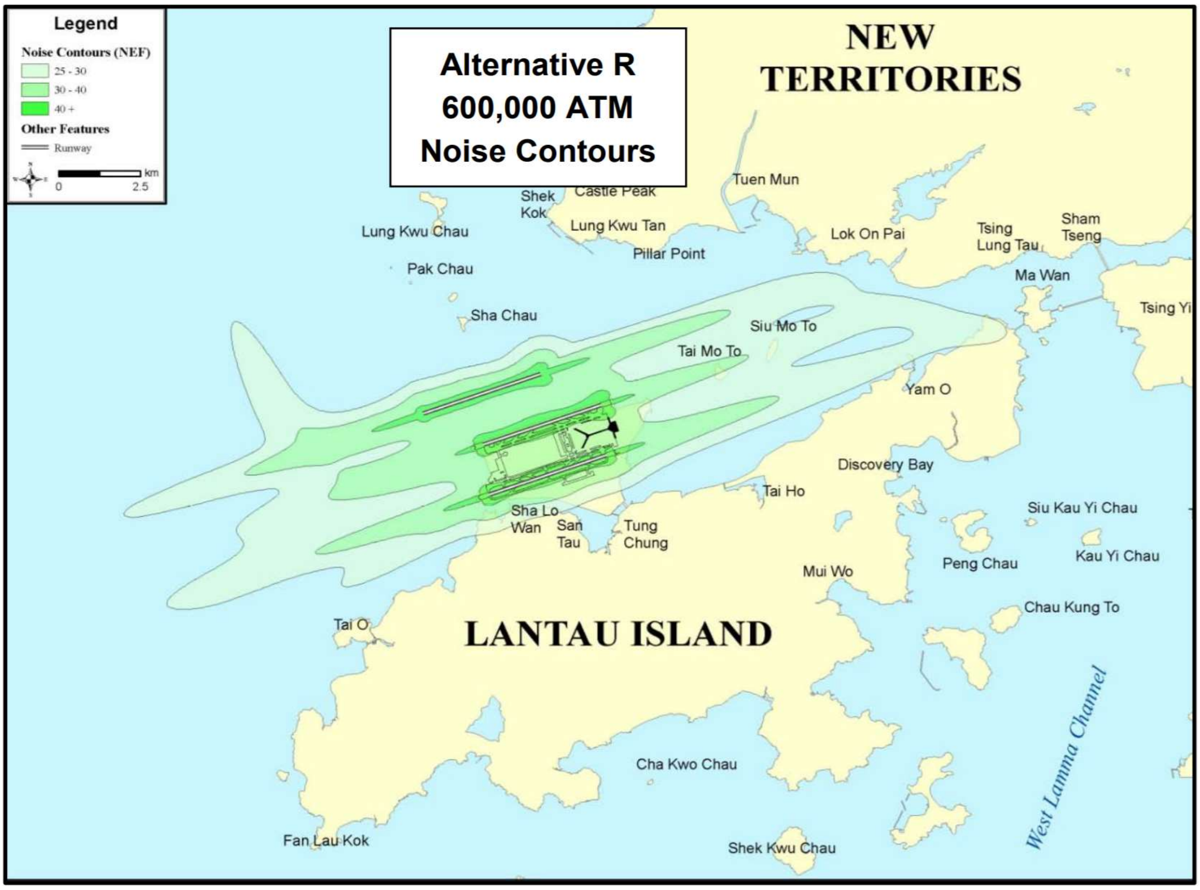


Figure 10.19 – Hong Kong International, 3rd runway predicted noise contours – Source: HKIA Masterplan 2030

When choosing a possible site for a new airport for London on the Isle of Grain the same logic as Hong Kong was used, to direct as many flights as possible over open water or over land areas with low populations. The resultant predicted noise contour (figure 10.20), showed that less than 4,000 people would have been in the 57dB L_{aeq} noise contour compared with over 1,000,000 people at Heathrow. The figure also shows that the shape of the noise contours is also very dependent on airspace design and the routing of aircraft to miss heavily populated communities.

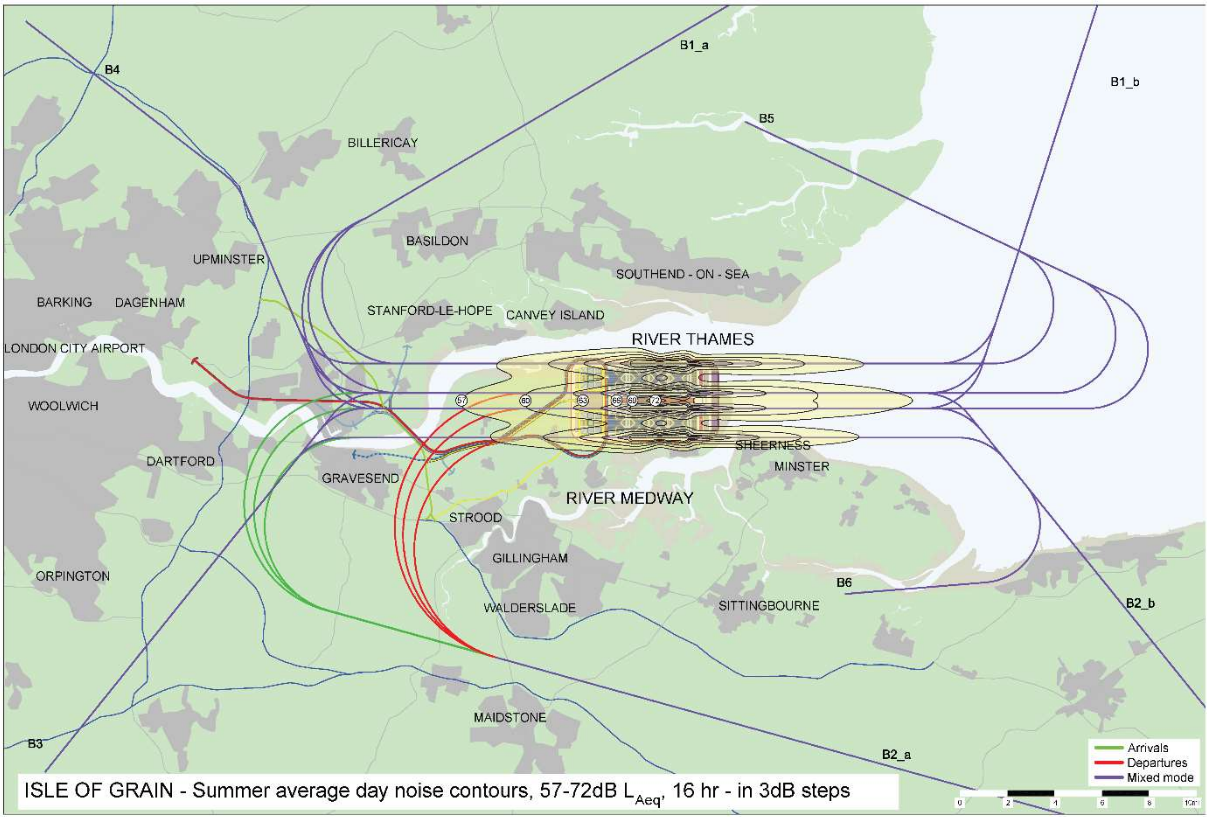


Figure 10.20 A New Airport for London, Isle of Grain Noise contours – Source: Atkins

10.10 Air Quality and Emissions

London Heathrow

Heathrow air quality report is shown in the figure below. The inset shows that areas to the north of Heathrow along the A4 Bath Road, highlighted in red, fail to meet the NO_2 air quality standards primarily due to road traffic serving Heathrow (figure 10.21).

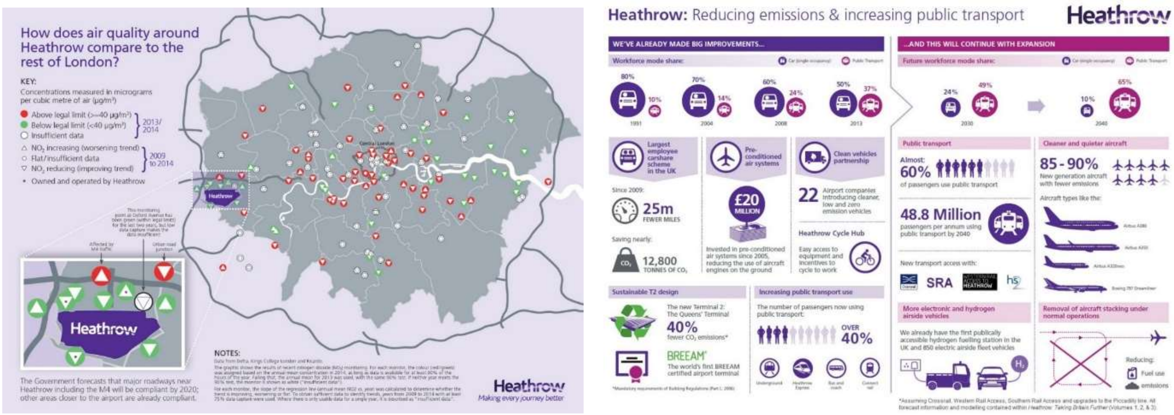


Figure 10.21 - Heathrow Air Quality Comparison Map and “Blueprint for Reducing Emissions”
Source: Heathrow Airport website

Research also shows that some 80% of NO_2 originates from road traffic rather than aircraft. While both aircraft and road traffic will become cleaner and more fuel efficient over time, the main proposal at Heathrow to limit its emissions comes from its surface access strategy.

This aims to deliver their commitment that there should be no more cars on the roads as the result of the expansion programme. Heathrow proposes to achieve this by:

- encouraging more passengers to use public transport, including the new Elizabeth Line and increasing the number of bus services. As part of the strategy Heathrow is one of two proposed locations to replace Victoria coach station which is due to close. The other complementary location is Stratford. These two initiatives require improvements to the passenger terminal interchanges to handle the increased volume of traffic.
- restricting the number of passengers coming by road by introducing a road charging scheme and limiting the numbers of staff who come by car to half present levels.
- diverting passengers away from using taxis and being driven to the airport ('kiss & fly') which produces two journeys for each arrival or departure. Instead they want to encourage passengers to drive themselves to the airport and park there for the duration of the trip ('park & fly'). This produces one journey for each arrival or departure halving the number of trips

The 'park and fly' strategy, however, produces a counter-intuitive result, a demand for more parking spaces, a concept which is proving difficult to sell to local communities who assume that this will inherently result in more traffic on the local roads.

Air quality initiatives at other airports are discussed in appendix A.

10.11 Climate Change

Higher atmospheric concentrations of greenhouse gases - notably carbon dioxide (CO_2) but also methane, NOx and others -cause the atmosphere to absorb more heat from the Earth's surface, and lead to higher levels of warming, or climate change (figure 10.22).

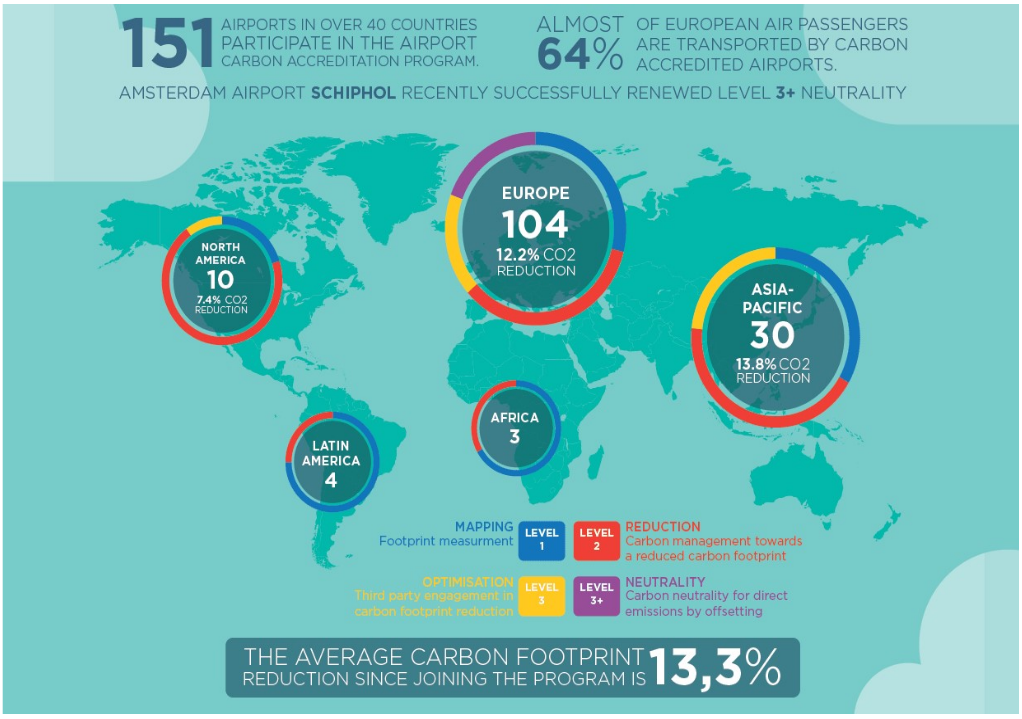


Figure 10.22 - Carbon Footprint – Source: TO 70 Consultancy

Airports and aviation generate greenhouse gases in three main ways:

1. Flights are by far the largest source. Aircraft emit large quantities of CO2 and NOx during flights, particularly during take-off and landing.
2. Ground traffic is the second largest source.
3. Airport buildings require electricity and heating and the energy production of which will generate greenhouse gases.

The movement to make Europe’s airports climate neutral was pioneered by Swedavia’s Stockholm-Arlanda airport, which achieved certification as the first carbon neutral airport in the world in November 2009.

From 2005 to 2008, Stockholm-Arlanda reduced its emissions by around 50% through increased efficiency measures and a switch to renewable fuels. An important contributor has been the aquifer that provides natural cooling in the summer and heating in the winter, which the airport says is the world’s largest energy storage space (figure10.23).

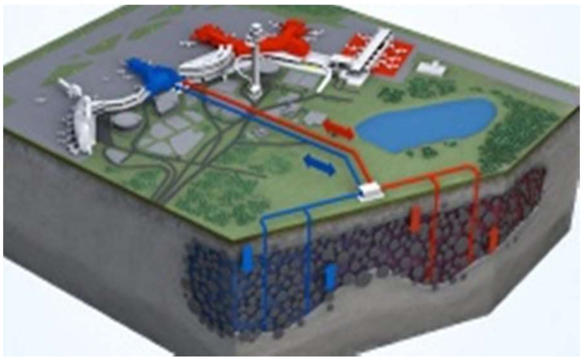


Figure 10.23 - Stockholm-Arlanda’s Aquifer
Source: LFV

“*For emissions that we have not yet been able to reduce on our own, we’re investing in projects in developing countries that absorb the equivalent amount*,” said Fredrik Jaresved, LFV Head of Quality Assurance and Sustainable Development. “*We’re proud that the contribution our colleagues have made has resulted in this accreditation, but we continue our work to reduce the remaining*

As part of efforts to cut energy consumption by a third by the end of 2010, LFV has also completed the installation of light-emitting diode (LED) lighting in the multi-storey car park next to Stockholm-Arlanda’s Terminal 5. It was the first time that LED lighting has been installed on such a large scale in Sweden. As part of efforts to cut energy consumption by a third by the end of 2010, LFV has also completed the installation of light-emitting diode (LED) lighting in the multi-storey car park next to Stockholm-Arlanda’s Terminal 5.

It was the first time that LED lighting has been installed on such a large scale in Sweden. A saving of more than 65% in energy consumption is expected to be achieved by switching from regular fluorescent lighting to LEDs, which not only have a longer life but also increase the amount of light by 10%. Kenth Arvidsson, Managing Director of Arlanda Energi, said that savings of up to 80% could be made once motion detector lighting was installed.

In 2017 twenty eight airports in Europe had achieved carbon neutrality Level 3+:

- Finland: Helsinki
- France: Nice Cote d'Azur
- Greece: Athens
- Italy: Rome Leonardo da Vinci, Milan Malpensa, Milan Linate, Venice
- Netherlands: Amsterdam Schiphol, Eindhoven
- Norway: Oslo, Trondheim Vaernes
- Sweden: Are Ostersund, Goteborg Landvetter, Kirunda, Lulea, Malmo, Ronneby, Stockholm Arlanda, Stockholm Bromma, Umea, Visby
- Turkey: Ankara Esenboga, Antalya, Izmur Adnan Menderes
- U.K. – London Gatwick, East Midlands, Manchester

Airport Carbon Accreditation permits the use of the following internationally recognised offset instruments.

- Certified Emission Reductions (CER)
- Emissions Reduction Units (ERU)
- Proprietary Verified Emission Reductions (VER)
- European Union Allowance (EUA)

To achieve this level of accreditation, an airport has to:

- Fulfil all requirements of 'Mapping', 'Reduction' and 'Optimisation'.
- Offset its remaining Scope 1 and 2 carbon emissions (GHG Protocol) to show its commitment to achieving carbon neutral operations for all direct emissions and indirect emissions over which the airport has control, using internationally recognised offsets.

The Neutrality level recognizes that the airport has achieved a 50 percent reduction in carbon emissions over the last three years. Additionally, it reflects that the airport is also actively engaging local stakeholders to lower their respective emissions and is also offsetting the remaining emissions under its direct control.

Many of the accredited airports are keen to market their accreditation and promote their low-carbon, eco-friendly airport management. The accreditation standard is however very limited in scope involving only an airport's direct emissions and omitting airline, handling agents, commercial and other partner activities. However, environmental activists would dispute that offsetting was permitted and also dispute that certification is related to direct airport emissions only, excluding all airline flying activities.

Appendix A sets down the climate change legal framework and includes examples of best practice at major international airports that have transparent environmental policies.

10.12 Ecology and Biodiversity

Biodiversity impacts are particularly significant if they affect sites of importance to nature conservation:

- special protection areas (for birds)
- special areas of conservation (for habitats) and wetlands,
- site of special scientific interest,
- endangered and protected species (eg The Chinese White Dolphin).

In some cases, the scale of biodiversity impacts that would accompany proposed airport developments have resulted in the plans being changed or – as in the case of the Thames Estuary airport proposal in London – contribute to the proposal being dropped altogether

In most cases ecological considerations have been taken into account in the detailed planning for the airport, with sufficient funding and time allowed within the project plans. Many examples exist of how airports actively eco-manage these areas are included in Appendix A.

Local issues such as biodiversity and threatened species are typically addressed by relocating species in an alternative setting, although this is clearly more difficult with marine and bird life.

10.13 Water

Many of the airports are located near waterways. This is often because the cheapest, flattest, and most desirable land suitable for airports is located near waterways. As a consequence, airport activities may cause water quality impacts due to their proximity to waterways. In particular, construction activities or seasonal airport anti-icing/de-icing activities are major concerns.

Construction often causes sediment-laden runoff to enter waterways. Biological and chemical breakdown of de-icing chemicals in airport runoff can cause severe dissolved oxygen demands on receiving waters. Operations or maintenance are other activities that may affect water quality. If not properly controlled, the resultant water quality impacts may adversely affect animal, plant, or human populations.

The main risk to water quality of airport operations arise from pollution due to fuel spillages, fire training activity and application of chemical for de-icing and anti-icing. This risk can be mitigated through effective design, construction and maintenance of pollution control systems and do not influence airport size providing sufficient space is allocated to water pollution treatment.

Indeed, it could be argued that large airports over 40mppa, which were found by the ACI to be more profitable than the group in the 25-40mppa category (see table3.2.8), are in a better position to afford comprehensive pollution control systems and that there are economies of scale when justifying expenditure on effective mitigation measures.

10.13.1 London Heathrow

The Heathrow pollution control system is made up of three major catchments:

- The Western and Southern Catchments discharges rainfall runoff from the Heathrow Pollution Control System into Clockhouse Lane Pit.
- The Eastern Catchment discharges rainfall runoff from the Pollution Control System into the River Crane (figure10.24).

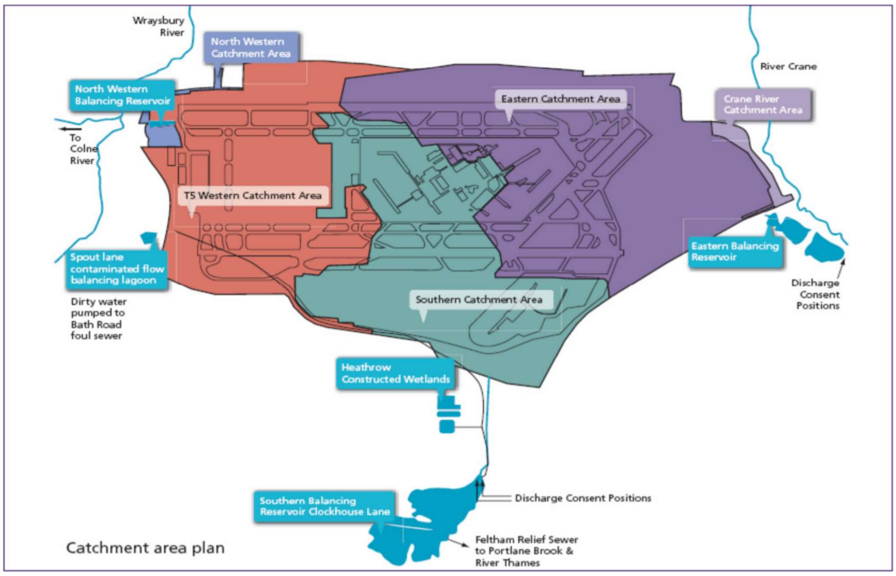


Figure 10.24 - Improvements to Heathrow Airport Water Discharges 2014-2018 – Source: Heathrow

Heathrow states *'that by working together with our staff, contractors and stakeholders, we want to:*

- *implement a technically feasible and not disproportionally expensive pollution management design to maximise existing pond flow attenuation, maximise BOD load capture for treatment and minimise BOD discharge to river*
- *implement an operationally flexible and resilient solution with fast recovery from de-icing events*
- *comply with future Environment Agency consent and other regulation*
- *control discharge flow rates to minimise flooding risk and benefit river under dry conditions*
- *minimise nitrogen and phosphorus concentrations, and add dissolved oxygen in the discharge to improve river water quality*
- *decrease sewage fungus potential downstream of our discharge by reducing BOD concentrations in river water*
- *minimise ecological and biodiversity changes from implementing this scheme'*

10.13.2 New York JFK

New York JFK airport has a long and uneasy relationship with conservationist groups seeking to maintain and enhance the water quality of Jamaica Bay, dating back to at least 1971 and the publication of the Jamaica Bay and JFK Airport Environmental Assessment. The figure from the Environmental Assessment below shows the close relationship between the airport and Jamaica Bay. Records show there is a long history of discharge of pollutants particularly de-icing fluid into the bay (figure 10.25).

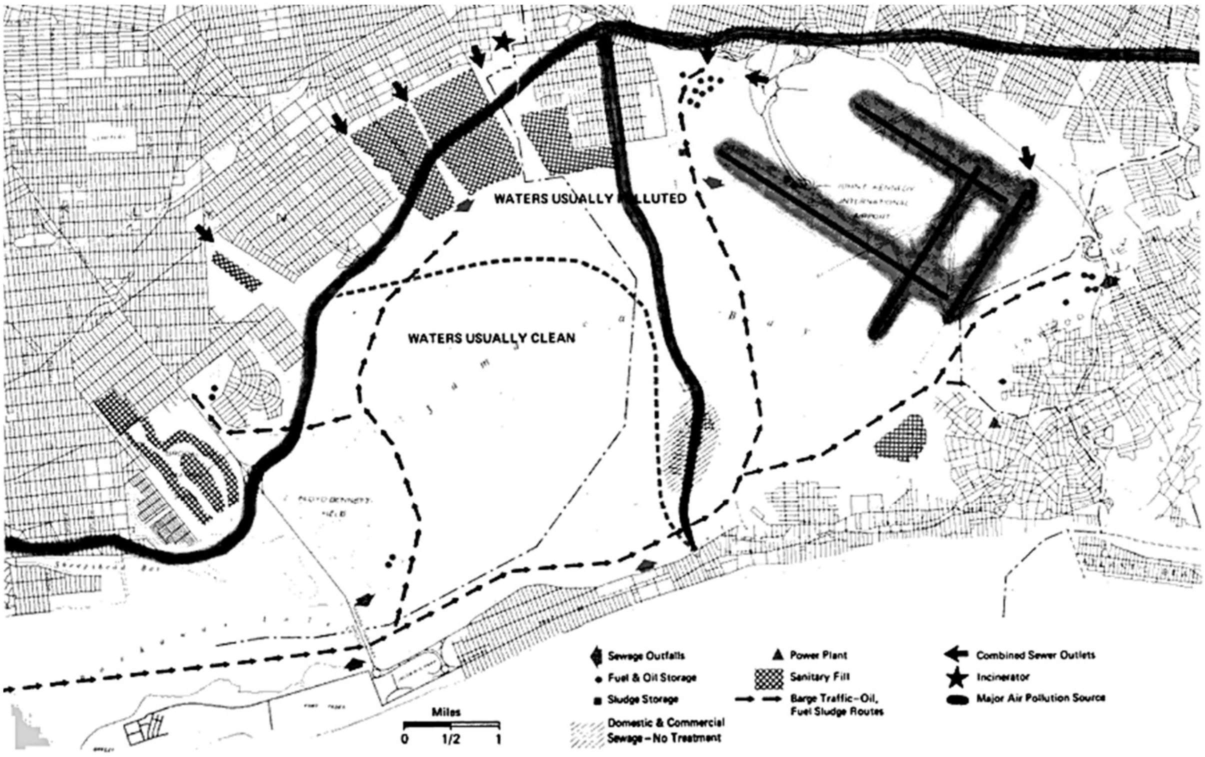


Figure 10.25 - Air and Water pollution Sources in Jamaica bay – Source: Jamaica Bay and JFK Environmental Assessment 1971

The Port Authority of New York and New Jersey lists the following sources as being of the most concern to water quality (Bosco Thomas L., 2015):

• De-icing/anti-icing operations

• Vehicle, equipment and aircraft fuelling

• Vehicle, equipment and aircraft maintenance

• Vehicle, equipment and aircraft washing

• Aircraft lavatory service operations

• Material and waste handling and storage

Such an extensive list does not provide any comfort that pollution control has kept pace with the growth in air traffic over the last fifty years.

The Port Authority's draft environmental assessment of 20th December 2019 covering the proposed revisions to New York JFK include the following modest commitments to environmental stewardship and sustainability (Port Authority of New York and New Jersey PANYNJ, 2019):

• Greywater Capture and Reuse – Greywater capture systems and cisterns are proposed with the capability to reduce stormwater runoff by 50 percent. Potential greywater uses include fireloop (sprinkler system), equipment cleaning (should any such facilities be contemplated near the terminal), and "purple pipe" (separate piping) greywater system for restrooms. The feasibility of these uses depends on the quality of the water and need for water treatment.

• Glycol Recovery – 60 percent of the annual volumes of deicing fluid applied to aircraft utilizing the North Terminal Development would be captured and either recycled or treated and disposed of off-airport at a wastewater treatment facility.

• Preconditioned Air and Ground Power – Preconditioned air and power would be provided at all gates. Remote ground power would be provided at all aircraft hardstand parking positions.

• All electrical GSE – Subject to commercial availability, an all-electric GSE fleet would be utilized at the expanded T5 facilities upon opening of each new gate.

• Renewable Energy – 50 percent of the energy use would be supplied by renewable energy sources.

• LEED Certification – Commitment to achieve LEED BD+C Silver Certification, in compliance with Port Authority Sustainable Building Guidelines and in compliance with Port Authority Sustainable Infrastructure Guidelines for applicable program elements.

10.14 Waste Management

Airports tend to be large generators of waste. The table below provides an indication of some of the information declared by individual airports that provide a guide as to the volume of waste generated (figure 10.26).

Airport	Annual Waste (tonnes)	Waste / Passenger (tonnes per '000 pax)	% Recycled
London Heathrow (LHR)	25,000	0.36	48.0
Amsterdam (AMS)	15,200	0.26	28.4
Frankfurt (FRA)	25,000	0.36	N/A
Seoul (ICN)	12,300	0.25	59.0
Hong Kong (HKG)	24,500	0.36	12.2

Figure 10.26 - Annual waste generated at airports
Source: Benchmarking airports based on a sustainability-ranking index S. Kılkıs and Atkins research

This is only a guide, however, as the figures do not reflect the total waste generated from airport activity, rather, the waste managed by the airport. Individual companies that have their own waste contracts do not declare this information. Heathrow for example estimates that the airport waste contract represents just 25% of the total waste generated at the airport.

Waste management policies being implemented at most major airports follow a similar strategy of reduce – reuse – recycle. Energy from Waste (EfW) plants are becoming increasingly popular as a means to address both issues. The viability of such plants is linked to the volume of waste processed. EfW plants to reduce reliance on fossil fuels, reduce overall greenhouse gas emissions and reduce waste going to landfill, however, this needs to be balanced against implications for local air quality when siting the plant.There are solutions to managing waste, but the issue has not proved to be a constraint to airport growth, because they are technically reasonably easy to implement.

10.15 Community Surveys

In 2005, Eurocontrol, in conjunction with the University of Westminster, explored views of European citizens regarding the growth of air transport through focus groups run in the United Kingdom, France, Spain and Romania - interviewing people who did not live near airports. The results were analysed and published by Eurocontrol in a publication entitled "Citizens' Views on Air Traffic Growth" - Results of European focus groups examining public perception of air travel growth (Pilon, 2006).

In general there was a deal of scepticism about whether safety and environmental information is ever presented in an unbiased manner, so that work done in this arena is not always regarded as credible and is increasingly challenged.

The main effect of negative public responses to airport development is that airports plan their air traffic movement routeings and operations to minimise noise impact, historically the main environmental complaint against airports, using techniques that are described in 10.7.

10.16 Direct Action

There has been increasing objection to airport development in some parts of the world, often resulting in protest ranging from peaceful demonstration to direct action. Some examples of this are discussed below:

10.16.1 Frankfurt

Following construction of the third runway at Frankfurt-Main airport, a protest movement began in the Terminal building every Monday. The objections to the airport's expansion stemmed mainly from environmental grounds. Despite the beneficial economic impact of Frankfurt airport for the regional economy, there was considerable public hostility to further development as shown in the figure below.

On 28th September 2015, the 150th Monday evening protest highlighted the impact of the new flight paths on sleep patterns and quality of life. The protests are said to draw between 600 and 3,000 people who were affected by aircraft noise. Concern is increasing that the appetite for more radical action is growing. Frankfurt started out by operating two of the three runways simultaneously and has been compelled to introduce a night-flight ban of flights. The curfew covers a six hour between 11 p.m. to 5 a.m. The ban has had particular impact on Lufthansa Cargo for whom night flights were a core element of the business model. Although the runway was built, the Monday protests continue against the development of Terminal 3, and specifically the impact of additional air and road traffic that will be generated (figure 10.27).

*Figure 10.27	Local residents protest at Frankfurt-Main Airport – Source: Airport Watch*

10.16.2 London

Protesters against a third runway at Heathrow have taken to direct action, scaling the security fence and occupying the northern runway (Figure), and as recently as November 2016, blocking the M4, a major motorway leading to the airport, by chaining themselves to each other, and causing major disruption (figure 10.28).

*Figure 10.28	Local residents protest at Heathrow Airport - Source: Airport Watch*

Such forms of direct action are likely to get increasingly disruptive and illustrate the depth of feeling about the environmental and social impact of airport expansion. A recent trend, however, has been the involvement of 'professional protestor' or 'eco-warrior' skilled in disrupting construction works and developing increasingly sophisticated plans to disrupt and delay such projects.

Protest movements are becoming more vociferous, well organised and better informed. This affects existing airports, who seek to expand, more than new airports on green field sites and is one of the principal constraints to growth. In many developed countries, there is significant and increasing opposition to airport expansion on environmental grounds. The primary arguments used include:

- There is no need as the internet is reducing the demand for face-to-face business meetings and airports have been adept at increasing volumes of traffic within their existing boundaries.
- Alternatively, some argue that demand should not be met or it should be diverted to other secondary airports with room to grow.
- People should restrict travel to limit climate change to which aviation is an important and increasing contributor.
- Carbon trading is not accepted as an appropriate response.
- The impact of contrails (water vapour trails from aircraft) have negative environmental impacts and are anticipated to attract more attention.

Japan is, to date, the only country to have changed airport planning policy as the result of protest group activity, by constructing all new airports since Narita on artificial off-shore islands. In Europe the norm is now to expand existing airports rather than construct new airports, as this is regarded as the path of least resistance. The last European airport to open on a new site was Munich in 1992. There is, however, one new exception, Centralny Port Komunikacyjny (CPK) the planned new hub airport to serve Poland.

10.17 Extreme weather events resulting from climate change.

The following factors have been identified as needing to be addressed to maintain airport operational resilience as the result of extreme weather events:

• Temperatures	Increasing number of days of heat wave Increasing number of days of drought
• Precipitations	Increasing number of days with extreme rain Snow and ice, thunderstorms and lightning
• Winds	Trend changes to wind direction Increased wind speeds, hurricanes and typhoons
• Sea level	Raised sea level of approximately 1 metre Big waves from hurricanes and typhoons
• Biodiversity	Evolution of biodiversity resulting in additional bird strikes Accommodating changes to habitats for protected species

A number of Asia-Pacific Airports are already designed for extreme weather events. For example Kansai has already withstood typhoons and earthquakes without significant damage. However, there is always a risk that operations need to be suspended during extreme weather events. By contrast New York JFK has been criticised for not taking into account the predicted raising of sea level by a metre in their environmental assessment of 2019. Many airports have contingency plans to operate at lower traffic levels during extreme weather events and then progressively restore full scale operations. By contrast, and with the notable exception of providing sustainable drainage (SUDS) and improving flood defences, there is little evidence that airports are investing in new infrastructure to address anticipated extreme weather events.

10.18 Conclusion and the future of airport environmental sustainability

Understanding the full environment impacts of air travel, and its impact on airport design, is still in its infancy. In the past noise nuisance has dominated the environmental agenda, but now air quality and especially climate change are regarded as increasingly important and potentially even more challenging to address.

The Airports Council International (ACI) has put forward the following definitions for its 6 Level Carbon Accreditation Programme:

Level 1 –Mapping (110 airports worldwide are recognised at this level by the end of 2020)

- Determine emissions sources within the operational boundary of the airport company.
- Calculate the annual carbon emissions.
- Compile a carbon footprint report

Level 2- Reduction (94 airports worldwide are recognised at this level by the end of 2020))

- All of the above plus:
- Provide evidence of effective carbon management procedures.
- Show quantified emissions reductions

Level 3 – Optimisation (62 airports worldwide are at this level by the end of 2020)

- All of the above plus:
- Widen the scope of carbon footprint to include third party emissions.
- Engage third parties at and around the airport.

Level 3+ – Neutrality (62 airports worldwide are recognised at this level by the end of 2020)

- All of the above plus:
- Offset remaining emissions for all emissions over which the airport has control with high quality carbon credits (i.e. airports are required to compensate for their remaining carbon emissions that cannot be reduced by other means by offsetting)

Level 4 – Transformation (1 airport worldwide is recognised at this level by the end of 2020)

- Define a long-term carbon management strategy oriented towards absolute emissions reductions, aligned with the objectives of the Paris Agreement (i.e. transform their operations with absolute emissions reductions in mind, while also strengthening their stakeholder engagement)
- Demonstrate evidence of actively driving third parties towards delivering emissions reductions.

Level 4+ – Transition (2 airports are recognised at this level)

- All of the above plus:
- Offset the residual carbon emissions over which the airport has control, using internationally recognised offsets (including staff business travel)

These are not very demanding targets as they exclude aircraft emissions and those from surface access traffic and offsetting by purchasing carbon credits allows the dilution of on-airport measures. The language used could easily mislead people into believing that more has been achieved than is the actuality. For example the objective related to aligning with the Paris Agreement only requires the airport to keep it in mind rather than achieve it.

Heathrow for example, which in 2020 was certified at Level 3 – Optimisation, has recently put forward its own definitions relating to carbon emissions and global warming.

- *Carbon neutral – Emissions are offset through purchasing carbon offsets.*
- *Net zero carbon – Residual carbon emissions are offset by an equal volume of carbon removals.*
- *Zero carbon – No emissions are released into the atmosphere.*
-

Heathrow, state they aim to achieve net zero carbon by the mid-2030s, but this will not be an ambitious enough target for many environmentalists who will push for zero carbon including all aircraft and surface access emissions and without requiring any offsetting.

It is anticipated that new renewable technologies such as electrification of ground service vehicles, coaches and delivery vehicles, retrofitting ground-source heating systems and installing solar and wind power, will help reduce the growth of carbon emissions at airports over time but require new infrastructure. As a result considerable strengthening of electrical supplies, together with the provision of charging facilities and new battery storage to reduce peak demand will be required. This will need to be combined with reducing demand, for example for air conditioning and baggage handling systems which are notoriously heavy users of electricity.

The use Environment targets and standards are expected to become more onerous over time and affect large airports more than small airports. Concerns focus on aircraft noise, local air quality and greenhouse gas emissions from aircraft and surface access vehicles.

Local protest groups increasingly seek to influence decisions on airport location and expansion particularly in highly populated areas. This is in part due to the larger number of people affected as well as the greater land take. Large airports also induce increased economic activity and traffic generation in the surrounding communities, so that while the surrounding communities can benefit financially they can also suffer environmentally. There is evidence that the protest movement in Japan over the construction of Narita airport has had sufficient impact to change government policy and influence the choice of sites for new airports not just in Japan but over a wide area in Asia. Protest movements worldwide are becoming more vociferous, well organised and better informed.

Technological advances that are typically more affordable in large airports are expected to mitigate the adverse effects to some extent. Noise, air quality and climate change requirements will become increasingly difficult to achieve as airports expand and standards become more demanding. Local issues such as biodiversity and threatened species are typically addressed by relocating species in an alternative setting. With regard to bird and marine life the technique that is usually adopted is to remove their food source and replace it in another location. In the case of Hong Kong, based on international experience and past Chinese White Dolphin (CWD) monitoring data obtained in the construction of HKIA in Chek Lap Kok, dolphins are predicted to return after the 3rd runway project is completed as long as the remaining habitats are healthy.

In some cases, environmental impacts have to be balanced. For example, minimising noise and air quality impact indicates a remote site while maintaining biodiversity and minimising the threat to threatened species can be a contra indication to moving to a new site.

This affects existing airports who seek to expand more than new airports on green field sites, selected to minimise environmental impact from the outset. Environmental impact as a result of airport operations, is generally considered to be one of the principal constraints to growth. In some cases, it can be argued that a single larger airport, sited further from the conurbation it serves, has less impact on the environment than several smaller airports closer to the urban centre handling the same volume of traffic.

Environmental and sustainability issues have in the past seldom been regarded as constraints to growth. Rather greater awareness of the impacts are leading to greater efforts and advances in technology to manage, minimise, and mitigate those impacts which rely on greater levels of community engagement.

However, in some cases the scale of impacts, and the costs and risks associated with mitigation, which accompany proposed airport developments have resulted in the plans being changed or – as in the case of the proposed Thames Estuary airport in London – contribute to the proposal being dropped altogether. Where new airport sites have been selected, the principal driver has tended to be the hard constraints of surrounding land use and its availability to support airport development rather than the impact of noise or air quality. While large airports have evolved and expanded capacity over time the future evolution of existing airports is primarily governed by their sustainability, balancing economic, social and environmental considerations.

The sites for new 'greenfield' airports can be selected in order to minimise environmental impact on the adjacent communities. This typically results in them being able to meet demand with less onerous environmental restrictions on their operations or future growth. However, as airports grow they attract both commercial and residential development into the surrounding areas that can later become a constraint to future airport development. This has been described as the 'Aerotropolis' effect. Without strategic land use planning and rigorous development control of the airport's hinterland, today's development opportunity can become tomorrow's constraint, as noise and emissions adversely affect newly developed areas.

Typically the expansion of an existing airport is preferred to the construction of separate airports, where space and local environmental conditions permit such expansion. The latter typically only becomes an option if environmental constraints frustrate further growth of ATMs, or the site is too small for further facility expansion.

It is relatively rare to designate smaller airports as reliever airports, except in the United States where they predominantly handle domestic rather than international traffic. However, international examples of this strategy include Amsterdam Schiphol / Lelystad, Singapore Changi / Seletar, and Tokyo Haneda / Iberaki; these are examples of locations where a decision has been taken to upgrade existing facilities rather than construct completely new airports by developing reliever facilities specifically for smaller/slower aircraft to reduce pressure on the main hub and allow it to focus on handling larger aircraft.

The Institute of Economic Affairs (IEA) in the UK has attempted to argue for de-politicising airport expansion. In a paper the IEA proposed a removal of the airport capacity issue from national politics, with market orientated solutions to noise and carbon emissions externalities (Niemietz, 2013). These arguments have not gained traction, as airport expansion remains very much a political decision. In general, we want to travel as economically as possible, but do not want the negative impacts to affect us directly. This reaction has been characterised as 'not in my back yard' or 'NIMBY'.

Potentially the most difficult environmental challenge for the future comes from global warming. The recent furore in the press about the Foster scheme to build the exclusive Red Sea Airport for executive jets at Amaala in Saudi Arabia (figure 10.29).comes from a challenge by the Architects Climate Action Network (ACAN).

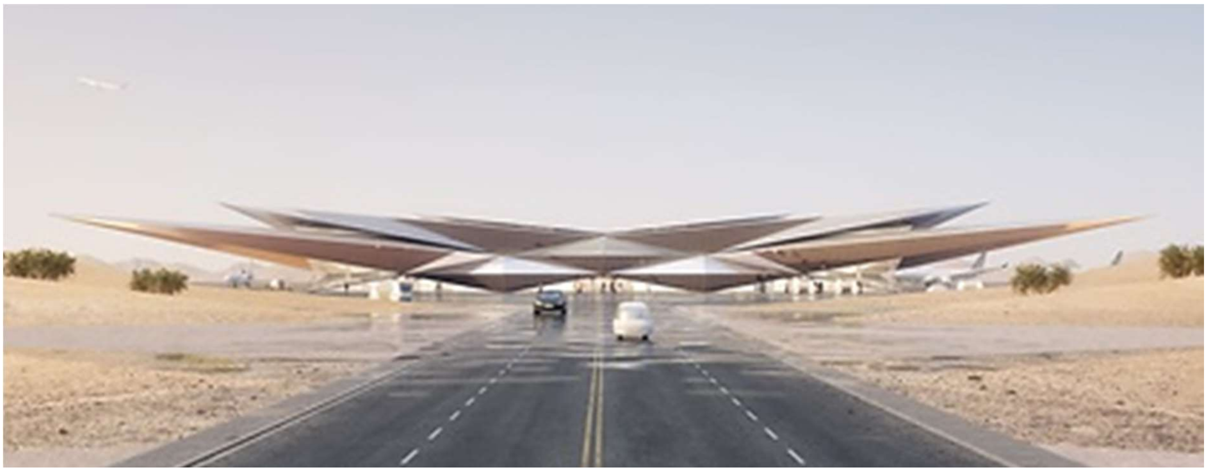


Figure 10.29 – Amaala, Saudi Arabia – Source: Foster + Partners

ACAN have stated that *'Anything that encourages the expansion of the aviation industry and the associated rise in the burning of fossil fuel should be viewed as off-limits for architects concerned about the rate at which our planet is warming. It is as simple as that we should be working to bring about a moratorium on the expansion of air travel.'*

Foster + Partners and Zaha Hadid Architects, the UK's largest and third-largest architecture firms, were founding signatories of the Architects Declare movement, which advocates a shift to sustainable construction to help avert climate and biodiversity breakdown. However, both resigned from the network in December 2020 after ongoing criticism of their continued involvement in new airport projects.

11 Summary Airport Case Studies

11.0 Introduction

Several airport projects have been selected to investigate in more detail the innovations they instigated. Specific projects have been chosen to illustrate the origin of key step changes in airport design and how they influenced subsequent design. Many have been looked at over their lifetime to see how the challenge of growth and change has been addressed.

1 Huffman Prairie 1904– First Airfield
2 Berlin Johannisthal 1919 – First scheduled service
3 Croydon 1920 & 1928 – Most publicised pre-war terminal, first air traffic control tower
4 Konigsberg 1922 – First passenger terminal
5 Berlin Tempelhof (THF) 1928 & 1939- Busiest and largest pre-war international airport
6 Gatwick (LGW) 1936 &1958 – Prototype satellite and rail interchange
7 Le Bourget (LBG) 1919 and 1937 – Original dispersed terminal & first linear terminal
8 La Guardia (LGA) 1939 – Transition design with pier and level separation
9 Chicago O'Hare (ORD) 1948 – Mid field terminal, multiple finger piers, airbridges
10 St Louis Lambert (STL) 1956, Floating roof, cabin fit-out, pier, two level forecourt
11 New York Idlewild (JFK) 1962 – Airport city concept, spirit of flight at TWA terminal
12 Washington Dulles (IAD) 1962 – Jet Age planning, mid-field master plan
13 Los Angeles (LAX) 1962– Satellite with underground access and Theme Building
14 Dallas Fort Worth (DFW) 1973 – Linear/unit terminal, transfer infrastructure, hub,
15 Paris Charles de Gaulle (CDG) 1974 Circular Terminal & Satellites, Ph2 Linear Terminal
16 Atlanta (ATL) 1980 – Mid field satellite, toast rack master plan, transit, multi runway
17 Stansted (STN) 1991 - Floating roof, single passenger level terminal, satellite, transit
18 Kansai (KIX) 1994 – Long span roof, linear terminal, scale, artificial island, transit
19 Hong Kong (HKI) 1998 –Road/rail/sea/air Interchange, integrated roof, aerotropolis
20 Kuala Lumpur (KUL) 1999 – T1 Cruciform satellite & T2 LCC Transfer Terminal
21 Seoul Incheon (ICN) 2001 - Terminal with piers & satellite, Skytrax first place airport
22 Bangkok Suvarnabhumi (BKK) 2006 – Mid-field terminal, multiple piers without transit
23 Madrid Barajas (MAD) T4 2006 – Only terminal to win the RIBA Stirling prize
24 London Heathrow (LHR) T5 2008 & T2 2014 – 1st and 5th placed Skytrax terminals
25 Dubai International (DXB) 2010– Underground terminal, premium differentiation
26 Beijing Capital (PEK) 2008 - Largest terminal to date, hybrid pier and satellite
27 Istanbul Grand (IST) 2019 – Transfer hub, multiple piers, aerotropolis
28 Beijing Daxing (PKX) 2019 – Complex parametric form, multiple piers, aerotropolis
29 Mexico City (MEX) 2022 - Organic roof design using parametric modelling
30 Dubai World Central (DWC) 2025 - Largest terminal and transfer hub for 220mppa

These summaries are supported by studies in further detail that are included as Appendix M.

11.1 The Wright Field, Huffman Prairie, Dayton, Ohio 1904

Following their successful first flight of 59 seconds and covering 852ft against a headwind of 20mph at Kittyhawk on December 17th 1903 the Wright brothers returned to their home town of Dayton where they created the first permanent airfield

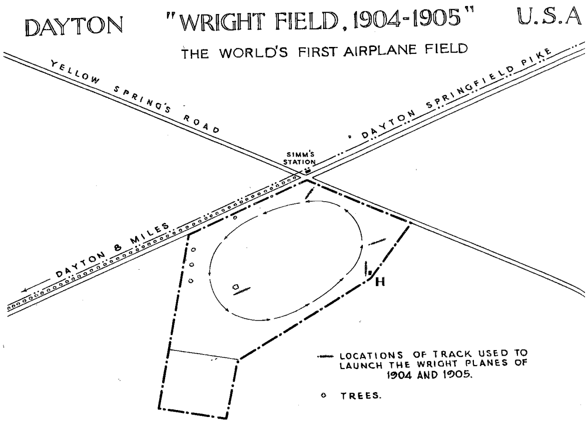


Figure 11.1.1 - Dayton, Wright Field – Source: Airports by John Walter Wood

The 'Wright Field' included two features that weren't to make it to later airports, the guide rail launch track and the catapult, both designed to overcome friction during launching. However, both concepts have been adopted by aircraft carriers. The adjacent drawing (figure 11.1.1) appeared in a 1940 publication "Airports" by John Walter Wood. It was derived from a sketch made by Orville Wright in 1935

The drawing also shows a feature indicated with an H that was to become a standard feature of all subsequent airports, the aircraft hangar. The hangar measured 44ft x 16ft, and housed two Wright planes but only after the front elevators had been removed and can be seen together with the catapult in the photograph below (11.1.2).

Figure 11.1.2 Start of the first flight of Flyer III, June 23, 1905, Orville at the controls. The hangar is just left of centre and the catapult tower is on the right – Source: US library of Congress.

The Wright field at Dayton showed the importance of having a level field with the minimum of obstructions around the edge to make it suitable as an airfield. It also had good public transport access via the train service from Dayton to Simms Station, adjacent to the site which is how the Wright brothers reached the field. The only design element there, which can still be found in the modern airport, is the provision of a hangar to house the aircraft. Other features such as the catapult and guide rail for assisted take-off are used in aircraft carriers but not at airports.

11.2 Berlin, Flugplatz Johannisthal, 1919

Berlin Johannisthal was the airport from which the first scheduled services flew in 1919, with passengers handled through an existing hangar. Berlin Johannisthal had been in existence for some ten years before scheduled flying started. It opened in 1909 as the first civilian airfield and was known at the time as 'Motorflugplatz Johannisthal-Andershof' as it was on the border between the two communities. The airfield had earlier been used for the round Berlin air races in 1909, for aircraft manufacture and then military use during the First World War. Over time a series of hangars had grown up around the perimeter of the airfield which became the model for European airfield layouts in the 1920s and 1930s.

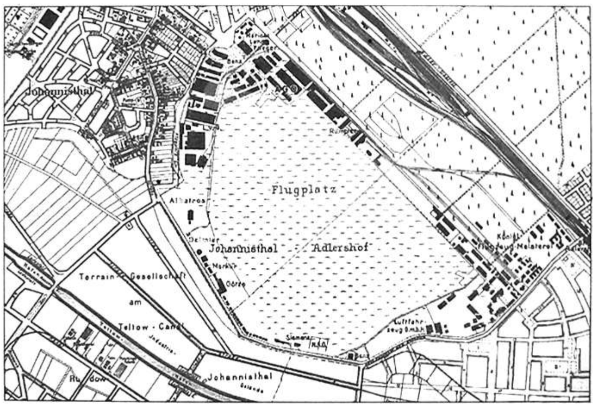


Figure 11.2.1 Flugplatz Johannisthal Plan 1916 - Source: Wikimedia

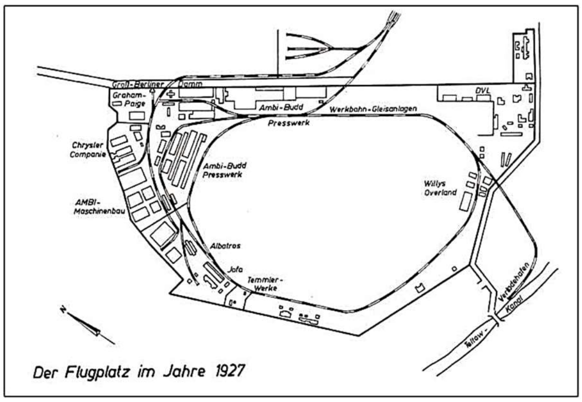


Figure 11.2.2 Map of Berlin Johannisthal 1927 – Source: Grin.com

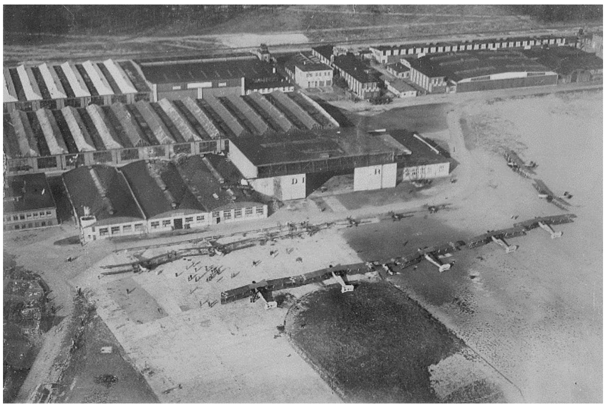


Figure 11.2.3 Flugplatz Johannisthal Hangars 1920 Source: Alamy

Figure 11.2.4 Berlin Johannisthal – First scheduled flight 05.02.1919 to Weimar – Source: Wikipedia

The use of the airfield sharply diminished after 1923 when Berlin Tempelhof opened and after civilian flying was eventually banned in 1931 it became an important test installation for the secret development of the Luftwaffe.

The enduring legacy of Berlin Johannisthal is the idea of handling passengers from the hangar. This approach later reappeared in the 'Lean to' concepts that were prevalent in the USA during the 1930s and more recently in executive terminals that support business aviation and at the Virgin Galactic Spaceport.

11.3 Croydon Airport 1920 to 1928 and 1928 to 1959

During its short life as a civilian airport Croydon introduced a number of innovations that make it important in the evolution of airport design. It is also home to the oldest surviving terminal building (figure 2.01) (1928).

The main innovations include:

- the integration of the major airport service functions into one structure, the terminal
- the invention of the control tower to direct aircraft movement
- the use of radio and telephone for communication and navigation
- the first airport hotel and restaurant
- the only airfield expansion solely for safety reasons
- the first provision of lighting to facilitate night flying
- the erection of an airship mast
- the foundation of Imperial Airways
- the installation of direction finding equipment
- the invention of the Mayday distress call (m'aidez in French)
- the first recorded complaint and legal action about noise nuisance

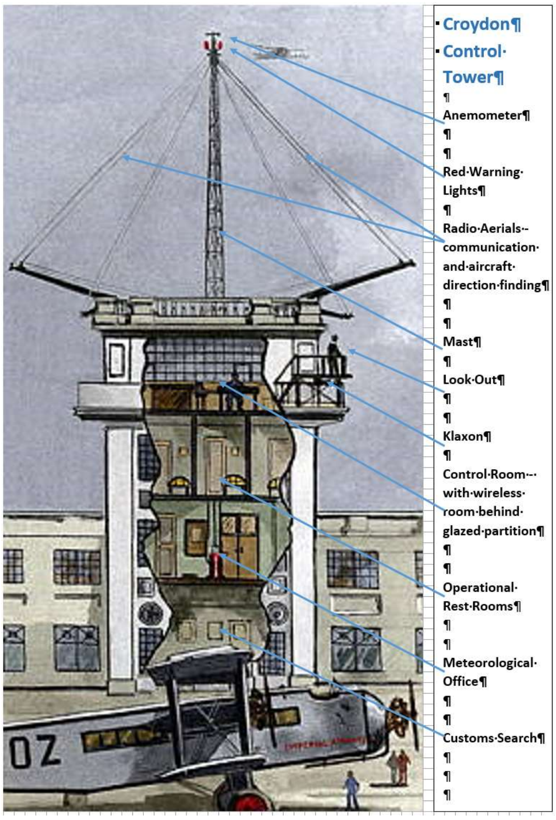


Figure11.3.1 Croydon Control Tower + annotation
Source: Fine Art America - Poster by Sheila Terry

Croydon Airport was by far the most publicised pre-war airport, in books, newspapers, magazines, periodicals and films. The terminal, with its logical sequential layout based on the requirements for passenger processing, was a major innovation and became the benchmark against which all subsequent pre-war airport designs have been compared. The control tower (figure 11.3.1) was physically the world's largest, most technologically advanced and comprehensive air traffic control (ATC) operation at the time. Its format remains essentially unchanged in the control towers of today.

Ultimately Croydon airport was too small and located too close to London. The grass airfield was unsuited to the new larger and heavier aircraft and was surrounded by residential areas making expansion impossible. It was not considered for post-war use and scheduled services were reduced with the opening of Heathrow in 1946. However, the airport remained in operation for some scheduled services and general aviation until its final closure in 1959. By contrast, many of the terminal planning, safety, operational and commercial innovations first seen at Croydon have influenced subsequent airport designs.

11.4 Flughafen Königsberg-Devau (KGD) 1922

Königsberg Airport is recognised as the first airport that was laid out specifically for civilian flying and the first example of a new building type, the passenger terminal, although it was at this time simply known as the administration building. Königsberg received special attention in the 20s and 30s, as an otherwise isolated German enclave, because of its strategic location as the capital city of East Prussia (now Kalingrad in Russia). It was separated from Germany by the Danzig corridor that linked Poland with the Baltic Sea. Flying was seen as a way of overcoming this territorial split. The airport master plan included a terminal building located in the corner of a grass airfield between two arched hangars, set at right angles to one another (figure 11.4.1 &2). The city’s tram service was extended from the railway station to the airport in 1924 after the opening of the airport.

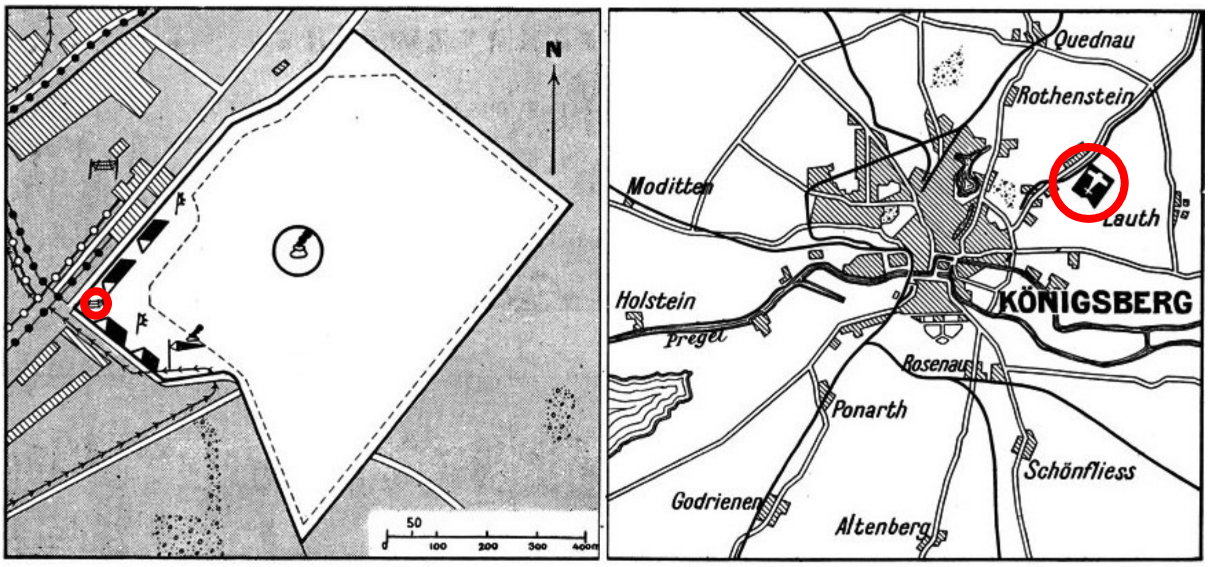


Figure 11.4.1 Königsberg site plan and Location Plan – Source: Die Deutschel Luftfart (Treibel, 1992)

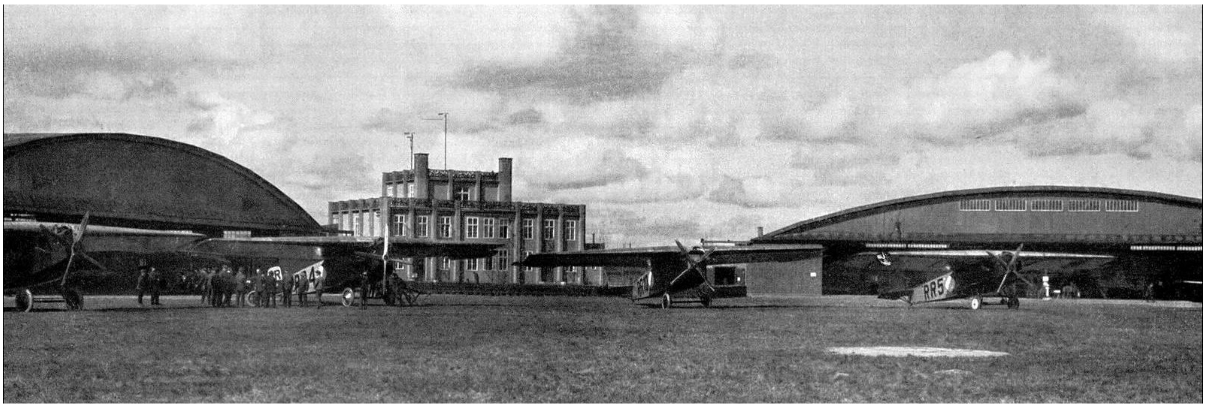


Figure 11.4.2 Königsberg seen from the airfield – Source: https://www.bildarchiv-ostpreussen.de/

While this might have been the first purpose designed terminal there is little evidence it influenced subsequent design and was largely unknown until it was rediscovered by Wolfgang Voight and published in Buildings for Air Travel in 1996. The terminal was short lived and was replaced by a new larger and more modern terminal in the early 1930s which was in turn demolished by the occupying Russian Force in 1945.

11.5 Berlin Tempelhof (THF) 1928 and 1939

Designed as the successor to Berlin Johannisthal, pre-war Berlin Tempelhof was the busiest international airport in the world in the 1930s, in part because of its strategic location as the focus of the Lufthansa network and because Germany used the development of civil aviation as a cover for re-armament, heavily subsidising the development of the national airline and the creation of a range of airports of which Berlin Tempelhof was the most important.

The site plan below (figure 11.5.1) illustrates the location of the first terminal (1928), (figure 11.5.2) shown with a broken outline, and the new terminal and hangar complex (figure 11.5.3) in the north-west corner of the site (1939). As can be seen the airfield was extended but was still a grass field while the new terminal was radically larger, and designed to handle traffic that was 30 times greater than the existing demand.

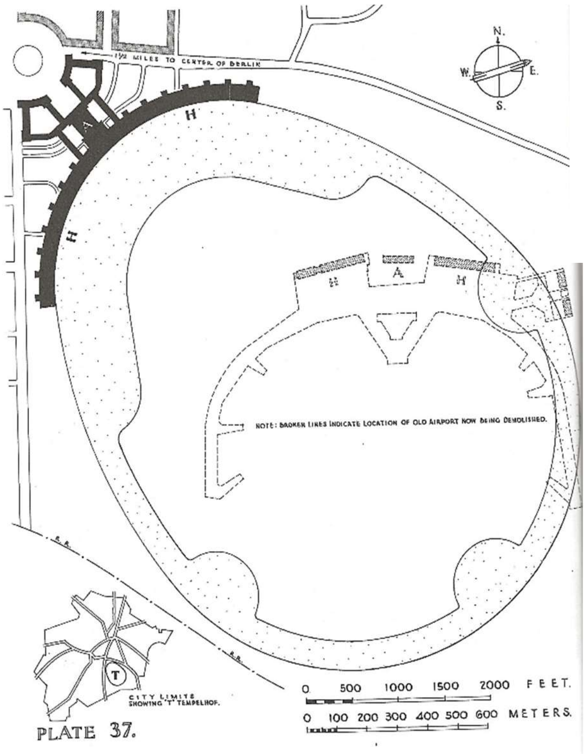


Figure 11.5.1 – Berlin Tempelhof site plan showing the 1st and 2nd terminals Source: Airports 1940

11.5.2 Berlin Tempelhof 1 1928 – Source: Deutsch Lufthansa AG

11.5.3 Berlin Tempelhof 2 1955, view under cantilever canopy - Source: http://peterpapke.d

The cantilever canopy of the second terminal allowed aircraft to be boarded under cover but this concept fell out of favour with the advent of the passenger boarding bridge. The second terminal was the largest in the world when designed in the 1930s and has been described by Norman Foster as the 'Mother of all Airports.' It introduced a number of innovations, especially connectivity to the public transport network and multiple gaterooms that allowed several aircraft to be handled simultaneously. It was also designed for long term growth to last until AD 2000. However its unique location close to the centre of the city, which was regarded as a virtue when it opened, was ultimately the reason for its closure when the resultant environmental impact was no longer considered acceptable.

11.6 Gatwick (LGW) 1936 & 1958

Gatwick has seen a number of innovations: the development of the circular form as a precursor to the satellite, its use of retractable passenger boarding canopies, its connectivity to the national rail network and latterly its flexibility to respond to growth and change. These features have all influenced the subsequent evolution of airport design. The terminal (figure 11.6.1) at the first Gatwick airport can be seen as the precursor to the development of the circular satellite and the passenger boarding bridge. The 1983 extension saw the reintroduction of the circular satellite accessed by an automated people mover.

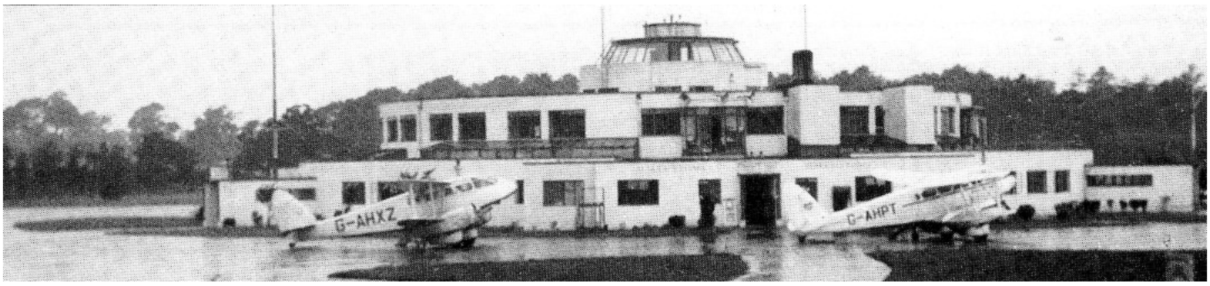


Figure 11.6.1 Gatwick 'Beehive' Terminal 1936 - Source: UK Airfields and Airports

Figure 11.6.2 Gatwick 1958 - Source: ukairfieldguide.net

Figure 11.6.3 Gatwick 1983 – Source: Gatwick

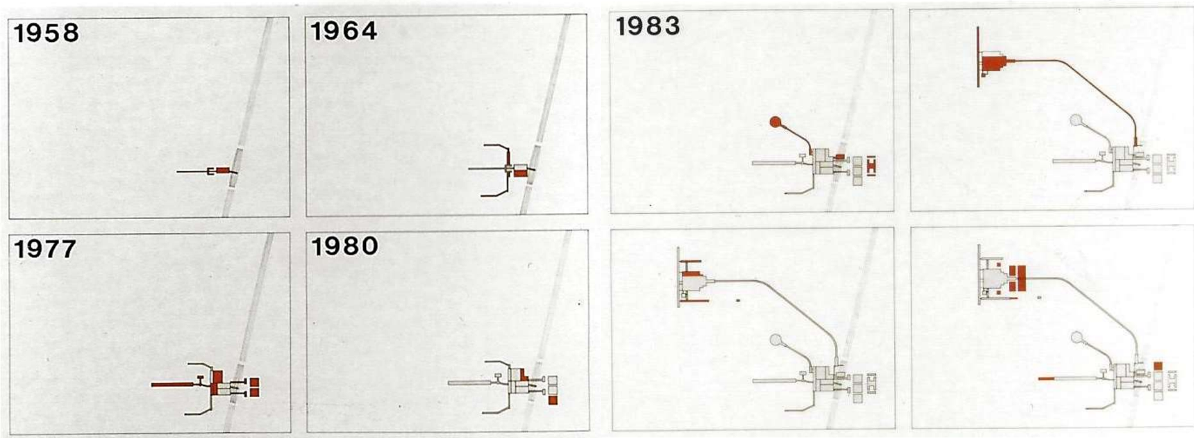


Figure 11.6.4 Evolution of Gatwick from 1958 to1988– Source: YRM (reproduced with permission from RMJM)

The excellent connectivity to the main line railway are features of both the first and second airports. The adoption of modular interchangeable components, a distinctive feature of the second airport, has enabled it to respond to growth and change over many years, (figure 11.6 2, 3 & 4), a feature that has frequently been repeated in subsequent airport designs.

11.7 Le Bourget (LBG) 1919, 1923 & 1937

The first airport at Le Bourget was unusual in perpetuating the dispersed layouts of the former military airfield. The location of the first dispersed passenger complex (1923) is highlighted in green, the hangars in blue, while the replacement new linear terminal (1937) is shown in red in the aiport plan of 1939 (figure 11.7.1). The second terminal however, was the first purpose designed linear terminal and a leading example of Classic Moderne or Art Deco Style (figures 11.7.2 & 11.7.3)

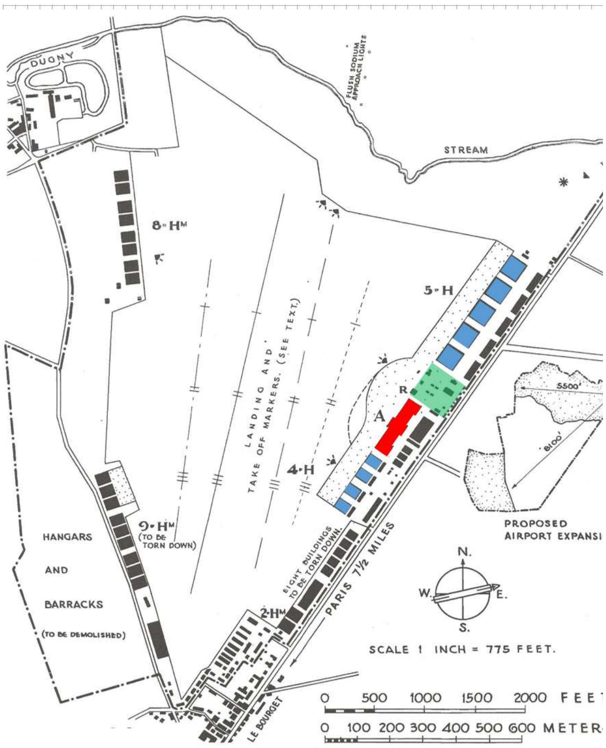


Figure 11.7.1 Le Bourget, Site Plan 1939, Source: Airports – John Walter Wood 1940

Figure 11.7.2 Le Bourget, Landside view Source: picclick.f

Figure 11.7.3 Le Bourget, Airside view of control tower - Source: del campe

Labro's description of his design having a 'prow with a long wing' is compared with the shape of the Farman Goliath Aircraft in figures 6.221 & 6.222 and shows a remarkable similarity of form, but his inspiration an aircraft that was by then long obsolete.

While Georges Labro, in theory, embraced the idea of future extension to facilitate growth and change, the terminal was only designed for a single departing and a single arriving flight at one time. However, after the war Labro proposed modifications to the terminal to segregate domestic and international passenger flows and extend the airside face of the building. Further airside extensions were introduced as part of a modernisation programme in 1964 to increase the airside waiting space.

Although Le Bourget became functionally obsolete as an airport, the infrastructure was not life expired and has been put to good new uses as both the terminal and airfield have been re-used for general aviation, as a museum, exhibition hall and event venue, showing airport architecture can be re-purposed when it ceases to function as originally designed.

11.8 New York – LaGuardia (LGA) 1939

LaGuardia (LGA) included several innovative features, so that it has become recognised as a key transition between the earlier simple terminal and later linear terminal designs. These included:

- the Main Terminal (red) for land planes projected into the airfield (figure 11.8.1),
- a two level forecourt separating departing and arriving vehicles (figure 11.8.2),
- a curved ‘Skywalk’ which can be seen as a precursor to the linear pier (figure 11.8.3),
- direct access to Grand Central Parkway (green arrow) linking with Manhattan ,
- a second circular Marine Air Terminal (blue) catered for international flying boats

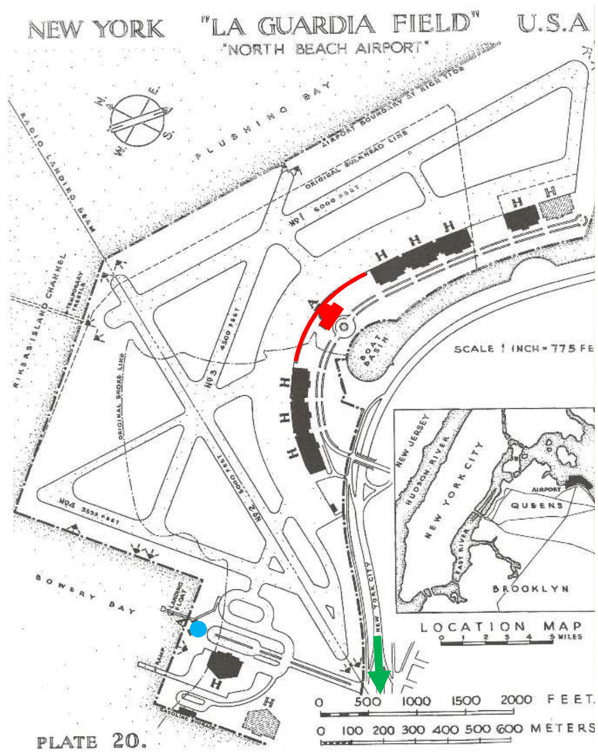


Figure 11.8.1 La Guardia Masterplan 1939
Source: Airports, John Walter Wood 1940

Figure 11.8.2 La Guardia, aerial landside view – Source: stuckattheairport.com

Figure 11.8.3 La Guardia, airside view of landplane terminal and ‘skywalk’ – Source: Pinterest

Following the war, the Marine Air Terminal became the airport’s international departure point for land planes, but larger aircraft and a need for more space prompted other carriers to follow Pan American’s lead and move to Idlewild Airport by the end of the decade. However, the postwar growth in domestic air traffic more than compensated for these losses as LaGuardia cemented its reputation as the city’s “close-in” airport of choice for short to medium-haul domestic flights.

Despite rebuilding in the 1960s the airport has more recently come in for a lot of criticism, mostly due to the condition of the central terminal, with one example being President Joe Biden’s comment that his experiences at LGA make him feel as though he were ‘*in a third world country*.’ The evolution of LaGuardia shows that ideas that were once considered forward looking and avant-garde can easily become out of date with the growth of traffic, requiring the airport to be reinvented for every generation.

11.9 Chicago O’Hare (ORD) 1947

The City of Chicago appointed Ralph Burke, the City’s former chief engineer to plan a future airport on Orchard Field, extending the former Douglas Aircraft Company Factory and Airbase. He prepared a very ambitious master plan for the airport to replace Midway airport. His master plan was formally adopted by the City in December 1947. The finger pier concept, first conceived at O’Hare, has inspired many generations of terminal design including Washington Friendship, St Louis Lambert, Gatwick South Terminal and Schiphol and Frankfurt airports. It also pioneered the development of the aircraft boarding bridge. The airport was subject to continuing updates, both during construction and subsequently in use, with runway extensions and terminal improvements incorporated into evolving masterplans to cater for new aircraft and traffic growth (figure 11.9.1).

Figure 11.9.1 - Chicago O’Hare, Master Plan 1948 – Source: Chicago Tribune Graphics

The innovation of the finger pier at Chicago O’Hare has proven to be one of the most ubiquitous and long lived terminal concepts. Schiphol and later Frankfurt airport are direct evolutions of the pioneering radiating pier concept first seen at O’Hare. But the concept at O’Hare has evolved several times to suit increasing aircraft size, the introduction of jet aircraft and changes from parallel aircraft parking to nose in parking. Most recently, as seen in the United Terminal and the future master plan, the advantages of the satellite system in providing unobstructed aircraft movement and an increase in overall capacity within the same site are considered to outweigh the easy passenger connectivity of the finger pier.

The radial runway pattern has not had the same longevity, giving way after a series of steps to multiple parallel runways as newer generations of aircraft have become less sensitive to cross winds. The story of Chicago O’Hare is, then, one of repeated innovation to accommodate the growth and change that comes with increasing passenger volumes and aircraft movements. Its ability to adapt is demonstrated by the fact that it was the busiest airport in the world in 2018 measured by the number of aircraft movements at 904,000atms.

11.10 St Louis Lambert (STL) 1956

St. Louis Lambert International Airport is one of the most historic airports in the United States as the home of Charles Lindbergh the first person to fly the Atlantic singlehanded. The terminal is notable for a number of innovations, including the separation of departing and arriving vehicles into a two level forecourt, and the early adoption of the finger pier concept which safeguarded space for the later introduction of airbridges (figure 11.10.1). It also pioneered the use of escalators to allow passengers to change level and incorporated for the first time a mechanical baggage handling system using conveyors. Another important feature is the signature vaulted copper roof of the iconic terminal (figure 11.10.2).

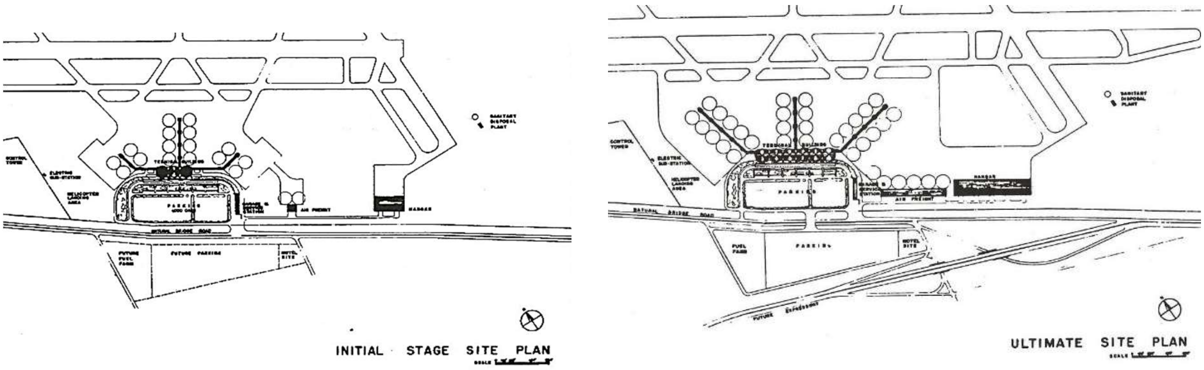


Figure 11.10.1 St. Louis, Lambert, initial and ultimate site plans c.1951 –
Source: St Louis Municipal Airport, Economic Studies

Figure 11.10.2 St Louis, Lambert, aerial view showing extended 4th terminal module & finger pier - Source: CMJ

The terminal prefigured the glamour of jet travel, with its aerodynamic lines and a series of low-slung arches that celebrate the idea of flight. As well as the vaulted roof the interior was also a trend setter by virtue of its freestanding cabins, a feature that influenced Saarinen and later Foster, and has become the norm in recent airport designs where a soaring roof is de-rigueur. A simplified linear version of the roof can be seen at Dubai International that was designed by Yamasaki's successor practice HOK which reuses some of the motifs of the St. Louis window pattern (figure 6.118).

11.11 New York, Idlewild (JFK) 1948 & 1962

New York Idlewild (JFK) introduced the Terminal City concept, a glamorous name for a mixture of individual airline terminals. It was a compromise that was presented as a new vision of the future but was in practice an uncoordinated free for all with individual airlines developing their own terminals (figure 11.11.1). The airlines were, however, originators of some of the most advanced terminal concepts and most evocative images of the jet age.

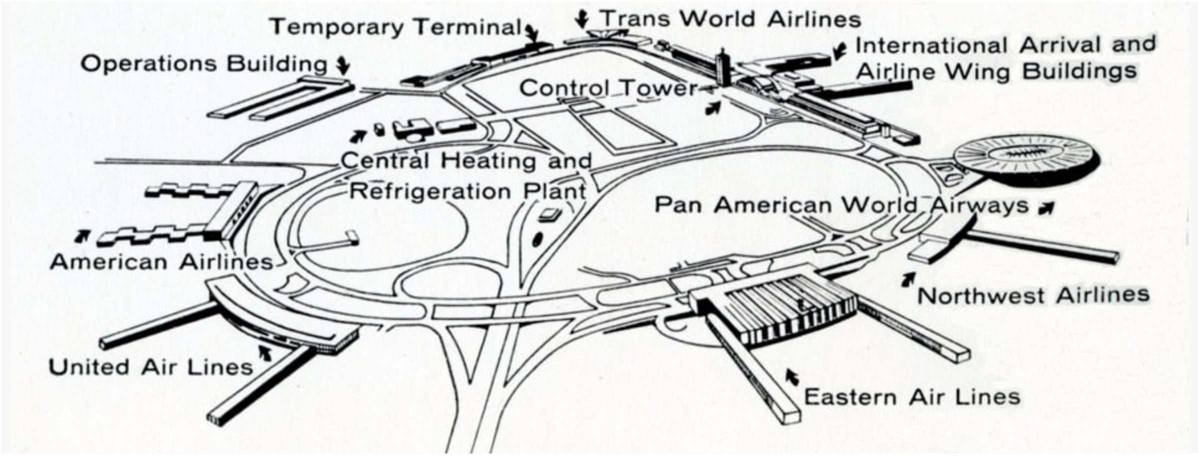


Figure 11.11.1 Idlewild, the terminal city concept with multiple airline terminals – Source: Architecture USA

JFK has been progressively expanded (figure 11.11.2) is currently spilt across six separate terminals (figure 11.11.3), constructed in stages since 1948, and connected by the AirTrain light rail that was retro-fitted and by various complex access roads. Future plans involve the creation of fewer and larger unified terminals that would allow easier transfers for passengers with flight connections.

Figure 11.11.2 New York, JFK, Aerial view - Source Architecture Daily Photo: Jeffrey Millstein

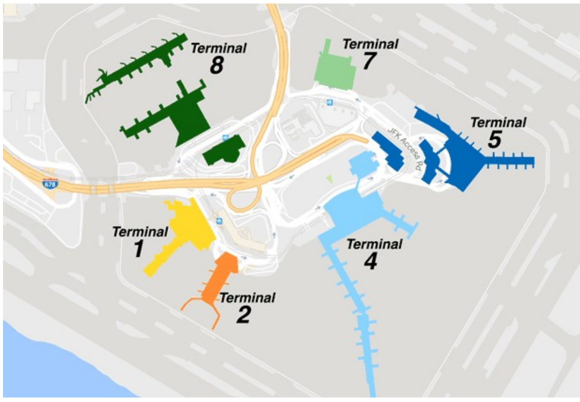


Figure 11.11.3 New York, JFK Terminal area plan Source: JFK Airport

The history of JFK airport shows that the airport has been able to evolve to suit changing circumstance, but there can be little doubt that if there had been less of a free for all and more overall master planning the airport could, today, have successfully handled more passengers. The planned way forward is with fewer but larger terminals. As it is, the airport which was once in the vanguard of innovation and pre-eminent in the USA, has been overtaken in volume of traffic and quality of service by many other airports. The TWA building, now converted to a hotel, reminds us of the glamour of the jet age and with its soaring bird like roof still perfectly captures the spirit of flight.

11.12 Washington, Dulles (IAD) 1962

Washington Dulles was the first new airport master planned for the Jet Age (figure 11.12.1). It boasted a number of innovations that have become the norm for subsequent major international airport designs, including:

- a simplified runway configuration
- a toast rack apron layout
- a mid-field terminal location
- a central control tower
- a landside gyratory road system
- a clear span terminal roof
- an indeterminate architecture
- a safeguarded metro link

Washington Dulles' greatest virtue has been its ability to accommodate growth and change without losing either its simplicity of layout or integrity of form because expansion was planned from the outset. The one feature that was to prove a wrong move was the proposal to use mobile lounges to access aircraft seen in this film strip: https://youtu.be/FL-mjc1sgX4.

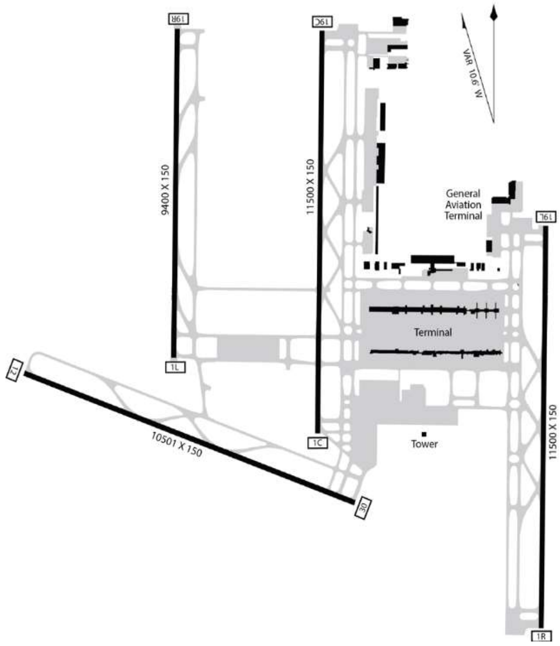


Figure 11.12.1 Washington Dulles, Masterplan - Source: FAA

Figure 11.12.2 Washington Dulles interim update with remote satellites still served by mobile lounges – Source: Library of Congress

The masterplan and the indeterminate architecture of the mid field terminal have facilitated major changes after opening (figure 11.12.2). Changes include extending the terminal seamlessly, adding a landside metro to Washington DC, introducing a linear pier and satellites accessed by an underground transit system and adding a third parallel runway. This has been achieved without damaging the character of Eero Saarinen's original concept, and has reinforced its role as a major hub airport and gateway to the USA. Its masterplan and midfield terminal layout continue to influence the design of large airports to this day.

11.13 Los Angeles (LAX) 1962

Los Angeles (LAX) pioneered the satellite concept (figure 11.13.1), accessed by underground walkways and developed one of the most enduring images of the Jet Age, the Theme Building.

Figure 11.13. 1 Los Angeles International aerial view 1963 – Source: airporthistory.org

Later, to increase the number of stands available for aircraft parking, the satellites were reconnected with the head house terminal to create a series of finger piers. The resultant cul-de-sacs have resulted in less convenient aircraft circulation but increased capacity.

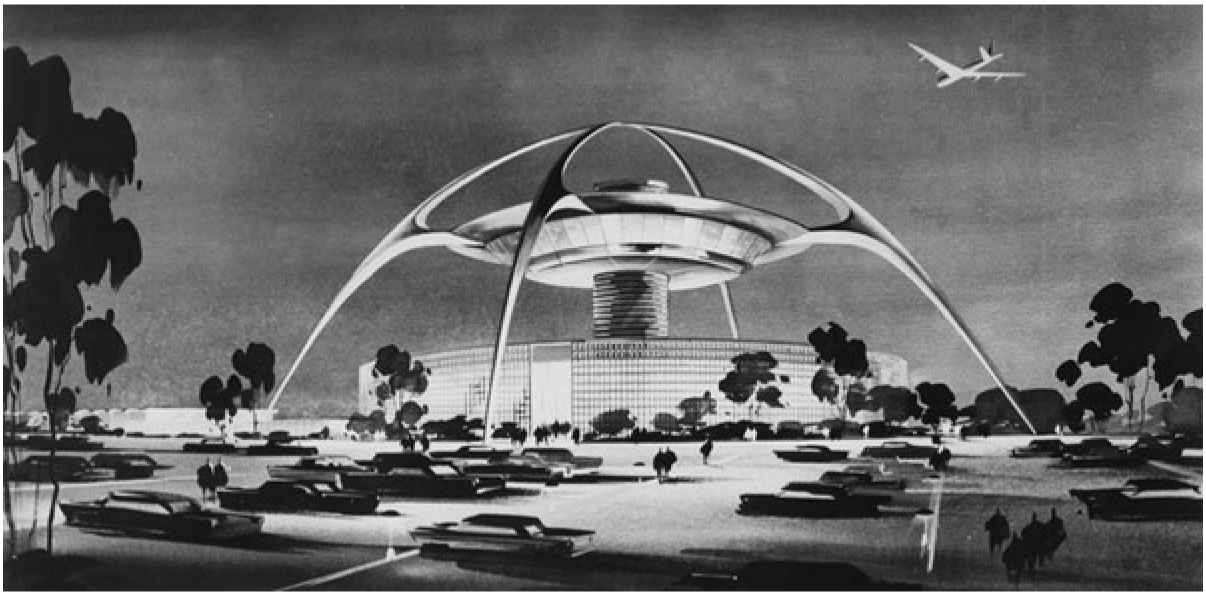


Figure 11.13.2 Los Angeles (LAX) Theme Building – Source: California Historical Society Collection, USC Libraries

The Theme Building (figure 11.13.2) is the most memorable image of the Jet Age at LAX and was immensely popular at the time but has become obsolete as the introduction of security has moved the passenger dwell time from landside to airside. It is now just a memory of what the Jet Age once promised.

11.14 Dallas Fort Worth (DFW) 1973

Dallas Fort Worth was designed to replace two separate airports, Dallas Love and Meacham Field, serving Fort Worth. When it opened in 1974, it was the largest airport in the world with four semi-circular unit terminals that stretched out along a landside central spine linked by an elevated APM. The original masterplan provided for thirteen terminal buildings along the central spine. The International Terminal (figures 11.14 1&2) was added later.

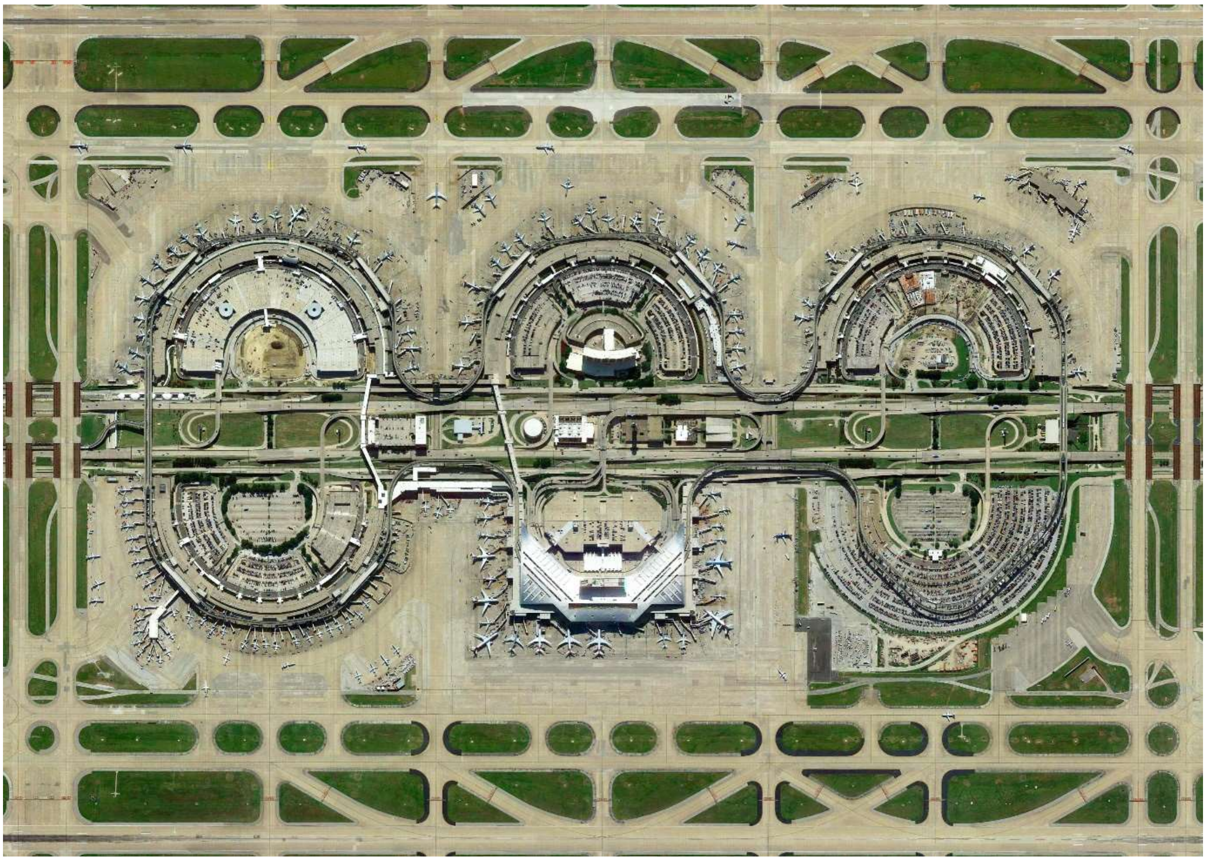


Figure 11.14.1 – Dallas Fort Worth Terminal Zone- International terminal at the centre bottom is a later centralised addition – Source: fromabove.altavista.org

Figure 11.14.2 Dallas Fort Worth International Terminal, Skylink Transit in the foreground – Source: Wikipedia

The central landside spine of the masterplan, and the unit terminal concept, once popular features, have largely been superseded by the centralised midfield terminal concept seen at Washington Dulles. The complex transit system has also not been replicated. However, the idea of replacing individual airports close to the city centre with a single, larger and more remote airport serving a wider catchment has become the norm for new large hub airports.

11.15 Paris, Charles de Gaulle (CDG) 1974

The original master plan envisaged a series of 5 circular terminals supported by satellites (figure 11.15.1). Fifty years later the annual capacity is now almost eight times that figure and the original master plan has evolved radically as new concepts (linear terminals and satellites) have been introduced to address lessons that have been learnt (figure 11.15.2).

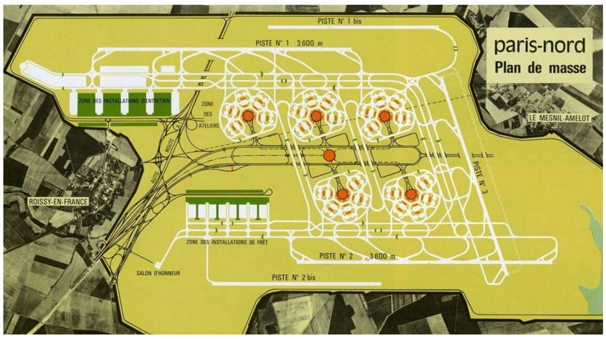


Figure 11.15.1 Paris, Charles de Gaulle 1965
Source: Sideshare.net Jeanmarie-Chevallier ADP

Figure 11.15.2 Paris, Charles de Gaulle 2015
Source: Wikipedia- By CellarDoor85 – 52031981

One area where the airport has excelled is in the provision of rail services and an associated public transport interchange. This facility is integrated with Terminal 2 between Terminal 2 A&B and Terminal 2 C &D. It links the airport directly with the French TGV international rail network.

The most recent design for Terminal 4 abandons the previous individualistic concepts and incorporates a more conventional single, large processing building with a series of piers under one continuous roof (figures 11.15.3).

Figure 11.15.3 Paris, Charles de Gaulle Future Terminal 4, with T2 in the foreground & circular T1 top left – Source: cdg.parisaeroport.fr

Could it be that the airport has finally learnt the lessons from its previous architecturally striking but functionally flawed designs, and understands that operational efficiency, commercial opportunity and designing for growth and change underpin successful airports?

11.16 Atlanta, Hartsfield (ATL) 1980

The evolution of Atlanta airport can be seen as a microcosm of the evolution of airports in general. It started with passenger services handled out of a lean-to hangar (1931) and then has been successively rebuilt as a simple terminal design (1931), then a linear terminal (1948) which was expanded with single storey finger piers. It was then rebuilt as a Chicago-like multiple pier concept (1961), and then reinvented itself as a hub airport with multiple mid-field satellites fed from terminals at each end of the airport (1980). An evolution of the 'Toast Rack' master plan (figure 11.16.1 & 2) has served the airport well ever since and allowed it to expand progressively with additional runways and terminal capacity.

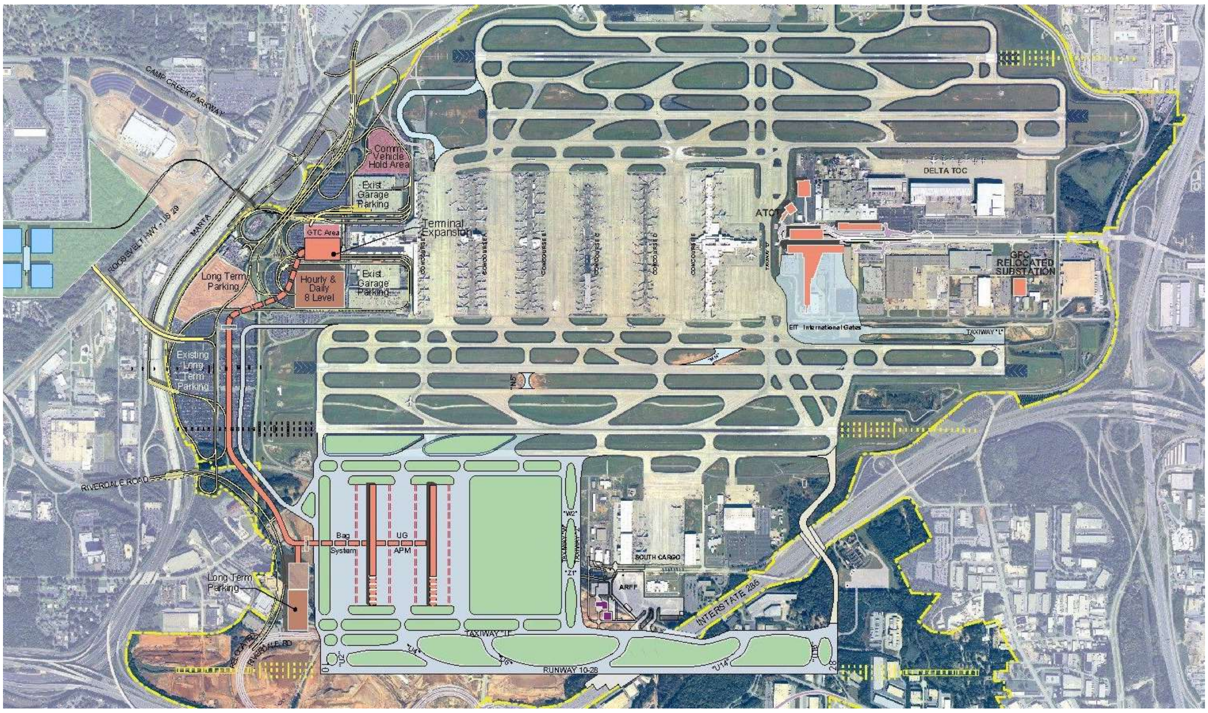


Figure 11.16.1 Atlanta Hartsfield Long Term Master Plan with 5th parallel runway to the south and new mid-field terminal area – Source: Art Papers: The possibility of an airport

Figure 11.16.2 Atlanta Hartsfield aerial view (5th runway at top of photo) – Source: Flickr MFMinn 2012

The layout is recognised as being the most space effective and operationally efficient for aircraft movement of any in the world, but requires a complex and expensive transit system to link the terminals with the satellites. Atlanta is currently, and has been for some years,the busiest airport in the world, measured by passenger numbers, handling 110mppa in 2019.

11.17 London, Stansted (STN) 1991

The philosophy, promoted by Norman Foster, that underpins the design of Stansted Airport's terminal (figure 11.17.1), is immensely important in setting a new trend in terminal design. He later codified these ideas in his essay 'Re-inventing the Airport' of 1996 (Appendix H). The ideas he popularised include the following:

- The airport should be thought of as an interiorised experience with a flexible layout under an umbrella roof, derived from his experience of working with Buckminster-Fuller on the Climatron Office.
- Services should be removed from the roof and replaced in an undercroft.
- There should be flexibility to reconfigure the layout as growth and change dictated.
- Daylight should be filtered through the roof, as well as the facades, and artificial lighting designed to be bounced back from the ceiling to avoid a dark ceiling at night.
- Passengers should, as far as possible, walk in straight lines towards their destination, drawn to the light.

Figure 11.17.1 London Stansted, stage 1 expansion of terminal - Source: New Civil Engineer

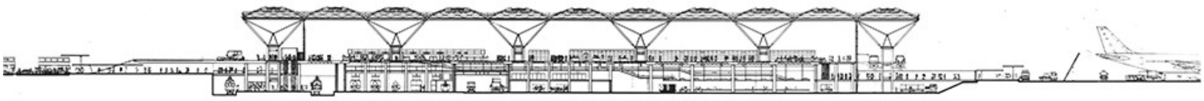


Figure 11.17.2 London, Stansted cross section through terminal - Source: Foster + Partners

Many of the features that were pioneered at Stansted figure widely in subsequent airport terminal designs: the use of a floating roof as the main symbol of flight (figure 11.17.2), the integration of a railway station under the terminal with direct access, the adoption of a rapid transit system to take passengers to the gates, the use of freestanding cabins to enclose shops, offices, toilets and support areas. For the first stage of expansion additional departures and arrivals modules have been added seamlessly, but for the most recent stage the philosophy has been abandoned and a separate arrivals building has been shoehorned expediently into a gap between the terminal and adjacent hotel that has been built too close to allow for long term expansion.

11.18 Osaka, Kansai (KIX) 1994

Osaka, Kansai was the first of a new generation of very large international airports. While Stansted had been designed for 7.5 million passengers Kansai was designed to handle 25-30 million passengers per annum. The masterplan by ADPI and terminal design by Renzo Piano broke new ground by creating the airport on an artificial island in Osaka Bay (figure 11.18.1). It was the first planned for the new generation of Super Jumbo aircraft with wingspans of up to 80 metres and has now been extended to provide a second runway. The learning from this project has been used in subsequent airports reclaimed from the sea including Chubu Centrair in Japan, Hong Kong Chek Lap Kok and Seoul Incheon.

Figure 11.18.1 Osaka, Kansai aerial view showing second runway - Source: Pinterest i.pinimg.com

Figure 11.18.2 Osaka, Kansai, landside canyon, airside gates & check-in - Source: Fondazione Renzo Piano

The shape of the roof of the terminal arises from work on the dynamic lines of the air flows circulating in the building, and the curves of the "wings" of the building are the result of the application of a toroidal geometry allowing vision of the apron from the control tower. The influence of Kansai on later architectural designs can be see most clearly at Heathrow Terminal 5 which was designed by Richard Rogers, the former partner of Renzo Piano for the Pompidou Centre, particularly in the landside 'canyon', the airside gate lounges and in the long clear span terminal roof over the main check-in concourse(figure 11.18.2).

11.19 Hong Kong, Chek Lap Kok (HKG) 1998

The Hong Kong Chek Lap Kok design was the result of collaboration between Foster+ Partners, architects, Mott MacDonald, engineers and BAA airport planning. The plans were based closely on the initial masterplan by the Geiner-Maunsell consortium which envisaged a large terminal linked to a Y-shaped pier and X shaped satellite with an underground people mover. Foster and team, however proposed a number of improvements including the integration of the railway station with the terminal by ramps and the adoption of a single continuous vaulted roof, which integrated the terminal into a single form.

Figure 11.19 1 Hong Kong, Chek Lap Kok, Master Plan 2030 ultimate development of satellite to terminal 2 on the left and the existing Fosster designed terminal to the right - Source: HKIA

Hong Kong is the first airport planned from the outset as an 'Aerotropolis', with an integrated commercial, residential and leisure district which is described in chapter 9.6. As Norman Foster described in his essay 'Reinventing the Airport' (see appendix H) the design for Hong Kong builds on his experience of designing Stansted. Key differences in approach include the fact that the terminal is planned on two levels with Departures above Arrivals instead of the single level solution at Stansted and the structure is largely concrete to suit local availability of materials with only the roof in steel. Unlike Stansted the building services have been disassociated from the structure

Figure 11.19.2 Hong Kong, Skypier and Sky City land, sea air Interchange Source: SOM.com

Most recently, the new masterplan for 2030 (figure 11.19.1) shows that the airport is capable of further expansion to include a third runway and second terminal. A major innovation subsequent to the opening is the expansion of the SkyPier (figure 11.19.2) to cater for cross-border ferries from China creating an interchange between land, sea and air travel.

11.20 Kuala Lumpur (KUL) 1999

Phase 1 of Kuala Lumpur International Airport featured a linear terminal for domestic and short haul traffic linked to two cruciform satellites with a transit system, although to date only one satellite has been constructed (figure 11.20.1). The transit is unusual in that it rises out of the ground at the satellite end to reach a passenger level at first floor level while the cruciform shape of the satellite which it serves shortens walking distances when compared with the linear satellite, although it is not as efficient in land use.

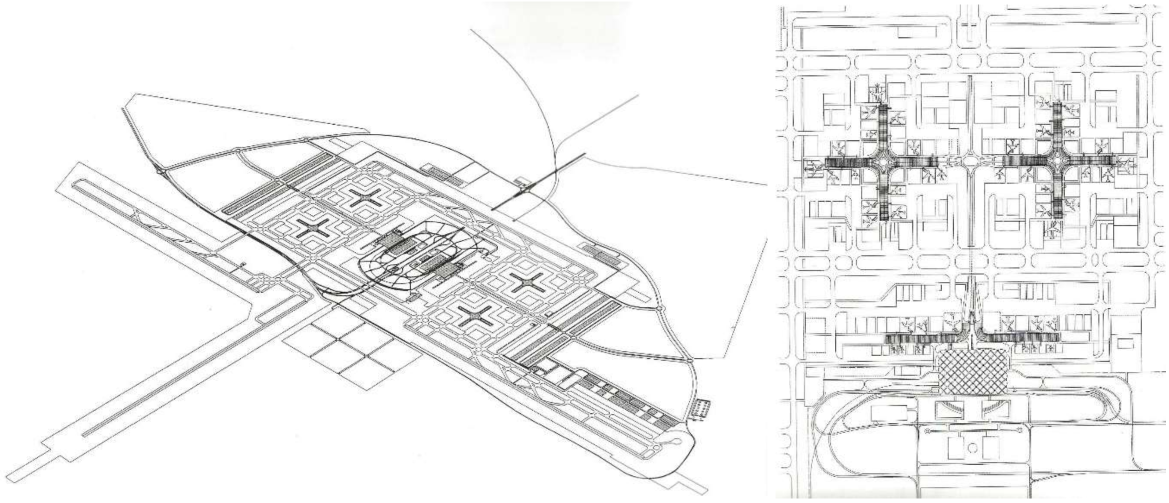


Figure 11.20.1 Original KLIA Master Plan - Source: skyscrapercity.com

Figure 11.20.2 Kuala Lumpur International Masterplan 2017 - Source: Malaysia Airports @ FIATA conference

The differences between the concepts of Terminal 1, with its cruciform satellite and Terminal 2 with its attached piers, shows that there can be more than one appropriate solution at an individual airport to suit different markets (figure 11.20.2). Terminal 1 is designed for full service airlines while Terminal 2 has been constructed within a lower budget and without a transit system to suit the low cost carrier operation.

11.21 Seoul Incheon (ICN) 2001

Seoul Incheon was built on land reclaimed from the sea between Yeongjong Island and Youngyu Island (figure 11.21.1). The airport supports one of the most ambitious Aerotropolis concepts to date. Unusually, only international air traffic is handled through Incheon while the complementary domestic services continue to be served through the existing Gimpo airport. The rail link, accessed via a dramatic interchange (11.21.2), is unique in handling transfer passengers to Gimpo, while also being designed to continue to the capital Seoul.

Figure 11.21.1 Seoul, Incheon, Aerial views of T1 &T2 phase 1 - Sources: fromabove.altervista.com & IIAC

Figure 11.21.2 Seoul, Incheon Interchange - Source: Ken Eckert / WikiCommons

Seoul Incheon airport has, for the last ten years, topped worldwide passenger satisfaction surveys, because provision has always kept ahead of demand and because of its wide range of leisure facilities and excellent connectivity. The airport demands careful attention as a benchmark because it achieves such high satisfaction levels. The Aerotropolis development has met a lot of criticism being a soulless place to live, a typical reaction to most new towns and cities, but it has helped the hinterland to build on airport driven growth.

11.22 Bangkok Suvarnabhumi (BKK) 2006

Suvarnabhumi Airport was originally designed to operate as many as 76 flights an hour on two simultaneously operating mixed mode runways. At opening it had 51 aircraft stands and 69 remote parking bays for wide-bodied aircraft and was designed to handle over three million tons of cargo annually. With a second terminal it is now planned to handle 100 mppa (figure 11.22.1). The terminal was, at the time, one of the largest to be designed without a satellite, with the attached piers forming a double cruciform (figures 11.22.2).

Figure 11.22.1 Bangkok, Suvarnabhumi, 2030/2040 Master Plan - Source: Skyscraper City

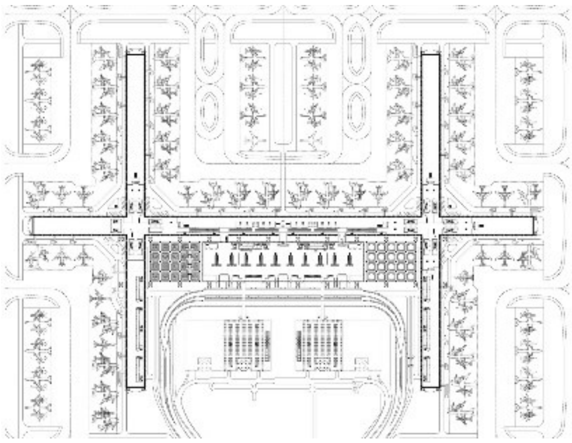


Figure 11.22.2 Bangkok, Suvarnabhumi, terminal gate layout and aerial view –
Source: Airport Builders and Chukoh Chemical Industries Ltd

With a total capacity of more than 30 million passengers per annum in the first phase and an ultimate capacity of 100 million passengers per annum, the new airport is one of the most important airports in Asia and has become a major transfer hub. However, for the transfer passenger, while the circulation pattern is very simple and clear, the pier layout can result in some very long walking distances.

11.23 Madrid Barajas (MAD) 2006

Aena, the airport operator, describes Madrid Barajas as ‘The Gateway to Latin America’. It was designed as a hub airport and is mainly used by the One World Alliance, including Iberia and British Airways as complementary to Heathrow. It is located 15km northeast of Madrid and linked to the city by a regional rail line and an underground metro. It has a unique masterplan with four widely spaced runways, which are slightly misaligned, with the terminals on the perimeter and a new satellite located mid field (figure 11.23.1). Terminal 4, designed by Richard Rogers was opened in 2006 (figures 11.23.2 & 11.23.3), and is the only airport terminal to have won the RIBA Stirling Prize.

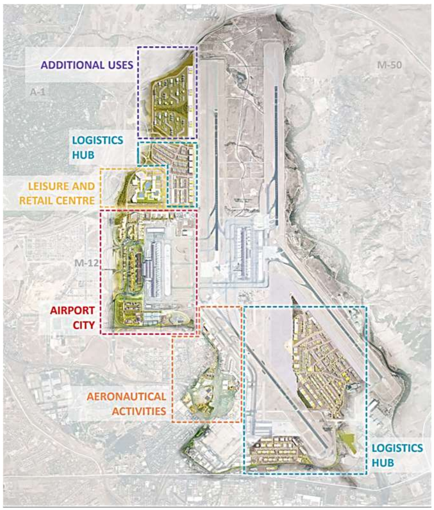


Figure 11.23.1 Madrid Barajas, Masterplan - Source: Aena

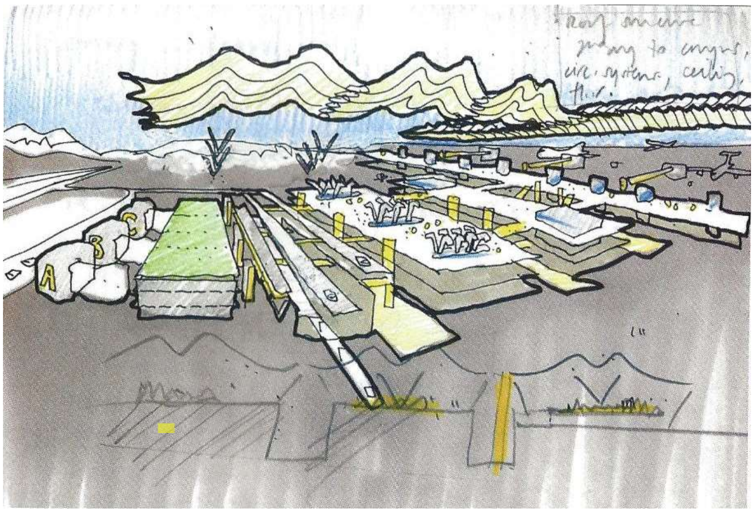


Figure 11.23.2 ‘Magic Carpet’ Roof Concept – Source: Rogers Stirk Harbour + Partners

Figure 11.23.3 Madrid Barajas, Magic Carpet Roof – Source: Rogers Stirk Harbour + Partners

It is interesting to compare Madrid Barajas, with Heathrow Terminal 5 where the RSH team developed similar conceptual ideas in parallel. The main differences are that the Madrid site is far more generous allowing the terminal to spread out and allow daylight to penetrate to the lower levels, and the overall floor area at 1,158,000m^2 is more than twice the size of Heathrow T5.There are, however, similarities, for example, both are hub airports for One World Alliance airlines, British Airways and Iberia, who engaged YRM to look after their interests, and both airports have terminals linked to remote linear satellites by an underground transit system.

11.24 Heathrow (LHR) T5 2008, T2 2014 and the Heathrow Expansion Programme.

This case study focuses on the evolution of the airport as it moved into the 21st century, first with Terminal 5, subsequently Terminal 2 and latterly the Heathrow Expansion Programme that looks forward towards 2050 with the addition of a third runway. As the site is very restricted all these projects have been influenced by the Atlanta Hartsfield linear satellite concept which is a model of effective land use and efficient aircraft movement.

The original Heathrow war time master plan has been discussed in chapter 7 (figure 7.23) and its unique underground surface access concept in chapter 8 (figure 8.42). The underground surface access has over time proven to be one of the most intractable constraints to the evolution of the airport around which subsequent upgrades have had to be planned. The T5 project is illustrated below (figures 11.24.1, 11.24.2 & 11.24.3).

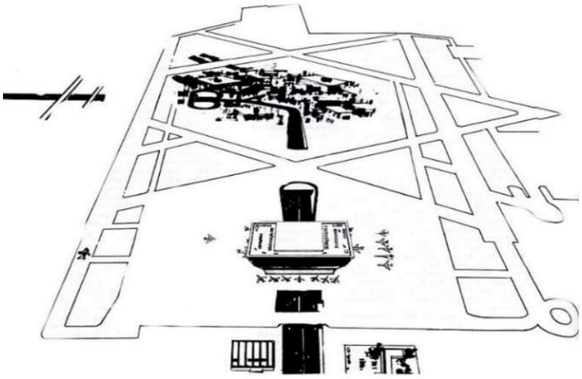


Figure 11.24.1 - Early Concept for Heathrow T5 with a motorway under the terminal (1976) Source: BAA

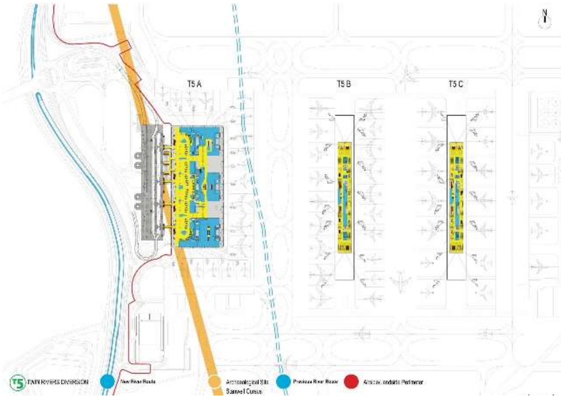


Figure 11.24.2 - Heathrow T5 'Toast Rack' Master Plan Source- Rogers, Stirk Harbour + Partners

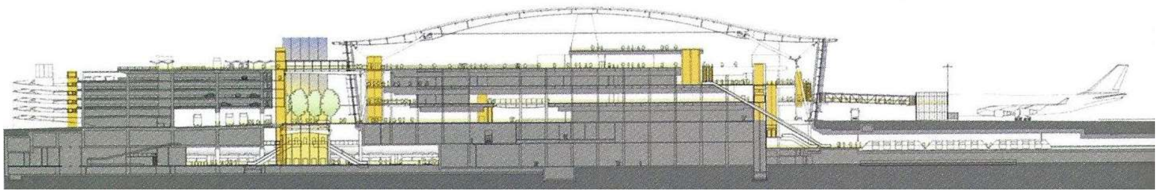


Figure 11.24.3 Heathrow Terminal 5 Sections – Source: Architects Journal

Figure 11.24.4 Heathrow Expansion Project – Source: Grimshaw Architects

All these projects have followed the efficient Atlanta 'toast rack' model with linear satellites as the airport is uniquely restricted in area. It has the smallest area per passenger handled of any of the major airports. However, this has resulted in complex connectivity. The Heathrow Expansion Project (figure 11.24.4) is currently on hold.

11.25 Beijing Capital (PEK) 2008

Beijing Capital Terminal 3 can be seen as an evolution on a larger scale, of the concepts that Foster developed initially at London, Stansted and refined and expanded at Hong Kong, Chek Lap Kok (figures 11.25.1, 11.25.2 and 11.25.3).

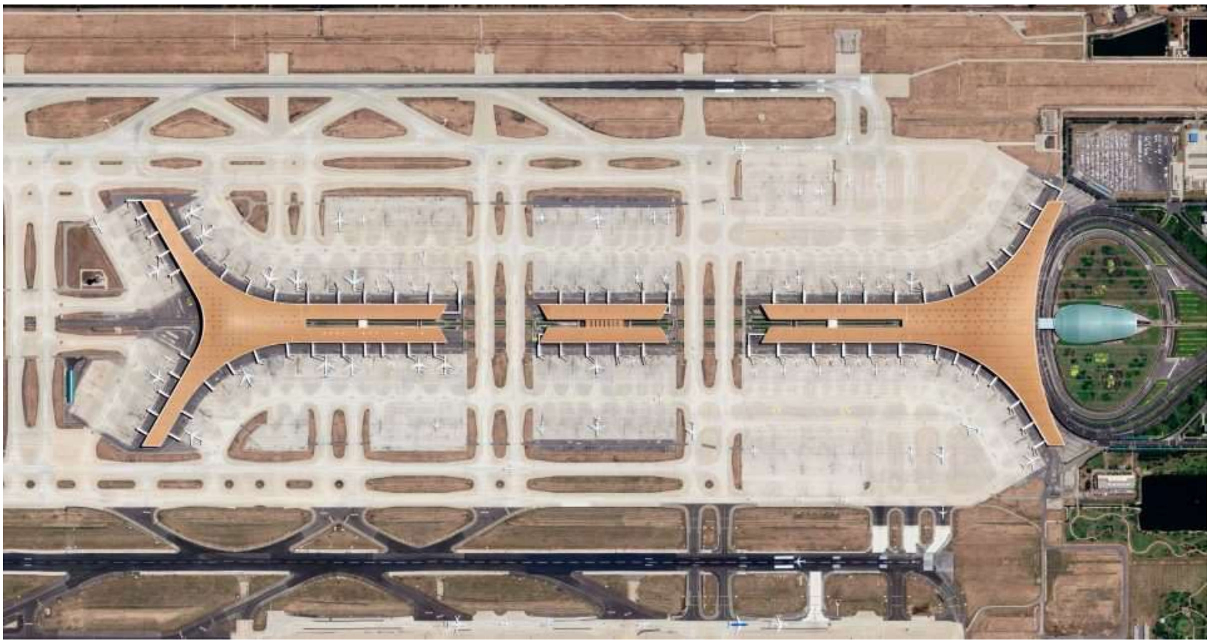


Figure 11.25.1 Beijing Capital Terminal 3 Aerial View – Source: Google Earth

Figure 11.25.2 Beijing Capital Interior - Source: Foster + Partners, Photographer: Nigel Young

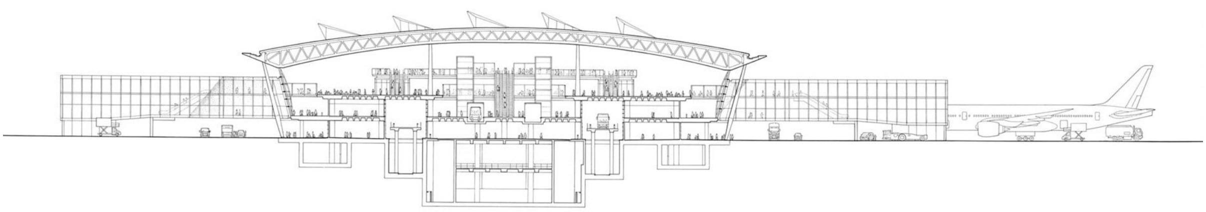


Figure 11.25.3 Beijing Capital Sections through satellite – Source: Foster + Partners

The efficiency of the layout has enabled Beijing Capital Airport to be the second airport in the world to exceed 100mppa, the great majority of whom pass through the Foster designed terminal.

11.26 Dubai International (DXB) 2010

Today Dubai International boasts the world's only underground terminal (figures 11.26.1 & 11.26.2). It provides direct access to the satellite (figure 11.26.3). This was necessitated by the limited size of the site and development had grown up around what had originally been a desert location, constraining expansion. When completed, Terminal 3 was the largest building in the world by floor space, with over 1,713,000m^2 (18,440,000 ft^2) of space, capable of handling 43 million passengers in a year. The airport has now surpassed Heathrow as one of the world's busiest international airports, serving more than 89 million passengers a year in 2018, and is unusual with more than 80% of passengers being transfers.

Figure 11.26.1 Layouts of Underground Terminal Departures and Arrivals Areas – Source: Dubai Airports

Figure 11.26.2 Dubai International Underground check-in concourse – Source: Qantas Magazine

Figure 11.26.3 Dubai International Retail Mall in the satellite concourse Source: getbybus.com

Paul Griffiths, Chief Executive of Dubai Airports, has said of the underground terminal:

'Terminal 3 is unique. Firstly, it's one million square metres – twice the size of Heathrow's Terminal 5. Secondly, the whole terminal has been built underground, yet it feels like a large cathedral. Thirdly, it is the first terminal in the world that has been designed specifically for the A380' (2020 ACI EUROPE Airport Business, 2008).

As the new Dubai World Central has been delayed, plans are being developed for Dubai International to grow even further, largely by creating additional remote stands. At present its underground terminal is unique, but it shows an approach that maximises efficient land use and so may be applicable to constrained airports in future. The satellites (figure 11.26.3) are dominated by an extensive retail offer making passenger circulation and wayfinding less intuitive and more complex.

11.27 Istanbul Grand (IST) 2019

The project opened fully in 2019, after a ‘soft’ opening at the end of 2018, and it will be delivered in a number of stages. On the opening of the first phase it is expected to serve 90 million passengers per year, while on completion it will rise to 150 million. The claim is that it will then be the world’s busiest airport.

Istanbul Grand is a rapidly expanding new hub airport and boasts the largest terminal yet designed without a transit system, at least in phase 1, with 71 passenger boarding bridges accessible from its finger piers, most of which can handle two narrow bodied aircraft. The layout bears comparison with that developed for Bangkok Airport. At a later stage it will be expanded to include a satellite and second terminal. Istanbul Airport City is discussed in chapter 9.8.

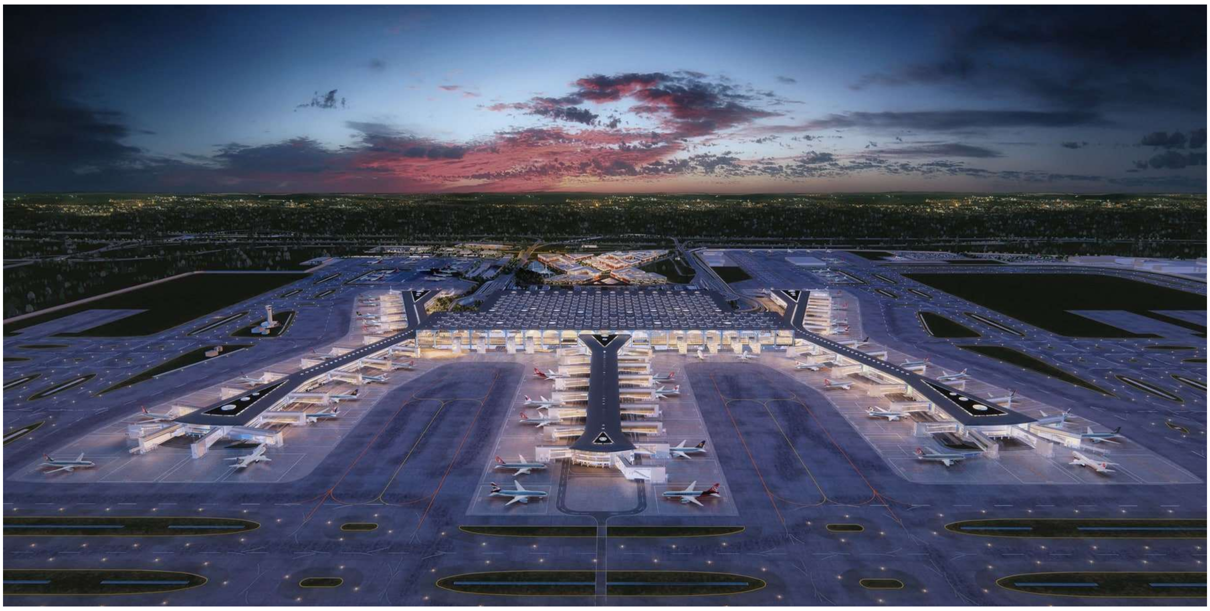


Figure 11.27.1 Istanbul Grand, Aerial View - Source: IGA by Havilimani Vaz Aci, via Architectural Digest

Figure 11.27.2 Istanbul Grand – CGI of Departures Concourse – Source: Grimshaw

Figure 11.27.3 Istanbul Grand CGI of Airside Lounge & Retail Mall – Source: Haptic Architects

The terminal plan has similarities to Bangkok (figure 11.27.1), but what distinguishes Istanbul from other terminals with piers is its size, as there are 71 passenger boarding bridges all accessed from the main terminal building without the use of a transit. Despite a simple and logical interior layout (figure 11.27.2 & 3) very long walking distances are the result.

11.28 Beijing Daxing (PKX) 2019

The original master plan for Beijing Daxing was developed by NACO, but the competition winning scheme, from Aeroport de Paris and Zaha Hahid, proposed a large terminal with five arms as piers. The 6th arm was formed by a landside transport interchange. The new mega-airport hub was designed to handle up to 45 million passengers per year by 2021 and reach 100 million in the future with the development of a second terminal (figure: 11.28.1). Unlike the Atlanta ‘Toast Rack’ this concept prioritises short passenger walking distances over ease of aircraft movement.

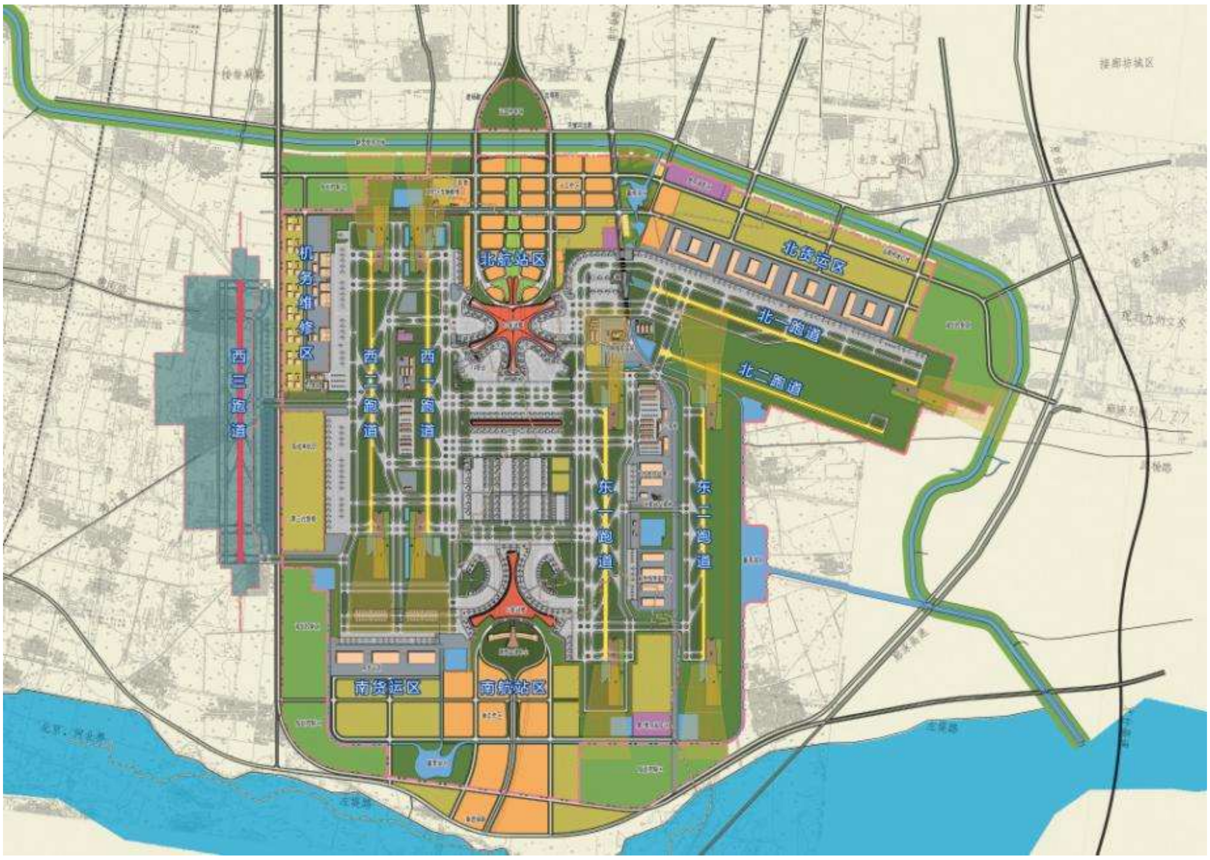


Figure 11.28.1 Beijing, Daxing Master Plan - Source: kaskus.co.id

Figure 11.28.2 Beijing, Daxing, Aerial View, nearing completion 2019– Source: Wikipedia Photo:王之桐

The definitive closed and curved form of the terminal (figure 11.28.2), like Saarinen’s earlier TWA building, may make later modification difficult, though the very large internal spans do provide scope for alteration of the layout. Only time will tell whether this concept provides sufficient flexibility to accommodate growth and change.

11.29 Mexico City (MEX)

Mexico City Texcoco Airport is a partially built megastructure which was supposed to be Mexico City's New International Airport but it was abruptly cancelled in late 2018. Instead, the current Mexican government plans to build an international airport at Santa Lucía airbase north of the city.

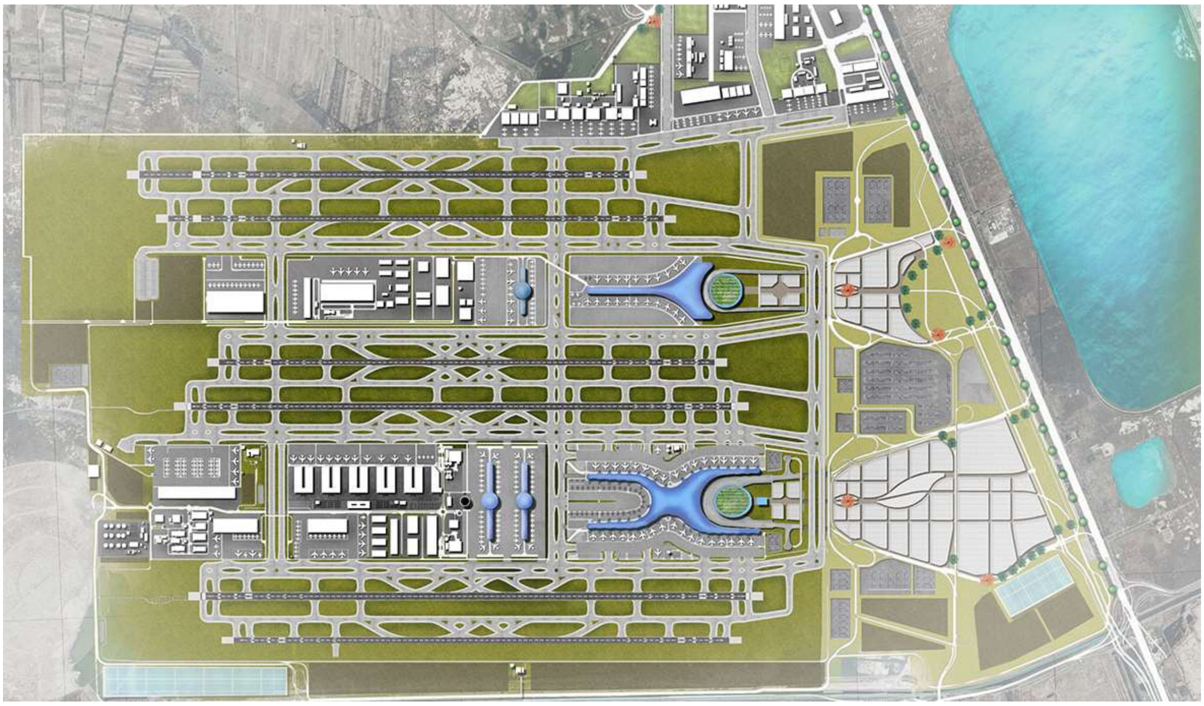


Figure 11.29 1 Mexico City, Masterplan with 6 runways and 2 terminals – Source: Landrum and Brown

The terminal was designed by Norman Foster and Mexican Architect Fernando Romero . The terminal has a monumental scale inspired by Mexican architecture and symbolism. The roof of the terminal represented an eagle with its wings open to take flight (figure 11.29.1). The X was also intended to be symbolic of the country's name "México".

Figure 11.29.2 Mexico City International, Departures Forecourt – Source: Dbox for Foster & Partners

Figure 11.29.3 Mexico City International, Departures Lounge – Source: Dbox for Foster & Partners

Mexico City would have been one of the new type of terminal architecture, a Megastructure which is characterised by being so large that it cannot be understood from the ground (figures 11.29.2 & 11.29.3). So instead of the main entrance being the key view, it is the aerial view that becomes the focus, a view that no-one can see in reality, and interior views, that only give a partial understanding of the terminal, that predominate.

11.30 Dubai World Central (DWC)

Dubai World Central is planned to become the world's largest airport with an ultimate capacity exceeding 220 million passengers a year and 16 million tonnes of cargo per annum. The airport forms the heart of a greater Aerotropolis project covering 140 km², in six zones: Logistics City, Commercial City, Residential City, Aviation City and Golf City (figure 11.30.1).

The airport will ultimately have five parallel runways, each 4500 metres long. The main terminal building will house a fully automated baggage handling system capable of handling around 240 million bags per annum. The cargo facility will allow air to sea connections to Jebel Ali Port and Free Zone in less than four hours via a dedicated road.

Figure 11.30 Dubai World Central, Model – Source: Leslie Jones Architecture

Figure 11.30.2 Dubai World Central, Satellite – Source: Leslie Jones Architects

What makes Dubai World Central different is that it is designed primarily as a transfer hub with over 80% of passengers transferring through the satellites (figure 11.30.2) and it handles only international and no domestic traffic. It is also much larger than all other terminals with a design capacity of 220mppa so there is no opportunity to avoid the use of a transit system. The other difference is that it eschews the curvilinear approach of the previous airports in favour of a simpler orthogonal geometry which will allow it to be constructed more easily using a modular phased approach as traffic increases.

11.31 Conclusion

The case studies show that individual airports have successfully employed many different concepts as they have developed over time. All the early terminals followed the simple terminal formula without planning for growth. The first airport to take a long term view was the second terminal at Berlin, but it did this by grossly oversizing the facilities compared with the anticipated traffic. However, it did last for the 60 years for which it was planned. It finally closed in response to criticism of its unacceptable environmental impact on the nearby city centre.

In the post war period a variety of concepts developed, linear, unit, and finger pier, and circular, linear cruciform satellite. The 1947 masterplan for Chicago O'Hare with its multiple finger piers has proved adaptable to larger aircraft and increased volumes of traffic and has influenced subsequent designs at St. Louis Lambert, London Gatwick, Amsterdam Schiphol and Frankfurt Main. The pier concept was revived in a larger form and supported by a transit at Hong Kong International which has been until recently the largest terminal under a single roof. The multiple pier concept has enjoyed a revival in the 21st Century as the benefits of being able to access a large number of stands from the main terminal without resort to a transit system have been better appreciated as can be seen at Istanbul Grand.

The unit terminal, with its benefit of short walking distances and close parking was realised in its most developed form at Dallas Fort Worth, which benefitted from a uniquely elaborate transit system to facilitate easy transfers and allowed it to become one of the major hubs. The later development of the international terminal has seen the unit terminal concept abandoned in favour of the now universally adopted centralised approach which minimises staffing costs through security and maximises retail footfall.

Linear terminals are most often planned where developments are proposed parallel with the runway, such as Heathrow Terminal 4, the main terminal building Madrid Barajas T4 and Kansai, but unless, like Kansai, they employ a transit they are inherently limited to a relatively small scale of say 10-20 mppa before walking distances become unacceptable.

The airports with smaller satellites - New York (TWA), Los Angeles and Paris, Charles de Gaulle - have all abandoned them in later developments. The TWA building has been abandoned and a linear terminal has been built around it for the low cost airline Jet Blue. The satellites at Los Angeles have been joined back to the terminal to form finger piers, and later developments at Paris, Charles de Gaulle have adopted a linear terminal development, supported by large linear satellites. The airport is planning a large finger pier concept for the proposed Terminal 4.

It is interesting that Atlanta, Hartsfield has progressively morphed from simple terminal, to linear terminal, then finger pier and latterly to a mid-field terminal with linear satellites accessed by an underground transit. It is currently the busiest airport in the world. In many ways it epitomises the evolution of airport design in its response to the challenges of growth and change. Its influence can be seen at Denver, and the progressive redevelopment of Heathrow and Washington Dulles. It is recognised as the most efficient format in terms of land use and aircraft movement, but comes with an expensive transit system.

Stansted also employed the transit as an architectural device to separate the satellites from the terminal when walking distances would have been perfectly well satisfied by piers, and indeed in later phases the pier concept has been reintroduced. Stansted, however, did pioneer the floating steel frame roof which has been employed in most subsequent major airports as the ultimate symbol of flight.

New York, Idlewild (JFK) shows what can happen when masterplan concepts break down in the face of commercial expediency that allows a free for all with separate terminal designs that compete in an uncoordinated way. Most of their terminals have become obsolete, especially the most architecturally striking ones, the TWA terminal and Pan American World Port because they were over-designed to meet the very specific airline needs of the day. It is perhaps significant that the airlines that commissioned such bespoke designs Pan American and TWA no longer exist and their terminals have become obsolete.

By contrast the indeterminate planning of the midfield terminal at Washington Dulles has stood the test of time and shown itself to be adaptable and flexible and able to respond to growth and change while still delivering the highest quality architectural design.

Dubai International is unique in being the only underground terminal in the world, but its importance lies in that for each passenger handled the airport occupies the smallest site area of any major international airport so we may well see a revival of this concept as airports become increasingly congested.

The current generation of new airports has seen the re-emergence of large multiple finger pier concepts at Bangkok, Suvarnabhumi, Seoul Incheon Terminal 2, Istanbul Grand, Beijing Daxing, and Mexico City with the objective of avoiding the use of a transit system, at least in the early years of development.

The largest planned airport to date, Dubai Word Central will have four very large multiple cruciform satellites handling 50 - 60 million passengers a year, and like Stansted will have no passengers boarding aircraft directly from the terminal. The airport is unusual in having a very high transfer rate at over 80% no it perhaps not surprising that it prioritises ease of transfer over direct departures and arrivals.

So, in conclusion, airport masterplan and terminal design concepts have largely evolved in response to increasing traffic volumes and those that have proved most durable are those that have planned for growth and change from the outset.

12. Key Turning Points

12.0 Introduction

This chapter proposes that there are key turning points in the evolution of airport design at approximately 20 year intervals: Pioneering Era – 1920 – 1940, Evolutionary Phase - 1940 – 1960, Jet Age – 1960 – 1980, Transfer Interchange – 1980 – 2000 and Mega Hub – 2000 – Present. This is followed by a discussion of current trends in the evolution of airport design. It ends by considering how airports have learned from others and what embryonic ideas there are for the future.

12.1 Key turning points in the evolution of airport design

This research indicates that commercial airport design can best be categorised into a series of stages of some two decades each, with only limited exceptions.

1. Pioneering Era – 1920 - 1940
2. Evolutionary Phase - 1940 - 1960
3. Jet Age – 1960 - 1980
4. Transfer Interchange – 1980 - 2000
5. Mega Hub – 2000 - Present

12.2 Pioneering Era 1920 -1940

While commercial flying started in 1919, the few services that operated at this date were all from former military airfields that had become redundant at the end of the First World War. Directly after the war commercial aviation was banned so one of the first flights on the 8th February to publicise the merits of the Farman Goliath aircraft, carried former pilots who all travelled in uniform carrying mission orders. This aircraft had been converted to handle passengers from its wartime role as a heavy bomber and was admired by Le Corbusier and later, as discussed in chapter 5, informed the plan form of Le Bourget Airport. Scheduled domestic services had begun a few days earlier between Berlin, Johannisthal and Hamburg on February 5th, no doubt provoking the flight of the Farman Goliath. International services followed a few months later between London, Hounslow and Paris, Le Bourget.

Airports of this period typically had grass airfields and the main permanent buildings were hangars as aircraft were so flimsy they had to be stored indoors when not in use. One of the best descriptions of the characteristics sought for an aerodrome was by Nigel Love describing his initial impressions of the field that was to become the site of Australia's first aircraft assembly and manufacturing company and later Sydney, Kingsford-Smith airport. The first fare paying passengers were carried from this aerodrome between Sydney and Melbourne in 1920 making it, after Schiphol, the second oldest international airport in the world.

Seeking an aerodrome on which to establish his aircraft manufacturing business he found a bullock paddock at Mascot, on Botany Bay near Sydney. In addition to the flat surface, its approaches were clear of obstructions on all sides, an important safety consideration from the outset. He wrote:

> *"It was covered by a pasture of buffalo grass which had been grazed so evenly by the sheep and cattle running on it that it simply left nothing to be desired."* (Eames, 2000, p. 14)

It is one of the oldest airports in the world that continues to operate today, benefitting from its location next to Botany Bay which allowed it to accommodate the flying boat services of the 1930s and 1940s, and later permitted the expansion of the airport to accommodate jet aircraft and the long runways they required by reclaiming land from the sea.

This ability to adapt to changing circumstance can also be found at two other of the oldest airports in the world, Amsterdam, Schiphol (1920) and Boston, Logan(1922) which were both constructed on reclaimed land. Boston however boasted the first hard surfaced runway in 1922, while Schiphol was only the second airport in Europe to have a concrete runway when it was upgraded in 1939. This was a feature that was to become universal after the Second World War as increasing aircraft weight rendered grass airfields unsuitable.

The first purpose designed terminal was built at Konigsberg Airport in 1922 but there is no evidence that it influenced any subsequent designs. The new terminal at London, Croydon (1928) was however was highly influential and widely published and analysed in specialist aviation publications of the late twenties, thirties and forties. It contained the first control tower and introduced the first airport hotel. It contained most of the elements of the modern terminal, excepting security which was not to emerge until the seventies in response to hijackings and then made more rigorous to counter terrorist attacks. Croydon was, however, only designed to handle one departing and arriving flight at a time.

At the beginning of this period it was not clear whether aircraft or airships would dominate, and for a time some believed that aircraft would prove to be more suitable for short range flights while airships would hold sway in the long haul market. So, many airports such as Croydon, Tempelhof and Ford Dearborn were designed to handle both aircraft and airships. However, after a series of setbacks culminating in the loss of the Hindenburg at Lakehurst New Jersey it became clear that the aeroplane would dominate future air travel.

The Pan American Airways terminal at Miami was significant because for the first time a terminal was designed to suit a specific airline operation and it was the first terminal in the USA designed to handle international flights.

While Croydon looked backwards to a Beaux Arts model for its aesthetic and Miami followed a contemporary Art Deco aesthetic, the international style restaurant at Leipzig-Halle (1929) with its floating roof looked forwards to a later generation of terminals where the floating big roof has been used to capture the spirit of flight.

The first terminal at Berlin, Tempelhof demonstrated that terminals could be built in phases while still maintaining business continuity at all times. It also introduced the idea of linking the terminal to the underground Metro system, to provide an integrated transport network, and also pioneered runway lighting to permit night flights.

An early design theoretically capable of handling multiple flights simultaneously can be found at Gatwick Airport 'Beehive' (1936). The circular plan owed much to the winning competition design for the 1929 Lehigh Airport Competition which had been widely published. The latter design boasted a hexagonal satellite with telescopic walkways providing covered access to the aircraft parked around its perimeter with and underground walkway linking the building to the main terminal. These features were incorporated into the circular Gatwick design. Gatwick was also the first airport to be linked to the mainline railway via its own station, and pioneered the integration of rail and air travel as a single offer. Despite these innovations the boggy landing conditions on Gatwick's grass field meant that this capability was rarely needed.

There is evidence of cross fertilisation of design ideas between Europe and the USA in books, periodicals and lectures. This can be seen in books like Steadman Hanks survey of European airports for an American audience, or the Norman and Dawbarn lecture to the Royal Aeronautical Society following their visit to new airports in the USA and numerous articles in architectural and engineering journals.

Throughout this pioneering period commercial aviation needed financial subsidy, either directly from governments in Europe, or indirectly via the postal service in the USA. Airports did make many efforts to supplement their income by holding flying shows as major spectator events and from increasingly sophisticated catering offers.

The first signs of evolution from these simple beginnings can be found at the second terminal at Berlin Tempelhof and New York, La Guardia where designs were developed so that multiple aircraft could be turned around simultaneously. La Guardia was also the first airport to be designed with more than one terminal, though the international flying boat terminal closed when flying boat services ceased. Washington National Airport, was designed in the 1930s as an exemplar airport as a part of Roosevelt's 'New Deal'. Construction was started in1938 but was not completed until 1941. Its main contribution is to advance the mechanisation of processes at check-in, baggage handling and aircraft turnaround introducing types of equipment that are still in use today.

With so many new ideas and technological innovations in this period, airport design fits conveniently within Banham's description of this period as 'The First Machine Age', but it certainly does not fit with his description on aviation being in a 'Pastoral Phase'. Most of the major airports in the USA had been constructed with hard surfaced runways from the late twenties and were progressively being introduced in Europe in the late thirties. Many of the ideas we see in modern airports had their origin in this most creative of design periods.

12.3 Evolutionary Phase 1940 -1960

Airport design during this period got off to a slow start as design efforts were directed into the Second World War, and commercial flying was largely curtailed though scheduled services regularly flew from Berlin Tempelhof right up to April 1945. Several masterplans were produced during the war that looked forward to a peaceful future. Some were more farsighted than others. Notable were plans for London, Heathrow, New York, Idlewild and Chicago, O'Hare. They all included multidirectional concrete runways and terminals in the middle of the runway system, rather than on the periphery of the airfield, an idea that had been dismissed as unsafe in previous decades, but was now to become the norm.

1940 saw the initial introduction of aircraft with tricycle undercarriages rather than the tail dragging types of the pioneering era, which made the possibility of airbridges more practicable. Four engine aircraft models such as the Douglas DC4, permitted larger and heavier and faster aircraft designs with increased range. This in turn made hard surfaced runways a necessity and progressively made flying boats obsolete, particularly as land planes were now capable of flying the Atlantic with a reasonable payload, albeit with intermediate stops in, Newfoundland, Iceland and Ireland.

Airlines were responsible for a number of initiatives during the period particularly in the United States. Eastern Airlines proposed both the finger pier concept and the apron drive airbridge, while United Airlines pioneered the latter's introduction at Chicago O'Hare. Delta Airlines introduced the hub and spoke concept as early as 1955. Meanwhile Pan American Airways introduced economy fares in 1953 dramatically increasing the volume of traffic. Many airlines introduced lounges for frequent flyers following the example of American Airlines who had first opened one at La Guardia.

The airport city idea first emerged at New York Idlewild, initially as an expedient concept where individual airlines designed and funded their own terminals while the FAA funded the overall airport infrastructure, because the original centralised terminal concept could not be afforded by the airport authority. This led to a hotchpotch of individualistic terminal designs which may have originally been seen as innovative, but have not survived the test of time and are now largely either demolished or rebuilt.

The far-sighted Chicago O'Hare master plan of 1947, was arguably the most influential master plan and terminal design of the period, and its finger pier and radiating centralised concept were later widely imitated at airports such as Schiphol and Frankfurt. The master plan estimated that 22 million passengers would fly through the airport in 1970 but even this prediction, which was considered wildly optimistic at the time, proved to be a substantial underestimate of growth in demand, with the actual throughput in 1974 being 37.6 million passengers making it by some margin (12 million passengers) the busiest airport in the world. The concept however has proven adaptable to even higher levels of traffic handling some 80 million passengers in 2018 and is only now undergoing a radical expansion programme, made possible by changing the space consuming radial runway layout to multiple parallel runways thereby releasing substantial areas for new stands and expansion of the terminals.

Finger pier concepts first became operational at Washington Friendship in 1952, followed by St. Louis Lambert 1955 and Gatwick 1958, while Chicago O'Hare finally became fully operational in 1962 after numerous updates increasing runway lengths and revising the terminal geometry to suit ever larger aircraft types.

Aesthetic developments can be seen at St. Louis, Lambert with its lightweight shell roof and freestanding cabins inside, a strategy later adopted by Eero Saarinen for the TWA terminal at New York JFK and Washington Dulles. At Gatwick a Miesian version of the International

Style provided an aesthetic framework that allowed the airport to remain functionally and visually coherent for many years despite extensive growth and change.

St. Louis Lambert was also advanced in introducing piers, mechanical means of handling baggage carried on conveyors and moving people on escalators between levels, introductions described by the architectural press at the time as ‘new-fangled’. It also segregated departing and arriving passenger vehicles on to an upper and lower forecourt. All these innovations have become the norm in subsequent terminal designs. It was an era of increasing size and mechanisation.

12.4 Jet Age 1960 – 1980

There was a false start to the jet age in 1952 with the introduction of the structurally flawed De Havilland Comet on a route between London and Johannesburg and later other Commonwealth routes. It immediately ended the reign of flying boats on BOAC’s long haul routes, but services were suspended in 1954 after a series of crashes. It was relaunched in late 1958 as the Comet 4 shortly before the Boeing 707 was introduced. The707 radically transformed commercial aviation with its large seating capacity, and with the 320 version introduced in 1962 the ability to cross the Atlantic non-stop with a full payload.

Jet flights brought with them, a requirement for much longer runways and a radical increase in noise nuisance causing the rise of the environmental protest movement as New York, Idlewild (JFK) and Chicago, O’Hare were adapted to the new larger jets with longer runways. A series of new terminals were designed specifically to support jet operations, including the Pan Am and TWA terminals at Idlewild, and new jet age airports at Los Angeles International (LAX) and Washington Dulles.

The first of these terminals Pan American’s Worldport at Idlewild (JFK), which opened in 1960, can be seen as a transitional design with its overhanging canopy conceptually reminiscent of Berlin Tempelhof, and its open aircraft access walkways an anachronism when apron drive airbridges had already been introduced. Its oval form was inherently difficult to expand and its elegance was lost with the extensions that overwhelmed the simple original. Its major legacy, however, was the introduction of nose-in aircraft parking, which was much more space efficient that self-manoeuvring parallel parking and is now universally adopted at new large airports.

The Iconic TWA terminal that opened in 1962 captured perfectly the spirit of fight at the dawn of the jet age, but while its sculptural form is rightly admired its planning was so bespoke that it proved difficult to adapt to larger aircraft, increased volumes of traffic and new operational practices. An innovation that has been widely copied is the satellite concept with an above ground link.

Los Angeles International Airport (LAX) (1961), was originally designed in the late fifties with a circular terminal and satellites, but evolved into lozenge shaped satellites accessed via underground pedestrian links with passenger conveyors. Over time the satellites have been progressively linked back to the entrance buildings to become conventional piers. The LAX Theme Building also produced one of the most futuristic and enduring airport images evoking the space age but like the TWA terminal has become redundant as airport processes have changed.

Eero Saarinen's second airport design for Washington Dulles (1962) has had the most profound influence on subsequent airport design, with an impact greater than any other airport before or since. It boasted the simplification of runway layout made possible by the improved performance of jet aircraft in cross wind conditions, a mid-field terminal layout, with a central control tower, and gyratory landside road layout that has become the norm for all recent airport multi runway plans. Its surface access included a dedicated road link and safeguarded for a metro link that was installed later. The airfield layout was the first to adopt the 'toast-rack' layout which optimised aircraft movement between the runways.

The terminal building with dramatic upswept clear span roof , although constructed in concrete can be seen as the forerunner of the modern long span steel structures that are an integral part of contemporary airport design. The interior incorporated freestanding cabins, reminiscent of exhibition stands, accepting that the interior had become a flexible stage set. The terminal also introduced the concept of an indeterminate architecture, that looked complete and resolved whether in its original size or when extended. These ideas predate Norman Foster's claims to have originated the ideas by thirty years.

The one feature that was to prove a wrong move was the proposal to use mobile lounges to access aircraft. Saarinen enlisted the help of Charles Eames to produce one of the most compelling cartoons promoting an airport concept of operation. For a time mobile lounges were all the rage, and several new airport designs were developed following these principles including the ill-fated and short-lived Montreal, Mirabel airport. Mobile Lounges proved to be slow, unreliable and expensive and ultimately were not able to carry sufficient numbers of passengers, as aircraft sizes grew and the volume of passengers increased. Washington Dulles' greatest virtue has been its ability to accommodate growth and change without losing either its simplicity of layout or integrity of form because that was planned from the outset, a feature that many more recent designs have failed to address.

The 1970s saw the Introduction of Concorde, the Boeing 747 and other wide body jets, aircraft that were heavier and required even longer runways and forced many of the major airports to strengthen and lengthen their runways. As terminal sizes increased to handle these larger volumes of traffic and multiple terminals proliferated, the alternative to either walking or riding on a bus or in a mobile lounge was to travel on an automated people mover (APM).

The APM was originally introduced as a ride to reach various attractions at Disneyland, but was first adapted to airport use at Tampa Airport. The most complex system was installed at Dallas Fort Worth (DFW) (1973) to link together the multiple unit terminals and allowed a concept that was particularly suited to originating and destinating (O&D) flights to work effectively for transfer passengers. Transfer passengers were provided with unrivalled panoramic views of the airfield as they rode between the multiple semi-circular terminals.

Dallas Fort Worth had, at time of opening, the largest land take of any in the world and its layout with a central access spine and multiple terminals was much copied, including the stillborn 3rd London airport at Maplin Sands and later the original masterplans for Hamburg Kaltenkirchen, Paris, Charles de Gaulle and numerous subsequent airport design by Aeroport de Paris (ADPI).

12.5 Transfer Interchange 1980 - 2000

Atlanta introduced a new era in airport design when it opened in 1980, as the world's largest passenger terminal complex and designed to handle 55 million passengers a year. The previous airfield and terminal designs had followed the trends of the day initially with multi-directional runways supported by a unit terminal, to be replaced with a terminal with a linear pier, followed by a terminal with radiating finger piers based on the Chicago O'Hare concept.

The 1980 Atlanta concept, with parallel runways, but no cross wind runway and a mid-field terminal supporting a series of linear satellites linked by an underground automated people mover set a new trend. Atlanta has an exceptionally high proportion of transfer traffic at around 80%, so was specifically designed to make transferring as simple and speedy as possible. Atlanta, although designed to handle primarily domestic traffic and predominantly smaller aircraft, can be seen as the prototype for a series of later international terminals designed to facilitate transfer traffic.

The concept has a number of acknowledged benefits, including maximising efficiency of land use, and optimal aircraft circulation and has been copied by a number of subsequent designs including Denver, Heathrow Terminal 5 and the update to Washington Dulles. Set against those virtues the layout requires an expensive people mover and stations to link the terminal and satellites. The people mover can never be 100% reliable so the designers wisely included walkways and passenger conveyors to act as a back-up in the event of failure. The other limitation is that the narrow satellite gives limited opportunities for retail and concessions. This was later addressed by widening the satellite at the centre to allow a better commercial offer. However the concept has been sufficiently robust to allow Atlanta to be progressively expanded to handle over 100 million passengers per annum and remain the busiest airport in the world.

Other satellite concepts have proved less durable. For example Paris, Charles de Gaulle circular terminal 1 (1973) surrounded by series of small satellites, proved impossible to expand and has unusually counter-intuitive passenger movement. The original master plan envisaged a series of similar circular terminals, but the second phase of development abandoned this concept and substituted a series of linear terminals, with T2 A & B opening in 1982, but this too was later abandoned and the latest expansion is in the form of linear satellites.

Throughout this period terminals following other concepts continued to be built, for example Amsterdam, Schiphol continued to expand their single terminal concept by adding additional finger piers while Heathrow's Terminal 4 (1986) followed a linear concept, as did the much larger Osaka Kansai (1994). The latter incorporated transit systems to carry passengers to the end of the very long pier.

Kansai also marked a radical change of direction in the siting of airports that has influenced many subsequent designs. The Japanese Airport Authority scarred from the bitter experience of facing the protest movement that had grown up in opposition to Tokyo, Narita decided to create an artificial off-shore island in Osaka Bay for Kansai Airport. They have continued with this approach with all subsequent new airport developments.

In 1986, The British Airports Authority was privatised starting a worldwide trend that required airports to improve their return on investment. This has resulted in commercial offers absorbing an increasing percentage of investment and requiring a larger share of floor space in the terminal. Heathrow now aims to support its day to day operating costs entirely from commercial revenues, while airport charges support investment in capital expenditure. Similarly airport master plans have evolved to support increased levels of airport related development to generate higher revenues from parking, hotels and other property developments, giving an impetus to the Airport City concept.

However, during this period Airport Cities continued to evolve in a relatively unplanned way around existing airports which had proved to be a catalyst for growth in their surrounding hinterland. Examples of the evolution of Airport Cities around existing airports include Heathrow, Gatwick, Schiphol, Frankfurt and Charles de Gaulle in Europe and Atlanta, Dallas Fort-Worth, Chicago O'Hare and New York JFK in the United States. The very success of airport related development has, however, now become a major constraint to airport expansion with noise, air quality and congestion affecting the surrounding communities and has led to ever better organised and more vocal protests against airport expansion.

A reversal to this trend of ever larger and more complex airports came when American domestic carrier Southwest introduced the concept of a low cost airline in 1979, following deregulation in the United States. They developed it throughout the following decades with the sole objective of offering cheap airfares to consumers. This created a situation where already established flag ship carriers or legacy airlines lost a significant amount of the market share to these newly formed low cost airlines, purely because of their ability to charge a lower price over traditional full cost airlines.

The Low Cost Carriers (LCCs) typically used existing airports, which had formerly been the major airport of the city but were now underused and relegated to secondary status by the construction of newer airports. Initially Southwest was prohibited from issuing through ticketing that involved a transfer but soon realised that they could sell passengers two separate tickets allowing them to self-transfer, and avoid the costs incurred by legacy airlines. These secondary airports, because of the relative simplicity of their infrastructure, were able to offer lower landing charges. Examples include Chicago Midway, Houston Hobby and Dallas Love. The operational concept that was to form the model for later Low Cost Airlines included:

- network: Point to point high frequency routes
- distribution: Travel agents and call centres, no tickets
- fleet: High utilisation, same type of aircraft across the fleet
- airport: Secondary airports with short turnaround times
- sector length: Short (around 400nm)
- staff: High productivity with competitive wages and profit sharing

LCCs introduced a number of innovations aimed at reducing the cost of airfares. For example Southwest introduced internet ticketing in 1996, and Alaska Airlines internet check-in in 1999, essential initial moves that have later affected terminal design, initially reducing the demand for airline ticketing desks and then check-in desks.

12.6 Mega Hubs 2000 – Present

The current generation of designs are responding to several new influences:

- the rise of Global Alliances requiring larger and more complex interchanges
- the development of LCCs needing to cut costs
- the introduction of new aircraft types
- the expectation that an airport focussed Aerotropolis can induce growth in the surrounding area
- ever more stringent security requirements with greater space requirements for both passengers and baggage checks
- increasing demand for environmental mitigation
- higher expectations of commercial income

These are discussed in turn in the subsequent sections:

12.7 Future Growth

There is a strong link between economic well-being, measured by GDP, and the propensity to travel. Social mobility within Europe has been helped by the growth of LCCs and has in turn stimulated significant growth, both in business and visiting friends and relatives (VFR) travel. For the future both Boeing and Airbus forecast the greatest growth in Asia (appendix F). So that is where we should expect the most innovative design in future, while in Europe and the USA, where the market is mature we should expect a greater focus on process improvement to eke more capacity out of existing infrastructure.

The Covid 19 pandemic has brought an abrupt halt to the growth of air travel and indeed has resulted in a dramatic contraction during 2020. Whether this will result in a significant permanent change to the growth trajectory cannot be determined at this stage. In the past where events have slowed growth, for example the 9/11 attack of 2001, the SARs epidemic of 2003 or the global recession of 2008, growth has quickly resumed.

There is however one example of an event that had a permanent effect on the structure of the industry. The 9/11 attack on New York's Twin Towers has led directly to the imposition of much stricter security controls altering the infrastructure and perception and cost of air travel. The tragedy also contributed directly to the demise of Concorde as many of the clientele using the supersonic service were killed in the attack, and demand never recovered. The demise of the British Airways Concorde service had an important commercial dimension rather than being solely a safety or re-certification issue.

As the direct result of Covid 19 many multinational companies have elected to do business by video conferencing rather than face to face meetings and have even suggested they will never return to using expensive air travel. Covid 19 could therefore lead to a requirement for more sophisticated passenger screening and Port Health medical facilities, a permanent reduction in business travel and the associated provision of airline lounges in airports, and the further commoditisation of air travel through the growth of low cost airlines (LCCs).

12.8 Global Alliances

Global Alliances are an aviation industry arrangement where two or more airlines agree to collaborate in providing marketing branding and in helping travellers making inter-airline 'codeshare' connections with other airlines. They were formed either side of the Millennium; The Star Alliance was founded in 1997, One World in 1999 and Sky Team in 2000. Their foundation helped give an impetus to a new generation of international hub airports specifically designed to make transfer from one flight to another as easy and as reliable as possible.

To achieve this new infrastructure was required and new operating practices were needed to facilitate the transfer of both passengers and baggage. At the same time security requirements became more onerous, requiring security screening of both transfer passengers and baggage, so the size and complexity of major terminals increased.

A new generation of international transfer hubs was designed for Asia and the Middle East including Hong Kong, Kuala Lumpur, Beijing Capital, Seoul Incheon, Dubai International and Abu Dhabi among others to achieve competitive minimum connection times (MCTs). In the meantime major projects were initiated at established airports such as Singapore Changi, London Heathrow, Amsterdam Schiphol and Frankfurt to maintain their competitiveness in the transfer market in response to this new airline business model.

12.9 Low Cost Carriers

While the rise of the Global alliances led to ever more complex and sophisticated terminals, the growth of Low Cost Carriers (LCCs) pulled in the opposite direction towards simplicity. They focused on point to point operations and avoided the cost and complexity of transfer traffic. Simplification also led to the use of standardised aircraft types B737 & A320, to keep operating and maintenance costs as low as possible.

This in turn has made it possible to standardise the layout of aircraft parking on the apron as can be seen at Brussels Charleroi one of the few airports to be designed specifically for Ryanair. The subsidy that was required to build that new airport has now been outlawed by the EU so further new airports designed specifically for LCCs are unlikely in Europe. Some LCCs like easyJet are increasingly choosing to fly from mainstream airports even though they object to the major subsidy given to transfer traffic, often of around 50%, which in their view unfairly favours legacy airlines.

LCCs, such as Norwegian, AirAsia X and Tiger Air are increasingly moving into the long haul market where transfer traffic becomes more important. In response Gatwick, for example, is providing self-transfer facilities to allow passengers to check-in transfer bags in the reclaim hall to avoid passengers having to drag their bags through the normal check-in process in the landside concourse. Kuala Lumpur has taken this a step further by designing Terminal 2 with full transfer facilities even though it is specifically targeted at AirAsia LCC, while Terminal 1 continues to serve Malaysia Airlines and the One World Alliance.

12.10 New Aircraft Types

The introduction of the Super Jumbo, as the Airbus A 380 is commonly described, required new airfield and terminal infrastructure. The aircraft was first introduced into regular service in 2007, but had been planned for long before. Initially airports had to speculate on how large the aircraft might be, with airports such as Kansai, Hong Kong and Heathrow and Paris, Charles de Gaulle designing for wing spans in the order of 83 to 85 metres, but eventually a new Code F standard was devised assuming the aircraft would fit within and 80 metre x 80 metre box was agreed on. Appendix D sets down some of the main characteristics of commercial aircraft as they have evolved over time.

This in turn generated changes to the airfield, with increased runway width, wider spaced taxiways, larger stands and new apron equipment and airbridges to serve the upper deck of the aircraft. This investment may yet prove to have been unwise, as with less than 300 ordered, the programme is due to be terminated in 2021. The future of long haul aircraft seems to be with very large twin jets that are more economical. The Boeing 777 -800 & 900 series, now being tested by Boeing as a successor to the B747, has folding wingtips that allow the aircraft to manoeuvre on the ground within the space allowed for the previous largest Code E aircraft the Boeing 747-400 which had a wingspan of 65 metres.

There is also a view that other large twin jets such as the Boeing 787 'Dreamliner' and the Airbus A 350 will lead to more point to point flights bypassing the new Super Hubs. However, with more than 80% of all orders for these new aircraft coming from established legacy carriers it is more likely that it will lead to an increased range of long haul destinations being served from the existing major hub airports driving their expansion even further.

12.11 Aerotropolis

There has been evidence for some time that an airport development can induce growth in the surrounding hinterland. Hong Kong International was one of the first to plan for that in a holistic way incorporating for new communities as well as businesses into their master plan. Since then many new airports have sought to follow their example, particularly in Asia and the Middle East, including Kuala Lumpur, Seoul Incheon and most ambitious of all Dubai World Central.

12.12 Technology

The current era has been described as the Digital Age, a period when the internet has opened up new opportunities. Alaska Airlines was the first to offer online check-in. The system was initially offered on a limited basis starting in the second quarter of 1999, and was available to the general public on selected flights the following quarter. Since then, a growing number of airlines have introduced the system.

British Airways researched the Alaska Airlines approach for their operation at Heathrow Terminal 5. This led directly to their new design for check-in, where three check-in options are available depending on how much of the process has been completed at home on-line.

This was followed up shortly after opening with the introduction of self-service baggage drop.

Proposals for the use of autonomous vehicles are being developed, and trials at a number of airports are under way. Only Dubai World Central is planning for separate infrastructure to support the operation of autonomous vehicles, others are relying on integrating autonomous and conventional vehicles on the existing airside road network.

12.13 Environment

The following preliminary conclusions can be drawn from the research about the impact of environmental considerations on future airport development:

- The environment is emerging as a key business management topic for airports around the world. In response to societal expectation, environmental factors are increasing in importance in order to meet society's expectations for sustainable development.
- Environmental benchmarks are about meeting the targets that society deems appropriate to sustainable growth. An optimal capacity may be considered as one that stays within agreed environmental standards.
- Environmental standards/targets are anticipated to become more stringent over time; however, the ability to achieve them is made possible with advances in technology.
- Noise remains the single most important environmental topic.
- There is not yet an internationally agreed common approach to noise measurement.
- There is growing awareness and concern about health issues related to air quality as well as the impact of climate change and the need to reduce greenhouse gasses.
- Large airports in urban areas are likely to find it increasingly difficult to meet rising expectations and public awareness of environmental issues. They will need to utilise new and emerging technologies in order to increase capacity and meet the trend of more stringent targets.
- The preservation of endangered species, flora and fauna is a key issue for individual sites.
- Aircraft taxi distances tend to increase as airports grow. This can lead to longer 'engine on' times for aircraft whilst on the ground, affecting air quality, local noise and increasing greenhouse gasses.
- Environmental and sustainability issues are not always regarded as constraints to growth. However, in some cases the scale of the impact that would accompany proposed airport developments have resulted in the plans being changed or – as in the case of the Thames Estuary airport proposal in London – contribute to the proposal being dropped altogether.
- There has been increasing objection to airport development in some parts of the world, often resulting in protests ranging from peaceful demonstration to direct action.

More sophisticated environmental mitigation is expected at every new airport development, including electrification of vehicles, more sustainable energy sources, a reduction in embedded carbon and recycling. However, noise and air quality and traffic impact remain the most serious concern of local communities. This has led directly to more remote locations for new airports being chosen often on land reclaimed from the sea. All new airports in Japan have been built on artificial islands since Kansai in 1994.

12.14 Commercial

Commercial revenue has continued to play an ever more important part of an airport's finances, so an ever greater proportion of space is being devoted to commercial operations, this has changed the look and feel of airside lounges forcing them to be inward rather than outward looking. Airports have yet to come to terms with internet shopping which with the opportunities offered by home delivery could turn retail outlets at airports into showrooms.

Food and Beverage offers are becoming more ambitious, sometimes reflecting local or ethical considerations. This is in part because LCCs no longer serve meals as part of their offer and at least on short haul routes legacy carriers are beginning to follow their example. Also as security requirements become more onerous airlines are requiring passengers to check-in earlier potentially leaving passengers with more leisure time in the departures lounge.

12.15 Learning – Communality by dissemination from one airport to another

Communality in the approach to airport design can be attributed to common processes with only minor variations adopted throughout the world, common international standards, extensive comparative benchmarking, conscious programmes of learning from other airports and frequent airport conferences where ideas are shared.

Landmark publications include:

- US Air Service - Plans for Many Landing Fields 1919 (Wheat, 1920).
- National Advisory Committee for Aeronautics - How to lay out and build an airplane landing field – Archibald Black 1922 (Black, 1922).
- RIBA airports competition 1928, (Flight, 1929).
- Lehigh airport competition 1929, (Black, 1930) which directly influenced Chicago Municipal Airport which was for many years during the late 1930s the busiest airport in the world.
- First National airport Conference, Cleveland, Ohio, 1929 (Bednarek p48).
- Second National Airport Conference, Buffalo, New York, 1930 (Bednarek p49).
- FAA, CAA and EASA publications
- Conferences – RAeS 1932 Presentation by Norman & Dawbarn of their American visit
- International standards and publications - ICAN, ICAO, IATA, FAA and EASA

- Time and motion studies e.g. Berlin Tempelhof, Washington Dulles and Heathrow T5
- Benchmarking studies Stedman Hanks 1928, John Walter Wood 1940, Atkins 2016

12.16 Learning: Writers and Critics

J. G. Ballard gives us an optimistic vision of the social value of the Airport in his article for Blueprint in 2000. The first part of the second paragraph was reproduced as the preface to the book Aerotropolis by John Kasarda.

'At an airport like Heathrow the individual is defined not by the tangible ground mortgaged into his soul for the next 40 years, but by the indeterminate flicker of flight numbers trembling on a screen. We are no longer citizens with civic obligations, but passengers for whom all destinations are theoretically open, our lightness of baggage mandated by the system. Airports have become a new kind of discontinuous city whose vast populations are entirely transient, purposeful, and, for the most part, happy. An easy camaraderie rules the departure lounges, along with the virtual abolition of nationality—whether we are Scots or Japanese is far less important than where we are going. I've long suspected that people are truly happy and aware of a real purpose to their lives only when they hand over their tickets at the check-in.

I suspect that the airport will be the true city of the 21st century. The great airports are already the suburbs of an invisible world capital, a virtual metropolis whose border towns are named Heathrow, Kennedy, Charles de Gaulle, Nagoya, a centripetal city whose population forever circles its notional center and will never need to gain access to its dark heart. Mastery of the discontinuities of metropolitan life has always been essential to successful urban dwellers—we know none of our neighbors, and our close friends live equally isolated lives within 50 square miles around us. We work in a district five miles away, shop in another, and see films and plays in a third. Failure to master these discontinuities leaves some ethnic groups at a disadvantage, forced into enclaves that seem to reconstitute mental maps of ancestral villages.

But the modern airport defuses these tensions and offers its passengers the social reassurance of the boarding lounge, an instantly summoned village whose life span is long enough to calm us and short enough not to be a burden. The terminal concourses are the ramblas and agoras of the future city, time-free zones where all the clocks of the world are displayed, an atlas of arrivals and destinations forever updating itself, where briefly we become true world citizens. Air travel may well be the most important civic duty that we discharge today, erasing class and national distinctions and subsuming them within the unitary global culture of the departure lounge.'

Paul Andreu, Architect to ADPI and designer of Charles de Gaulle Airport argued in the preface to Airport Builders:

'*Terminals have become more important these days than cultural places such as museums or theatres where societies used to assemble. This is because their space is at the locus meeting between what is most universal, mobile and modern – the aeroplane, that dangerous marvel – and what is most primitive – the sense of belonging to a place and the very deep-seated desire to fly, to be somewhere else at once.'*

Speaking later to Architecture Daily Paul Andreu went on to say:

'The very first commercial airports started to appear in the 1920s. So by 2000, working on airports for almost 40 years, I was involved in designing this building type for half of its existence, and it really started to grow and change dramatically right at the time when I started. Airports no longer change; they just grow in size; there is no new concept. And, unfortunately, now many seemingly different building types converge around shopping experience. So many projects have become very commercial. There are airport versions of commercial malls, railway station versions, museum versions... Everything is a commercial centre.'

However, neither of these views takes account of the revolution inspired by the digital age, where communicating through mobile phone, tablet or laptop is taking precedence over talking to our fellow travellers. We have yet so see where this latest revolution will take terminal design but there are already developments with personalised transportation and messaging services that could change the future look and feel of the terminal building**.**

12.17 Embryonic ideas for the future

The concept of the airport as an interchange will continue to evolve as the synergy between land, sea and air transfer is realised, giving rise to new linking spaces between each of the processing elements that have been called Third Space.

Retail concepts will have to change to respond to on line buying through the internet, potentially making the conventional approach to walk through duty free shops redundant and giving way to show rooms, and the experience economy (e.g. Changi, Vancouver).

Health, safety and security measures will become ever more demanding and are expected to require additional space, but the focus will be on making the process as seamless and non-intrusive as is compatible with meeting ever higher standards.

Designing within environmental limits – noise, air quality and global warming is only just beginning, and as yet airports have not set themselves very demanding goals. Public opinion will no doubt require both airports and airlines to reduce their carbon footprint and overall environmental impact.

However, there are a number of promising avenues to explore such as autonomous vehicle movement and electrification of ground vehicles and alternative fuels for aircraft.

As a result of the Covid 19 pandemic it is expected that aviation will take some time to recover and in the meantime airports will have to concentrate on process improvements to reduce their cost base, while simultaneously introducing systematic health checks that will inevitably require both additional infrastructure and new processes. While traffic volumes are reduced it is obviously a good time to make improvements that might otherwise disrupt the business but few airports will have the financial resilience to take advantage of the opportunity this downturn in traffic presents.

There are few instances of airports investing in new infrastructure to cater for reduced traffic levels. However, a notable exception is Pittsburgh which was faced with a major and permanent downturn in traffic following the demise of US Airways which used it as its main hub. It has elected to rebuild its landside terminal functions and related surface access to be adjacent to the cruciform airside satellite (figure 6.81), reducing the number of stands and the size of the complex and eliminating the underground transit system that linked the terminal and satellite.

Lastly, to answer some of the challenges identified above digital design has much to contribute. As well as facilitating the introduction of more sophisticated processes, it will be able to offer more personalised experiences to those who embrace new technology, with the risk of alienating those on the wrong side of the digital divide, and in particular first time travellers, who will still need to be assisted.

So 2020 may yet be regarded as a new turning point in the evolution of airport design, which leads to retrenchment, downsizing and simplification, rather than further growth which has to date resulted in continuing expansion and complication of airports. The latter has been the story of the first 100 years of airport design.

13 Conclusion

13.0 Introduction

The conclusion returns to the reason for undertaking the research and discusses whether the initial aims and objectives have been realised. It then reviews the methodology and presentation of the results and argues that this research is indeed a contribution to knowledge. This is followed by considering the scope for further research. Lastly it returns to the original research question about the line of development and the secondary issue of whether airport architecture is inherently transient and doomed to obsolescence.

13.1 Confirming the reason for research

I embarked on this research, because as a practising architect who has specialised in airport design for over thirty years, I have always been interested to understand where the ideas we now take for granted originate from, but have been frustrated that most existing literature celebrates the final product but seldom considers where the ideas come from, or what changes are subsequently made to cope with new circumstances.

13.2 Realisation of aims and objectives

The aim of this research has been to explore the evolution of the historic relationships between the design philosophy, functional requirements, new technological opportunities, environmental constraints and the resultant physical form of airports. The research question has been to determine;

The line of development of airport design,

and consider as a secondary research topic,

Is airport architecture inherently transient and doomed to obsolescence?

This research has been supported by the collection and interpretation of supporting evidence such as drawings, photographs and designers' writings and contemporaneous articles. It has identified the particular contribution made by individual architects, engineers and planners. It has also identified whether there are any key turning points or step changes in the evolution of airport design. The results of the research are outlined in 13.4. **,** and the line of development summarised in 13.7.

As a secondary objective Reyner Banham's critique that *'airport design is inherently transient and doomed to obsolescence'* has been considered to understand whether it has general applicability or is a product of the dismal state of affairs that he found at Heathrow in the 1960s. The outcome is addressed in 13.8.

13.3 Methodology

The methodology has been to seek out primary sources such as original photographs, drawings, master plans, film clips and eyewitness accounts, contemporary reviews and government reports. This has been supplemented by conference papers that often speculate on the impact of future developments such as the advent of the Boeing 747 or Airbus A 380 before airports have been designed to receive them.

Research has been helped because so many resources, and in particular photographs, are available on line and the American Library of Congress has for many years maintained a complete bibliography of airport publications. It has been possible to acquire many of the original contemporary writings. An unexpected bonus has been the discovery that images of many early airports have been recorded in newsreel film clips (appendix J) and on postcards, though many of the latter have been touched up to present idealised images.

13.4 Limitations of the Methodology.

A limitation of this research is that it is difficult to achieve a balanced perspective on the most recent of developments so there will be plenty of scope for future generations to re-evaluate the work. In particular, it is too soon to identify the permanent effect of the Covid 19 Pandemic and so the potential implications discussed in Chapter 12.7 might be regarded as little more than educated speculation. It is also not always possible to demonstrate conclusively that one advance informed subsequent developments, particularly as designers are particularly reluctant to attribute the sources of their inspiration. However, it is possible to establish the sequence of events and establish the line of development.

13.5 Results

The results of the research have been presented in a series of themes in individual chapters which each address the individual objectives of the research:

- Chapter 2 shows that airports are unique because of their city scale and complexity but also because of the speed of change to which they have to respond.
- Chapter 3 indicates that the architecture, engineering and planning of airports are underpinned by distinct philosophies that are of necessity drawn together by the multidisciplinary nature of airport design.
- Chapter 4 introduces the key external influences on airport design and in particular identifies that increasing scale, rather than commercial or safety and security pressures, though important, has had the greatest impact on the operation and therefore the evolution of airport design.
- Chapter 5 identifies the technological innovations that have enabled the advance of airport design, but also discusses persistent ideas that have not made it into the mainstream of airport design either because they are technically flawed, or uneconomic or have been superseded by simpler processes or superior technology. The latter ideas have frequently been publicised because of their seductive imagery rather than because there is a real need or a suitable technology available.

- Chapter 6 focuses on the development of the terminal in a largely chronological sequence from the initial pioneering concepts to the simple terminal, linear terminal, unit terminal, finger pier, satellite, mid-field hub and underground terminal as responses to the increasing numbers of passengers handled. It shows that where volumes of traffic remain modest the earlier concepts are still relevant. It also discusses the key operational and commercial issues that designers have had to address that recur with each generation. Finally it shows that there are multiple approaches to architectural design that continue to be relevant but that capturing the spirit of flight has been a key preoccupation.
- Chapter 7 shows that the design of the airfield has evolved in direct response to the increasing size, weight and performance of aircraft, moving at an early stage from the grass field to multi-directional hard surfaced runways. The introduction of jet aircraft, however, has allowed the simplification of the airfield. Runways were longest in the early days of the Boeing 747 but as aircraft performance has improved the need for very long runways has reduced. Multiple parallel runways are now the norm in large airports.
- Chapter 8 traces the development of the airport as an interchange, and shows how concepts of integrating land, sea and air travel have evolved as airlines, and the Global Alliances in particular, increasingly have to rely on transfer passengers as well as direct point to point passengers to fill their aircraft and make routes profitable. The research also shows that just providing the appropriate infrastructure is not sufficient it also relies on the airline providing connecting services.
- Chapter 9 investigates the origin of the terms airport city and aerotropolis and reveals they had little to do with their current use. The catalytic benefit of an airport to the local economy is illustrated by the Gatwick experience. The understanding that airports can drive growth in the local and wider community has led to the emergence of the airport city and aerotropolis as planning concepts. The key difference between airport city and aerotropolis being that the former focuses on logistics and commercial development the latter also includes development of a community with housing and leisure facilities.
- Chapter 10 reveals that airports have been slow to respond to challenges of environmental sustainability with only Japan changing their airport development policy to build their newer airports as artificial islands. Beyond that airports tend to employ changes to operating practices, rather than changes to design to provide some level of mitigation.
- The case studies in chapter 11 which trace the evolution of selected individual airports shows how airports have been able to evolve over time and answer the charge that they are doomed to obsolescence.
- The key turning points in the evolution of airport design are identified in Chapter 12 with the conclusion that airport development can be split into approximately twenty year periods.
- The conclusions are summarised in this Chapter 13 with the view that airport and master plan concepts have largely evolved in response to increasing traffic volumes,

and that those that have proved most durable and avoided obsolescence are those that have planned for growth and change from the outset.

This is complemented by a series of appendices to support the research.

13.6 Contribution to knowledge

This research has made the following contributions to knowledge through understanding the evolution of airport design and addressing each of the individual objectives.

1. Tracing the evolution of airport design from the first commercial flights in 1919 over a period of a hundred years to the present day. Most writing has to date focused on airport design at a particular moment in time, or considered the social, economic or political influence on the evolution of airports. This research concludes that the primary driver to the advances in airport design, and the development of new master planning or terminal concepts, has not been social, economic or political influences that other researchers have focused on or the stylistic, aesthetic and cultural values discussed by many critics but has quite simply been the growth in volumes of passengers handled and the increasing size and speed of the aircraft.

2. Researching the cross fertilisation of airport design ideas across continents, where previously studies have typically focused on development in either Europe or most particularly the USA. Research has shown that from as early as 1929 when Stedman Hanks visited Europe to learn what best practice could be introduced in the USA and Norman and Dawbarn's visit to the USA to research best practice, which was presented to the Royal Aeronautical Society in 1932, there have been conscious efforts to learn from the operational experience of others.

3. Demonstrating that innovations in airport design require the cross fertilisation of design ideas on a multi-disciplinary basis, from architectural, engineering, planning and more recently environmental and information technology disciplines to deliver advances.

4. Considering the limitations of particular concepts by showing how individual airports have evolved over time in a series of benchmarking case studies. Several airports have evolved from the earliest unit terminal concept, to sprout piers and then be reconfigured with satellites and mid-field terminals as the volume of traffic increases.

5. Re-evaluating Reyner Banham's view that airport design is inherently doomed to obsolescence, by considering how well airports have coped with growth and change and reinvented themselves for each new generation in the manner of cities.

6. In conclusion it is the first academic study that seeks to understand the evolution of airport design holistically, and across continents. It considers the design philosophies that underpin the designs, the functional layouts that have been developed to

respond to ever increasing volumes of passengers and size and speed of aircraft, and a more demanding and sophisticated travelling public and the measures introduced to respond to ever more complex operational requirements. It then considers the resultant form of the airport.

13.7 Scope for further research

Airport Design encompasses a very wide range of design challenges and this research has of necessity been limited in scope and focused on the history of the evolution of airport design, so there are several other complementary avenues of research that are still open. It will, in any case, be necessary to review and update the research every generation as our understanding of what drives good airport design widens. Other more specialised areas of historical research could include:

- non-public parts of the airport: Hangars, Cargo, Control Towers
- effect of current innovations including digitisation and autonomous vehicles
- sustainable airport design, - how airports balance economic, social and environmental issues given changing societal values
- the evolution of processes, such as check-in, security, immigration, baggage handling and aircraft turnaround and their impact on planning and design
- the design of airspace and navigation aids
- further case studies such as Amsterdam Schiphol, Singapore Changi and Denver

There is also scope for more numerical and statistical research. One of the most common questions airports ask is 'How do I compare with my competitors', but there is no commonly agreed methodology for undertaking benchmarking. For example some airports compare themselves with others in terms of annual aircraft movements and passenger traffic, while others compare by reference to busy hour rates. But even here there is a variety of definitions about what peak capping formula to use. There is not even agreement about how and what elements of a building should be measured.

Another aspect of airport design that is worthy of further research is the relationship of airport design, including the IATA level of service standards, to the results in passenger service monitors such as QSM or Skytrax. Comparative results are often closely guarded by airports and are seldom available to designers. Even where they have been made available they require detailed scrutiny to separate issues that designers can influence such as walking distances or wayfinding from management issues such as cleanliness of toilets or helpfulness of staff, which seem to dominate the results, but are of little help to the designer.

There is also scope for qualitative research based on interviewing airport operators, which was not pursued in this case as their perspective would be limited to the recent past and not the earlier history on which this thesis on the evolution of airport design also relies.

This thesis was largely written before the coronavirus outbreak; following it the airline industry may take a different form, as businesses in particular have adapted to travel restrictions and more meetings are held electronically. It is expected that in turn airport design will have to change due to the reducing demand for business class travel and increasing pressure for routine health checks and for operational cost reduction. Further automation aided by the expansion of Artificial Intelligence is likely to be the response, presenting an opportunity for research on the changes that emerge in the subsequent era.

13.8 Line of Development

This research shows that there is a straightforward line of development driven primarily by growth in the scale of operation and enabled through technological evolution. It is perhaps ironic that Banham, who admired the Futurists so much, did not recognise in airport design that growth and change could be a basis for creating an enduring indeterminate architecture. In the Manifesto of Futurist Architecture, Sant'Elia had underlined changeability as a quality of futurist architecture:

'From an architecture conceived in this way no formal or linear habit can grow, since the ***fundamental characteristics of Futurist architecture will be its impermanence and transience****.* ***Things will endure less than us. Every generation must build its own city****. This constant renewal of the architectonic environment will contribute to the victory of Futurism which has already been affirmed by words-in-freedom, plastic dynamism, music without quadrature and the art of noises, and for which we fight without respite against traditionalist cowardice'* (Sant'Elia, 1914)

Some airports have proven to be particularly resilient and adaptable, particularly those that have been built on reclaimed land, and away from the city centre. Some early coastal reclamation schemes have given rise to airports of exceptional longevity. The land for Amsterdam Schiphol (1916 Military use /1920 Civilian use) was reclaimed from the Haarlemmermeer after a dyke had been built and the land drained. The coastal location for Sydney Kingsford Smith (1920) initially allowed it to handle both land aircraft and sea planes and later allowed it to be extended into the bay on several occasions. Boston Logan (1922) has been expanded into the bay from the original site a number of times. Each of these airports is less constrained by adjacent development than inland airports and have therefore been able to expand with less adverse noise impact.

However, where the airport was built on reclaimed land but near the city centre as Hong Kong Kai Tak, expansion while initially possible, was ultimately unsustainable by its very proximity to the city centre. It was closed in 1998 after the opening of Chek Lap Kok.

The legacy of this approach can be seen in the series of new Japanese airports that have been built on artificial islands, and airports such as Hong Kong, Chek Lap Kok and Seoul Incheon that have been created by reclaiming land from the sea. These sites are all relatively remote from the cities they serve and allow aircraft to take off and land over the sea, and so minimise noise nuisance, but the fact that they are in undeveloped and unspoilt areas results in other environmental challenges.

Others have sought to plan for a very long term vision of the future. The second terminal at Berlin Tempelhof, designed in the 1930s, was planned with the year 2000 in mind. For the traffic of the period it was dramatically oversized, and was served by a grass airfield that was already obsolescent, but with the addition of concrete runways and with minimal updating to the terminal building it continued to serve the city until 2007.

In part its longevity can be attributed to the far sighted inclusion of multiple gate rooms, allowing several aircraft to be turned around simultaneously where previously airports could only handle one arrival and one departure at a time. This capability had proved invaluable during the Berlin Airlift when aircraft landed and took off again every three minutes to bring supplies to the beleaguered city during the Russian blockade of 1948 and 1949.

Like most city centre airports the noise generated by aircraft taking off and landing, particularly after the introduction of jet aircraft, was eventually considered unacceptable. This led directly to its ultimate demise despite its unrivalled convenience.

The 1947 master plan for Chicago O'Hare was one of the most far sighted airport proposals in seeking to accommodate unprecedented growth. While Chicago Midway, which it was planned to replace, had only just reached a million passengers a year, O'Hare looked forward to passenger volumes of over 50 million a year. Its approach in introducing multiple finger piers has been widely copied. It was progressively modified to accommodate larger aircraft, even before it opened for business, initially to handle the first generation of jets and later wide bodied aircraft including the Boeing 747. The configuration's limitation on aircraft movement has ultimately been addressed by progressively transforming the pier layout to a satellite concept, but the finger pier is still relevant today for all but the very largest airports.

Arguably the most influential airport of all time is Washington Dulles, designed by Eero Saarinen. Its mid-field planning concept has been copied by most subsequent multi-runway airport masterplans, while the terminal design introduced the concept of indeterminate architecture to airport design. It also has the distinction of being one of the architecturally most memorable designs, as it perfectly captured the spirit of flight in the form of its soaring roof. Washington, Dulles' major contributions to the advancement of airport design, includes a jet age master plan, mid field terminal, a toast rack layout for aircraft parking on the apron and safeguarding for the later introduction of a mass transport system to the city. It also pioneered the use of an indeterminate architecture in airport design, which has subsequently been realised in the seamless extension to the terminal building.

Not every decision proved correct. Mobile lounges to provide access to the aircraft proved to be a blind alley, being slow, cumbersome, uneconomical, unreliable and expensive to operate, but this became apparent only after several other airports had followed this example only to regret it later. Fortuitously the absence of airside infrastructure proved to be a bonus in the long term as it allowed a satellite and underground transit system to be retrofitted at relatively low cost, turning the airport into an effective transfer hub.

Atlanta Hartsfield can be seen as a logical development of the Washington Dulles concept with satellites linked by a transit from the outset instead of remote stands served by mobile lounges. The masterplan has been shown to be optimal in allowing for unconstrained aircraft movement and is more space efficient than any other layout. On the downside it relies on a very large and complex automated people mover system with over a 100 cars to allow passengers to transfer form one satellite to another, and each satellite is sub optimal in size and layout in terms of commercial income.

For the next generation of airports, Hong Kong Chek Lap Kok can be regarded as the most influential. It was a pioneer in being designed to accept the new generation of Super Jumbos the A 380, and in serving as a major international transfer hub for Cathay Pacific and the newly established One World Alliance. It also demonstrated that the pier concept can handle a far greater level of traffic than had been previously assumed by the addition of a transit system to overcome long walking distances. Architecturally it showed that a very large terminal could be visually integrated under a single roof form.

The most recent stage of development is still emerging but includes larger mid field terminals and satellites and multiple widely spaced runways. The first of these to begin operation is Istanbul Grand, which serves as the transfer hub for Turkish Airlines. The design responds to a new master planning objective of handling 90mppa through a single terminal, using finger piers to avoid the use of a transit system in phase 1, and over 150mppa through the airport in the ultimate phase.

Beijing Daxing also opened in 2019 and showed how a very large terminal could be designed without needing satellites and a transit system by employing multiple radiating piers in a star shaped configuration.

An even larger hub airport Dubai World Central, with multiple satellite terminals and planned to handle over 220mppa is on the drawing board. This will be, when opened, the largest airport and most ambitious Aerotropolis in the world.

The evolution of airport design is therefore largely about responding to growth, both in passenger volumes and the size and performance of aircraft. The older models of airport layouts and terminal designs still work perfectly well for smaller scale operations as can be seen in the exploitation of older secondary airports by Low Cost Carriers.

Currently the ultimate planning constraint to the size of airports is the ability to handle, in the airspace design, more than three streams of simultaneous arrivals and four streams of simultaneous departures.

For many potential large scale airport projects it is now the acceptability of the environmental impact and the ability to underwrite financially such large scale development, with new hub airports costing many billions of pounds, that is the ultimate constraint to growth.

13.9 Obsolescence

In addressing Reyner Banham’s contention that airport design is ‘inherently transient and doomed to obsolescence’ it is clear that his despair of airport design was in part because he could see the rate of change at airports was so great, particularly at Heathrow, that design concepts were quickly becoming outdated and obsolescent.

There are several types of obsolescence: functional obsolescence, economic obsolescence, and physical obsolescence. Airports and terminals can be subject to all three.

Some of the main drivers of obsolescence include:

- changed scale of operation - handling unexpected growth or contraction
- changed legal requirements – responding to safety, security and regulation
- changed business objectives – privatisation and commercial exploitation
- changed customer/passenger expectations - market segmentation
- changed airline business models – Global Alliances and Low Cost Carriers
- technological advances that have progressively introduced mechanisation, automation and now digitisation.
- life expired infrastructure and individual components

Airports have proven to be remarkably adaptable in responding to these pressures, in part because they are seen as the vanguard for change both by operators and customers, and partly because when airports reach a certain size they can be very profitable and have sufficient funds to allow them to grow and change. A number of mitigation strategies have been employed by airports to accommodate growth and change. They include:

- Adaptable modular design (e.g. Gatwick North Terminal)
- Long term view of future demand (e.g. Berlin Tempelhof and Chicago O'Hare)
- Indeterminate design that safeguards for future expansion (e.g. Washington Dulles and Stansted)

By contrast airports and terminals that are specifically wedded to an individual operating model such as the TWA or Pan American terminals at JFK or Paris Charles de Gaulle terminal 1 have proven unsuited to growth and change.

Airports can now be the size of cities. Charles de Gaulle is 1/3rd the size of Paris while Denver Airport is larger than the City of Denver. Growth and change are an inherent part of cities and likewise growth and change are a part of airports. We differentiate between growth and change in vibrant and dynamic cities and the architecture of individual buildings becoming obsolescent (cities we admire most include those subject to greatest change (London) and those that have been unchanging for centuries (Bruges).

Banham was right to complain about poor design, chaotic organisation, temporary buildings and short term expediency that were a part of early 60s Heathrow. In the same year, however, some of the most iconic airport designs were being realised in the USA, the TWA terminal at Idlewild (JFK), Washington Dulles and the Theme Building at LAX. Unlike the original Europa Terminal at Heathrow (later T2 and now demolished), these concepts were futuristic and captured the public imagination and are all recognised as buildings of historic interest.

The airports that survive best are arguably those which combine, careful site selection far enough away from city centres but with good connectivity to the city centre, with the ambition to create a landmark of architectural merit that celebrates the spirit of flight and incorporates a planned approach to accommodating growth and change.

We do need to remember that for all our best intentions to foresee the future the level of investment in airports is such that longevity is prerequisite. We have to live with the legacy of airport designs for many generations. In the words of Winston Churchill speaking in the House of Commons on October 28th 1944:

'*We shape our buildings; thereafter they shape us*'.

His words are particularly apposite as airports increasingly have to focus on expansion, and have to contend with legacy issues, as there are unlikely to be many totally new airports in the developed world.

13.10 Postscript

The final words, however, belong to Mies van der Rohe, which YRM quoted in their Heathrow Terminal 5 competition entry, for although he never designed an airport he set down a criterion by which many designers believe they should be judged, in which airport architecture and technology come together to reflect the spirit of the age;

Architecture depends on its time.

It is the crystallization of its inner structure,

the slow unfolding of its form.

That is the reason why technology and architecture are so closely related.

Our real hope is that they will grow together,

that someday the one will be the expression of the other.

Only then will we have an architecture worthy of its name:

Architecture as true symbol of our time.

Source: Conversations with Mies van der Rohe, Extract from Architecture and Technology, 1950

Appendices

Appendix A – Environmental policies and technical considerations

Airports, supported by the International Civil Aviation Organisation (ICAO) and the International Air Transport Association (IATA), have sought to widen the definition of sustainability beyond that of environmental impact, to include social and economic benefits. In 1983 ICAO established a Committee on Aviation Environmental Protection (CAEP) which assists the Council in formulating new policies and adopting new Standards and Recommended Practices (SARPs) related to aircraft noise and emissions, and more generally to aviation environmental impact. Its scope of activities encompasses noise and air quality. It also advises the Council on aviation environmental trends including future air traffic projections and assessment of the likely impact of proposed policies and developments by both airlines and airports.

The figure below illustrates ICAO's goals to quantify and mitigate environmental impact, highlighting the importance given to Aircraft noise, greenhouse gases (GHG) and local air quality (figure A.01).

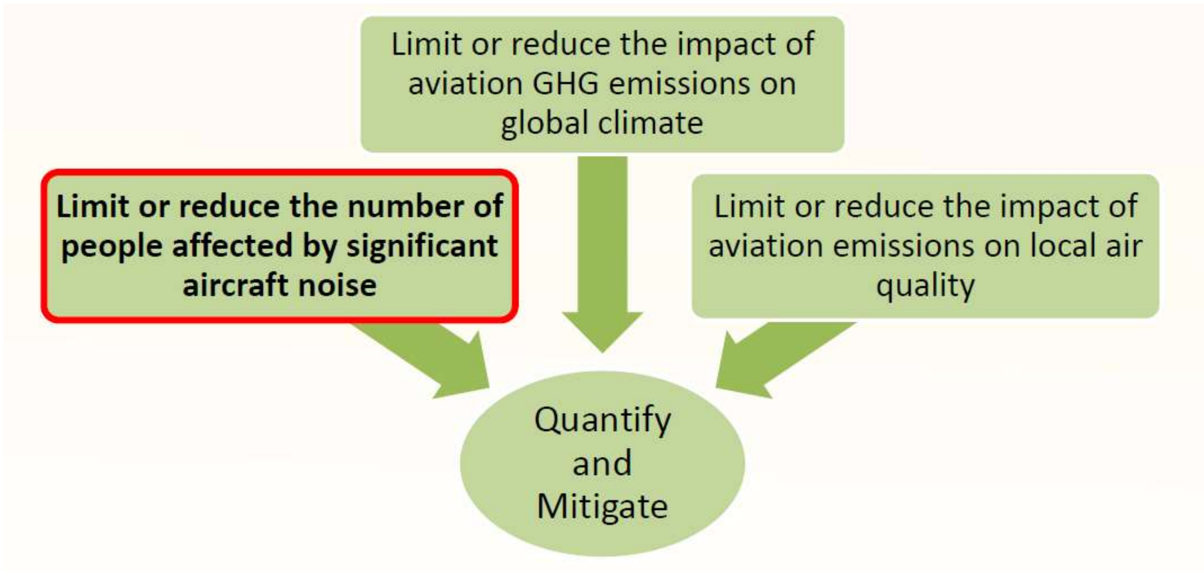


Figure A.01 - ICAO Environmental Goals
Source: ICAO Symposium on Aviation and Climate Change

The 39th Assembly of ICAO at Montréal, 6 October 2016 codified the following environmental protection measures (ICAO, October 2016)

•	Endorsement of a global market-based measure (GMBM), the first-ever market-based measure adopted by an entire industry sector.
•	Recognition of the ongoing work to develop a new supersonic noise Standard for future aircraft, and the possible certification of a supersonic aeroplane in the 2020-2025 timeframe.

•	Recognition of the development of a new non-volatile Particulate Matter (nvPM) Emissions Standard for all turbofan and turbojet aircraft with rated thrust greater than 26.7kN (first-ever).
•	Support for the ICAO aspirational goals on CO2 emissions reduction and recognition of progress on all elements of the Basket of Measures
•	Recognition of the development of a new global CO2 emissions certification Standard for New Type and In-production aeroplanes (first-ever).
•	Acknowledgement of the partnership agreement between ICAO and ACI that focuses on various cooperative initiatives for greener airports.
•	Recognition of significant achievements in assisting States to develop their State action plans for CO2 emissions reduction, leading to the submission of 101 State plans to ICAO
•	Consideration of future policy issues such as: environmental aspects of aircraft end-of-life (e.g. aircraft recycling); and climate change risk assessment on international aviation, including identification of adaptation measures

The key topics are considered in turn:

Noise (unwanted sound)

The first issue was how to measure noise nuisance, a debate that is still continuing today, with varying definitions adopted by the FAA (USA), CAA (UK), EASA (EU) and other national regulatory bodies. All measure noise in terms of sound pressure, dBA, but use different adjustments to establish a noise footprint that reflects perceived annoyance. For example: within North America noise is measured according to Perceived Noise decibels – PNdB. This measure combines the actual sound level and a weighting or annoyance factor based upon the variation of frequencies within the noise.
Within Europe noise is generally measured according to – Lden. The Lden (Day Evening Night Sound Level) is the average sound level over a 24 hour period, with a penalty of 5 dB added for the evening hours or 19:00 to 22:00, and a penalty of 10 dB added for the night-time hours of 22:00 to 07:00
The UK measures noise according to Leq, an equivalent Continuous Sound Level, measured in dB(A).

ICAO quantifies noise by EPNdB, a measure of human annoyance to aircraft noise, (which has special characteristics) and persistence of sounds. Certification quality EPNdB cannot be directly measured; it has to be calculated in a standard manner as described in ICAO Annex 16 - Environmental Protection, Volume I - Aircraft Noise to the Convention on International Civil Aviation.

ICAO Balanced Approach

Much of ICAO's effort to address aircraft noise over the past 40 years has been aimed at reducing noise at the source. Aeroplanes and helicopters built today are required to meet the noise certification standards adopted by the Council of ICAO.

Noise standards for new aircraft types, are established by ICAO, and published in Annex 16 volume 1, one of the technical annexes to the Convention on International Civil Aviation (Chicago, 1944). Noise limits are set at three points: two for take-off (one underneath the flight-path, and one to the side,) and one for approach (underneath).

New aircraft types have to demonstrate that they meet these limits to be allowed to operate. The Annex is split into a number of “Chapters”, which contain appropriate standards for different aircraft types, Chapter 4, is the latest standard for subsonic jets, and came into force for newly certificated types at the beginning of 2006.

ICAO adopted its first noise standard in 1972. Since then noise certification standards have become progressively more stringent with the development of a series of Noise Standards/ chapters.

The initial standards for jet-powered aircraft designed before 1977 were included in Chapter 2 of ICAO Annex 16. The Boeing 727 and the Douglas DC-9 are examples of aircraft covered by Chapter 2. Subsequently, newer aircraft were required to meet the stricter standards contained in Chapter 3 of the Annex. The Boeing 737-300/400, Boeing 767 and Airbus A319 are examples of "Chapter 3" aircraft types. The newer Boeing 787 and Airbus A350 are examples of Chapter 4 aircraft types (figure A.02).

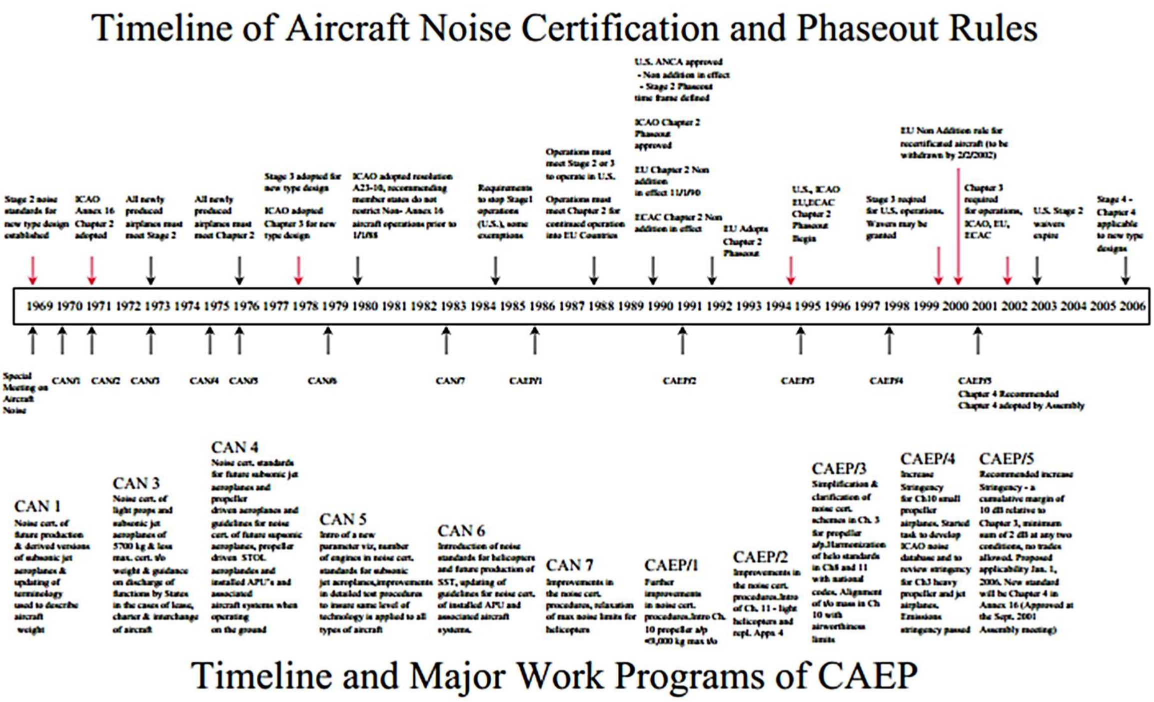


Figure A.02 - Timeline for the implementation of enhanced noise certification standards – Source: The Boeing Aircraft Company

In 2001, the ICAO Assembly unanimously endorsed the ICAO Balanced Approach to Aircraft Noise Management by adopting Resolution A33-7. The core principle of the Balanced Approach is that the noise situation at each airport is unique and that there is no one-size-fits-all solution.

The ICAO Balanced Approach identifies four elements to address noise around airports: reduction at source, land-use management and planning, noise abatement operational procedures, and operating restrictions. Operating restrictions are seen as a last resort with such measures that limit or reduce airport throughput. Restrictions that may impact airlines, passengers and local economies should not be introduced as a first resort but only after a full assessment of all available measures to address a demonstrated noise problem at an airport.

The prime purpose of noise certification is to ensure that the latest available noise reduction technology is incorporated into aircraft design and incorporated into operating procedures, to ensure that noise reduction offered by technology is reflected in noise level reductions around airports.

Research shows that aircraft noise has reduced over time (figure A.03) while the number of flights and passengers at Schiphol increased between 2004 and 2014 without an increase in the level of noise (figure A.04). It should be noted however that the number of individual noise events is an important factor in disturbance, and so a reduction in noise contours may not be matched by any reduction in 'annoyance' if combined with an increase in aircraft numbers.

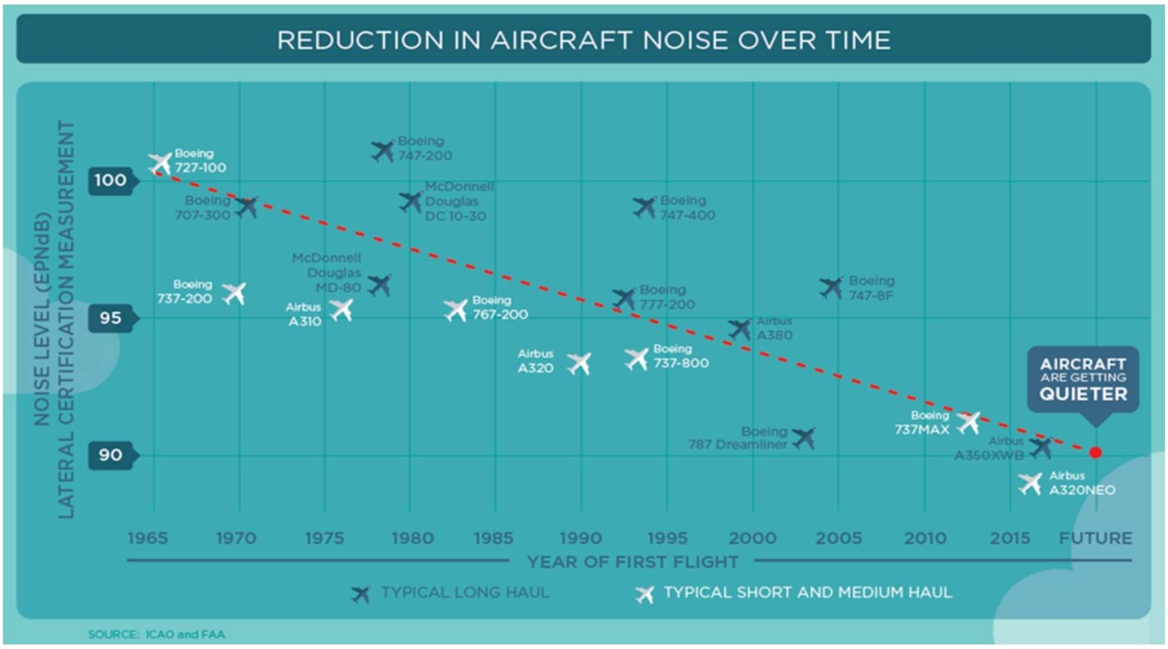


Figure A.03 - Aircraft Noise Characteristics Source: TO Consultancy

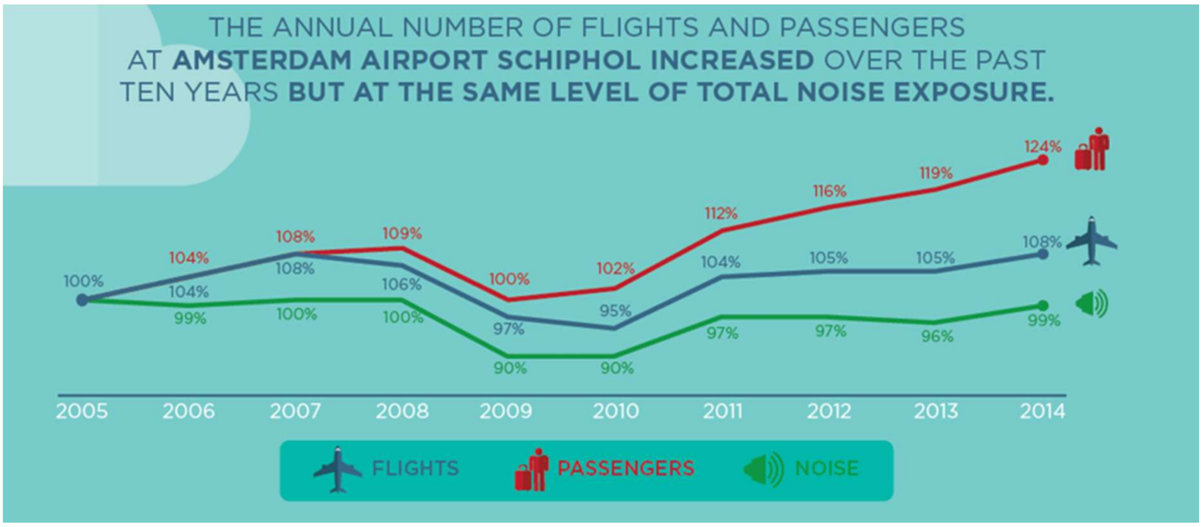


Figure A.04- Aircraft Noise at Amsterdam Schiphol - Source: TO Consultancy

The figure below illustrates a similar pattern for Heathrow airport. The graph shows that the population exposed to a noise level of 57dBA or above has halved over a period of 25 years, whilst air traffic has grown by a third over the same period (figure A.05).

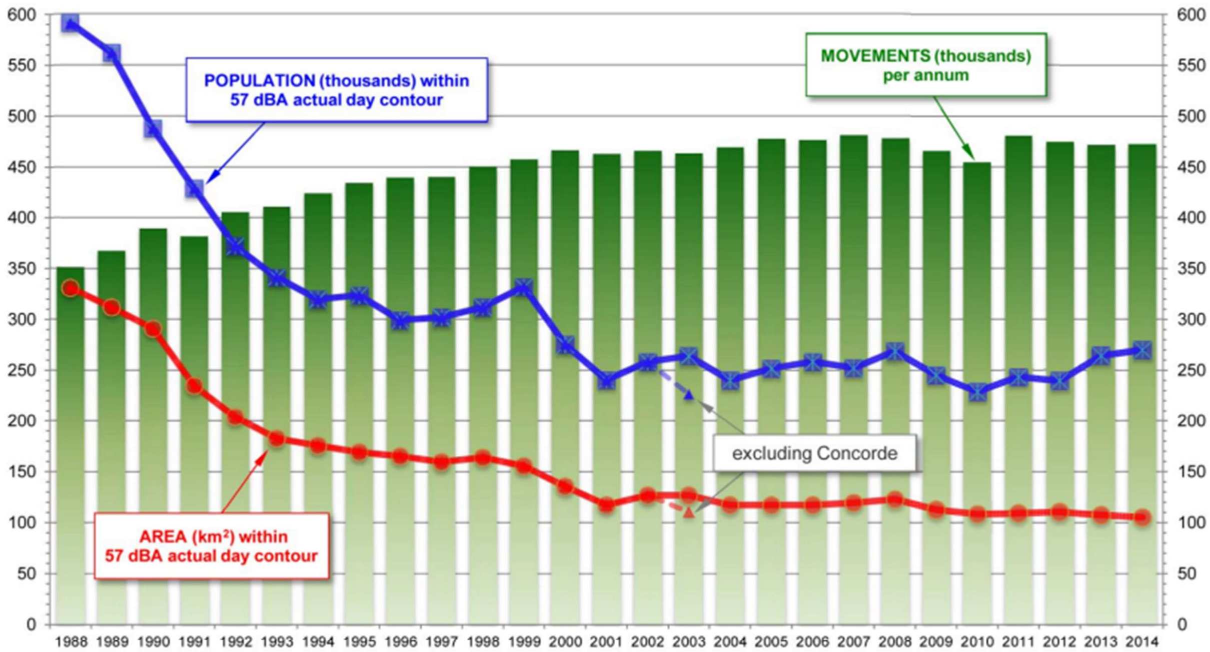


Figure A.05 - Heathrow annual traffic & summer day Leq noise contour - Source: CAA ERCD report 1501, 2014

Airframe noise reduction is still in its infancy compared with engine noise reduction. It is now be regarded as the prime source of noise for landing aircraft. The following diagram shows some of the noise generators from the airframe (figure A.06).

Figure A.06 - Jet Aircraft Effective Perceived Noise Level (EPNL) – Source: vibrationdata.wordpress.com

The figure below shows an approach to measurement but it ignores the actual numbers of aircraft movements so London Heathrow, Paris Charles de Gaulle and Frankfurt that have the highest number of movements overall do not appear in the chart. This is a slightly disingenuous way of presenting noise impact (figure A.07)

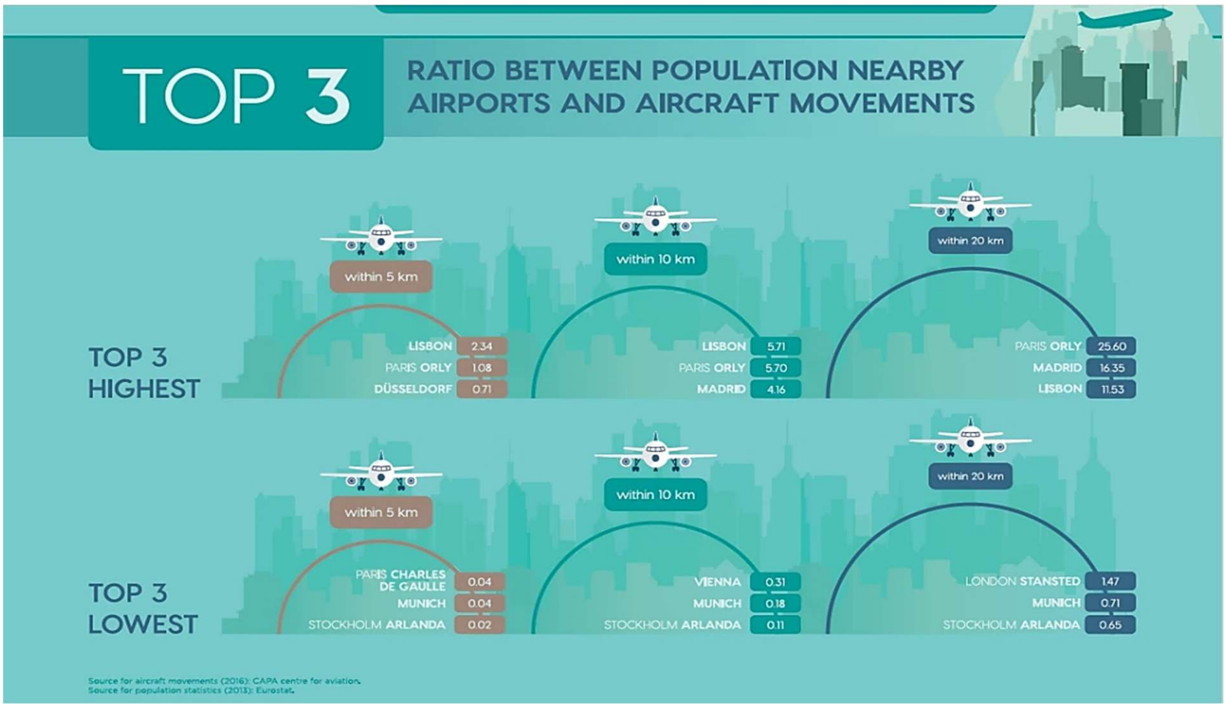


Figure A.07 Populations close to airports per aircraft movement
Source: TO 70 Consultancy, CAPA centre for aviation & Eurostat

Noise contours measure a combination of sound pressure measured in dBA and frequency of exposure but use different adjustments to establish a noise footprint that reflects perceived annoyance. The variety of ways of presenting noise information bedevils attempts to compare noise impact at different airports. Some of the varieties of ways of presenting noise impact follow.

Operating restrictions on aircraft

- Night curfews**:**
  This can involve an outright ban on all night flights. For example Frankfurt Airport bans all aircraft movements between midnight and 6am, while London Heathrow, Paris Charles de Gaulle and Amsterdam Schiphol all severely limit the number of night flights or apply noise quotas.
- Runway alternation:
  There is increasing public demand for providing extended periods of noise relief (nightly, daily and weekly) by alternating the use of runways and airspace routeings. Most major airports employ restrictions on night flights and where possible design approach and departure routes to minimise the impact on the ground. As an example, in Autumn 2016, the Chicago Department of Aviation submitted a 'Fly Quiet Runway rotation plan' for Chicago O'Hare to the FAA for approval. The proposal established a weekly rotation of overnight runway closures that will remain operational during the night. The plan is intended to balance distribution of exposure to noise and provide respite to residents by allowing them to plan ahead. On a more local level, as part of the planning conditions for the Terminal 5 project, Heathrow undertook to use inner taxiways for movement of aircraft at night, so as to reduce impact of ground movement on local residents.

- Noise Directives:
  Legislation has been applied in some regions to prevent or limit certain noisy aircraft types from landing at specific airports. It is common for airports in Europe to use fees and charges to differentiate between noisier and quieter aircraft and offer incentives to airlines to operate quieter aircraft. Fines have been introduced at many airports for departing aircraft that exceed predefined limits. At some airports, this money has been redistributed into local community projects.

- Local agreements**:**
  Heathrow for example signed an agreement with a local village, which prevents the use of runway 09L for take-off, other than in an emergency.

- Grant schemes:
  Sound insulation grants are offered by some major airports to local residents who are affected by noise in order to mitigate their exposure.

- Financial penalties:
  These have been introduced at many airports for departing aircraft that exceed predefined limits. For example, airlines at Heathrow pay approximately ten times more to fly Chapter 3 aircraft than they do for the quietest aircraft such as the B787 Dreamliner. At some airports, this money has been redistributed into local community projects.

Since 1999, the World Health Organisation (WHO) has recommended that night noise should not exceed 45 dB Leq. In 2009 WHO Europe updated this guidance to recommend that the maximum noise level at night should be reduced to 40 dB Leq.

Noise Contours at Airports

The following images of noise contours at international airports show that there is a large variety in ways of measuring and presenting the impact of noise on the local communities.

Port Authority of New York and New Jersey.

The following map shows the noise contour included in the 2014 environmental assessment of New York JFK (figure A.08).

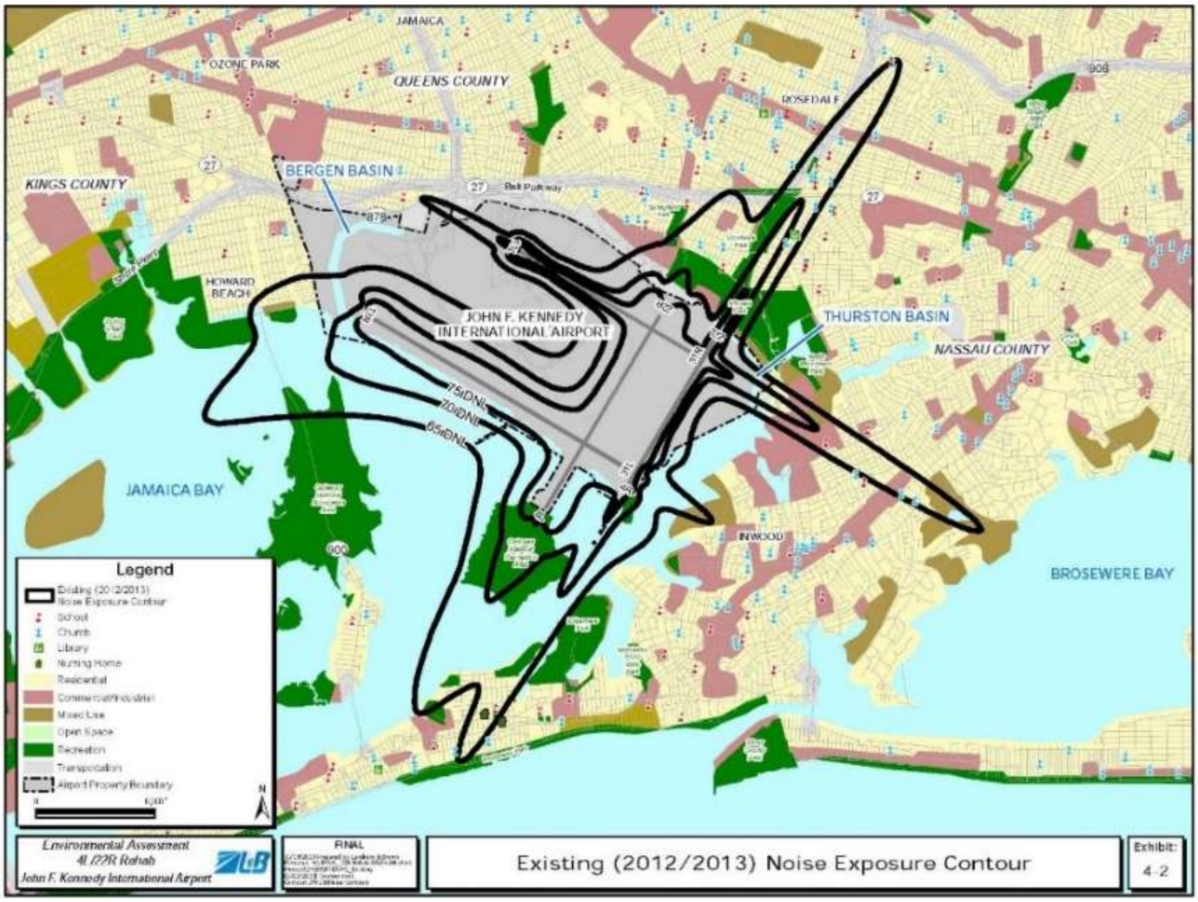


Figure A.08 - New York JFK noise contours 2012/2013 – Source: JFK

Hong Kong International

The Civil Aviation Department (CAD) of Hong Kong currently issues noise limits for HKIA using the FAA's Integrated Noise Model (INM). The noise impact arising from aircraft operation is represented by the Noise Exposure Forecast (NEF), a criterion that takes into account the duration of flyover, the peak noise level, the tonal characteristics and the number of aircraft movements in both the daytime and night-time period.

For the new airport at Chek Lap Kok, the Hong Kong Planning Standards and Guidelines stipulate a more stringent criterion of NEF 25 contour (as against NEF 30 for Kai Tak Airport) for planning of noise sensitive land uses. This criterion is claimed by the airport to be in line with the international standards adopted by other developed countries.

The map of the anticipated noise contours after the third runway has been built clearly shows the advantage of locating take-off and landing over water at Hong Kong International (figure 10.27 in chapter 10).

London Heathrow Airport

The following maps show the 2013 and 2014 predicted and actual noise contours for London Heathrow (figures A.9 and A.10).

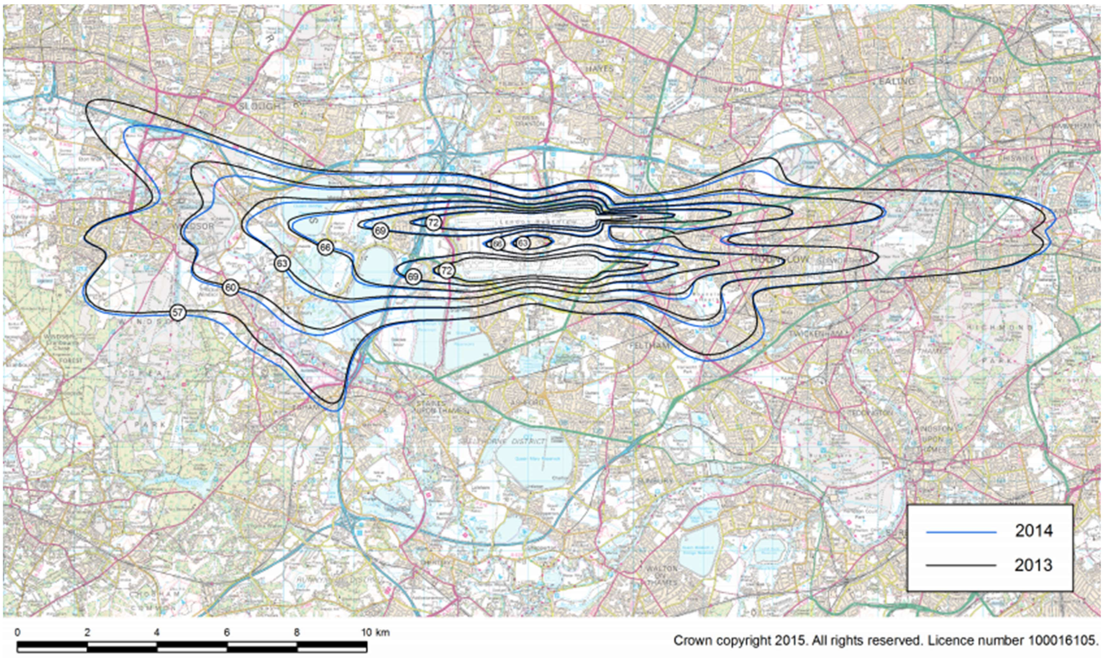


Figure A.09 Heathrow Standard Day Leq noise contours
Source: ERCD REPORT 1501 Noise Exposure Contours for Heathrow Airport 2014

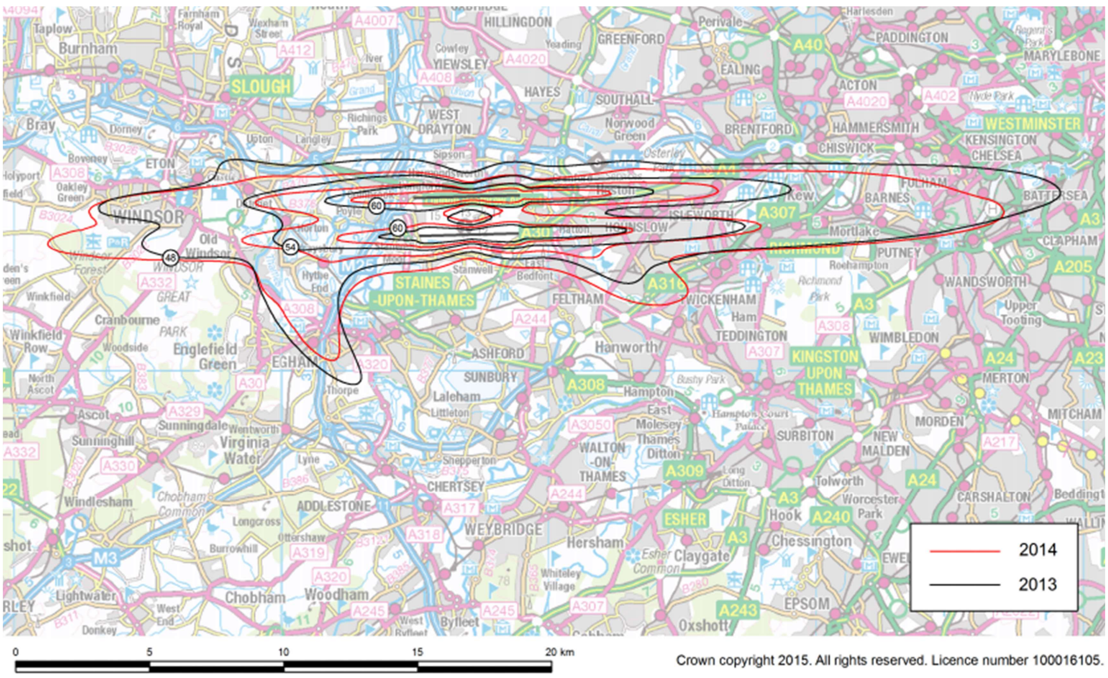


Figure A.10 Heathrow Night Actual Leq noise contours
Source: ERCD REPORT 1501 Noise Exposure Contours for Heathrow Airport 2014

Amsterdam Schiphol Airport

The map below shows the 2015 noise contours for Amsterdam Schiphol (figure A.11). The contour shows where a noise impact of 58 decibels (orange) or 48 decibels (blue) can be expected around Schiphol in average weather conditions. This contour is not static but has a bandwidth, as the noise disturbance can vary because of changes in the weather as shown by the variable width of the orange and blue areas.

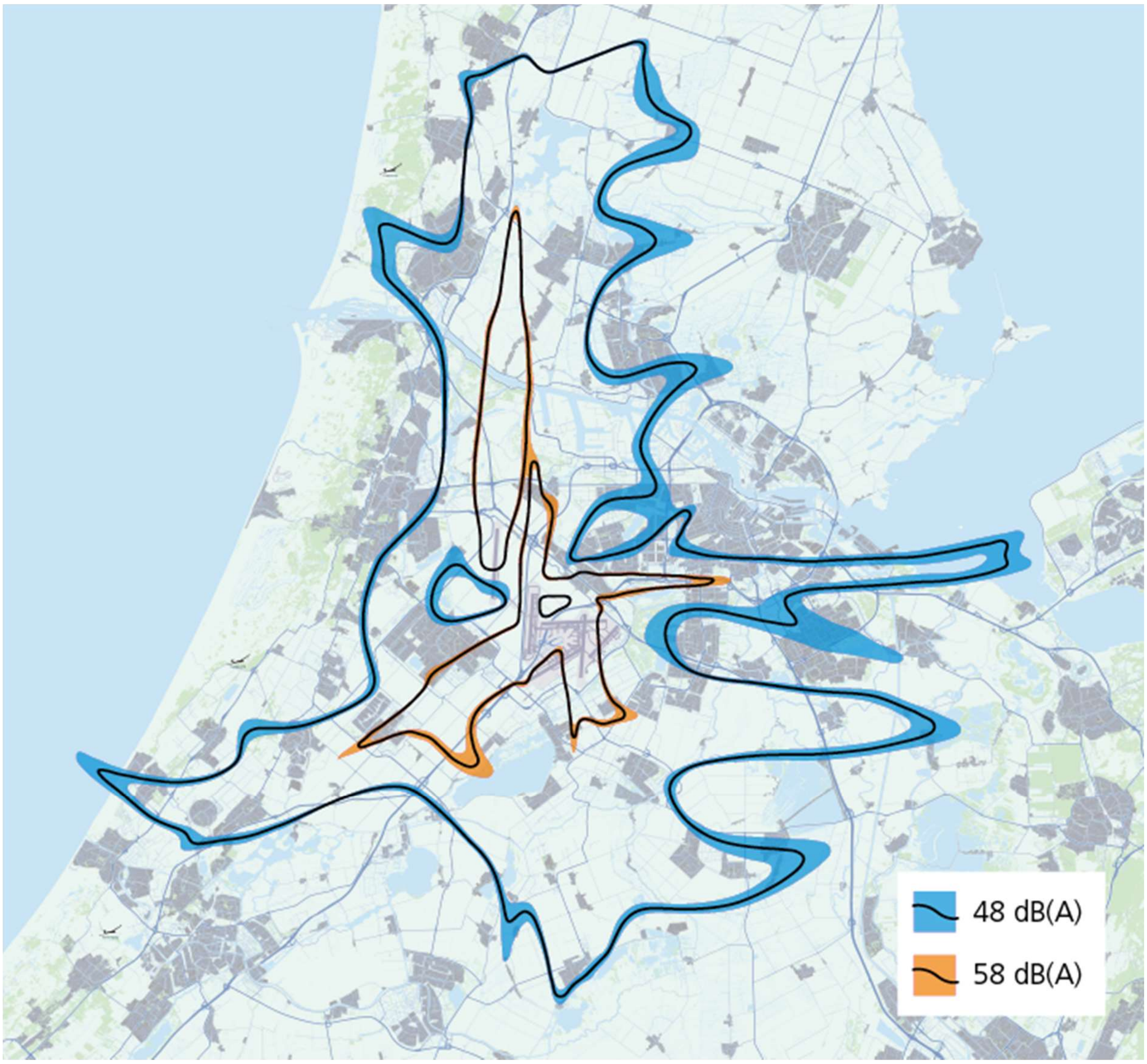


Figure A.11 - The 58 and 48 Lden noise contours at Schiphol - Source: Schiphol EA

Singapore Changi Airport

The Government's decision to shift Singapore's main international airport from downtown in Paya Lebar to Changi at the eastern tip of the island has been instrumental in ensuring that the majority of Singapore's population is not affected adversely by aircraft noise despite the continual growth of air traffic. Furthermore, as the land surrounding airports is generally zoned for non-residential use, the number of households around Singapore's airports affected by aircraft noise is relatively small.

Noise abatement considerations are factored into Changi Airport's long-term airport master planning. Three out of four runway ends at Changi Airport lead almost directly into the sea. Only departures towards the south on Runway 1 fly over a small portion of land, which has been designated for non-residential use. Noise studies are conducted regularly to update the noise contours around Changi Airport. The results of these studies are shared with URA for future land-use planning. However Singapore Changi do not publish noise contour maps for general consumption.

Dubai International Airport

The graph below shows that with the rise in traffic levels the noise exposure in the surrounding community is still increasing (figure A.12). The airport does not currently set stringent noise standards although somewhat belatedly the much noisier Chapter 2 aircraft are being progressively phased out, but aircraft still take off and land over heavily populated areas.

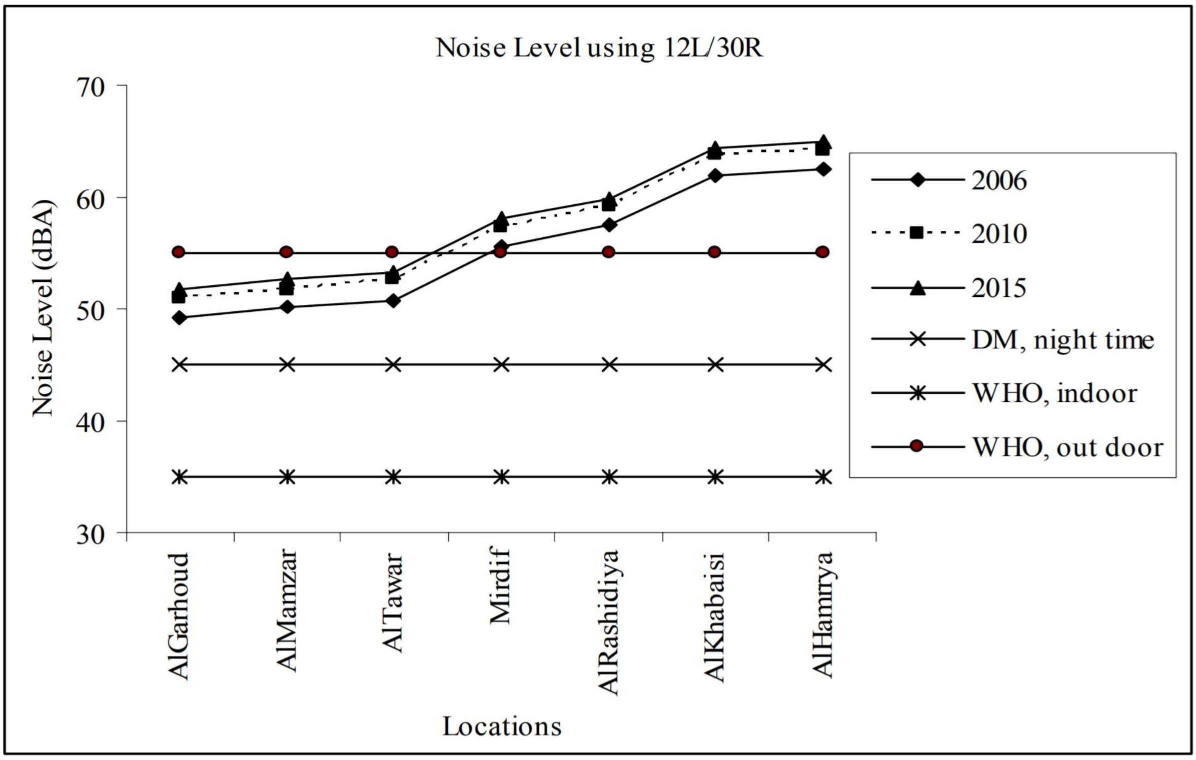


Figure A.12 Noise Level in the vicinity of DIA using one runway 12L/30R
Source: Dubai Airports Environment Management Pla

Frankfurt

The airport's noise target includes achieving a lower number of people impacted by aircraft noise than specified in the expansion plan with 701,000 aircraft movements (night protection zone = 183,026 residents, day protection zone 1 = 28,980 residents) (figure A.13). The image shows that the noise contours closely follow the flight routes identified in blue.

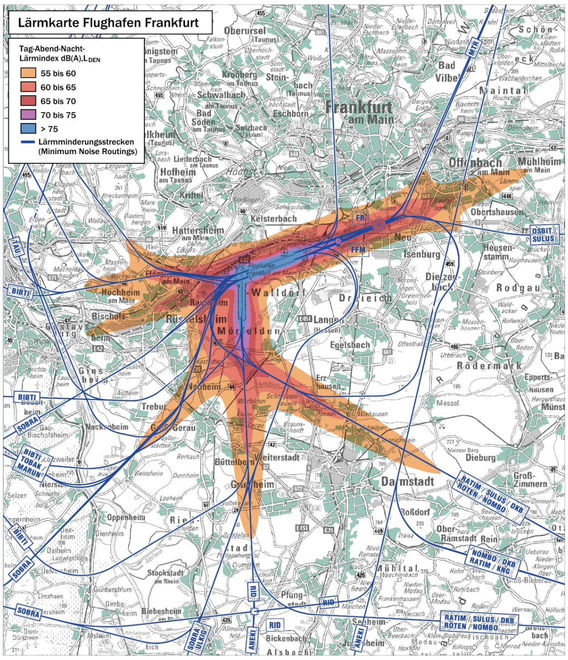


Figure A.13 Frankfurt Main flight paths and noise contours 2016 - Source: Wikimedia

Air Quality and Emissions

In 2005 the World Health Organisation (WHO) released Air Quality Guidelines offering global guidance on the thresholds and limits for key air pollutants that pose risks to health. The guidelines indicated that by reducing particulate matter (PM10) pollution from 70 to 20 micrograms per cubic metre (μg/m^3), air pollution-related deaths could be reduced by approximately 15%. The WHO 2005 guideline limits, therefore set out to achieve the lowest concentrations of PM possible.

On average, aircraft are responsible for only about half of the emissions produced at and around airports (ICAO, 2004). Even with improvements to aircraft, the rapid growth of aviation means that its contribution to air pollution is increasing overall. Aircraft typically generate between 8 and 50 kg of NOx per landing/take-off cycle (depending on aircraft type). Airports and aviation related activities generate air pollution through a range of sources:

- Combustion of aviation fuel produces nitrogen oxides (NOx), carbon monoxide (CO), sulphur oxides (SOx), hydrocarbons and particulates. It also releases the greenhouse gas carbon dioxide (CO_2).
- As engines are working inefficiently on approach (as they only use about 30% of the available power) a certain amount of unburnt kerosene is released. These unburnt fuel droplets are a source of volatile organic compounds (VOCs).
- As aircraft tyres get worn and burnt during take-off and (especially) landing, they release particulate matter (PM).
- Fuel dumping by aircraft releases unburned aircraft fuel into the air. This is a rare occurrence and usually only takes place in emergencies. In these circumstances,

aircraft are expected to dump fuel over water where possible, and at an altitude where it is likely to evaporate before reaching the surface.

- Vehicles travelling to and from the airport, and ground service equipment (e.g. tugs for aircraft and baggage, fuel and catering vehicles, buses and vans) generate NOx, CO_2, particulates and (indirectly) ozone through the burning of petrol and diesel fuel.
- Fuel storage tanks and transfer facilities can lead to the release of volatile organic compounds.
- Aircraft and airfield maintenance (e.g. painting, metal cleaning and de-icing), and emergency and fire-training use complex chemicals which can release volatile organic compounds.
- Construction of airport-related projects can lead to dust, emissions from activities such as asphalt laying.

WHO air quality guideline values are set out in the following table (figure A.14):

NO2	PM2.5	PM10	Sulphur dioxide (SO2)	Ozone (O3)
40 μg/m³ annual mean	10 μg/m³ annual mean	20 μg/m³ annual mean	20 μg/m3 24-hour mean	100 μg/m3 8-hour mean
	25 μg/m³ 24-hour mean	50 μg/m³ 24-hour mean	500 μg/m3 10-min mean	-

Figure A.14 - WHO Air Quality Guidelines - Source: WHO

United Kingdom

The Aviation Environmental Federation UK (AEF) reports that emissions from the aviation industry are forecast to grow both in real terms and as a proportion of the national total. In the UK, the share of emissions taken up by aviation is predicted to grow from around 6% today to 25% by 2050, even if the sector is successfully capped at level of 37.5 MtCO2 (equivalent to UK aviation emissions in 2005) which has been recommended by the Committee on Climate Change. The figure below shows the average levels of NO_2 across London in 2010 and displays Heathrow airport as a hotspot next to central London (figure A.15).

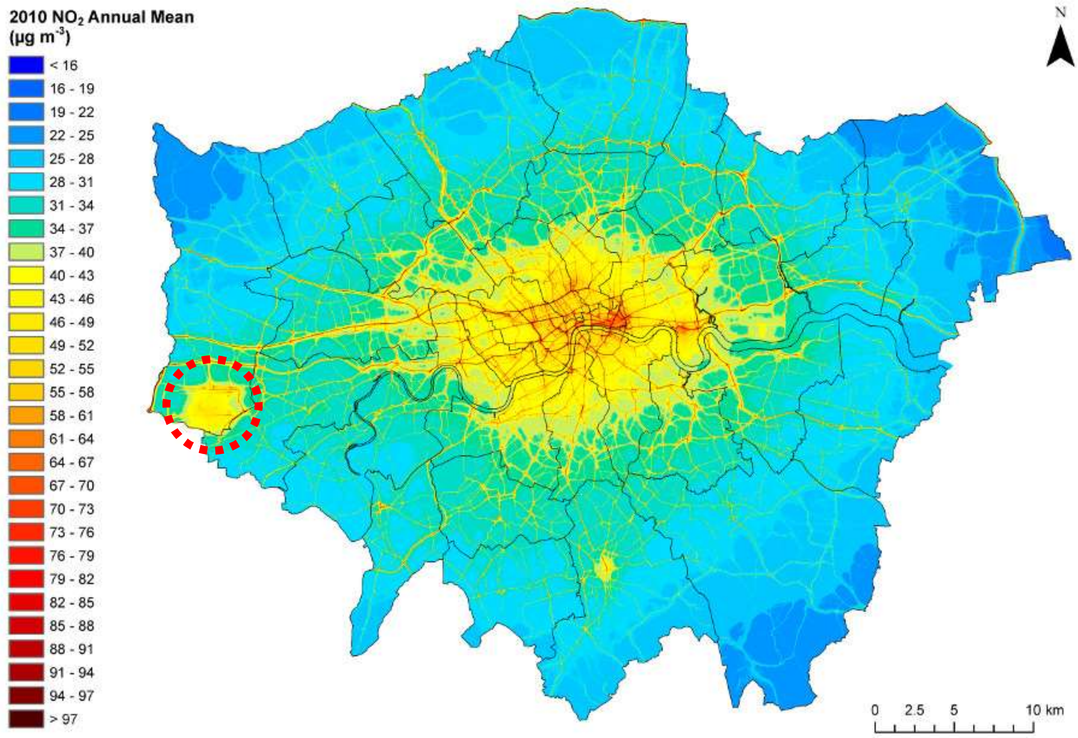


Figure A.15 - Average levels of NO_2 across London in 2010 shows the concentration of No_2 around Heathrow (circled in red) to central London levels- Source: Cleaner Air for London

Amsterdam Schiphol

Prompted by public concern, a study 'Air Pollution and Amsterdam Schiphol Airport' by The National Institute for Public Health and the Environment (1991) was carried out.

The results of these measurements and model calculations indicate that Schiphol Airport's relative contribution to regional concentration levels is less than 10% for the pollutants considered. The contribution from highway traffic in the Schiphol area is of a similar order of magnitude. The resulting regional concentration levels are higher than national average values, but do not exceed those of urban areas. Additional investigation of some aerosol samples using the Ames test revealed no increased mutagenicity. The results of this air pollution study coincide with those of a parallel public health survey in the Schiphol region, which found cancer mortality similar to that expected in urban areas.

Hong Kong

The Hong Kong Environmental Protection Department set out Air Quality Objectives (AQOs) which are listed below (figure A.16).

Pollutant	Averaging time	Concentration limit [i] ($\mu g/m^3$)	Number of exceedances allowed
Sulphur dioxide	10-minute	500	3
	24-hour	125	3
Respirable suspended particulates (PM_{10}) [ii]	24-hour	100	9
	Annual	50	Not applicable
Fine suspended particulates ($PM_{2.5}$) [iii]	24-hour	75	9
	Annual	35	Not applicable
Nitrogen dioxide	1-hour	200	18
	Annual	40	Not applicable
Ozone	8-hour	160	9
Carbon monoxide	1-hour	30,000	0
	8-hour	10,000	0
Lead	Annual	0.5	Not applicable

Figure A.16 - Hong Kong Air Quality Objectives
Source: Hong Kong Environmental Protection Department website

Climate Change

Scientific research shows that the average temperature of the planet's surface has risen by 0.89 °C from 1901 to 2012. Compared with climate change patterns throughout Earth's history, the rate of temperature rise since the Industrial Revolution is high.

Aviation is estimated to account for 2% of the world's CO_2 emissions. IATA estimates that CO_2 emissions per seat kilometre have reduced by 80% since the introduction of jet aircraft but of course the number of flights has increased even more.

The key greenhouse gases are:

- Carbon dioxide (CO_2)
- Methane (CH4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF6)
- Ozone (O_3)

Kyoto Protocol

Following several years of discussion and negotiation, the Kyoto Protocol, finally adopted in 1997, provided worldwide recognition of the impact of human activity, and in particular the contribution of greenhouse gasses, to global climate change. The protocol, which came into effect on 16 February 2005, set emissions targets for individual nations.

The maximum emissions (measured as the equivalent in CO_2) that a country may emit over a given period in order to comply with its emissions target is known as the Party's assigned amount. The individual targets for Annex I Parties are listed in the Kyoto Protocol's Annex B below (figure A.17).

Annex I Parties[a]	Emission limitation or reduction (expressed in relation to total GHG emissions in the base year or period inscribed in Annex B to the Kyoto Protocol)[b]
Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland	−8%
United States of America[c]	−7%
Canada, Hungary, Japan, Poland	−6%
Croatia	−5%
New Zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

[a] At the time of publication of this manual, the amendment to the Kyoto Protocol that contains an emissions target for Belarus (−8%) had not been ratified by a sufficient number of Parties for it to enter into force.
[b] Countries with economies in transition have flexibility in the choice of base year.
[c] Country which has declared its intention not to ratify the Kyoto Protocol.

Figure A.17 - Kyoto Protocol Annex B Emissions Targets

The following highlights examples of best practice at major international airports that have transparent environmental policies.

New York

The New York Port Authority makes the following statement about reducing Greenhouse Gas (GHG) and Criteria Air Pollutant (CAP) Emissions:

'*In a pioneering move for a public agency, the Port Authority established a Sustainability Policy committing to reduce GHG emissions from Agency, tenant and customer operations by 80% by 2050 using 2006 as our baseline. The Sustainability Policy complements existing efforts, such as the Clean Air Strategy, to reduce CAP emissions'* (figures A.18 & A.19).

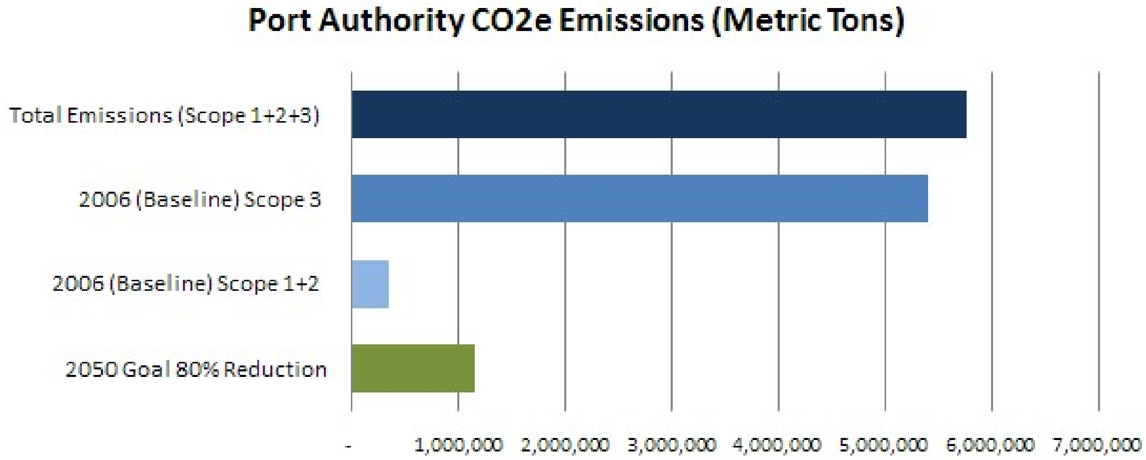


Figure A.18 - New York Port Authority emissions targets

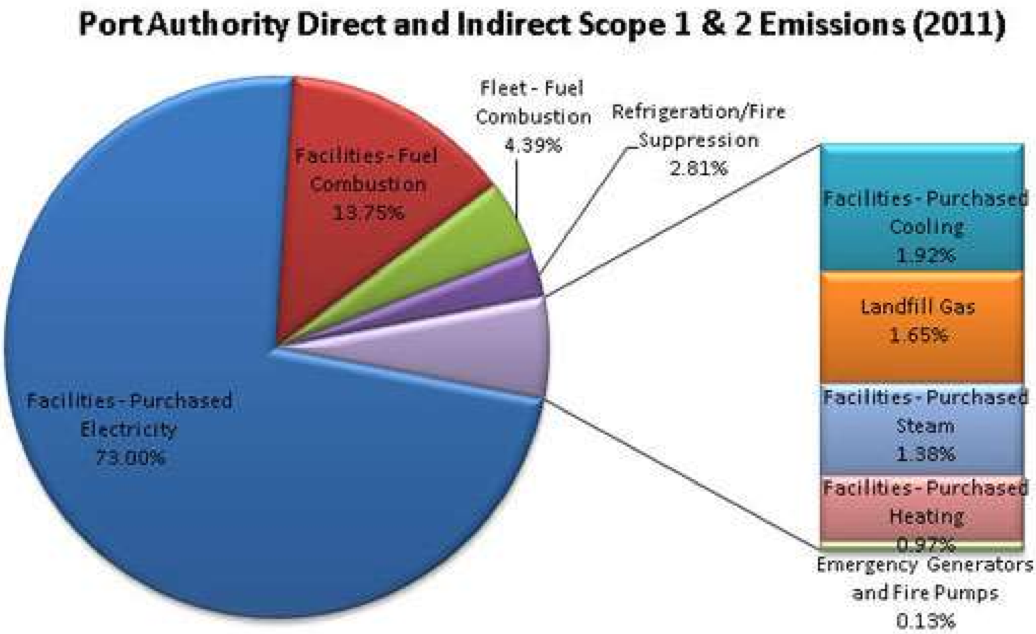


Figure A.19 - New York Port Authority emissions monitoring 2011

Amsterdam Schiphol

Schiphol aims to generate 20% of its energy requirements in a sustainable manner at the Schiphol location by 2020. It is also one of the few airports that claims to be carbon neutral.

London Gatwick

In 2010 Gatwick launched its Decade of Change strategy where it set targets across all key sustainability areas including energy consumption, water use, waste, carbon emissions, air quality and public transport use - all for delivery by 2020.

Gatwick achieved carbon neutral certification for 2016 through its use of 100% renewable energy (since 2013) together with offsets for the remaining carbon emissions generated by the airport. The offsets were gained by subsidising the Kar-demir Bozyaka wind farm project in Izmir province, Turkey.

Frankfurt International

Frankfurt applied the following targets as published within their environmental statement:

- Climate protection target: Reduction of CO2 emissions per traffic unit by 30%, from 3.7 kg/TU in 2005 to 2.6 kg/TU in 2020.
- Greenhouse Emissions: Reduction of CO2 emissions by 238,000 tons in 2020 despite airport expansion.

London Heathrow

Heathrow set the following climate change target:

- Climate Change: A 34% reduction in CO2 emissions from energy used in buildings (1990) by 2020.

Seoul Incheon

Incheon International Airport Corporation (IIAC) set up a medium to long-term plan to become the world's leading low-carbon, eco-friendly airport in line with the company's new management strategies as well as the new Korean government's environmental policies. Specifically, it will work to achieve five goals including the following: ACI Airport Carbon Accreditation, 100% installation of LED lighting, and 3% energy self-reliance by 2020 (figure A.20).

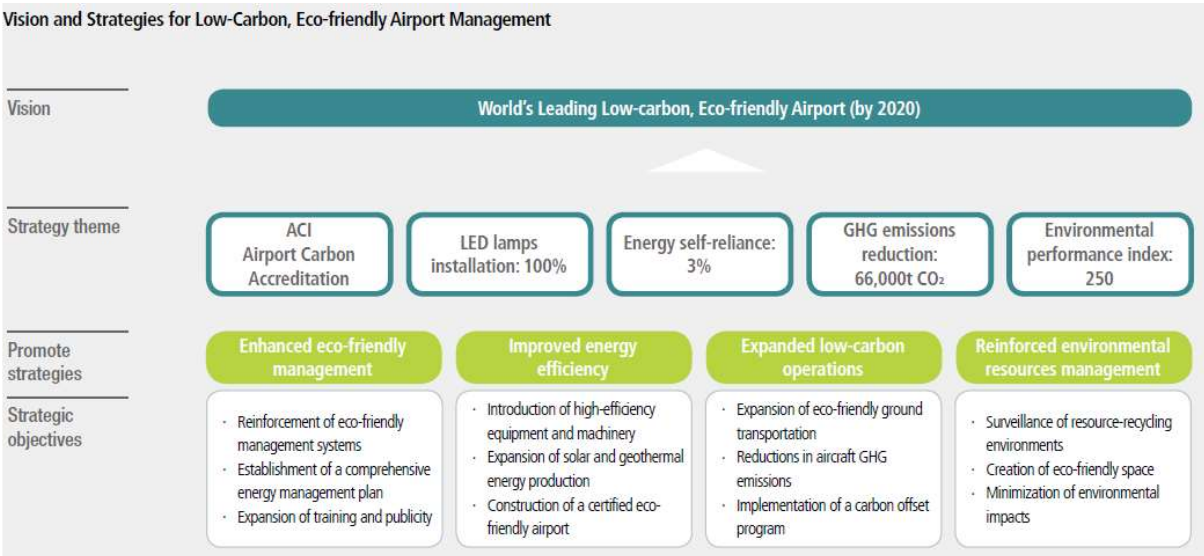


*Figure A.20-	Incheon's low carbon vision and strategy*

Ecology and Biodiversity

Many examples exist of how airports actively eco-manage the areas they affect. The following are examples of biodiversity policies adopted by airports around the world.

Seoul, Incheon

The airport regularly carries out comprehensive environmental impact assessments covering its terrestrial and maritime ecosystems including groundwater. It has also compiled data on the fauna and flora in the region and has taken immediate actions when any of the country's legally protected or endangered species are at risk.

Chicago O'Hare

The airport has a well-established Raptor capture and release programme. In 2012 alone over 1,000 birds were released into neighbouring habitats, well away from the airport which also consequently lowers the risk of wildlife strikes.

Western Sydney Airport

Whilst developing the Environmental Impact Statement for the proposed new Western Sydney Airport ecologists discovered a number of threatened species listed under national legislation such as the grey-headed flying-fox. Mitigation measures included a biodiversity offset package which includes translocation of habitat and foraging grounds as part of the enabling works.

New York, JFK

Since 2009, JFK has had problems with diamondback terrapins. Trapped animals are measured and micro-chipped and then released in wildlife sanctuaries.

Water

The major types of contaminant are listed in the table below (figure A.21):

Compounds emitted	Type of pollutant	Origin of pollution	Environmental impact
PAHs	Combustion gases Fuel, oil, grease	· combustion of aviation fuels · combustion of engine fuels · vehicle maintenance shop operations · fueling operations · engine test cell operations	· mutagenic, carcinogenic · the resistance of trees to pests and disease · impairs growth of biomass and lowers its quality · adverse effect on fungi, algae, lichens · contamination of surface waters and soils · the consumption of dissolved oxygen · hinders re-oxygenation of streams · may form sludge deposits that could interfere with stream self-purification processes
PCBs	Chemical stabilizers	· aircraft maintenance operations (heat exchanger fluids, chemical stabilizers, and in hydraulic systems) · plasticizers in natural and synthetic rubber products such as adhesives, installation materials, flame retardants, lubricants, chemical stabilizers in paints, pigments and oil varnishes at airports	· highly toxic · carcinogenic
Cationic detergents Anionic detergents Non-ionic detergents	Detergents	· cleaning of aircraft, ground vehicles and airport aprons · repairs to aircraft engines and ground vehicles	· may cause foaming in aeration basins · may cause partial sludge flotation through release of carbon dioxide
Cations Anions	· De/anti-icing chemical wastes · Cleaning wastes	· de/anti-icing operations · cleaning of aircraft and ground vehicles · paint application and removal · steel hardening · metal plating	· may interfere with biological activity · consumption of dissolved oxygen · are toxic to human beings, livestock, and aquatic life
Phenols Formaldehyde	Combustion fuels	· partial oxidation of fuel (phenols) · photochemical reactions with unburnt fuel such as benzene, xylene, toluene (formaldehyde)	· consumption of dissolved oxygen · may form sludge deposits that could interfere with stream self-purification processes and with biological activity
Metals	Corrosion pollutants	· chromium plating · copper stripping · anodizing operations · corrosion of aircraft parts and ground vehicles	· may interfere with biological activity and may complicate sludge disposal are toxic to human beings, livestock, and aquatic life

Figure A.21 - Common contaminants at airports – Source: Department of Analytical Chemistry, Chemical Faculty, Gdansk University of Technology 2012

Community sentiment towards aviation

In order to assess community sentiment towards air transport and airport development the United Kingdom Department for Transport commissioned a set of surveys. Summary responses are illustrated below (figure A.22).

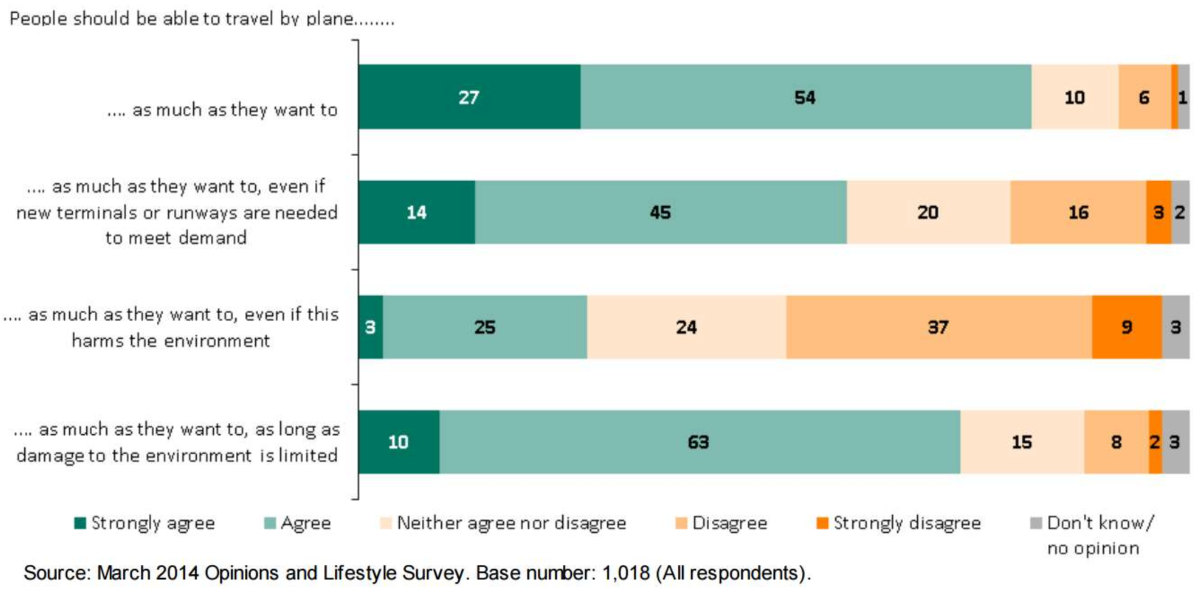


Figure A.22 - Survey by UK Department for Transport regarding community sentiment towards air travel
Source: United Kingdom Department for Transport

The report reflects mixed views towards airport development but revealed interesting responses, notably:

- 47% said they would support expansion, and 20% said they opposed expansion of their local airport.
- 57% of respondents agreed with the statement '….in order to boost the economy new terminals and runways should be built'.
- 73% agreed that people should be able to travel as much as they want, as long as damage to the environment is limited.
- In response to a direct statement that people should be able to travel by plane as much as they want to, even if it harms the environment, the proportion of people that agreed dropped to 28%, revealing growing awareness of, and concern for, environmental issues and global warming in particular.

The UK Department for Transport (DfT) surveys indicate that more people are in favour of airport expansion than against. However, they also revealed growing dissent over time and changing attitudes, with almost twice as many people disagreeing with expansion in 2014 compared to 2006.

Appendix B – Airports Timeline

Date	Airport	Location	Architect/ Engineer	Innovation	Influence
1903	Kittyhawk	North Carolina	Wilbur and Orville Wright	Hangar Guide Rail	
1904-5	Wright Field	Dayton, Ohio, USA	Wilbur and Orville Wright	First Airfield Catapult & guide rail Detachable wheeled undercarriage	
1909	Frankfurt Airshow	Frankfurt, Germany		Train Station Tramway Rapid Transit Runway	Prototype Interchange
1913	Aerial Navigation Act	UK		Government given powers to designate areas for landing	Controls locations of airports
1914	Statione Aeroplani Treni		Elio Sant'Elia Futurists	Roof top runway Poetry of Flight	Road/Rail/Air Interchange
1914	Hangar & workshops		Eric Mendlesohn		Streamlined Imagery
1919	ICAN	Internation al	International Commission on Air Navigation	First world agreement to regulate air traffic	
1919	Municipal landing Fields for Air Service	USA	Army Air Service	Specification guidelines for airports	
1919	Flugplatz Johannisthal, constructed as a military airfield in 1908	Berlin, Germany		First Scheduled flight to Weimar from a former military airfield and manufacturing factory	Corner of hangar used for passengers
1919	Hounslow Heath	London, UK		25.08.1919 First Departing Scheduled International Flight to Le Bourget, Paris by Aircraft Transport & Travel Ltd	
1919	Le Bourget	France		First Arriving Scheduled International Flight. Landing point for Lindberg's 1927 solo transatlantic flight in 'The Spirit of St. Louis'	

1919	Dutch Royal Airlines for the Netherlands and its Colonies (Koninklijke Luchtvaart Maatschappij voor Nederland en Koloniën - KLM) was founded	Holland		Royal charter granted 12.09.1919, foundation 12.10.1919. KLM's first pilot, Jerry Shaw, flew from London to Schiphol in a leased De Havilland DH-16.- 07.05.1920	World's oldest airline
1920	Croydon	London, UK		Operation transferred from Hounslow Heath First Control Tower and First Hotel	
1920	Schiphol	Amsterdam, Holland		Hangar No 1 in 1920	Oldest airport (& airline KLM) still operating on the same site
1922	Konigsberg	Kalingrad, East Prussia	Hans Hopp	First Terminal	
1922	Ville Contemporaine		Le Corbusier	Comparison with aircraft design	
1923	Airways and Landing Fields	USA	Us Army Air Service	Guidelines for establishing an aviation infrastructure	Chapter on constructing airfields
1923	Vers Une Architecture		Le Corbusier	Eyes that do not see 1. Ships 2. Airplanes 3. Automobiles	'a machine for flying' became 'a machine for living'
1923-1945 Term-inal phase 1 -1927 phase 2- 1928	Flughaven Tempelhof, A park 5km south of the Brandenberg gate, where Orville Wright gave a flying demonstration in 1909	Berlin, Germany	Paul and Klaus Engler	Masterplan published in 1925. Terminal competition in 1925. Phased terminal 1927/8 Airfield Lighting Curved form of terminal defined the oval airfield. First underground metro station Last scheduled flight in March 1945	Busiest airport in the world Circular grass airfield became the European norm
1924	Imperial Airways formed	UK		Formation 31.03. 1924 to serve overseas destinations	Start of operations 26.04.1924 flight to Amsterdam1

1925	Contract Air Mail Act (Kelly Act)	USA		Commercial carriers responsible for carrying mail under contract from the Post Office	Stimulated the creation and growth of commercial airlines
1926	Air Commerce Act	USA		Created an aeronautics branch within the department of Commerce (later the Bureau of Air Commerce)	Federal Government did not own, build or fund airports
1927	Metropolis, Film		Fritz Lang		Vision of STOL airport
1927	First solo flight across the Atlantic	USA to France	Charles Lindbergh	Lands at Le Bourget, Paris	Promotional tour of USA after flight encouraged the aviation bandwagon
1927 -9		USA		33 states passed enabling legislation to allow municipal airports	
1928	Air Bulletin No 2	Aeronautics Branch, USA		Site selection, field layout, types of building & equipment, lighting and marking	
1927	Ford Airport	Dearborn, USA	Albert Kahn	First US scheduled flights to Chicago. First concrete runway 2,500ft x 75ft (1929) First radio controlled flight	Concrete runways became the US norm
1928 - 1959	Croydon	London UK	Ministry of Public Buildings and Works	Integrated control tower Incorporated Customs and Immigration First Flight information display Purpose designed Hotel	Tall control towers became the norm
1928	RIBA Airport Competition	Site Mitcham Common, England	Winner Donald Hanks McMorran	Drive Through boarding and alighting	

1929-30	Lehigh Airport Competition	USA	Winner. A.C. Z & William.H. Harrison	Brief - Multiple Minimum of 4 concrete runways, covered boarding 257 Entrants 4 prize winners 12 honourable mentions	Multi-direction runways Satellite with underground link. Dry boarding 1.Retractible boarding canopies 2.Cantilever Canopies 3. Boarding Hangars Influence on Chicago Municipal, Gatwick, Tempelhof
1929	'Blind Flying'		Jimmy Doolittle	First instrument only flight, funded by the Daniel Guggenheim fund for the Promotion of Aeronautics in a Consolidated NY-2 two seat biplane 24.9.1929	Fund promoted a nationwide system of landing fields
1929	A1A Airfield Standards	USA	Department of Commerce Aeronautics Branch	Airport rating system A-E Facilities & Services 1–4 Landing Area Feet A-E Lighting facilities	
1929	Flughafen-Gaststatte	Halle - Leipzig		Allegorical reference to Flight	
1929	Schiphol	Amsterdam		Spectator Facilities, Control Tower	Built below sea level
1929	Fuhlsbüttel	Hamburg, Germany		Level segregation -Baggage/cargo -Passenger -Administration -Spectators	
1929		Cleveland, Ohio, USA Conference		200 participants	First Airport Conference
1929	International Airports	The Ronald Press Company	Stedman S. Hanks Author	Comparative study of European and US airports	First management and design guide

1931	Chicago, Municipal	Chicago, USA	Paul Gerhardt, City Architect	Twin parallel runways in 8 directions, Perimeter Terminal Phased master plan	Frequently busiest airport in the world
1932	Airport Development	RAeS, London	Nigel Norman and Graham Dawbarn	Lecture, American Airports	Introduced runways, passenger boarding canopy at Oakland
1933	Sushan	New Orleans		Reclaimed land, CAA model airport	
1935	British Airways Ltd			Merger of Spartan Air Lines & United Airways, followed by Hillman's Airways later in year	
1936	British Airways Ltd			British Continental Airways added	
1936	American Airlines			Douglas DC 3 enters service – 21 seats	First commercially viable airliner without airmail subsidy
1936	Gatwick 'Beehive' Martello Air Station	London South (Gatwick) Airport	Hoar, Marlow and Lovett	Own railway station Covered boarding	Prototype Satellite
1936	Bromma	Stockholm, Sweden	Paul Hedquist & Ernst Dierbach of Lufthansa	First concrete runways in Europe First Steel frame terminal	Built from comprehensiv e plans
1937	Scottish Airways			Merger of Northern & Scottish Airways with Highland Airways Ltd. British Airways Ltd held a 50% stake	
1937	Le Bourget	Paris, France	George Labro	Competition for new terminal for the Paris International Exhibition Theme: 'Art and Technology in Modern Life' First linear centralised terminal. Modular concrete construction, 233m long façade of glass	Closed in 1977, now home of the Paris air show

1937	Airports & Airways	RIBA Exhibition		A. Aircraft B. Airports C. Aerial Photography	
1938	Civil Aviation Act	Created Civil Aeronautics Authority (CAA)		Reform of regulation, removed ban on federal aid to airports & mandated the drafting of a national airport plan.	Prerequisite for Federal Washington National Airport
1939	Flughafen Tempelhof	Berlin, Germany	Ernst Sagebiel of the Reich's Air Ministry Berlin master plan by Albert Speer, to transform Berlin into Germania, the capital of the Greater Reich	Largest building in the world (until the Pentagon), designed for 30 times the 1936 traffic. 1200 metres long of terminal hangars and workshops Cantilever Canopy of 39metres for dry boarding Pier and Gaterooms Baggage lifts City centre Airport, Integrated into the urban environment and Limited by grass airfield	Enabled the Berlin Airlift Designed to last until 2000, closed finally in 2007
1939	Elmdon	Birmingham UK	Norman and Dawbarn	Canopy for dry boarding	Influenced by visit to Tempelhof
1939/ 40	La Guardia	New York, USA	Delano and Aldrich	Boarding Finger Level Segregation Elevated forecourt Arts Programme First airline lounge (American Airlines Admirals Club)	Prototype for linear pier
1940	Midway (formerly Municipal)	Chicago, USA		Linear / Multiple Unit Terminal	
1940	Airports: Some elements of design and future development		John Walter Wood & Charles L. Lawrance	Review of Airport Development & Masterplans	Comparative benchmarking study
1940	BOAC - British Overseas Airways Corporation formed			Merger of British Airways Ltd and Imperial Airways 01.04.40	First flight to Lisbon to connect to USA 04.06.1940

1940	Town Terminal	New York, USA		Check-in for TWA, United, Pan AM & Eastern	
1942-45	Wartime master plans			Terminal in between runways (not perimeter)	Influence on LHR,JFK,ORD,
1944	Heathrow	London, UK		Underground road, rail and metro links in masterplan	
1944	Chicago convention			Set down agreement for post war international flying	
1945	BEA – British European Airways set up			Served UK domestic and European routes	
1946				Douglas DC 4 introduced tricycle undercarriages to large commercial aircraft.	Level facilitated introduction of airbridges
1946	Airport Planning	John Wiley	Charles Froesch Chief Engineer & Walther Prokosch Architect	Multiple piers Taxiway bridge Apron drive airbridges	Eastern Airlines terminal design
1946	Federal Airport Act		CAA managed programme	Federal Aid Airport Programme (FAAP) authorised spending of 0.5 billion dollars over seven years on airports	Federal Government assumed responsibility for the National Air Transportation System
1946	Heathrow North	London, UK		Star of David runways. Tented encampment, replaced by prefabricated buildings before winter	
1946	BOAC starts services to USA			Lockheed Constellations on London – Shannon – Gander – New York	
1947	ICAO			Establishment of International Civil Aviation organisation	
1947	Chicago O'Hare	Chicago, USA	Ralph Burke	Masterplan with multiple finger piers	

1948	Idlewild (JFK)	New York USA		July 31st opens with 9 day airshow	
1948/9	Flughafen Tempelhof	West Berlin, Germany		Berlin airlift 1948-9	Multi-stream air traffic control
1950	Washington Friendship (Baltimore)			Finger pier, spiral baggage chutes, Departing and arriving passengers on 2 levels, 22 'Roomettes' with bed, shower and dressing table.	
1952	BOAC introduces jet services			Comet 1 entered service 02.05 1952 London to Johannesburg	
1953	Flughof Kloten,	Zurich International Airport	Alfried and Heinrich Oeschger	First European post war terminal. Last major airport with an open apron	Airfield views
1954	San Francisco	San Francisco, USA		Twin finger piers	Extended to 4 finger piers
1955	Heathrow Central Terminal Area	London, England	Frederick Gibberd	Tunnel access Multiple terminals Terminal 2 opened 17.04.1955. Terminal 03.11.1961, and Terminal 1 17.04.1971	First planned for multi – modal access
1955	Idlewild (JFK)	New York, USA		Terminal City	Airline designed terminals
1956	St Louis Lambert	St Louis, USA	Hellmuth, Yamasaki & Leinweber (later HOK)	Shell Roof Elevated forecourt Finger Pier Mechanical baggage Escalators	Freestanding interior cabins
1958	BOAC re-introduce Jet flights			Comet 4 introduced on London to New York 04.10.1958	
1958	Pan American Airways starts Boeing 707 aircraft			The aircraft's first commercial flight was from Idlewild Airport, New York to Le Bourget, Paris on October 26, 1958 with a fuel stop in Gander, Newfoundland. Location of passenger	

1958	Federal Aviation Act			Established the Federal Aviation Agency (FAA)	Made independent of Department of Commerce
1958	Chicago, O'Hare	Chicago, USA		Central terminal Finger piers	
1958	London, Gatwick	Crawley, Sussex UK	Yorke, Rosenberg and Mardall	Integrated rail under one roof, built over dual carriage way, First pier in Europe	
1959	San Francisco	San Francisco, USA		First apron drive airbridge	
1961	Orly Sud	Paris, France		First open plan gatelounge with direct aircraft boarding 'Orly' customs system at check-in. West satellite in 1969 and East Satellite in July 1970	
1961	Los Angeles (LAX)	Los Angeles, California, USA		First Satellite Terminal, and first installation of passenger conveyors, designed for Jets	Parallel aircraft parking gives way to nose in parking
1962	TWA Terminal, Idlewild (JFK)	New York, USA	Eero Saarinen	Expression of Fight Remote Satellite Opens in May	Circular satellite concepts
1962	Washington, Dulles	Washington D.C., USA	Eero Saarinen	Jet age master plan Toast rack apron Floating Roof Extendible concept Level segregated forecourts Plane mate aircraft access	
1963	Grand Central station, Pan Am Building	New York, USA	Walter Gropius, ACP	Roof top Heliport	Noise and safety issues
1966	BAA starts 01.04.1966			Takes over from the Ministry of Aviation as owner and operator of Heathrow, Gatwick, Stansted and Prestwick	

1967	Amsterdam Schiphol 'Schiphol Central'	Amsterdam, Holland		Terminal, and multiple piers and underground rail station opened 28.04.1967	
1970	Airport and Airway Development Act establishes Federal Aviation Administration	FAA, USA		Linked to Airport and Airway Revenue Act, switched funding to aviation community	Tax on tickets, fuel, freight, and aircraft registration
1970	Pan American Airways introduce B747			The 747 entered service on January 22, 1970, on Pan Am's New York–London route	
1970	Tampa	Tampa, Florida, USA		Airside Transit to satellites	
1971	Southwest Airlines starts			Co. set up in 1967, flights between DAL, SAT & IAH start 18.06.1971	
1972	Tacoma, Seattle	Seattle, Washington State, USA		Underground airside transit	
1973	Hanover, Langenhagen	Hanover, Germany		Arrivals, Departures level segregated	
1973	Oil Crisis			Makes first generation jets like the 707 expensive to operate	
1973	Dallas Fort Worth	Dallas Fort Worth, USA		Multiple linear terminals, later addition of transit makes it a transfer hub	
1974	T1 Charles de Gaulle (Roissy)	Paris, France	Paul Andrew, ADPI	Circular terminal with multiple satellites	
1974	British Airways formed 31.03.74	UK		Merger of BOAC, BEA, Cambrian Airways & North East Airlines	
1976	Concorde first scheduled flights British Airways and Air France	UK and France		First supersonic scheduled flights London to Bahrain and Paris to Rio de Janeiro	
1978	Schiphol Rail station opens			Links airport with southern Amsterdam	

1978	Airline Deregulation Act			Eliminated statutory economic regulation of the passenger airline industry. Abolished Civil Aeronautics board in 1985.	Led the way for Low Cost Carriers (LCCs)s
1979	The Airport Book		Martin Grief	History of Airport Design	
1980	Atlanta, Hartsfield	Atlanta, Georgia, USA		Toast rack layout, Underground transit Linear satellites	Busiest and most efficient airport layout in the world,
1981	Haj Terminal, Jeddah	Jeddah, Saudi Arabia	George Bunschaft SOM	Tent Roof Passive cooling	Impact on Stansted
1981	Changi Airport			Opening 01.07.1981	Regularly voted as one of the best airports
1981	T2 Charles de Gaulle	Paris, France	Paul Andrew, ADPI	Linear terminal, Morphs into pier and satellites	
1982	The airport and Airway Improvement Act	USA		Authorised funding of airports and noise compatibility programmes	
1985	Heathrow T1, T2 & T3-Central Terminal Area	London, UK		First underground metro link	
1985	Ryanair established			First flights Waterford to Gatwick using a 15 seat Bandierante	
1986	Heathrow T4	London, UK	Scott, Brownrigg & Turner	Arrivals/departures level segregation Central Security Open plan gatelounge	Level segregation has become the norm
1986	Schiphol Airport Rail Link			Rail extended to Amsterdam Central and so to the International rail network	
1987	London City Airport	London, UK		Stolport – 762m runway 7.5 degree glideslope	Glideslope subsequently reduced to 4.5 degrees

1988	Gatwick North Terminal	London, UK	YRM	Modular construction, designed for manufacture and growth and change First landside transit in Europe First retail shopping mall	
1990	Airport Safety and Capacity Act	USA		Allowed airports to impose a passenger facility charge for safety, security or capacity	
1990	Ryanair relaunched as a LCC			Business model based on South West Airlines, with low fares,, no free food or drink and a single aircraft type the BAC 111	
1991	Stansted	London, UK	Norman Foster	Floating roof tree structure, Integrated structure and services concept, Single level for flexibility, Remote satellites, Level change by transit extendible	Start of the celebrity architect cult
1994	Kansai	Osaka, Japan	Renzo Piano, ADPI master plan	Single long span roof Integrated transit Street Architecture (Canyon) Sinking reclaimed land	
1995	EasyJet starts			Low cost flights from Luton to Edinburgh, followed by Europe next year.	
1997	Chek Lap Kok	Hong Kong (Lantau Island)	Norman Foster	Integrated Interchange Largest single building terminal	
1999	One World Alliance formed 01.02 1999			British Airways, American Airlines, Cathay Pacific, Qantas and Canadian Airlines founder members	

2001	Aviation and Transportation Security Act	USA		Created the Transportation Security Administration (TSA)	
2007	Singapore Airlines introduce A380			Nicknamed Super-jumbo the first A380, MSN003, was delivered to Singapore Airlines on 15 October 2007 and entered service on 25 October 2007 with a flight between Singapore and Sydney.	Introduces upper deck boarding
2008	Brussels-South, Charleroi	Brussels, Belgium		Designed for Ryanair, Standardised Apron	Illegal cost subsidy
2008	Heathrow T5	London, UK		Toast rack master plan, Long span roof 155m, Forecourt 30 metres separation with landscape canyon,multi wave flow thru check-in, PRT	
2013	Dubai Terminal 3 and Concourse A	Dubai, UAE	HOK	Underground terminal, Premium passenger level segregation	Impact on later ADPI design at Beijing
2013	Atlanta, Hartsfield			5 runway masterplan, End around taxiways Dual toast rack	Busiest airport in the world, Pax and ATMs
2014	Mexico City Soeul Dubai Qindao	Future masterplans	Foster HOK ADPI/Dar es Handesar Atkins		
2014	New hub Airport, Isle of Grain,	London, UK	Atkins	4 runway hub Independent mixed mode operation Cruciform satellites as a transfer hub	180 MPPA, Largest planned airport
2014	Virgin Galatic Spaceport	USA	Foster	Integrated hangar and terminal	Return to 1919 principles at Berlin Johannisthal
2019	Istanbul Grand	Turkey	Grimshaw,	Multi-Runway Hub Airport & Aerotropolis	150 MPPA
2019	Beijing Daxing	China		Multiple piers in star configuration,	

Appendix C - Evolution of Selected Passenger Aircraft

Date in Service	Aircraft Type	Max Pax	Gross Weight	Top Speed	Wing Span	Number made
1919	AEG J11	4	1,040 kg	150kph	13.5m	-
1920	Farman Goliath	14	2,900 kg	170kph	26.5m	60*
1920	Junkers JU13	4	1,480 kg	160kph	14.5m	360
1925	Fokker Trimotor	12	5,200 kg	170kph	22m	250
1926	Ford 5-AT Trimotor	8	5,738 kg	240kph	24m	199
1931	Handley Page HP 42	32	12,701 kg	169kph	40m	8
1931	Junkers JU52	17	9,200 kg	290kph	29m	4,835*
1933	Boeing 247	10	6,192 kg	322kph	23m	75
1935	Lockheed Model 10 Electra	10	4,673kg	190mph	17m	149
1936	Douglas DC3	32	11,430 kg	333kph	29m	607*
1938	Focke-Wulf Condor	26	22,700kg	325kph	33m	276*
1940	Boeing 307 Stratoliner	33	19,050 kg	357kph	33m	10
1946	Douglas DC 4	52	28,800 kg	451kph	36m	80
1949	Boeing Stratocruiser	114	66,134 kg	604kph	43m	56
1953	Vickers Viscount	65	28,570 kg	566kph	29m	445
1957	Bristol Britannia	139	68,025 kg	640kph	43m	85
1952	De Havilland Comet 1, 2 &3	44	50,000 kg	740kph	35m	24
1958	De Havilland Comet 4	109	71,000 kg	805kph	35m	90
1958	Boeing 707	147	166,362kg	966kph	40m	1,010
1959	Douglas DC8	189	158,760kg	946kph	43m	1,191
1959	Sud Aviation Caravelle	80	52,000kg	805kph	34m	282
1964	Vickers VC10	212	151,953kg	933kph	46m	54
1964	Boeing 727	189	95,000kg	975kph	33m	1,832
1965	BAC 111	119	47,400kg	882kph	27m	244
1965	Douglas DC9, MD80/90, B717	134	49,900kg	811kph	28m	1,191
1967	Boeing 737 – Classic	115	42,111kg	933kph	29m	3,132
1970	Boeing 747 -100,200,300,400	524	412,769kg	920kph	65m	1,548
1971	Douglas DC 10 & MD 11	410	286,000kg	945kph	52m	227
1972	Lockheed L1011 Tristar	400	229,000kg	973kph	57m	250
1974	Airbus A300	266	171,700kg	897kph	45m	561
1976	Concorde	100	185,000kg	2179kph	26m	20
1982	B767, 100,200,300	287	204,121kg	913kph	52m	1,133
1983	BAE 146	128	42,182kg	894kph	26m	378
1983	B757-200,300	295	123,600kg	854kph	38m	1.050
1988	Airbus A318,319,320,321	240	93,000kg	904kph	36m	8,605
1994	Boeing 737 Next Gen & Max	215	71,400kg	907kph	35m	7,312
1994	Airbus A330	335	242,000kg	900kph	60m	1,439
1995	Boeing 777- 200/300	396	351,500kg	950kph	61m	1,538
2002	Embraer 170,175,190,195	124	50,300kg	871kph	29m	1,500
2007	A380	853	589,670kg	1020kph	80m	234
2011	Boeing 787	335	228,000kg	954kph	60m	781
2015	Airbus A 350	366	308,000kg	900kph	65m	235
2016	Airbus A 220 (Bombardier C series)	160	66,242kg	829kph	35m	56
2019	Boeing 777 800/900	414	351,100kg	TBA	65-72m	prototype

*Including military versions

Appendix D – Long Haul Low Cost Carriers

Long haul low cost operators in order of launch date

Airline or brand	Affiliation or parentage	Launch year
Jetstar	Qantas	2006
AirAsia X	AirAsia	2007
Scoot	Singapore Airlines	2012
Norwegian Air	Norwegian	2012
Air Canada	Air Canada	2013
Cebu Pacific	Cebu Pacific	2013
Jin Air	Korean Air	2014
Azul	Azul	2014
Thai AirAsia X	AirAsia	2014
NokScoot	Singapore Airlines	2015
Lion Air	Lion	2015
WestJet	WestJet	2015
Beijing Capital	Hainan Airlines	2015
Eurowings	Lufthansa	2015
Wow Air	Wow	2016
French Blue	N/A	2016
Level	IAG	2017

Note: Lion took delivery of its A330s in late 2015; it previously operated 747-400s but these were not operated under a long haul low cost model
Source: CAPA – Centre for Aviation

Appendix E – Airbus and Boeing growth forecasts

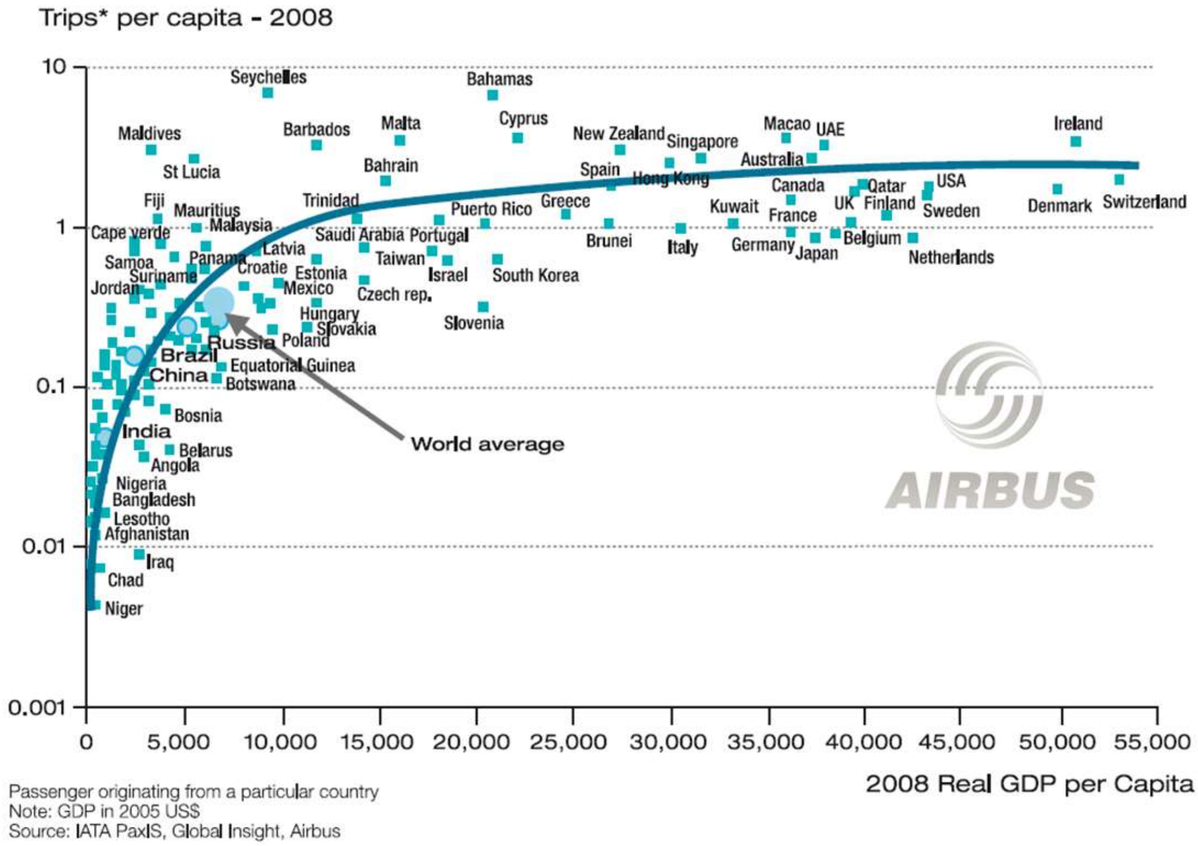


Figure E.01_ Propensity to travel, trips per capita, Airbus analysis – Source: Anna Aero

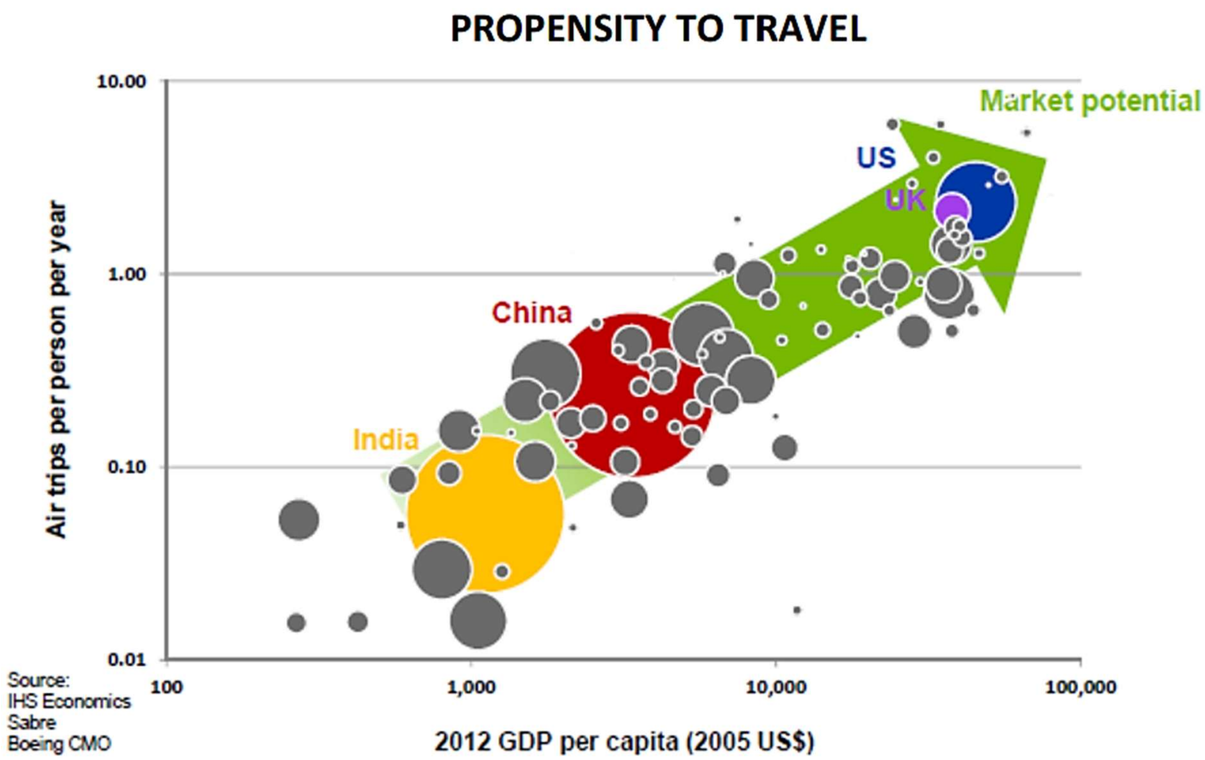


Figure. E.02 - Propensity to travel, air trips per annum, Boeing analysis – Source: Boeing Aircraft Corporation

Appendix F – Futurist Manifesto 1914

MANIFESTO OF FUTURIST ARCHITECTURE

No architecture has existed since 1700. A moronic mixture of the most various stylistic elements used to mask the skeletons of modern houses is called modern architecture. The new beauty of cement and iron are profaned by the superimposition of motley decorative incrustations that cannot be justified either by constructive necessity or by our (modern) taste, and whose origins are in Egyptian, Indian or Byzantine antiquity and in that idiotic flowering of stupidity and impotence that took the name of neoclassicism.

These architectonic prostitutions are welcomed in Italy, and rapacious alien ineptitude is passed off as talented invention and as extremely up-to-date architecture. Young Italian architects (those who borrow originality from clandestine and compulsive devouring of art journals) flaunt their talents in the new quarters of our towns, where a hilarious salad of little ogival columns, seventeenth-century foliation, Gothic pointed arches, Egyptian pilasters, Rococo scrolls, fifteenth-century cherubs, swollen caryatids, take the place of style in all seriousness, and presumptuously put on monumental airs.

The kaleidoscopic appearance and reappearance of forms, the multiplying of machinery, the daily increasing needs imposed by the speed of communications, by the concentration of population, by hygiene, and by a hundred other phenomena of modern life, never cause these self-styled renovators of architecture a moment's perplexity or hesitation. They persevere obstinately with the rules of Vitruvius, Vignola and Sansovino plus gleanings from any published scrap of information on German architecture that happens to be at hand. Using these, they continue to stamp the image of imbecility on our cities, our cities which should be the immediate and faithful projection of ourselves.

And so this expressive and synthetic art has become in their hands a vacuous stylistic exercise, a jumble of ill-mixed formulae to disguise a run-of-the-mill traditionalist box of bricks and stone as a modern building. As if we who are accumulators and generators of movement, with all our added mechanical limbs, with all the noise and speed of our life, could live in streets built for the needs of men four, five or six centuries ago.

This is the supreme imbecility of modern architecture, perpetuated by the venal complicity of the academies, the internment camps of the intelligentsia, where the young are forced into the onanistic recopying of classical models instead of throwing their minds open in the search for new frontiers and in the solution of the new and pressing problem: the Futurist house and city. The house and the city that are ours both spiritually and materially, in which our tumult can rage without seeming a grotesque anachronism.

The problem posed in Futurist architecture is not one of linear rearrangement. It is not a question of finding new mouldings and frames for windows and doors, of replacing columns, pilasters and corbels with caryatids, flies and frogs. Neither has it anything to do with leaving a façade in bare brick, or plastering it, or facing it with stone or in determining formal differences between the new building and the old one. It is a question of tending the healthy growth of the Futurist house, of constructing it with all the resources of technology and science, satisfying magisterially all the demands of our habits and our spirit, trampling down all that is grotesque and antithetical (tradition, style, aesthetics, proportion), determining new forms, new lines, a new harmony of profiles and volumes, an architecture whose reason for existence can be found solely in the unique conditions of modern life, and in its correspondence with the aesthetic values of our sensibilities. This architecture cannot be subjected to any law of historical continuity. It must be new, just as our state of mind is new.

The art of construction has been able to evolve with time, and to pass from one style to another, while maintaining unaltered the general characteristics of architecture, because in the course of history changes of fashion are frequent and are determined by the alternations of religious conviction and political disposition. But profound changes in the state of the environment are extremely rare, changes that unhinge and renew, such as the discovery of natural laws, the perfecting of mechanical means, the rational and scientific use of material.

In modern life the process of stylistic development in architecture has been brought to a halt. Architecture now makes a break with tradition. It must perforce [per forza] make a fresh start.

Calculations based on the resistance of materials, on the use of reinforced concrete and steel, exclude "architecture" in the classical and traditional sense. Modern constructional materials and scientific concepts are absolutely incompatible with the disciplines of historical styles, and are the principal cause of the grotesque appearance of "fashionable" buildings in which attempts are made to employ the lightness, the superb grace of the steel beam, the delicacy of reinforced concrete, in order to obtain the heavy curve of the arch and the bulkiness of marble.

The utter antithesis between the modern world and the old is determined by all those things that formerly did not exist. Our lives have been enriched by elements the possibility of whose existence the ancients did not even suspect. Men have identified material contingencies, and revealed spiritual attitudes, whose repercussions are felt in a thousand ways. Principal among these is the formation of a new ideal of beauty that is still obscure and embryonic, but whose fascination is already felt even by the masses. We have lost our predilection for the monumental, the heavy, the static, and we have enriched our sensibility with a taste for the light, the practical, the ephemeral and the swift. We no longer feel ourselves to be the men of the cathedrals, the palaces and the podiums. We are the men of the great hotels, the railway stations, the immense streets, colossal ports, covered markets, luminous arcades, straight roads and beneficial demolitions.

We must invent and rebuild the Futurist city like an immense and tumultuous shipyard, agile, mobile and dynamic in every detail; and the Futurist house must be like a gigantic machine. The lifts must no longer be hidden away like tapeworms in the niches of stairwells; the stairwells themselves, rendered useless, must be abolished, and the lifts must scale the lengths of the façades like serpents of steel and glass. The house of concrete, glass and steel, stripped of paintings and sculpture, rich only in the innate beauty of its lines and relief, extraordinarily "ugly" in its mechanical simplicity, higher and wider according to need rather than the specifications of municipal laws. It must soar up on the brink of a tumultuous abyss: the street will no longer lie like a doormat at ground level, but will plunge many stories down into the earth, embracing the metropolitan traffic, and will be linked up for necessary interconnections by metal gangways and swift-moving pavements.

The decorative must be abolished. The problem of Futurist architecture must be resolved, not by continuing to pilfer from Chinese, Persian or Japanese photographs or fooling around with the rules of Vitruvius, but through flashes of genius and through scientific and technical expertise. Everything must be revolutionized. Roofs and underground spaces must be used; the importance of the façade must be diminished; issues of taste must be transplanted from the field of fussy mouldings, finicky capitals and flimsy doorways to the broader concerns of bold groupings and masses, and large-scale disposition of planes. Let us make an end of monumental, funereal and commemorative architecture. Let us overturn monuments, pavements, arcades and flights of steps; let us sink the streets and squares; let us raise the level of the city.

I COMBAT AND DESPISE:

1. All the pseudo-architecture of the avant-garde, Austrian, Hungarian, German and American;

2. All classical architecture, solemn, hieratic, scenographic, decorative, monumental, pretty and pleasing;

3. The embalming, reconstruction and reproduction of ancient monuments and palaces;

4. Perpendicular and horizontal lines, cubical and pyramidal forms that are static, solemn, aggressive and absolutely excluded from our utterly new sensibility;

5. The use of massive, voluminous, durable, antiquated and costly materials.

AND PROCLAIM:

1. That Futurist architecture is the architecture of calculation, of audacious temerity and of simplicity; the architecture of reinforced concrete, of steel, glass, cardboard, textile fibre, and of all those substitutes for wood, stone and brick that enable us to obtain maximum elasticity and lightness;

2. That Futurist architecture is not because of this an arid combination of practicality and usefulness, but remains art, i.e. synthesis and expression;

3. That oblique and elliptic lines are dynamic, and by their very nature possess an emotive power a thousand times stronger than perpendiculars and horizontals, and that no integral, dynamic architecture can exist that does not include these;

4. That decoration as an element superimposed on architecture is absurd, and that the decorative value of Futurist architecture depends solely on the use and original arrangement of raw or bare or violently coloured materials;

5. That, just as the ancients drew inspiration for their art from the elements of nature, we—who are materially and spiritually artificial—must find that inspiration in the elements of the utterly new mechanical world we have created, and of which architecture must be the most beautiful expression, the most complete synthesis, the most efficacious integration;

6. That architecture as the art of arranging forms according to pre-established criteria is finished;

7. That by the term architecture is meant the endeavour to harmonize the environment with Man with freedom and great audacity that is to transform the world of things into a direct projection of the world of the spirit;

8. From an architecture conceived in this way no formal or linear habit can grow, since the fundamental characteristics of Futurist architecture will be its impermanence and transience. Things will endure less than us. Every generation must build its own city. This constant renewal of the architectonic environment will contribute to the victory of Futurism which has already been affirmed by Words-in-freedom, plastic Dynamism, Music without quadrature and the Art of noises, and for which we fight without respite against traditionalist cowardice.

Antonio Sant'Elia, Architect

Milan, 11th July, 1914

Originally published in Lacerba in July 1914

Appendix G –Comments by Eero Saarinen about Washington Dulles International Terminal Building

On the occasion of Eero Saarinen's last visit to the airport site before his death:

"I think this terminal building is the best thing I have done. I think it is going to be really good. Maybe it will even explain what I believe about architecture"

On the origins of the Mobile Lounge concept:

"As an airport, the Washington International Airport is unique in many ways. It is unique in one way, because it is the first commercial airport really to be planned from the start for jet airplanes."

"No-one asked us to grapple with the problem of a jet-age terminal beyond the question of pure architecture. But, I believe the architect has to assume that kind of responsibility. Therefore, together with the team of Ammann & Witney, engineers: Charles Landrum, airport consultant; and Burns & McDonnell, mechanical engineers, we decided to make a fundamental analysis of the whole problem of a large terminal for jet airplanes. It was a hard-boiled problem and we wanted to solve it in a hard-boiled way."

"We sent out teams with counters and stopwatches to see what people really do at airports, how far they walk, and their interchange problems. We analysed special problems of jets, examined schedules, peak loads, effects of weather. We studied baggage handling, economics, methods of operations, and so on. We reduced this vast data to a series of about forty charts."

"We found there were three very critical areas. One was the time and inconvenience of getting people to and from planes. We discovered the already tremendous distances passengers walk through terminals and the 'fingers' extending from them would become as nothing compared to the distances they would have to walk in jet terminals. Another critical area was the heavy cost of taxiing jet planes. A third consideration was the increasing need for the greatest possible flexibility in operations and servicing of aircraft."

"We became convinced that some new method of passenger handling had to be found. The soundest system seemed to be one that brought the passenger to the plane rather than the plane to the passenger. We discarded the European bus system because it has inconveniences, and did not want to take a negative step. Gradually, we arrived at the concept of the Mobile Lounge: a departure lounge on stilts and wheels, a part of the terminal which detaches itself from the building and travels out to wherever the plane is conveniently parked or serviced."

"As we investigated further, we became convinced the Mobile Lounge was a logical solution to the critical problem. We were aware that like a prototype vehicle, it wold be expensive and might have 'bugs'. But we believed it a sound system. We think we have made a real contribution. The Mobile Lounge will have a large application. It can be used in new terminals and it has obvious advantage for the economic, efficient expansion of existing ones."

On the design of the Dulles Terminal Building:

"The airport is unique in other ways, too. It is unique in being the national and international gateway to the nation's capital. It is unique in its ownership – The Federal Government. It is unique in being a part of the whole complex of buildings that create the image of our nation's capital. We felt the terminal should express all that in its architectural design."

"The tradition of Federal architecture is static, but a jet airport should essentially be non-static, expressing the movement and excitement of travel. We thought that if we could bring these two things together into a unified design we would have a very interesting building."

"There was also the problem of the site- a beautiful flat plain. In a way architecture is really placing something between earth and sky. We came to the conclusion that a strong form that seemed to both rise from the plain and to hover over it would look best. The horizontal element, or roof would be the highest element. It should be tilted forward so the building would be seen. The terminal should also have a monumental scale in this landscape and in the vastness of this huge airfield."

"The acceptance of the Mobile Lounge concept allowed us to make the terminal a single, compact building. We started with abstract, ideal shapes for the site and went through many forms – forms that might work aesthetically and functionally. Gradually, we arrived at the idea of a curved roof, high in the front, lower in the middle, slightly higher at the back."

"This roof is supported by a row of columns forty feet apart on each side of the concourse, sixty-five feet high on the approach side, forty feet high on the field side. It is like a huge, continuous hammock suspended between concrete trees. It is made of light suspension-bridge cables between which the concrete panels of the roof deck fit. The concrete piers are sloped outward to counteract the pull of the cables. But we exaggerated and dramatised this outward slope as well as the wide compressive flange at the rear of the columns to give the colonnade a dynamic and soaring look as well as a stately and dignified one."

"But how should this strong, hovering form be placed on the site? How should it be seen from the plain? How should it look a one approached and arrived? The closer you come to some buildings, the less you see. On a functional basis, we had carefully worked out approach ramps on three levels. Aesthetically, we realised we could make these ramps into a base for the terminal. Seen from a distance, as one drove down the access road and around the sunken parking lot, the building would seem to rise from this base and assert itself as a hovering form between earth and sky. Approaching closer and arriving, one would see the large colonnade. The control tower (whose form was arrived at after much study) was finally placed at the back of the terminal where it be seen in changing and good relationships to the terminal from the access and approach roads."

On the Dulles terminal interior, landscaping and zoning:

"We saw many other problems here as part of the architect's responsibility. There was the problem honky-tonk, Klondike of the interiors. We felt these should convey the same special and distinctive character we tried to give the architecture itself. Instead of the honky tonk, Klondike-like chaos of commercial space in most airports, all the interiors and commercial

space should be thoughtfully organised to be dignified and attractive. Inside and outside should be all one thing."

"There was the problem of long-term landscaping, which was worked out with Dan Kiley. There was the crucial problem of disciplined, long-term and imaginative zoning. Of special importance was the problem of some kind of continuing control in the terminal and its surroundings. We made proposals about these things which I hope will be carried out."

On how Saarinen evaluated the Terminal

"I don't think the terminal should be evaluated just as a work of art. I think we faced this job as an architect's problem in total relation to the present world. We tried to give a completely logical, imaginative, and responsible answer to the problem. I hope as such we have done a good job."

(Federal Aviation Administration, 1962)

Two global urban scenarios are rapidly unfolding. The first of these is the explosive growth of cities: by 2030 more than five billion of the planet's predicted eight billion inhabitants are expected to be living in cities. The second is the shift of balance of growth from the so-called 'developed' to developing' countries.
As an example of what this global shift means in comparative terms, in 1939 London was the highest populated city in the world. Ten years later it still shared the big-league with cities such as Paris, Milan and Moscow. However, at the turn of the new century a demographic map of the world reveals how the European cities have receded into a mini-league, while the concentrations of population elsewhere have enlarged and proliferated. This is particularly true on the Asian Pacific Rim.

One of the implications of this shift is migration around the globe on a very large scale. Airbus, for example, anticipates that by 2010 only twenty per cent of air travellers will be business passengers. A key indicator in this respect is the accelerated rate of investment in infrastructure in the Pacific Rim, particularly in airports, which are being built on a hitherto unparalleled scale. A further shift can be discerned in the nature of such infrastructure projects. The edges between infrastructure and architecture are becoming more blurred. We can see this in structures concerned with information transmission — communication towers and platforms, for example. But we can also see it in structures for physical communication, such as the airport. Is the airport infrastructure or is it architecture? Or is it perhaps inhabited infrastructure? As these edges become less finite, the distinctions between the role of the architect, the engineer, and the other professions become similarly blurred. New infrastructure projects are typically becoming more publicly accessible, more multifunctional, less unidirectional. Together these trends have the potential to create a new kind of airport building.

The first generation of airports — such as Hong Kong's Kai Tak, Berlin's Tempelhof, or Le Bourget in Paris — were located close to the city centre. The combination of an earlier age of smaller aircraft and a predominantly low-rise building infrastructure was compatible with an embedded urban airport. However, the pattern with these and similar early developments is that the city, as it expanded, finally engulfed them. Kai Tak probably stretched this model to its logistical and technical limit. The dramatic approach path into the airport memorably wove in between the tower blocks that had grown up around it, giving rise to an 'urban myth' about Jumbo Jets landing with washing hanging from their wings, plucked from the balconies of nearby flats. In London, the entrepreneurial vision that generated Heathrow's original Terminal One in the mid-1950s, and set the pattern for the first generation of large airports around the world, echoed the pioneering spirit of the London Underground in the 1930s. However, that impetus has been lost in the capital, and transportation projects habitually founder in the wake of an overdeveloped and stultifying bureaucracy. London Heathrow, in terms of international passenger movements, is currently the world's largest airport, with some 40 million visitors per annum. It has evolved over the last 50 years from a military airfield and a cluster of canvas tents nestling amongst market gardens, into four major terminals on a site covering 1100 hectares. In European terms this rate of growth might be considered rapid, but in terms of contemporary Asia it is closer to a snail's pace.

Compare Heathrow with the pattern of Hong Kong's Chek Lap Kok, or Shanghai's Pudong. In one tenth of the time that it has taken London's airport to grow, Hong Kong has overtaken it by realising even more capacity in a single massive building. By 2040, the airport's planned passenger capacity, at 87 million passengers and 375,000 aircraft movements per annum, will be the equivalent of Heathrow and New York's JFK airports combined.
In 1972 the British Airport Authority had the opportunity to anticipate the huge demands that would eventually be placed on Heathrow, and the transport infrastructure that serves it, and make a bold leap into the future. They almost did it. They identified a site at Foulness, in the Thames Estuary, to the east of London. Foulness, a former army artillery range, offered almost unlimited space - 50 square miles - on which to build a brand new airport, far from the restrictions of the city. It was the opportunity to scoop up all of the facilities then existing at Heathrow, together with those that would eventually be provided by the 'second' London airport at Gatwick and what was to become - after 40 years of negotiation and public inquiries - the 'third' London airport at Stansted. Foulness would have been to London as Chek Lap Kok is to Hong Kong, and involved similar travel distances. But the opportunity was lost. Construction began in 1973 and was abandoned in the face of entrenched opposition in 1974.

The Asian experience is very different. In Hong Kong, when the time came to select the site for a new airport there was no available land. The site itself had to be created. But far from being an obstacle to development, it became instead the catalyst for the largest construction project of modern times. In 1992, Chek Lap Kok was a compact mountain island rising out of the sea off the South China coast. In an ambitious reclamation programme that involved moving 200 million cubic metres of rock, mud and sand, the island's 100-metre-high peak was reduced to a flat seven metres above sea level and expanded to four times its original size. At 6 kilometres long and 3.5 kilometres wide, it is as large as the Kowloon peninsula.

From Chek Lap Kok, new road and rail links cross a causeway to Lantau to the south, and continue across two new bridges, including the typhoon-resistant Tsing Ma Bridge - the longest combined road and railway suspension bridge in the world - to reach Hong Kong itself. Thanks to the new railway line, three-lane highway, and Western Tunnel to Hong Kong Island, the entire journey between city and airport can be completed in approximately twenty minutes. In Hong Kong brand new physical infrastructure is already in place to support the airport's expansion over the next 50 years. Central London, meanwhile, has only belatedly begun to enjoy dedicated transport links to Heathrow. But even the Heathrow Express has to share ageing Intercity and suburban rail track, and the airport's planned expansion, in the form of Terminal Five, is mired (perhaps indefinitely) in an official inquiry. As London contemplates the nostalgia of its past and trades on a physical infrastructure largely inherited from the age of the horse and cart - long before the onslaught of the car - Hong Kong, which is already less than four hours' flying time from half of the world's population, plans strategically for the reality of global expansion and major shifts of population.

In this new world view, airports are the symbolic gateways to a city. In the past these might have been the portals in the castle walls, the harbour quayside or the train terminus. The need to create imposing and symbolically important structures to celebrate these points of arrival and departure would seem to be a constant over time, from antiquity to the present. In the newest generation of airports the gateway has to be pushed well beyond the city limits and linked with an umbilical cord of rapid transit. The more remote location not only protects the environment of the core of higher density cities, but creates the opportunity for the airport to expand as a destination in its own right. The rapid transit system can be suppressed below ground and emerge into the heart of a city. Our expansion of the Kowloon Station to accommodate some 80 million passenger movements a year to and from China is also a gateway to Hong Kong and part of the wider network of ground transportation supporting the airport.

During this shift from centralisation to decentralisation in airport design we have witnessed a passing phase in which individual airlines have commanded their own customised terminals. But the almost universal model of an airport in the Western world is one of incremental, ad-hoc growth.

Heathrow remains London’s principal airport. And although facilities at Gatwick and Stansted are growing, Heathrow is still expected to expand on its original site by adding yet more terminal buildings.

I can recall the previous head of the British Airport Authority, Sir Norman Payne, reflecting on nearly twenty years’ experience of London’s airports by saying that not once had any of the terminal buildings expanded in the way that their designers had planned. All their predictions had proved to be obsolete, rapidly overtaken by events. At Heathrow the end result is a non-finite architecture of individual structures, each in a state of continuous change and growth, with new ones being squeezed in wherever possible; the only limiting factors in this cycle being land and runway capacity. As a result, Heathrow is closer to the ‘concrete jungle’ of a 1960s’ new town than to the planned development of Chek Lap Kok or Osaka’s Kansai.

Perhaps the same tendencies will eventually overtake the thrusting Asian economies. Meanwhile the architectural rules are being rewritten by the sheer scale of these single-large-volume buildings, which have evolved from a combination of political will and the appetite to invest in a fresh start. At this size they pose unprecedented challenges and opportunities.

I can trace the lineage of our projects for the airports of Hong Kong, Shanghai and Bangkok back to our design for Stansted, which we began in 1981. But they are not simply bigger versions of the same concept: they are transformed by their mega-scale.
They are also rooted in the thirteen-year collaboration we enjoyed with Buckminster Fuller

before his death, in 1983, which influenced our projects during that time and beyond. This is true not only of those projects that were recognisably geodesic in form, such as the Knoxville Energy Expo and the Climatroffice, but also of the deep-plan office projects, such as the Willis Faber & Dumas Headquarters in Ipswich. Aside from an intrinsic concern for the relationship of mass and volume to the building's energy equation, Bucky's influence liberated our attitudes to scale, size and repetition.

The Climatroffice project, dating from 1971, points to a direction where the architecture is determined by a world of 'interiorised' buildings, which live within an envelope so diaphanous that its presence is perceived as being closer to the sky or clouds than to any conventional structure. The form of this minimal envelope is a manipulation of Bucky's optimum sphere, which can envelop the maximum volume within the minimum surface area. It is the sheer scale of the single volume membrane that reverses the traditional hierarchies. The mechanisms for creating order, orientation and routes through the interior space are independent of the enclosure, which from inside and out is anonymous and without scale, except for that of its surroundings which are reflected on its skin. The vast new airport terminals have some characteristics in common with these Fuller-influenced visions. The form of an airport terminal is of necessity extruded to provide linear frontage and although the exteriors are closer to a traditional building, the interior is increasingly determined by an architecture of individual buildings housed beneath the protective umbrella of a vast lightweight roof. This is an approach that we pioneered with the design of Stansted, which has subsequently become a model for airport terminals worldwide.

When we planned Stansted, we questioned, at the most fundamental level, the nature of a terminal building. Before Stansted, every large terminal essentially followed the same model: the structure would carry huge amounts of ductwork at roof and ceiling level to move large volumes of conditioned air; and there would be a reliance on artificial lighting, which generated a great deal of heat, and in turn required more cooling, with increasingly large ducts and more and more refrigeration plant. Furthermore, all that equipment had to be supported at roof level, and so the structure had to be enormous. The whole arrangement was incredibly wasteful of energy and other resources.

Stansted represents a departure point, one that was achieved by demonstrating that the old order of the 'serviced shed' could literally be turned on its head. At Stansted, the heavy engineering of mechanical plant rooms, metal ducts and supporting structure that made up the traditional roof are all relocated in an undercroft below the concourse level.
The undercroft is really the engine room of the building. It contains all the baggage-handling and environmental engineering plant and runs beneath the entire floor of the concourse, where it can easily be accessed via a service road. The heating, ventilating, air-conditioning and artificial lighting distribution systems that would in the old days have run through the roof space are all contained within the 'trunks' of the buildings tree-like structural columns as they rise up through the floor. The result is a lightweight membrane roof, which is freed simply to let in natural light and keep out the weather.

Flexibility for change is a vital consideration in such a volatile and expanding industry. This is another reason for the services undercroft. It is analogous to the void beneath a highly serviced office floor, which enables you to reconfigure the cabling to suit different layouts and changing technology. The headquarters building we designed for Willis Faber & Dumas, in Ipswich, in the early 1970s, was the first in Britain to be equipped with a raised 'aircraft floor'. Before Willis Faber it was only computer rooms that had a void below the floor for cabling; and Willis Faber is the only British insurance company not to have been forced to move into a new building in the 1980s in order to accommodate new communications technology.

The difference between these two examples is simply one of scale. Instead of cables, in the services undercroft one is presented with the possibility of moving or replacing the hardware of baggage handling systems, electrical generators and heating and ventilating plant. As an example of how far this principle can be stretched, at Stansted it was possible to insert a mainline railway station in the undercroft (for a direct link to the city) without disruption, even after the building had started on site.

A terminal building is in some ways also analogous to the aircraft it serves. The investment in a modern aircraft is so great that prolonged downtime for maintenance or upgrading is simply unaffordable. This has design implications. The engines, for example, have a relatively short design life when compared with the airframe, and will be replaced many times in the lifetime of an airliner. So in a modern aircraft, such as a Boeing 747, they are located in separate pods under the wing for ease of access and maintenance. This is in contrast to an earlier generation of aircraft, such as the Comet, where the engines were embedded into the airframe itself making them very difficult to access.

The modern terminal is locked into a complex international network of flights and connections and is even more sensitive to downtime. It is a 365-days-a-year, 24-hours-a-day operation. The roof of the old style terminal with its short-life elements such as mechanical equipment and light tubes sandwiched between structure and suspended ceiling was a maintenance nightmare. It was also a serious safety hazard, as the tragic fire at Dusseldorf airport, in April 1996, demonstrated. In that instance, a fire began in a flower kiosk and spread rapidly through the ceiling void of the arrivals hall, quickly engulfing the terminal. The advent of the undercroft solves all these problems.

There is no doubt that the quality of light and views in a terminal building contribute towards making it more friendly and spiritually uplifting. Added to that, this arrangement also uses much less energy, which is good news both for the environmentalists and the accountants.

At Stansted's natural light floods into the concourse through the glazed perimeter and apertures in the roof vaults. Suspended beneath the vaults are daylight reflectors, which shield the apertures and bounce light upwards onto the ceiling so that it is reflected indirectly at floor level. There is no 'black hole' effect at night. At dusk, as outside lighting levels diminish, artificial lighting hidden at the base of the 'trees' is projected onto the underside of the reflector so that the whole surface glows.

The principle of a single lightweight roof flowing freely over a multitude of different activities makes a quantum leap in the new generation of airports that we have designed for Hong Kong, Shanghai and Bangkok.

The essence of these new large terminals, following the Stansted pattern, is a single roof, flowing freely over a fertile ground plane, on which fully-serviced instant buildings can grow within a tempered climate of unbroken space. The possibilities opened up by this evolutionary response to the realities of mass air travel can be grasped as a civic opportunity, or merely exploited for their commercial potential. In the tradition of the great nineteenth-century railway stations these new terminals are the noble halls of our age, evoking a sense of occasion and bringing a new thrill to air travel.

For many people, however, air travel has become a stressful and confusing experience. In recognition of that fact, the terminal buildings at Stansted and Chek Lap Kok, are designed to make the traveller's experience as calm and pleasant as possible. Knowing that one can find one's way contributes greatly to this sense of wellbeing. The guiding principle was to ensure that the concourse would be a clear logical zone, and that movement through the building, from landside to airside, or vice-versa, would be as far as possible in a straight line, and at a constant level.

At Stansted, for example, you proceed in one fluid movement from the set-down point, to the check-in area, security and immigration controls to the departure lounges, from where you can see the planes standing on the tarmac. From there you are taken via an automatic tracked transit system to the pavilion-like satellite buildings from where you board your aircraft.

In the process you experience two architectural orders. The primary order is the lattice-shelled roof, which is supported on the outstretched branches of the 'trees'. The smaller, secondary, order is the flexible system of free-standing enclosures such as shops, banks, and bars which inhabit the space. There are none of the infuriating changes of direction and level that disfigure most major airports.

In Hong Kong, the airport's natural setting is spectacular. To the south is the backdrop of the Landau Mountains, while to the north, across the water, are the New Territories, also with mountains in the distance. Wherever passengers are within the building, they can enjoy unimpeded views out. The glass sides of the terminal are purposely left clear up to a minimum height of four metres, and clutter throughout is eliminated so that sight-lines are never blocked. The design accentuates natural orientation far beyond the airport itself: you can see the land, the water, and glimpses of the road and rail bridges in the distance, from the terminal; and you can see the aircraft. You know whether your plane is waiting on the 'land side' or the 'water side' and can orient yourself accordingly. This elemental approach, quite different from the claustrophobic boxes and tunnels that characterise so many airports, brings a sense of pleasure and drama back to flying.

The lessons of Stansted and Chek Lap Kok are that unimpeded views of the airside and landside, together with the natural order provided by a clear structure, can dramatically reduce the need for complicated signage systems or colour codes. In that sense they are 'analog' rather than 'digital' buildings, in so far as, like a traditional watch-face one can read them instinctively at a glance: there is no awkward conversion process from sign to route. Instead of a seemingly life-threatening maze the experience can be friendly, direct and reassuring. Of course, the ultimate clarity of direct movement will always be modified by the inevitable barriers of customs, immigration, security and degree of retailing. But these buildings are still very much open in spirit.

It is difficult to comprehend the scale of these buildings. Hong Kong's new terminal is so large that like the Great Wall of China - its distinctive Y-shaped plan-form is clearly visible on satellite photographs. At 1.27 km long, and with an area of 516,000 square metres, the terminal building is the largest enclosed public space ever made. Its roof covers 18-hectares - approximately the same area as London's Soho district. Within that, the baggage hall is large enough to contain five Boeing 747s wing tip to wing tip; you could drop Wembley or Yankee stadiums into it and still have room to spare. And the terminal's plant room alone, at 62,000 square metres, is large enough to contain Stansted's concourse twice over.
But although Chek Lap Kok is a huge building, in reality it can be thought of as quite compact, because it covers a very small footprint compared with the equivalent four terminals at Heathrow, while providing about 48 per cent extra space.

Nonetheless, the logistics behind the management of design and construction at this scale are awesome. To give just a few examples: the detailed design of the superstructure, including the roof, generated a print run of 125,000 drawings — in excess of 100,000 square metres of paper; at the peak of construction, there was a workforce of 21,000 on site; and the sheer size of this temporary community, and its isolation from the mainland, led to the creation of a 'smart card' cash-less society, based in a sizeable settlement of instant short-life hotels, offices and restaurants which sprang up on the island.

It is rare to encompass such extremes of scale and diversity in a single project. Moreover, all this was achieved at staggering speed. A total design that coordinated all the details of the airport's functioning, from aircraft parking to air conditioning, from security to shopping, was completed in just 21 months. Then, despite its heroic scale, and the fact that all building supplies had to be ferried to the island by boat, the building's superstructure took only 36 months to complete.

But perhaps the ultimate example of thinking big in Asian terms is the move from the old airport to the new. For a time they ran the two in parallel, while they tested the new airport's technical systems. Once they were satisfied, they changed from one to the other overnight. The whole operation was achieved within six hours. The logistics of that, in terms of moving people and equipment, are truly staggering.

The airport on this new scale assumes many of the properties of an urban settlement, which raises further questions of social responsibilities. Are the prime public spaces the equivalent of a city's main square? Are they to be protected, or squandered like so many places that become saturated with billboards and retailing? Should this inside world be subject to controls and restrictions similar to those that have evolved to cope with urbanisation in the world outside? Or is the terminal to be regarded as a cross between a department store and a theme park? Will the fake, half-timbered ‘ye olde pub’ that unfortunately graces one London airport ultimately find its equivalent inside an Asian terminal: perhaps a Chinese restaurant in the guise of a plastic junk afloat in space?

Significantly, the British Airports Authority presently makes as much money from retailing as it does from its airport business. Gatwick, for example, attracts half a million visitors a year: many more than go there to take a plane. These are not people going to meet somebody, or to say goodbye – they are just going to the airport to shop. Together, the BAA terminals contain more than 60, 000 square metres of retail space. Equally significantly, Chek Lap Kok’s shopping centre — which covers an area the size of the original airport at Kai Tak — is the only one in Hong Kong with one hundred per cent occupancy.

Does the terminal in this scenario finally become a market with airline travel as a by-product: a shopping mall which feeds off the captive audiences that follow the new trade routes of industry and leisure? Is it an incentive to proliferate the retail maze to bolster the airport’s profits? And, as hotels and the leisure industry investigate the potential of these new catchment areas, does the airport evolve into a settlement in its own right to attract people who are not even thinking about flying somewhere?

As cities grow and airports respond to the new centres of population it is worth sounding a cautionary note by recalling how one writer commented on the occasion of the fiftieth anniversary of London’s Heathrow: ‘Every human settlement is an organism. But this one, fuelled by the virtually unconstrained power of the market, is a monster out of science fiction, swallowing land and hamlets, continuously recreating itself, permanently ravenous. It can never get enough: enough land, money, noise, dirt, adrenaline, electricity, organisations, car parks, retail outlets, hotels, people. In this respect it is the image of us, and of our civilisation.’

Norman Foster
1996

Appendix I – Glossary of Terms

ACI – Airports Council International

AOA – Airport Owners Association

ASKs - Available Seat Kilometres

ATB – Automated Ticketing and Boarding Pass

ATET – Around the End Taxiway (UK)

ATM – Air Transport Movement (usually measured both hourly and annually)

BAA – British Airports Authority (UK)

CAA – Civil Aviation Authority (UK)

CUSS – Common User Self-Service Check-In

CUTE – Common User of Terminal Equipment (Check-In)

EASA – European Aviation Safety Agency

EAT – End Around Taxiway (US)

FAA – Federal Aviation Administration (US)

IANC – International Air Navigation Convention 1919 (predecessor to ICAO & sets up ICAN)

IATA – International Air Transport Association (Airline Organisation)

ICAN – International Commission for Air Navigation (Amends IANC & issues bulletins)

ICAO – International Civil Aviation Organisation (United Nations Organisation

KMs - Kilometres

LCC – Low Cost Carrier

MCT – Minimum Connection Time

MPPA Million Passengers per Annum

PAX – Passengers

PLF - Passenger Load Factor (RPK expressed as a percentage of ASK).

RPKs – Revenue Passenger Kilometres

RTKs - Revenue Tonne Kilometres

VFR – Visiting Friends and Relations

Appendix J – Selected Airport Film Strips and Video Clips

Wright Brothers first flights	https://youtu.be/CSIPgdgiecw
Wright Brothers at Huffman Prairie	https://youtu.be/MysW0vRwO08
La Grande Semaine d'Aviation 1909	https://youtu.be/pHSgXtPAZec
Top 15 largest airports in the world	https://youtu.be/5DWj5Jokykw
Amsterdam Schiphol 1916-2016	https://youtu.be/6Xvj_5JG1Oc
Atlanta Hartsfield 2016	https://youtu.be/7k0vNqLzah0
Beijing Daxing 2019	https://youtu.be/gBmr4pvivjs
Berlin Johannisthal 1909	https://youtu.be/LU3YJuckqtg
Berlin Tempelhof 1930s	https://youtu.be/qjWU5lEub9Y
Berlin Tempelhof 1938	https://youtu.be/PyIXixXwies
Berlin Tempelhof Airshow	https://youtu.be/cjY9T-ooD5Y
Berlin Airlift	https://youtu.be/rPty2ScofmY
Berlin Tempelhof –Then and Now	https://youtu.be/QsPcHHqxc5Y
Berlin Tempelhof Historic Berlin	https://youtu.be/-sXrkQA6KkQ
Chicago Midway & O'Hare	https://youtu.be/PUmi2I5YsWg
Croydon Airport 1924 -	https://www.youtube.com/watch?v=-VE4ukEHuKo
Croydon Airport terminal opening 1928	https://youtu.be/ugEBGY1nQn4
Croydon Airport 1938 -	https://www.youtube.com/watch?v=MPfL7Lb2Ms8
Gatwick Airport 1936 -	https://www.youtube.com/watch?v=SFMPBIHpaR0
Gatwick Airport 1958 -	https://youtu.be/y19Sxbp_fYo
Gatwick through the ages -	https://youtu.be/vXok56cZc9I
Heathrow Airport 1949	https://youtu.be/8qnuutCjoAk
Heathrow `Airport 1955	https://youtu.be/PsTS4gjVtrc
Heathrow History 1946 - 2014	https://youtu.be/j1iOr2oDEP0
Heathrow Runway 3 2019	https://youtu.be/_At_8ZfqSLo
Hong Kong Chek Lap Kok	https://youtu.be/MVC5BiQXk7A
Hong Kong Masterplan 2030	https://youtu.be/N7APHRsUUpk
Istanbul Grand 2019	https://youtu.be/yfwsjeV6uXQ

New York, La Guardia 1940	https://youtu.be/Qyr3j_Lp5Fs
New York JFK Pan Am 1960	https://youtu.be/qIgxQn6qBXw
Paris, Charles de Gaulle, 2017	https://youtu.be/tVcPd-_rhXw
Paris, Le Bourget 1938	https://youtu.be/2CaX56YBHxY
Oakland, California 1928	https://youtu.be/BzVU3EcKdUI
San Francisco, SFO	https://youtu.be/Ml5_B-KwfOw
Seoul, Incheon 2019	https://youtu.be/6rdTHm7_J6s
Washington Dulles 1962 -	https://youtu.be/FL-mjc1sgX4
Washington Friendship	https://youtu.be/r0itl49Dmw0

Appendix K - World Airline Traffic Growth 1929-2018

Traffic and operations data below reflects the system wide scheduled activity of passenger and cargo airlines operating worldwide, as recorded by ICAO; domestic operations within the former USSR are excluded prior to 1970.

Traffic and Operations: 1929-Present

Year	Aircraft Departures (000)	Aircraft KMs (mils)	Passengers (mils)	RPKs (mils)	ASKs (mils)	PLF	Freight Tonnes (mils)	Cargo RTKs (mils)
1929		90		170				
1930		120		270				
1931		135		330				
1932		140		405				
1933		155		545				
1934		160		650				
1935		200		920				
1936		230		1,225				
1937		265		1,410				
1938		300		1,685				
1939		295		2,030				
1940		300		2,530				
1941		340		3,280				
1942		320		3,580				
1943		325		4,265				
1944		415		5,490				
1945		600	9	8,000				240
1946		940	18	16,000				220
1947		1,140	21	19,000				400
1948		1,270	24	21,000				590
1949		1,350	27	24,000				760
1950		1,440	31	28,000	46,000	60.9%		930
1951		1,620	42	35,000	55,000	63.6%		1,100
1952		1,780	46	40,000	64,000	62.5%		1,200
1953		1,950	53	47,000	75,000	62.7%		1,270
1954		2,060	59	52,000	86,000	60.5%		1,370
1955		2,290	68	61,000	99,000	61.6%		1,610
1956		2,540	77	71,000	114,000	62.3%		1,800
1957		2,840	86	82,000	133,000	61.7%		1,960
1958		2,930	88	85,000	146,000	58.2%		2,040
1959		3,090	98	98,000	162,000	60.5%		2,350
1960	6,600	3,110	106	109,000	184,000	59.2%		2,650
1961	6,600	3,120	111	117,000	212,000	55.2%		3,080
1962	6,600	3,240	121	130,000	243,000	53.5%		3,580
1963	6,700	3,430	135	147,000	274,000	53.6%		3,970
1964	7,100	3,700	155	171,000	306,000	55.9%		4,670
1965	7,500	4,100	177	198,000	354,000	55.9%		5,900
1966	7,800	4,480	200	229,000	397,000	57.7%		7,230
1967	8,600	5,280	233	273,000	479,000	57.0%		8,420
1968	9,074	5,993	260	309,422	578,885	53.5%		10,503
1969	9,473	6,704	293	350,899	674,973	52.0%	4.0	12,286
1970	9,486	7,004	383	460,481	839,930	54.8%	6.1	15,087
1971	9,546	7,054	411	494,137	914,070	54.1%	6.7	16,125
1972	9,646	7,209	450	560,078	980,766	57.1%	7.3	17,801
1973	9,889	7,520	489	618,184	1,072,599	57.6%	8.2	20,408
1974	9,613	7,375	514	656,426	1,107,532	59.3%	8.7	21,900
1975	9,683	7,516	534	697,285	1,178,880	59.1%	8.7	22,270
1976	9,986	7,840	576	763,762	1,269,815	60.1%	9.3	24,571
1977	10,118	8,089	610	818,300	1,346,260	60.8%	10.0	26,805
1978	10,379	8,498	679	936,352	1,451,184	64.5%	10.6	29,205
1979	10,666	9,147	754	1,060,236	1,607,188	66.0%	11.0	31,436
1980	10,691	9,350	748	1,089,128	1,723,903	63.2%	11.1	33,057
1981	10,250	9,113	752	1,119,066	1,756,539	63.7%	10.9	34,675
1982	10,379	9,140	766	1,142,193	1,794,646	63.6%	11.6	35,413
1983	10,820	9,395	798	1,189,767	1,852,088	64.2%	12.3	39,112
1984	11,453	10,102	848	1,278,176	1,972,296	64.8%	13.4	43,978
1985	11,952	10,598	899	1,367,347	2,081,018	65.7%	13.7	44,236
1986	12,698	11,491	960	1,452,055	2,234,730	65.0%	14.7	47,735
1987	13,306	12,266	1,028	1,589,467	2,367,532	67.1%	16.1	53,021
1988	13,942	13,017	1,082	1,705,432	2,524,094	67.6%	17.2	58,099
1989	13,945	13,493	1,109	1,773,703	2,608,046	68.0%	18.1	62,202
1990	14,661	14,371	1,165	1,894,245	2,800,844	67.6%	18.4	64,121
1991	14,269	14,262	1,135	1,845,418	2,779,494	66.4%	17.5	63,630
1992	14,819	15,690	1,146	1,928,922	2,930,185	65.8%	17.6	67,761
1993	15,777	17,118	1,142	1,949,421	3,013,411	64.7%	18.1	73,671
1994	17,038	18,249	1,233	2,099,936	3,169,342	66.3%	20.5	82,626
1995	17,816	19,470	1,304	2,248,215	3,358,601	66.9%	22.2	88,765
1996	18,758	20,601	1,391	2,431,695	3,563,774	68.2%	23.2	94,996
1997	19,320	21,630	1,457	2,573,010	3,727,900	69.0%	26.4	108,870
1998	19,686	22,438	1,471	2,628,116	3,837,725	68.5%	26.5	107,575
1999	20,739	23,742	1,562	2,797,803	4,050,783	69.1%	28.1	114,373
2000	24,143	25,982	1,774	3,201,366	4,504,515	71.1%	29.6	133,572
2001	24,234	26,157	1,741	3,108,527	4,489,445	69.2%	28.1	124,942
2002	23,095	25,507	1,739	3,124,069	4,379,359	71.3%	30.6	134,059
2003	23,817	26,560	1,795	3,180,302	4,443,204	71.6%	32.6	140,373
2004	26,781	30,122	2,003	3,628,725	4,944,363	73.4%	35.8	154,838
2005	28,077	31,857	2,145	3,919,023	5,229,355	74.9%	36.7	158,674
2006	28,776	33,179	2,263	4,170,556	5,500,959	75.8%	39.0	169,365
2007	29,869	34,935	2,462	4,513,096	5,876,065	76.8%	41.4	177,261
2008	29,989	35,769	2,500	4,608,466	6,062,667	76.0%	39.9	176,052
2009	29,372	34,894	2,488	4,561,413	5,948,503	76.7%	40.0	160,439
2010	30,754	38,395	2,705	4,924,229	6,299,370	78.2%	47.6	191,486
2011	31,768	40,471	2,870	5,248,140	6,727,814	78.0%	48.7	192,196
2012	32,193	41,485	3,004	5,528,880	7,010,807	78.9%	48.0	190,433
2013	32,583	42,772	3,138	5,832,564	7,338,216	79.5%	49.1	191,562
2014	33,273	44,494	3,316	6,181,177	7,753,755	79.7%	50.7	200,709
2015	34,193	46,739	3,556	6,644,666	8,281,130	80.2%	51.0	203,680
2016	35,515	49,240	3,794	7,135,773	8,887,995	80.3%	52.8	210,868
2017	36,543	51,832	4,062	7,707,118	9,477,045	81.3%	56.6	230,445
2018	37,823	54,279	4,322	8,257,635	10,105,144	81.7%	58.0	238,361

Source: Airlines of America - airlines.org/dataset/world-airlines-traffic-and-capacity

Appendix L – Benchmarking of Runway Configuration Capacities

Runway Configuration										
IATA ADRM 8	44	60	80 - 88							
IATA ADRM 9	55	84	105	84+55=139	84x2 = 168	168+50=218	84x3=252	50x3 =150	50x4 =200	168 + 100 =268
IATA ADRM 10	55		90		117			110		
ICAO	50 - 59	56 - 60	99 -119	106-119	112 - 120	162- 179	168 - 180	150 - 177	200 - 236	211 - 239
FAA	50	60	99	50+60=110	120	120+50=170	60x3=180	150	200	219
DfT - SERAS	48	70	95	118	140			130		
Proposed	**45 - 55**	**60 - 70**	**80 - 100**	**110 - 120**	**120 - 140**	**170 - 190**	**180 - 210**	**135 - 150**	**180 - 200**	**220 - 240**
Benchmarking										
Heathrow			88 (SEG)	R3						
Paris					117					
Munich			90							
Amsterdam								110		
Gatwick	52 (55)		R2 98							
Copenhagen		83*								
Manchester		61								
Dubai		62								
Hong Kong			68							
Singapore			72							
Bangkok			76							
Atlanta ATL						168A 191M				
Chicago ORD										238M
Charlotte CLT								147A 138M		
Dallas DFW						170A 170M				
Denver DEN										224A 243M*
Hollywood FLL			66A 99M							
John Wayne Or. Co.	43A 44M									
Los Angeles LAX					143A 133M					
Memphis MEM				134A 115M						
Minneapolis MSP								114A 143M		
Phoenix PHX				96A 114M						
Salt Lake City SLC*								114A 125M*		
San Diego SAN	48A 48M									
Seattle SEA				78A 79M						
Tampa TPA			95A 95M							

Figure L 1 Capacity of International Airports Runway configurations measured in ATMs per hour
Sources: IATA, ICAO, FAA and individual airports in 2016

Appendix M – Airport Case Studies

1. *Huffman Prairie 1904– First Airfield*
2. *Berlin Johannisthal 1919 – First scheduled service*
3. *Croydon 1920 & 1928 – Most publicised pre-war terminal*
4. *Konigsberg 1922 – First passenger terminal*
5. *Berlin Tempelhof (THF) 1928 & 1939- Busiest and largest pre-war international airport*
6. *Gatwick (LGW) 1936 &1958 – Prototype satellite and rail interchange*
7. *Le Bourget (LBG) 1919 and 1937 – Original dispersed terminal & first linear terminal*
8. *La Guardia (LGA) 1939 – Transition design with pier and level separation*
9. *Chicago O'Hare (ORD) 1948 – Mid field terminal, multiple finger piers, airbridges*
10. *St Louis Lambert (STL) 1956, Floating roof, cabin fit-out, pier, two level forecourt*
11. *New York Idlewild (JFK) 1962 – Airport city concept, spirit of flight at TWA terminal*
12. *Washington Dulles (IAD) 1962 – Jet Age planning, mid-field master plan*
13. *Los Angeles (LAX) 1962– Satellite and Theme Building*
14. *Dallas Fort Worth (DFW) 1973 – Linear/unit terminal, transfer infrastructure, hub,*
15. *Paris Charles de Gaulle (CDG) 1974 Circular Terminal & Satellites, Ph2 Linear Terminal*
16. *Atlanta (ATL) 1980 – Mid field satellite, toast rack master plan, transit, multi runway*
17. *Stansted (STN) 1991 - Floating roof, single passenger level terminal, satellite, transit*
18. *Kansai (KIX) 1994 – Long span roof, linear terminal, scale, artificial island, transit*
19. *Hong Kong (HKI) 1998 –Road/rail/sea/air Interchange, integrated roof, aerotropolis*
20. *Kuala Lumpur (KUL) 1999 – T1 Cruciform satellite & T2 LCC Transfer Terminal*
21. *Seoul Incheon (ICN) 2001 - Terminal with piers & satellite, Skytrax first place airport*
22. *Bangkok Suvarnabhumi (BKK) 2006 – Mid-field terminal, multiple piers without transit*
23. *Madrid Barajas (MAD) T4 2006 – Design for Domestic, Schengen & International traffic*
24. *London Heathrow (LHR) T5 2008 & T2 2014 – 1st and 5th placed Skytrax terminals*
25. *Dubai International (DXB) 2010– Underground terminal, premium differentiation*
26. *Beijing Capital (PEK) 2008 - Largest terminal to date, hybrid pier and satellite*
27. *Istanbul Grand (IST) 2019 – Transfer hub, multiple piers, aerotropolis,*
28. *Beijing Daxing (PKX) 2019 – Complex parametric form, multiple piers, aerotropolis*
29. *Mexico City (MEX) 2022 - Organic roof design using parametric modelling*
30. *Dubai World Central (DWC) 2025 - Largest terminal and transfer hub for 220mppa*

1. The Wright Field, Huffman Prairie, Dayton, Ohio 1904

The Wrights began using Huffman Prairie, which they described as a swampy meadow, in 1904 with the permission of the field's owner, Dayton banker Torrence Huffman. The Wrights made about 150 flights in 1904-1905 leading to the development of the Wright Flyer which they considered to be the first practical airplane.

The 'Wright Field' included two features that weren't to make it to later airports, the guide rail launch track and the catapult, both designed to overcome friction during launching. However, both concepts have been adopted by aircraft carriers. The drawing on the following page appeared in a 1940 publication "Airports" by John Walter Wood. It was derived from a sketch made by Orville Wright in 1935 (figure M.1.1).

It clearly shows the locations of the guide rails and associated catapults which were relocated as required to suit the prevailing wind. The plane sat at one end of a 160-195ft long wooden rail on top of a detachable wheeled trolley. Ropes and pulleys connected the trolley to a 1,200 - 1,400 pound weight which fell 16.5ft from a 20ft tall wooden derrick. With the plane's engines revving, the weight was dropped, propelling the aircraft down the ramp and into the air.

The drawing also shows a feature indicated with an H that was to become a standard feature of all subsequent airports, the aircraft hangar. The hangar measured 44ft x 16ft, and housed two Wright planes but only after the front elevators had been removed (figure M.1.2).

The Wright brothers kept immaculate records of their achievements which they submitted to the Aero Club of America on 12th March 1906. Key events included their first complete circle on September 30th 1904 in their Flyer ll (figure M.1.3), a flight which lasted 1minute, 36 seconds and covered 4,080ft. Later on October 5th 1905, Wilbur made a spectacular flight in Flyer lll in which he circled the field 30 times in 38 minutes 3 seconds for a total distance of 24.2 miles (38,956 metres) before landing after running out of fuel (figure M.1.4)

Between 1904 and 1914 a series of aviation firsts took place at the 'Wright Field'.

- first controlled turn
- first circle
- first controlled bank
- first figure of eight
- first permanent flying school

It is also claimed that the first cargo flight took place at Huffman Prairie as a Wright plane flew several bolts of cloth to Columbus, about 55 miles away as publicity for a retail shop. Later Huffman Prairie became the first flying school. The United States Army Signal Corps purchased the field in 1917 and renamed it, along with 2,000 adjacent acres, Wilbur Wright Field. Later it became a part of the Wright-Patterson Air Force Base (figure 11.1.4). The 1905 Wright Flyer lll is preserved and is on display at Carillion Historical Park, Dayton.

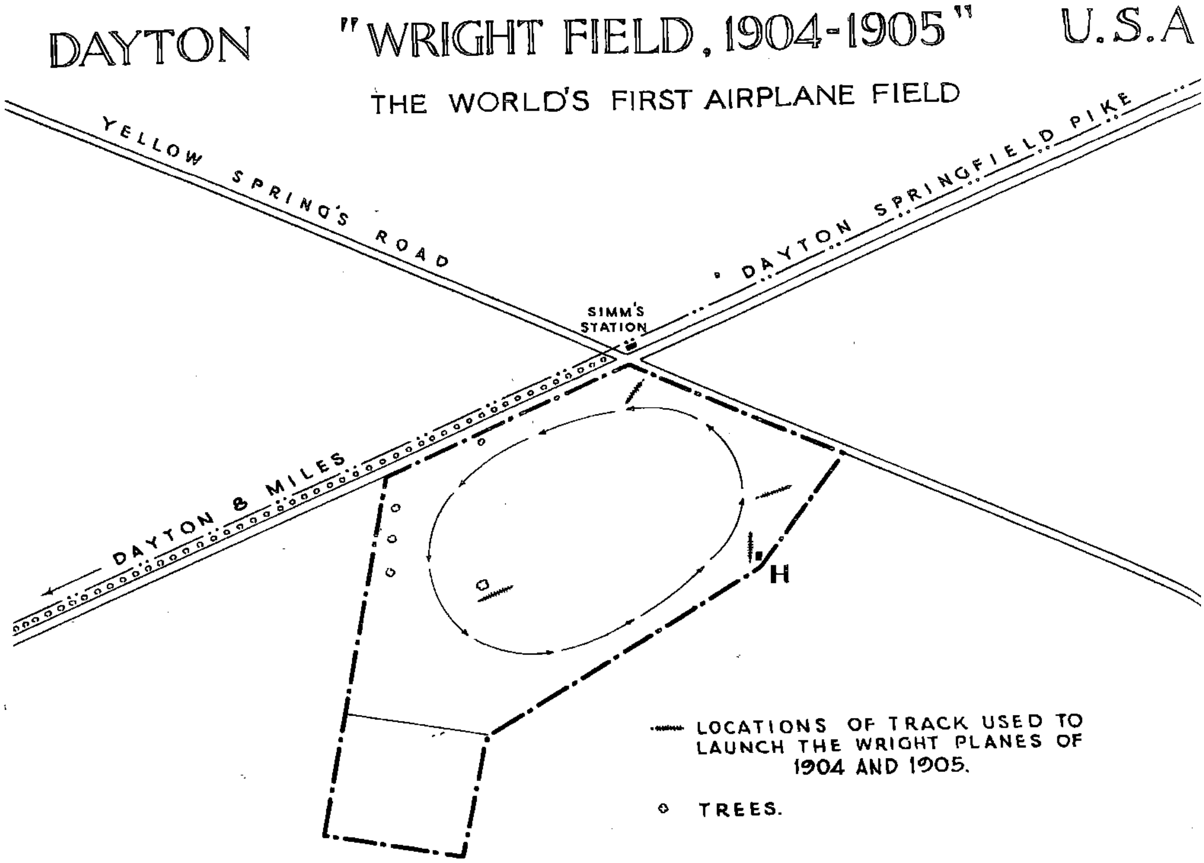


Figure M.1.1 - Dayton, Wright Field – Source: Airports by John Walter Wood

An eyewitness Amos I. Root, editor of 'Gleanings in Bee Culture', wrote in the 01.01.1905 issue; *'It was my privilege to see the first successful trip of an airship without a balloon to sustain it, that the world has ever made, that is, to turn corners and come back to the starting point…… When the engine is shut off, the apparatus glides to the ground very quietly, and alights on something much like a pair of sled runners, sliding over the grassy surface perhaps a rod or more.'* (Root, 1905)

Figure M.1.2 Dayton, Wright Field, Flyer 11 & Hangar, May 1904 - Source: US Library of Congress

Wilbur Wright provided a vivid description of Huffman Prairie in a letter to Octave Chanute, the scientist and pioneer aviator who had flown a series man carrying gliders before the Wright brothers:

"We are in a large meadow of about 100 acres. It is skirted on the west and north by trees. This not only shuts off the wind somewhat, but gives a slight downward trend. However, this is a matter we do not consider anything serious. The greater troubles are the facts that in addition to the cattle there have been a dozen or more horses in the pasture and as it is surrounded by barbwire fencing we have been at much trouble to get them safely away before making any trials. Also, the ground is an old swamp and is filled with grassy hummocks some six inches high, so that it resembles dog town"

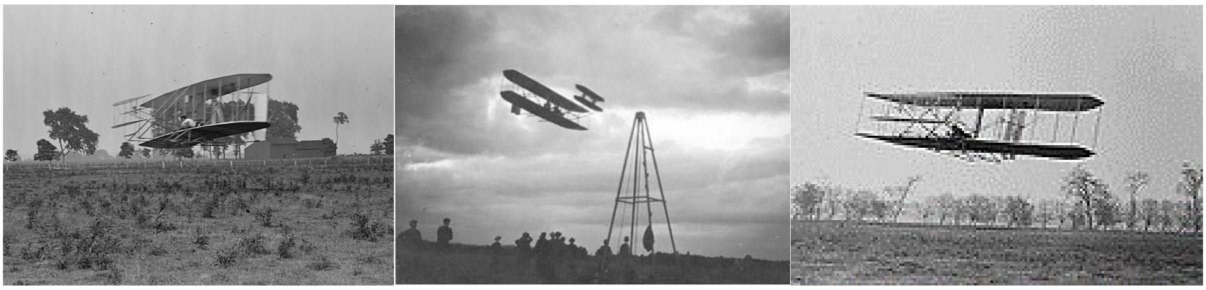


Figure M.1.3 Flyer II at the Wright Field, Dayton 1904 --Source: US Library of Congress

Figure M.1.4 Start of the first flight of Flyer III, June 23, 1905, Orville at the controls. The catapult tower, which they began using in September 1904, is on the right – Source: US library of Congress.

An electric 'Interurban' rail line between Dayton and Osborn ran by the field. Simms Road Station (figure M.1.1), the penultimate stop, was conveniently located fifty yards away. It took less than 30 minutes for the brothers to make the trip from their home in West Dayton. This might be regarded as the first rail-air interchange (figure M.1.5).

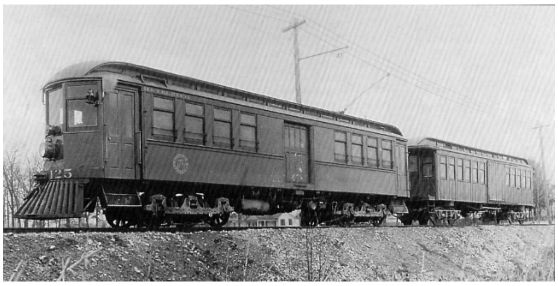
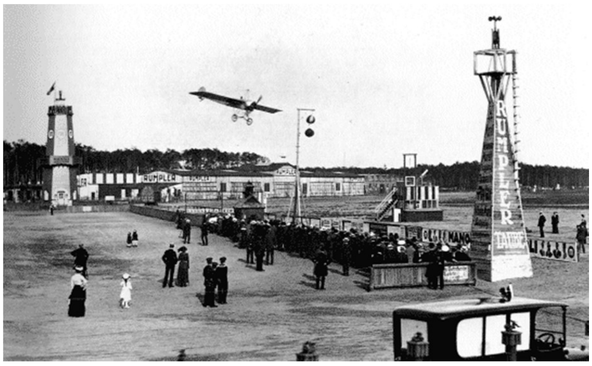


Figure M.1.5 Interurban Electric Rail Cars
Source: wright-brothers.org

2 Berlin, Flugplatz Johannisthal, 1919

Berlin Johannisthal had been in existence for some ten years before scheduled flying started. It opened in 1909 as the first civilian airfield and was known at the time as 'Motorflugplatz Johannisthal-Andershof' as it was on the border between the two communities.

The first aircraft to land there on 27th September 1909 was an Antionette flown by Hubert Latham, a Briton. The airfield attracted a number of aircraft manufactures to the site including, 'Fokker Aeroplanbau', 'Albatros Werke AG', Luft-Verkehers –Gessschaft AG', 'E.Rumpler Luftfahrzeugbau GmbH and 'Flugmaschine-Wright-Gesellschaft GmbH'. It also hosted a number of flying shows and air races for which two spectator stands were built, one for 2,300 people and a second one for 1,750 people. One of the best known events is the 'Rund um Berlin' (around Berlin) race on the 30th September 1913 (figures M.2.1 & M.1.2).



Figures M.2.1 & M.2.2 Berlin Johannisthal before the 'Rund um Berlin' race 1913 – Source: Leerstandsmelder.de and WordPress.com

1910 while a second airship hangar 'The Zepplin-Halle' was completed for the German Imperial Navy in September/October 1911 (figure M.2.3). Sadly this was overshadowed by the first multiple fatality air disaster when the Imperial Navy's L2 airship known as 'Zigarre' crashed when one of the Maybach engines exploded over the airfield killing all 28 people on board on 17th October 1913 (figure M.2.4).

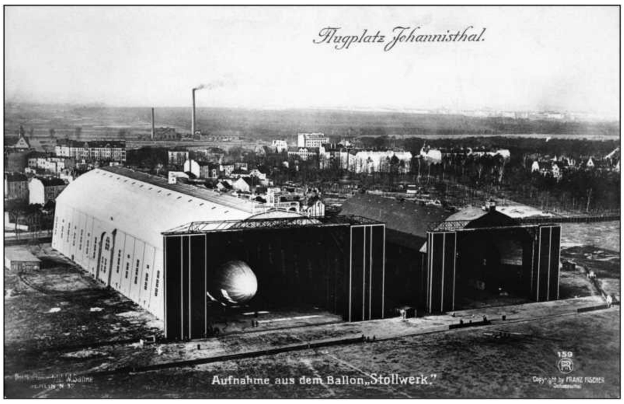


Figure M.2.3 Airship Hangars 1914, Berlin Johannisthal
Source: Lost and forgotten Berlin, - wordpress.com

Figure M.2.4 'Zigarre' Arship 1913
Source: Wikimedia

The airport became militarised with the outbreak of the First World War, when the focus became aircraft manufacture in the hangars.

Scheduled flying services began on 5th February 1919 in Berlin, initially with flights to Weimar by Deutsche Luft Reederei, (the forerunner of Lufthansa) with the twice daily service by Deutschemark Luft Reederei (German Air Shipping) to Weimar, home of the new German National Assembly. It is interesting to note that flying kit and motor transport to and from the aerodrome were provided as an inclusive part of the fare. Luggage was also carried free of charge, but the total weight of the passenger and baggage could not exceed a certain weight. Transferable serial tickets could also be purchased.

The first flight took off from Flugplatz Johannisthal with two pilots and carrying 40 letters and some 65 kilos of newspapers bound for Weimar (figure M.2.5). In the following months the average journey time on this route was 2hrs 11mins, with a record trip of 1hr 15mins. 538 flights were recorded by the end of April. A second route between Berlin and Hamburg was opened on 1st March, with 262 flights by the end of April. Further destinations were quickly added by the summer including, Breslau, Frankfurt, Leipzig, Hamburg, Hanover, Munich, Warnmünde and Westphalia. Longer flights were added later in the year including a six hour flight to Konigsberg to link East Prussia with Germany. Passengers were simply handled through the corner of a hangar (Ronald, 2012).

Bundesarchiv, Bild 183-T0126-510
Foto: o.Ang. | Februar 1919

Figure M.2.5 Berlin Johannisthal – First scheduled Flight 05.02.1919 to Weimar – Source: Wikipedia

The rapid advance of civil aviation in Germany produced consternation in the UK, with editor of Flight magazine writing on 24th July 1919:

> '*This seems to be in marked contrast to the laggard way of are conducting things here. We have not a single regular aerial service running even now – nearly at the end of July – and we see no real prospect of any such service being established for some time to come.'* (Flight, 1919)

The armistice at the end of the First World War had prohibited Germany from having an Air Force. Some members of parliament the UK press were concerned that the state subsidized development of civil aviation in Germany was a back door way of re-armament.

An early visitor to the Airport, on the 8th October 1919, was the Junkers F13 'Annelise' on her maiden flight en-route to Moscow (figure M.2.6). This was a revolutionary new aircraft type using monocoque construction of Duraluminium. The aircraft was the first to be designed specifically for civilian flight rather than converted from a military aircraft, and the world's first all-metal airliner. Although the F13 was initially not allowed to be operated in Germany after WW1 due to Allied restrictions (hence the promotional flight to Moscow) it was built for ten years until 1929 and sold 322 aircraft. In 1922 the ban on Germany's aviation industry was slightly reduced and Junkers F13s were delivered to German Air Transport Companies many being transferred later to Lufthansa (Zoeller, 2019).

Figure M.2.6 Junkers F13 Annelise -Source: Junkers.de

The following plans show how the airport developed from its early layout in 1910 (figure M.2.7) to its post war form in 1927 (figure M.2.8). At the centre is still the grass field, but the perimeter is much developed with hangars and factories served by an extensive railway network. The use of the airfield sharply diminished after 1923 when Berlin Tempelhof opened and after civilian flying was eventually banned in 1931 it became an important test installation for the secret development of the Luftwaffe.

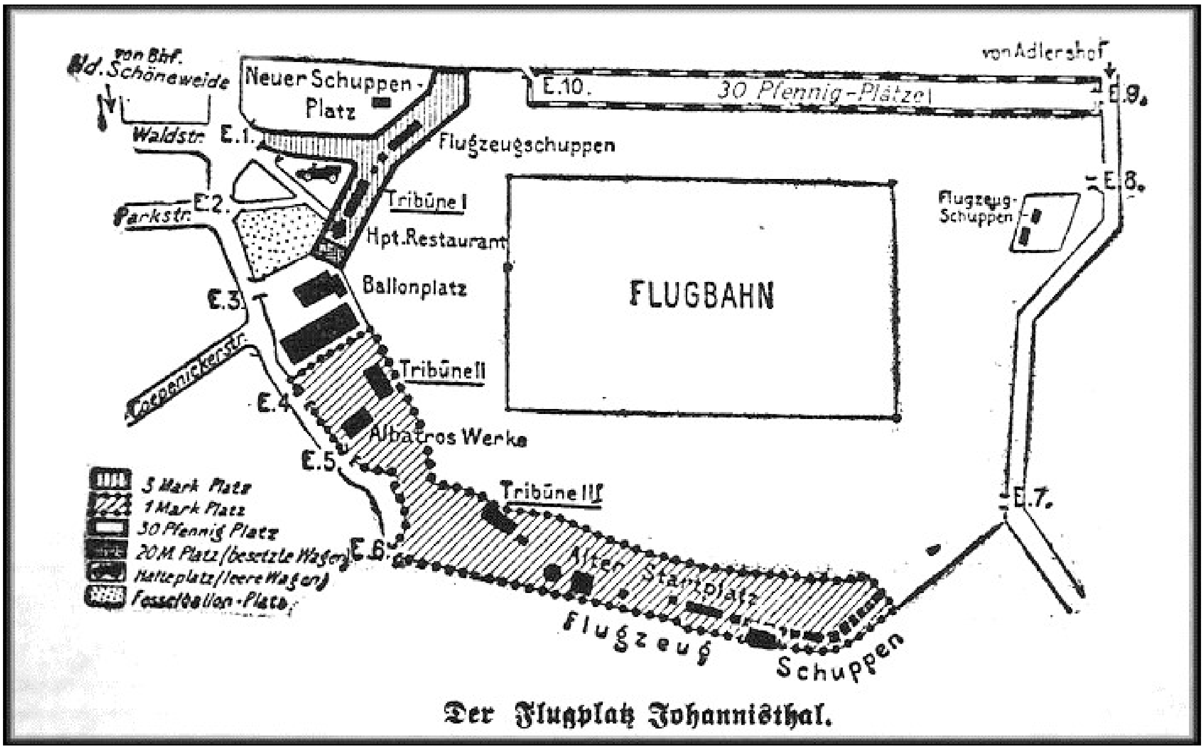


Figure M.2.7 Map of Berlin Johannisthal 1910 – Source: (Treibel, 1992)

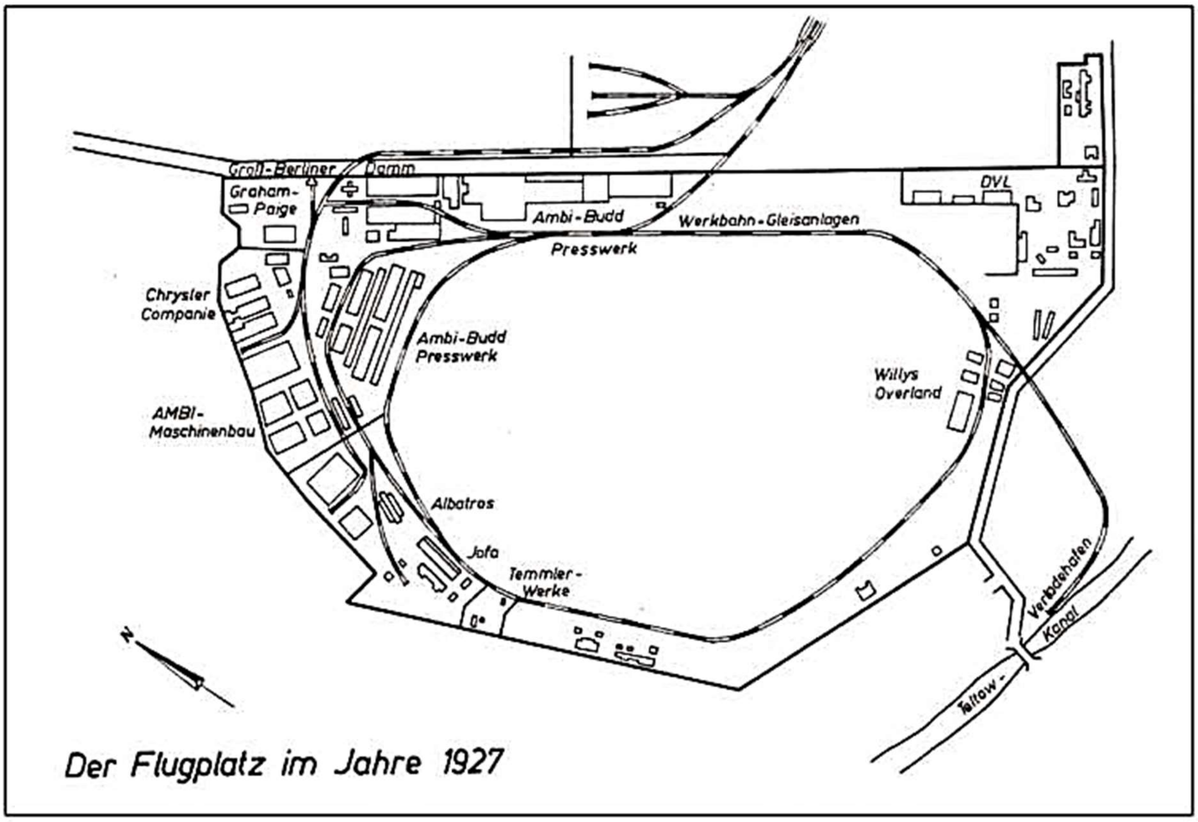


Figure M.2.8 Map of Berlin Johannisthal 1927 – Source: Grin.com

3 Croydon Airport 1920 to 1928 and 1928 to 1959

The First Croydon Airport

The first Croydon Airport was chosen as the Air Port of London (customs entry point for international flights) in succession to Hounslow Heath partly because it was no longer required by the Royal Flying Corps after the First World War and it was considered better to have an aerodrome to the south of London so that pilots would not have to fly over the city. It was also well connected to London by both road and rail and was less affected by fog.

It comprised a hotchpotch of buildings (figure M.3.1), serving a split airfield originally individually known as Beddington and Waddon Aerodromes, connected by a level crossing allowing aircraft to taxi from one field to another (figure M.3.2).

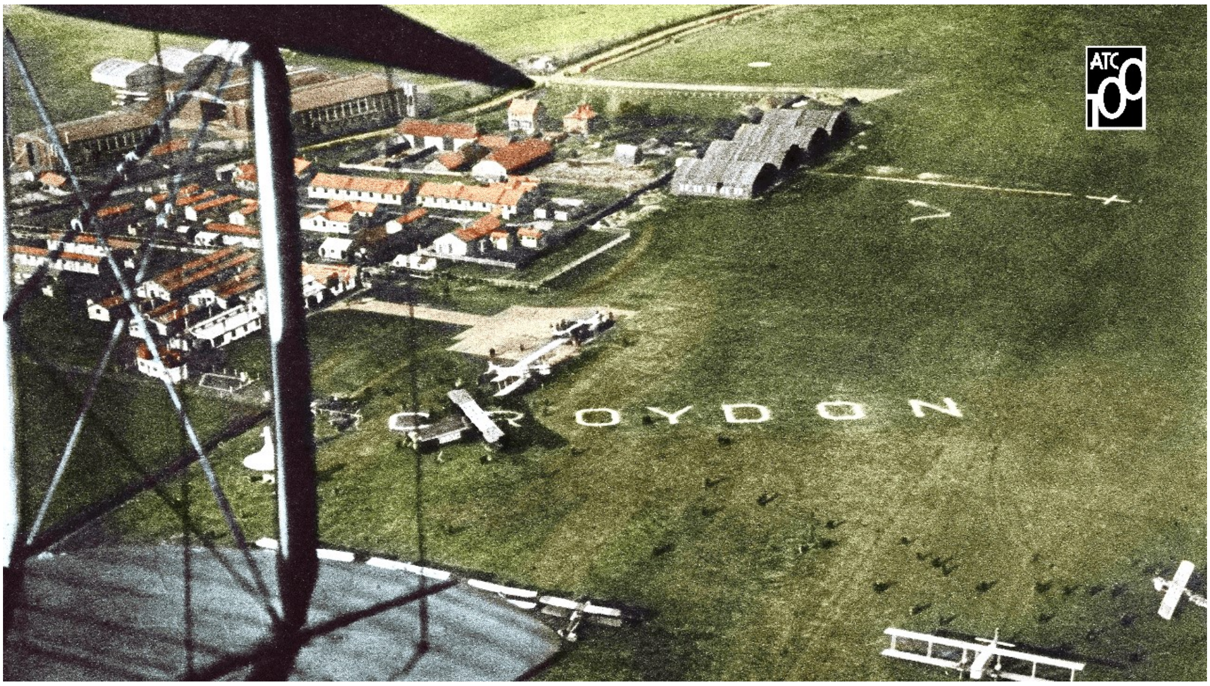
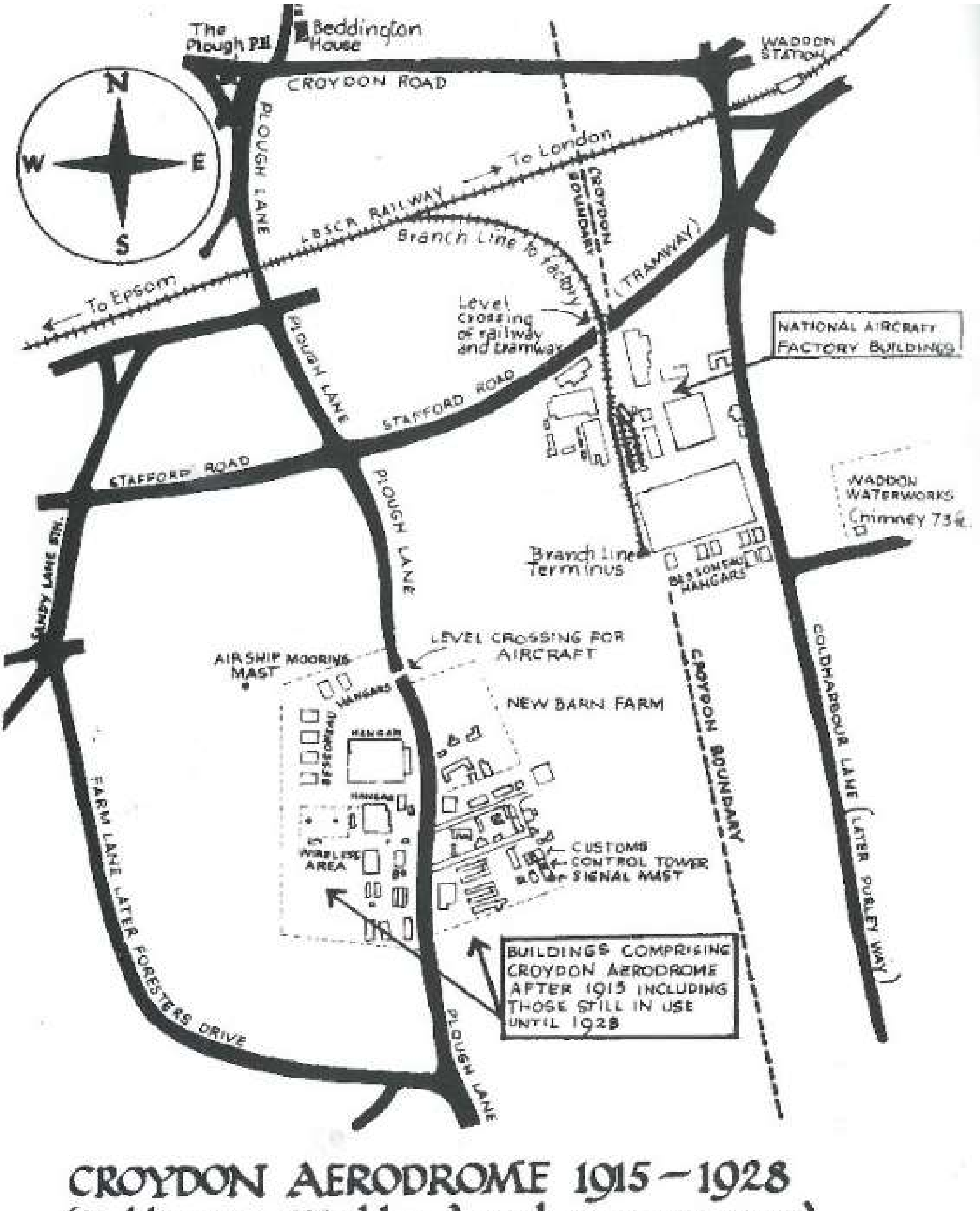


Figure M.3.1 Aerial view of the first Croydon Airport 1925 – Source: NATS in conjunction with Historic Croydon Airport Trust colourised by Marina Amaral



CROYDON AERODROME 1915 – 1928
(Beddington & Waddon Aerodromes 1915 - 1920)

Figure M.3.2 Croydon Aerodrome Plan 1920 -1928 – Source: London Borough of Sutton, Library Service

Croydon introduced the concept of the air traffic control tower, initially as a simple shack on an elevated platform overlooking both parts of the airfield (figure M.3.3). The Air Ministry commissioned a new building at Croydon Airport, to be "*erected 15 feet above ground level*" and with *"large windows to be placed on all four walls"* and known as the "*Aerodrome Control Tower*". It was first commissioned on the 25th February 1920, but was then extended upwards with a taller fully glazed lighthouse which housed experimental sound equipment to locate aircraft (the forerunner of radar)(figure M.3.4).

Figure M.3.3 Original Control tower and customs facility - Source: NATS in conjunction with Historic Croydon Airport Trust colourised by Marina Amaral

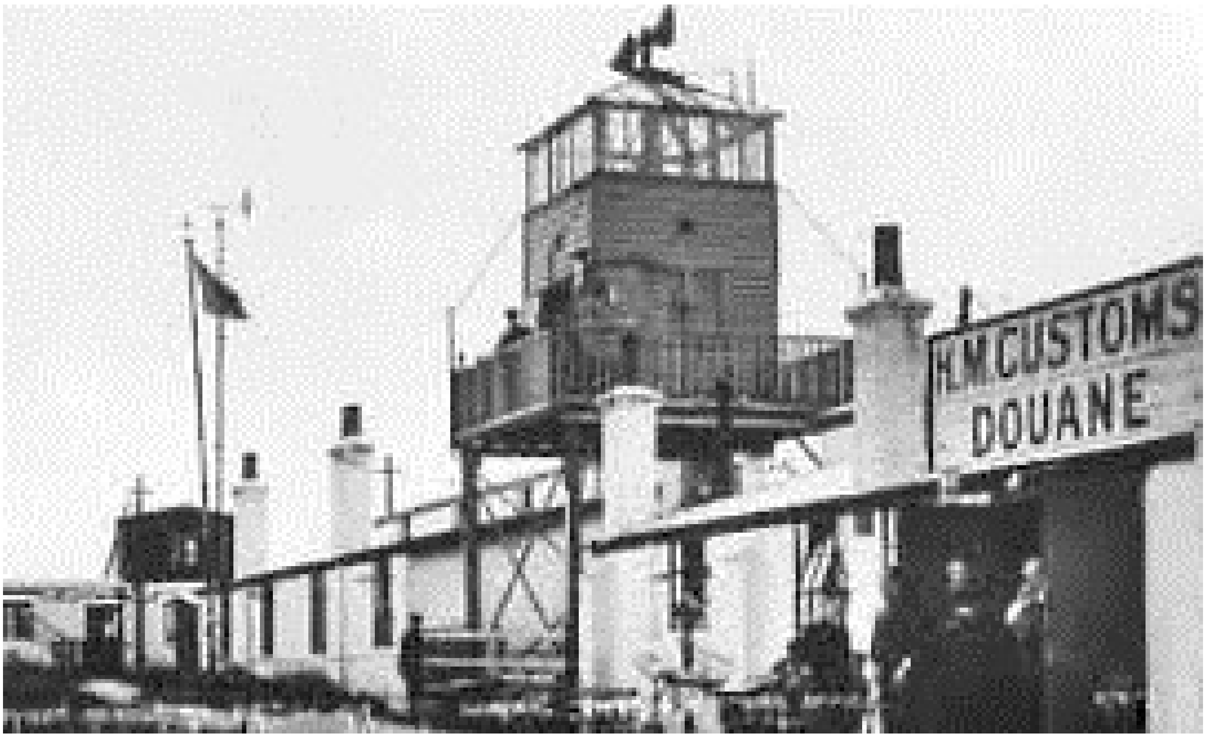


Figure M.3.4 Control tower extended vertically - Source: Historic Croydon Airport Trust

Early innovations included a short lived experiment to accommodate airships when a docking mast was erected in 1921 (figure M.3.7). It was soon demolished as pilots regarded it as a dangerous obstruction. However, not all innovative ideas were implemented; a letter to the Times in August 1924 suggested the Northern Line branch of the London Underground be extended to the airport, anticipating the later development at Berlin Tempelhof, but this idea was not taken up. Instead Waddon Station, now part of the Southern Railway, was the closest to serve the airport.

A few years later in 1927 Lowell Thomas embarked, with his wife, on a tour of Europe by air starting from Croydon Airport. He described his experiences in a book titled European Skyways. He was picked from his hotel on the Thames Embankment by Imperial Airways and travelled to the airport at Plough Lane which he described as '*The Aerial Crossroads of the British Empire.'* His experience started with breakfast at the Trust House Hotel, followed by a tour of the dispersed airport buildings which he referred to as a *'Harbour in the Fields'* (figure M.3.5). He described the airport as follows:

> *'The flying-field itself occupies a vast area two or three times the size of a university athletic field. Along one side are the cavernous hangars, or sheds, where the aircraft are protected from the rough weather and groomed by expert mechanics for the next flight. Hemming in the field on the other sides are the hotel and restaurant, machine shops, wireless plant, with its three lofty masts, police headquarters and a score of other buildings. Not the least important is the weather bureau, because without complete meteorological information along the air routes, commercial aviation would be a farce.*
> *Dominating the converted cow-pasture, figuratively and literally, rises a structure forty feet above the surrounding buildings. This is the Control Tower. And that man sitting up there is the aerial harbour-master. To visit the throne room of this czar of the heavens we climb, ship fashion, a narrow iron ladder. Aloft in this crow's-nest, with an uninterrupted view of the flying-field, sits this celestial ruler, whose official title is Civil Aviation Transport Officer of the London Terminal Aerodrome. But the pilots, with their instinct for short cuts, call him the C.A.T.O.*
> *In front of him spreads a huge map, showing all the air routes that radiate out from Croydon. At its side are signal button, telephones, and speaking tubes, by means of which he can keep in touch with the near-by offices, shops and hangars. His windows overlook the aerodrome. A great map painted on the top of his flat desk shows him the position of every plane that flies over the commercial air routes between London and the Continent. His head is adorned with wireless ear-phones, and he can talk even to the pilots of planes a hundred miles away. The CATO directs the movements of all aeroplanes entering or leaving Plough Lane and supervises the management of the whole Croydon Aerodrome.'……*
> *'I saw nothing in Europe that so intrigued and amazed me. The CATO in that Control Tower at Croydon is in direct communication with the pilot of every commercial liner within a radius of two hundred miles, and sometimes he can carry on a conversation with a pilot three hundred miles away. All passenger planes are equipped with the latest wireless sets, and the pilots can send messages as well as receive them. At any hour the pilots can talk directly to the men in Croydon Tower and hear their voices as clearly as if they were sitting in the crow's-nest.'*

This is an early recognition that what made Croydon stand apart from all other early airports was the excellence of its communication and air navigation systems. By contrast much of the physical infrastructure was makeshift as John Priest relates in his autobiography:

'*In those days before the new airport opened in 1928, the main road went straight through the middle of the airfield, with level crossing gates (figure11.3.6), just like railways, to hold up the traffic while an airliner crossed the road from the hangars to the passenger terminal. We were held up as the big three-engined bi-plane (probably an A W Argosy) went across the road under its own power. The pilot was sitting in the open cockpit wearing a trilby hat, which he politely raised to us for waiting for him.'* (Priest, 2015).

The following is an extract from the board that hung in the terminal building of the new Croydon Airport between 1928 and 1959:

'Croydon Aerodrome 1915-1928'

'Croydon Aerodrome has been used for national purposes continuously since December, 1915, when it was established as a part of the air defence of London…. The actual area used by these units (training squadrons) for landing was on the west side of Plough Lane. This road originally ran across the middle of the existing aerodrome, but was finally removed during the reconstruction of the aerodrome in 1928. During 1918 the National Aircraft Factory had been built on a site further to the east, adjoining what is now Purley Way. The portion of the present aerodrome immediately opposite the new buildings provided the test aerodrome for the National Aircraft Factory in 1918.

Croydon Aerodrome was adopted as the Customs Air Port of London in succession to Hounslow Aerodrome on March 29th 1920. From 1920 to 1927, the original Royal Flying Corps buildings on Plough Lane were used as a temporary measure (figure11.3.5). *The present buildings were constructed during the years 1926 to 1928 and were formally opened by the Lady Maud Hoare, D.B.E. on May 2nd, 1928.'*

Figure M.3.5 Croydon, Converted Royal Flying Corps Buildings - Source: Historic Croydon Airport Trust

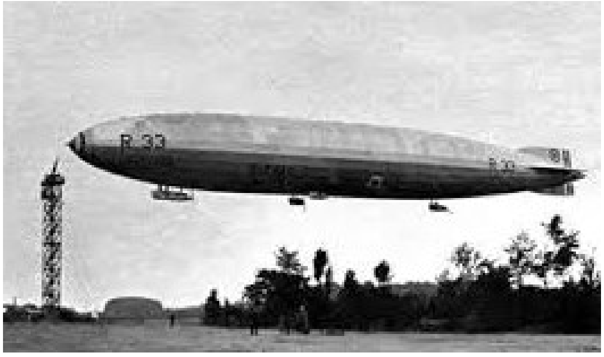


Figure M.3.6 – Bristol Tourer crossing Plough Lane
Source: Historic Croydon Airport Trust

Figure M.3.7 Croydon airship mast
Source: Historic Croydon Airport Trust

Transition and Tragedy

It was quickly apparent that the layout inherited from the RFC (RAF) was unsatisfactory, and plans were made to replace the dispersed facilities with a single terminal building handling all the necessary processing and administration functions for handling passengers on the existing Plough Lane site. This was a considerable advance over Le Bourget which had continued with a dispersed layout when they rebuilt in the previous year. Croydon was also the first airport to prepare a master plan with phased development that ensured business continuity during reconstruction (figure M.3.8).

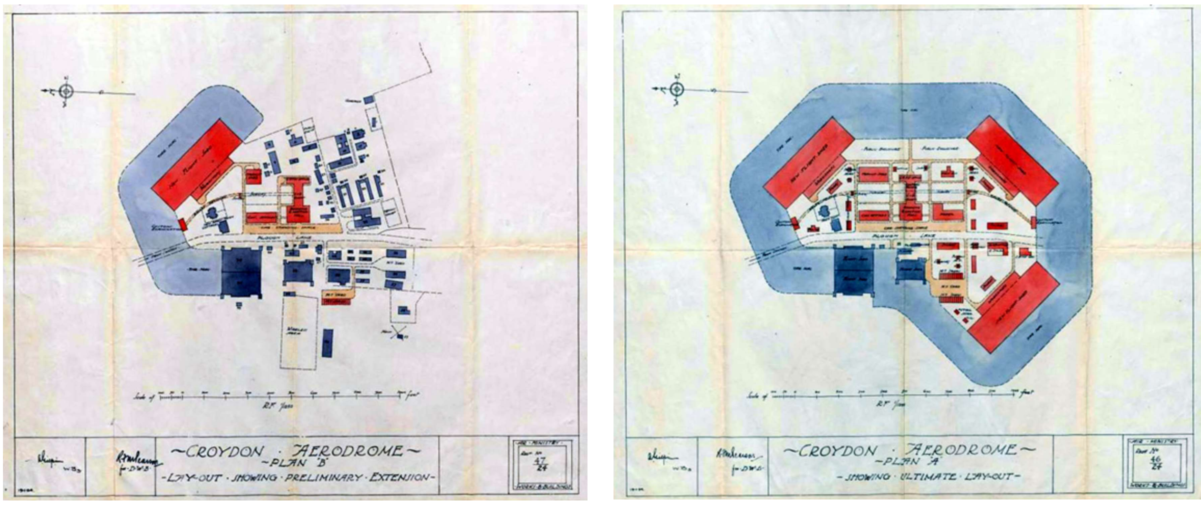


Figure M.3.8 Croydon Aerodrome, early re-development plans of 1924 – Source: Air Ministry National Archive via Historic Croydon Airport Trust

However, the plans were changed directly as the result of an air crash on Christmas Eve 1924, which resulted in an inquest and the first Public Inquiry in aviation history. The Imperial Airways de Havilland DH.34 aircraft, G- EBBX, bound for Paris le Bourget crashed a few minutes after take-off onto a garden in South Croydon killing all eight people on board. At the time it was the U.K.s worst civil air accident and resulted in the U.K.'s first Public Inquiry into an air accident, convened at the Royal Courts of Justice, The Strand, London on 23rd January 1925. The Inquiry looked into the shortcomings of the former World War One airfield and suggested safety could be improved by extending the grass runways. To extend the runways the airport would need enlargement and improvement requiring an Act of Parliament to enable the closure of Plough Lane and the amalgamation of the two airfields.

Evidence was given by Major Brackley who agreed that Croydon Aerodrome was unsatisfactory when the wind was south-westerly (prevailing wind). He said he had made suggestions to the Air Ministry with a view to improvements. Colonel Edwards, of the Air Ministry, outlined a scheme of extensions and alterations which, when completed would convert Croydon aerodrome into a satisfactory one. On the seventh day of the inquiry, it was announced that Croydon Airport was to be extended, with 150 acres (61 ha) of the neighbouring Beddington Aerodrome being absorbed into the current airfield, Plough Lane being diverted to allow this. An Act of Parliament would be needed before the expansion could take place, for which a bill was in preparation. Finance had been allocated to allow the expansion. Evidence was heard that Croydon was then considered to be the most suitable location for an airport to serve London. The summing up included the following statement about proposed improvements:

'Evidence has been given before me that the aerodrome at Croydon, especially with a south-west wind, is far from satisfactory. Colonel Edwards, the deputy director of air transport at the Air Ministry, has given detailed evidence of the steps which the Air Ministry propose by way of improving this aerodrome. It is proposed to add substantially to its present area, the additional land having been already acquired, and in order to make the land which has been acquired to the west available as part of the aerodrome, to divert Plough Lane, for which purpose a Bill is being prepared. These proposals are in general agreement with the suggestions for improving the aerodrome, made by the witnesses who gave evidence before me as to its unsatisfactory character.'

The published conclusion included the following statement:

- The aerodrome at Croydon is unsatisfactory. This was not the primary cause of the accident, and I do not say more than that it may have been a contributory cause.
- The Air Ministry should consider the question whether any and what limit should be fixed for the angle of climb, as also for the stalling speed, of aircraft carrying passengers.

An early revised version of the master plan, to the right, appeared in an article by Archibald Black in the American City Magazine in March 1926, titled 'London Makes a Mistake.' He commented: *'Unsatisfactory arrangement of buildings and equipment necessitates expensive removals and reconstruction*.'

The master plan shows an evolution of the terminal plans of 1924 but with the terminal/hangar complex relocated to the eastern boundary, adjacent to the newly opened Croydon By-pass, Purley Way (figure M.3.9).

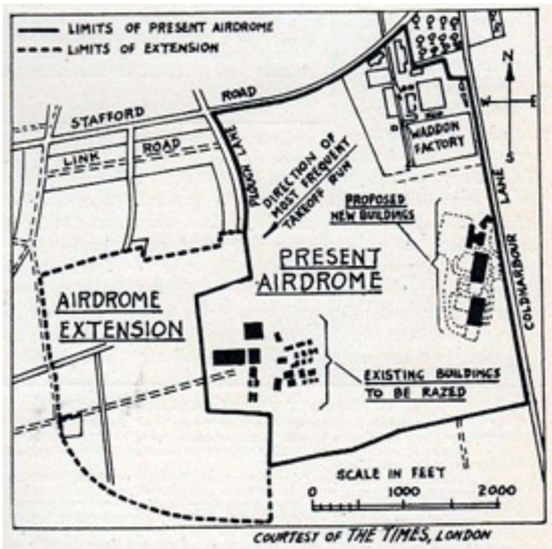
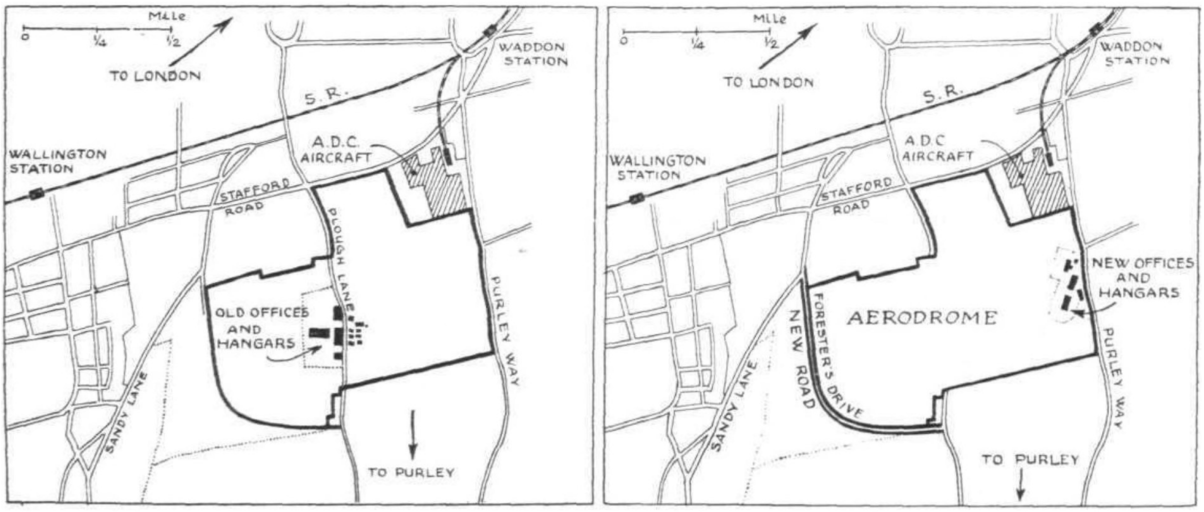


Figure M.3.9: Croydon revised Master Plan Source: American City Magazine, March 1926

The demolition of the existing facilities and closure of Plough Lane allowed the unification of the eastern and western airfields radically enlarging the landing area and so addressed one of the key findings of the Inquest and Public Inquiry. By December 1927 Plough Lane had been closed and the diversionary road, Forester's Drive, had been opened (figure M.3.10). This is rare example of an airport being expanded and improved primarily for safety reasons.



CROYDON AERODROME IMPROVEMENTS : Sketch maps showing Croydon aerodrome (left) old style—with Plough Lane, offices and hangars in the centre—and (right) as it will be under the new scheme, Plough Lane being replaced by the new road, Forester's Drive.

Figure M.3.10 Croydon Aerodrome Improvements 1927 – Source: airportofcroydon.com

The Second Croydon Airport

The Second Croydon airport saw the amalgamation of the eastern and western sections of the airfield by the closure of Plough Lane and its level crossing (figure M.3.2), and the construction of the new terminal building which opened in 1928 (figures M.3.11, M.3.12, M.3.13, M.3.14, M.3.15, M.3.16 & M.3.17). The major change to the terminal building from the preliminary proposals was the integration of the cargo facilities and agents' offices within the terminal rather than being in separate dispersed buildings and the inclusion of a new purpose designed hotel on an adjacent site.

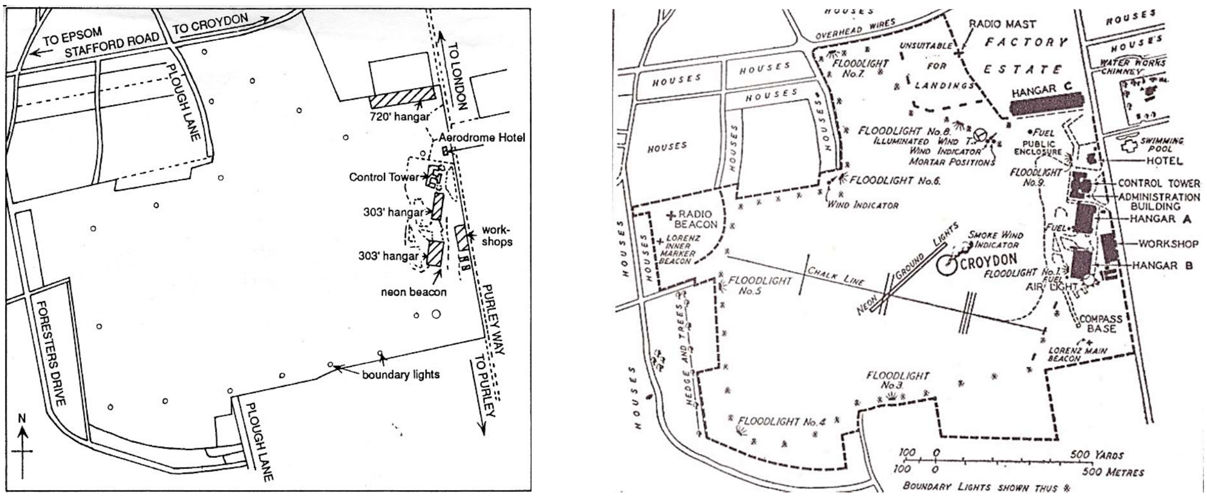


Figure M.3.11 Croydon Airport Site Plans 1929 and 1938 - Source: UK Airfield Guide

Figure M.3.12 Model of the terminal at the Croydon Airport Micro-Museum - Source: Photograph by 'The Croydonist'

Figure M.3.13 Croydon Airport Aerial Image – Source: Photo London Borough of Sutton, Museum and Heritage Services (Artist: Frank Sturges)

Ground-breaking in design, it was the first terminal to integrate the major airport service functions into one structure. The new terminal featured a rational symmetrical layout to facilitate the logical sequence of departing and arriving passenger movement. Considerable care was taken to introduce daylight to the main double-height concourse though an octagonal skylight. Despite its conservative neo-classical appearance the terminal employed a number of novel construction techniques including a steel frame clad with concrete blocks finished to imitate stone, and housed an unrivalled communications and navigation system.

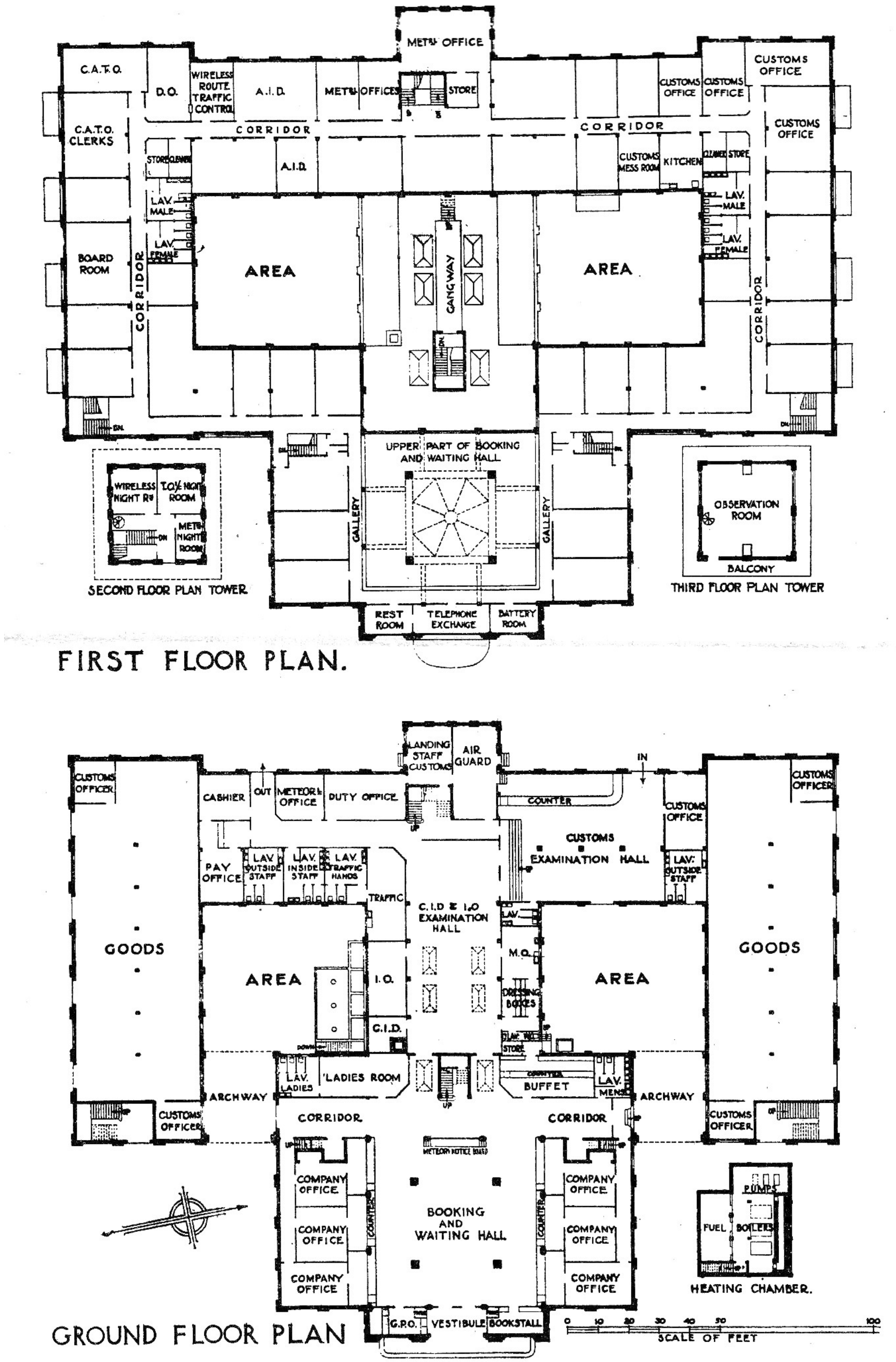


Figure M.3.14 Croydon Airport Floor Plans - Source: Aviation and the Aerodrome H. Angley Lewis –Dale 1932

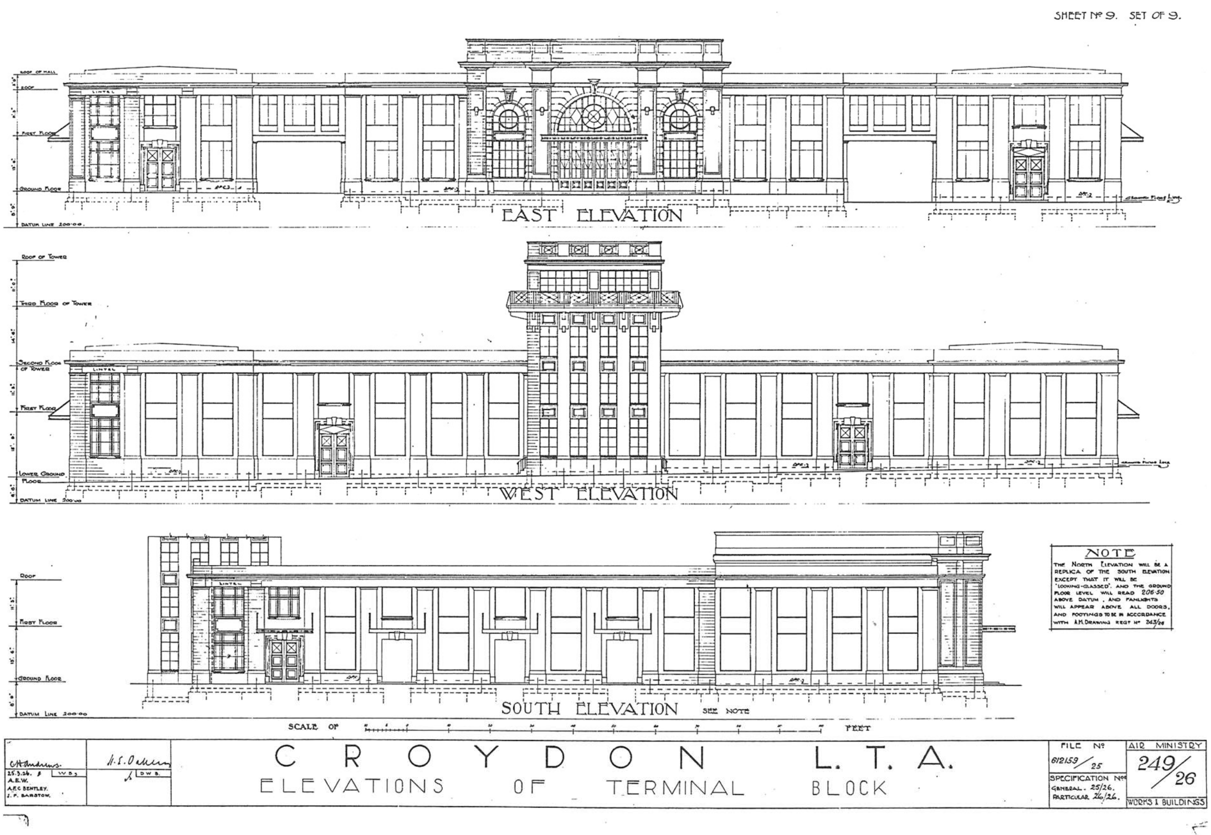


Figure M.3.15 Croydon Terminal 1928 - Elevations –
Source: Air Ministry Archive via Historic Croydon Airport Trust

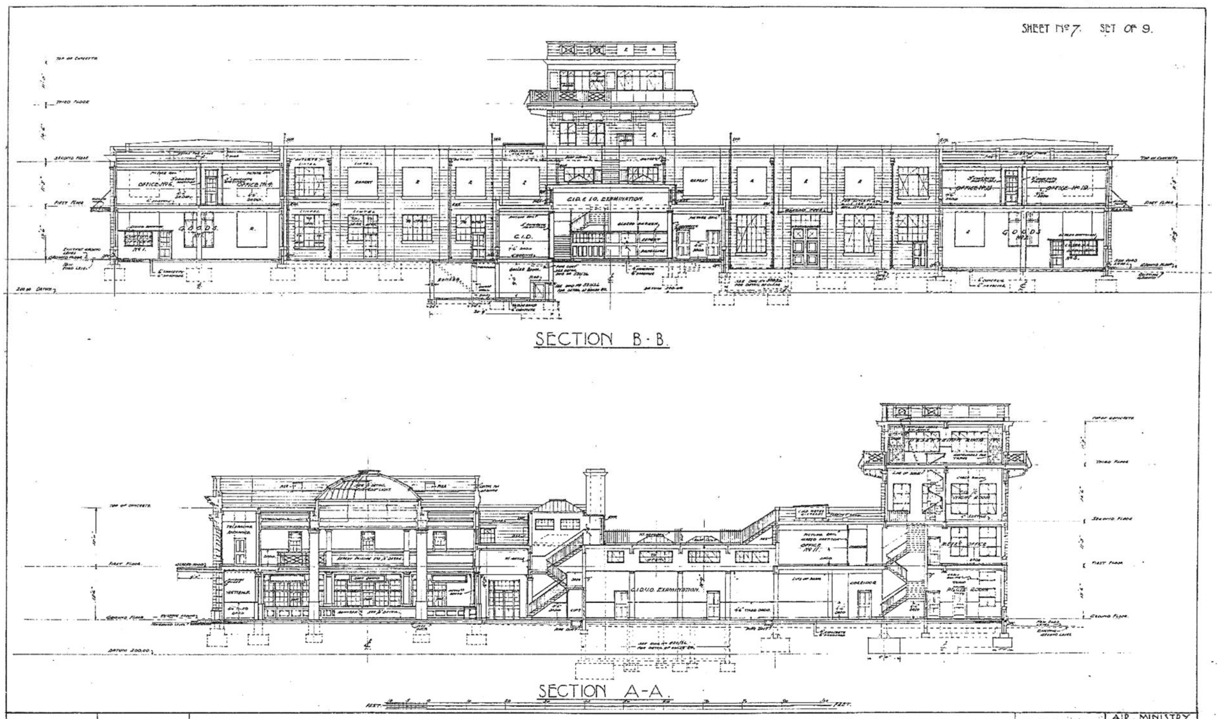


Figure M.3.16 Croydon Terminal 1928 - Sections –
Source: Air Ministry Archive via Historic Croydon Airport Trust

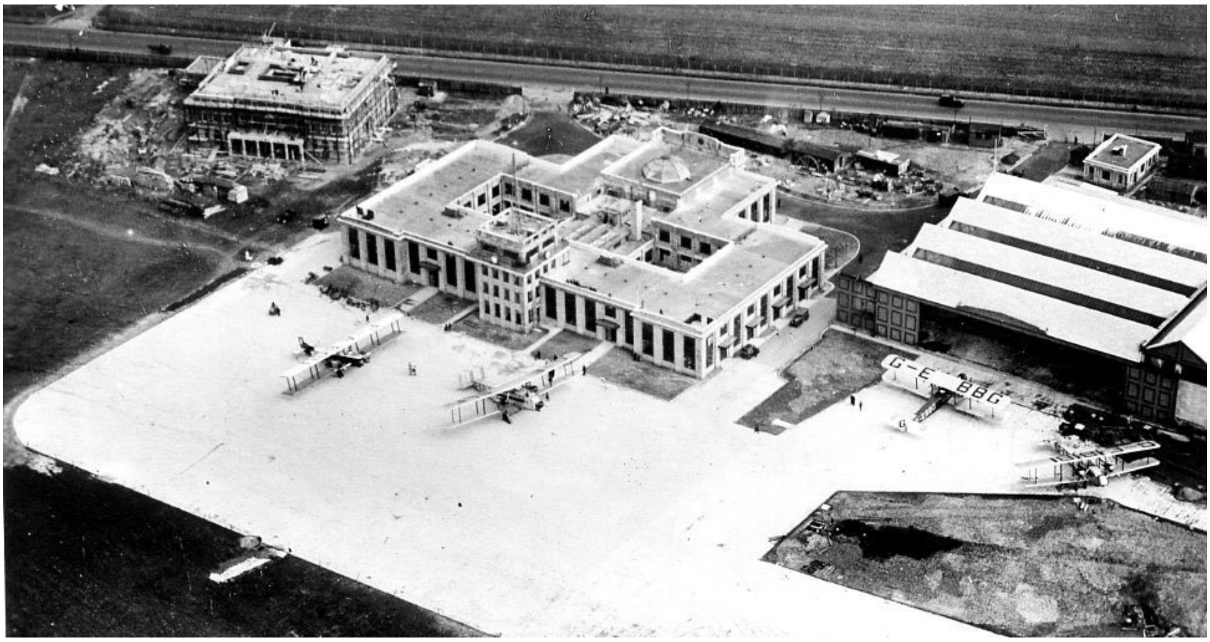


Figure M.3.17 Croydon, Aerial Photograph of terminal with hotel under construction –
Source: airportofcroydon.com

An integrated control tower formed the central element of the new terminal, which opened in 1928, influencing a generation of subsequent terminal designs (figures M.3.18 & M.3.19). The top level contained the visual control room while the floor below was dedicated to radio communications (figure M.3.20). The role of the first controllers was split between 'Radio Officers' who relayed messages to pilots (figure M.3.21), and the 'Civil Aviation Traffic Officers' who plotted their progress using paper maps and pins (figure M.3.22).

Figure M.3.18 Croydon Control Tower – Source: airportofcroydon.com

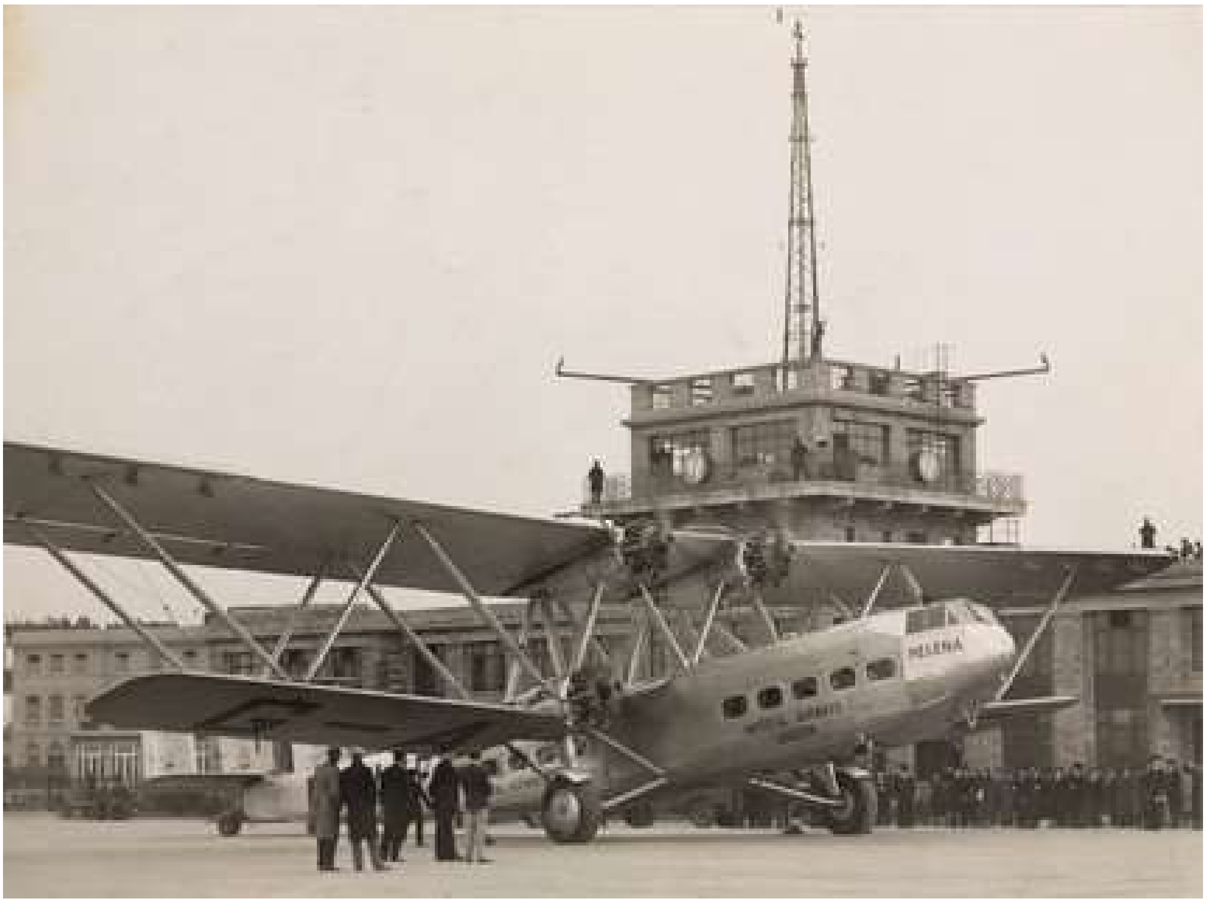


Figure M.3.19 Croydon control tower - Source: Historic Croydon Airport Trust


Figure M.3.20 Croydon communications room – Source: Historic Croydon Airport Trust

*Figure M.3.21 Croydon, 'Radio Officers' in the control room with the map room beyond-
Source: NATS in conjunction with Historic Croydon Airport Trust, colourised by Marina Amaral*

Figure M.3.22 Croydon, -'Civil Aviation Traffic Officer' (CATO) recording flight the progress of a in the map room - Source: NATS in conjunction with Historic Croydon Airport Trust colourised by Marina Amaral

Figure M.3.23- Croydon, News Kiosk
Source: Historic Croydon Airport Trust

Figure M.3.24 Croydon, Flight Information
Source: Historic Croydon Airport Trust

The terminal had most of the facilities of the modern terminal: a set down and pick-up forecourt, check-in desks, immigration and customs areas, simple baggage facilities, a shop (figure M.3.23) and catering outlet, support offices, and an early flight information system (figure M.3.24). However it did not have two facilities that are found in the modern terminal, passenger and baggage security search and an airside lounge. The terminal changed little in the decade that it operated until the Second World War intervened, as passenger numbers increased slowly and the airport never reached its design capacity.

Stedman Hanks, in his 1929 book on international airports, included these words in his description of the terminal:

> '*This building is as complete in detail as is the modern railway station. Every convenience is included for the comfort of the air traveller. The large waiting room provides comfortable seats for those awaiting departure. A bulletin board shows the schedule of departures and arrivals of all airplanes engaged in regular operations over scheduled routes as well as a large weather map showing wind directions and heights of clouds. Ticket offices are conveniently placed as are telegraph facilities and also a branch post office and an express office…….The airport hotel is located just north of the administration building, and though not large in size, is a very popular adjunct to the airport.'* (Hanks, 1929)

He went on to describe with enthusiasm some of the features of the airfield:

> *'The lighting equipment that has been installed at Croydon is rather elaborate and is quite a departure from the methods used in this country (USA). Landing lights are sunk into the field to denote the landing direction. These lights show the direction of the prevailing wind and can be automatically changed by remote control from the tower. A red, fog-piercing neon light beacon is available; it has a definite flashing characteristic. A mobile floodlight unit has been installed on a specially designed motor truck and is used to floodlight that part of the airport on which a night landing is to be made. Fixed red lights are mounted om all obstructions and the outline of the airport is indicated by flashing red lights mounted on 4ft standards*' (Hanks, 1929).

With the exception of adding a third level to the cargo wings, the terminal remained essentially unchanged until commercial aviation ceased with the outbreak of the Second World War in 1939 as seen in the following photograph (figure M.2.25).

Figure M.3.25 - The de Havilland DH 91 Albatross Fortuna in front of the control tower at Croydon Airport in 1939 – Source: Aeroplane Monthly Nov 1984 (Colin Ambrose).

In his 1940 book, Airports, John Walter Wood was less complimentary:

'As at many other airports, haphazard rather than careful planning characterises the present airport. Too narrow a flightway has been left between the main group of airport buildings and the long hangar adjacent to the aircraft factory, and the airport buildings bear little relation to each other and to the landing area' (Wood, 1940).

'The grimly sombre airway station has unnecessarily long and circuitous circulation for passengers and inadequate buffet space. In part counterbalancing the above limitations in planning, the air traffic control of Croydon has always been noted for its excellence, and has all the equipment related to flight operation' (Wood, 1940).

Mr John Dower, Chairman and Secretary of the RIBA Aerodromes Advisory Committee in the 1930s, took a dim view of Croydon Airport's architectural merit stating that, *'Croydon is a dull and grim sobriety and does not express aviation at all!'*

However, the terminal has now been listed by Historic England at Grade II* for reasons that include:

- Historic interest: as a very rare surviving example internationally of the first wave of purpose-built airport terminals and as Britain's first international airport.
- Architectural interest: for the incorporation of an integrated control tower, among the first in the world, establishing with its rational layout, the design framework for the majority of Britain's air terminals until the 1950s.
- Technological interest: for its role in pioneering developments in air traffic control, ground-to-air radio navigation and communication and air-cargo and air-mail.
- Internal interest: for its impressive booking hall which retains some original features.
- Military interest: as a tangible reminder of the airport's service in the Second World War as a front-line airfield during the Battle of Britain and its origins during the First World War.

While the terminal changed little, communications, airfield lighting and navigation aids at Croydon saw rapid advances in technology in pursuit of enhanced safety during the 1930s.

4 Flughafen Königsberg-Devau (KGD) 1922

Königsberg received special attention in the 20s and 30s, as an otherwise isolated German enclave, because of its strategic location as the capital city of East Prussia (now Kalingrad in Russia). It was separated from Germany by the Danzig corridor that linked Poland with the Baltic Sea. Flying was seen as a way of overcoming this territorial split.

The airport was built at the site of the former Kalthof proving ground of the Prussian Army on the road from Königsberg to Labiau (present-day Polessk), named after the nearby village of Devau. The airfield had previously been used for military purposes during the first world war as apart of Germany's defences against Russia. The plan below shows the wartime layout in 1917, with a pair of hangars built in the western corner at right angles to one another prior to the construction of the terminal (figure M.4.1).

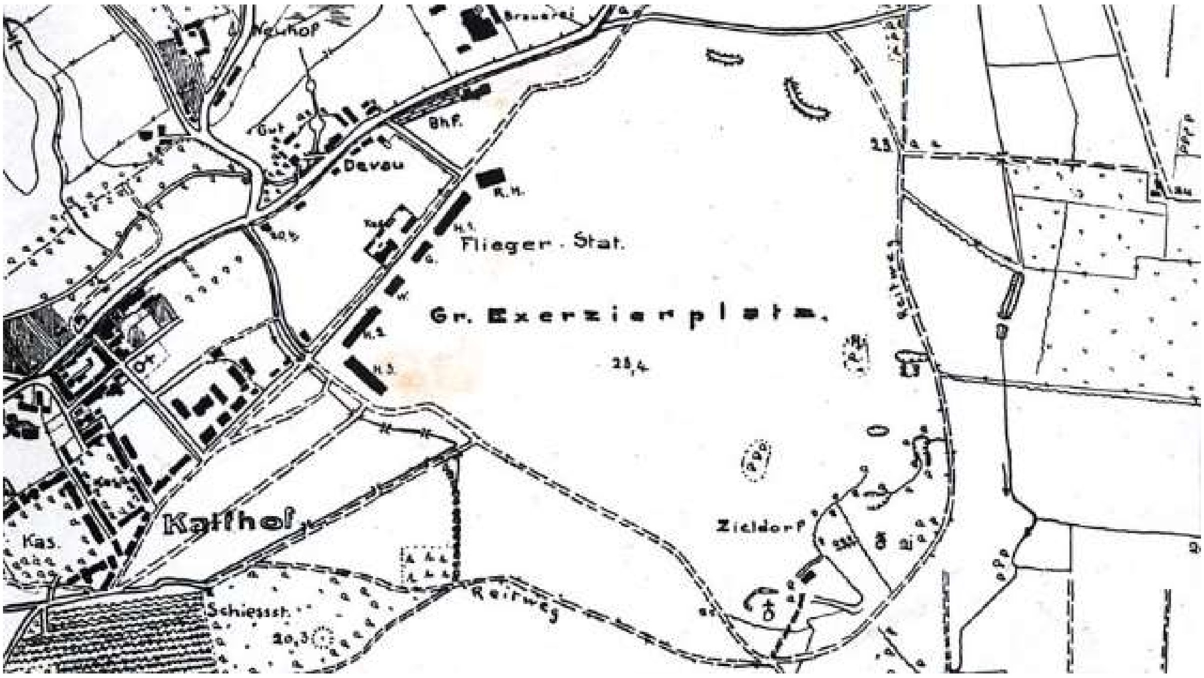


Figure M.4.1 Königsberg Aerodrome - Source: Atlas of Airfields 1917

In 1919 the revolutionary new all metal Junkers F13 'Annelise' landed at Königsberg on its way to Moscow as a part of a marketing initiative.

Deruluft, the joint Soviet-German airline, and a predecessor of Aeroflot then introduced a scheduled service between Konigsberg and Moscow on May 1st 1922. Konigsberg became an integral part of the route of an early scheduled air service between Berlin and Moscow.

Figure M.4.2 Deruluft Poster – Source:Pinterest.Ru

From 1926, Devau Airport was also used by Deutsche Luft Hansa, which set up the first night flying connection between Königsberg and Berlin as well as air links to Tilsit and Memel (Klaipėda).

The following map below shows how it integrated with the German network in 1925 (figure M.4.3). The airport helped to reduce the isolation of Königsberg as it became a focal point for the routes between Berlin and the Baltic States and Moscow in the 1920s and 1930s.

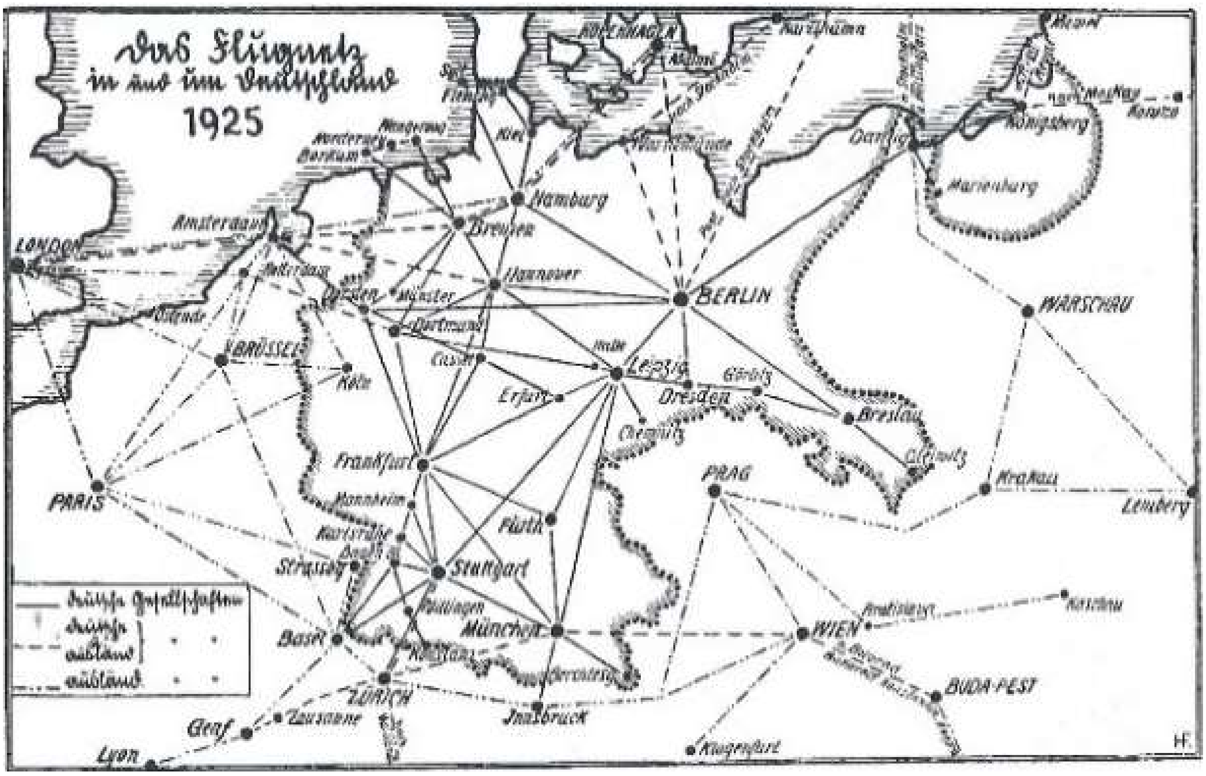


Figure M.4.3 The Lufthansa flight network 1925 - Source: Die Deutschel Luftfart (Treibel, 1992)

The strategic importance of the airport was reinforced by the first scheduled night time mail service with Berlin Tempelhof on May 1st 1926. Later both Hitler and Goebbels visited the airport in 1933.

While the general shape of the field was preserved after the First World War two new arched hangars and a purpose designed terminal were built. The airport master plan included a terminal building located in the corner of a grass airfield between two arched hangars, set at right angles to one another. This replaced the wartime layout which had simpler hangars on the same sites but no terminal building. This new layout can be seen in the following extract from the Flight Manual for the German Reich (figure M.4.4 & M.4.5).

The location of the airfield in relation to the city is shown in the site plan and location plan (figure M.4.6). This is followed by an aerial photograph of the terminal and adjacent hangars (figure M.4.7).

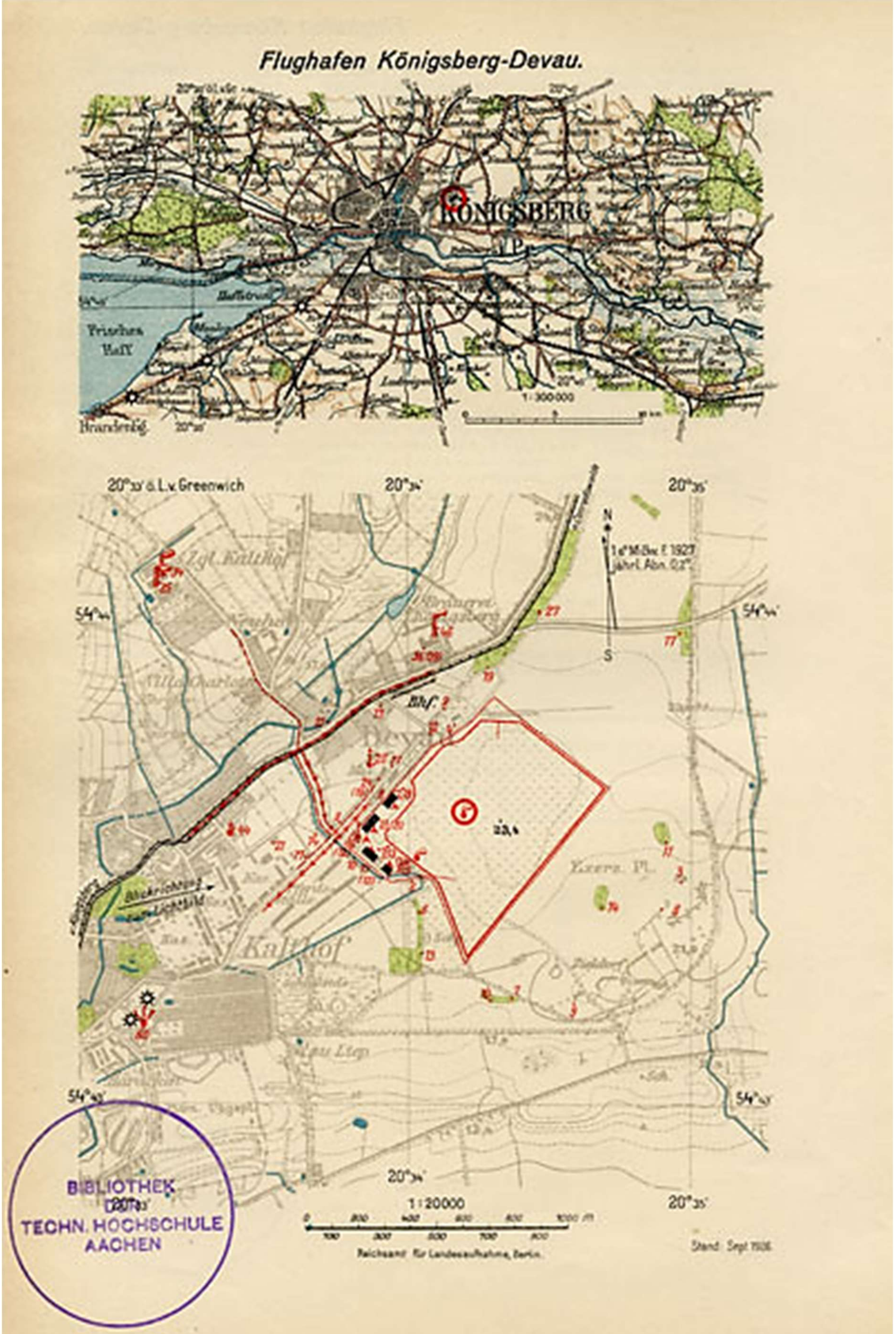
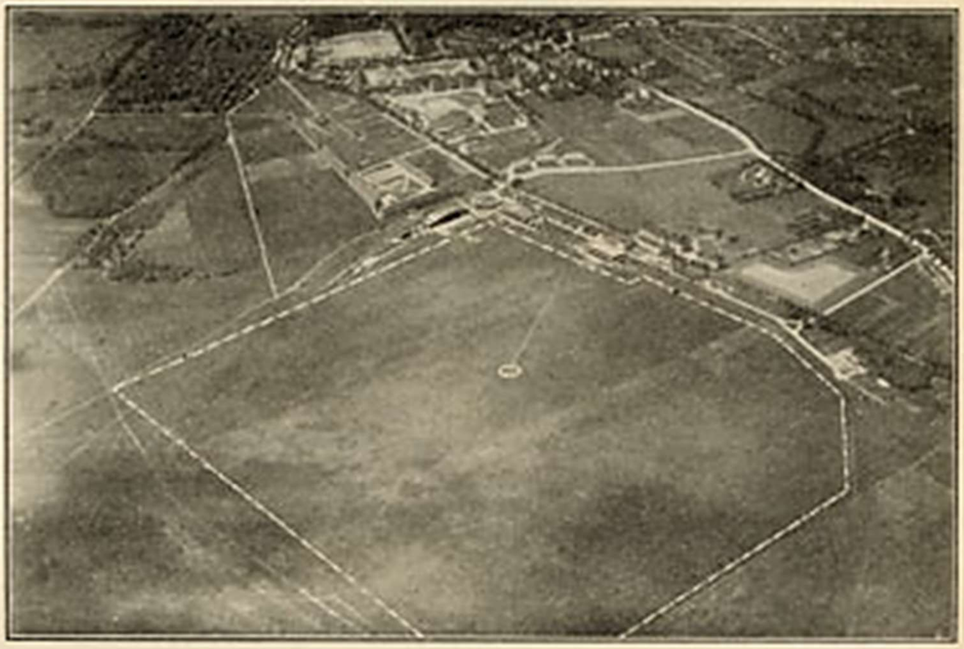


Figure M.4.4 Extract from a Flight Manual for the German Reich - Source: Flughandbuch für das Deutche Reich



Flughafen Königsberg-Devau.

Erläuterungen:

Unternehmer:	Magistrat Königsberg (Stadtamt VI), Flughafenverwaltung, Königsberg i. Pr.
Verwalter:	Firma Robert Meyhöfer, Königsberg. Drahtanschrift: Haslingers, Königsberg Pr.
Verkehrsgesellschaften:	Deutsche Luft Hansa A. G., Bezirksleitung Ost, Königsberg i. Pr., Drahtanschrift: Lufthansa Königsberg i. Pr., Deruluft, Deutsch-Russische Luftverkehrsgesellschaft, Königsberg i. Pr., Drahtanschrift: Deruluft Königsberg i. Pr.
Kennzeichen des Flughafens bei Tag:	Im Rollfeld weißer Kreis von 25 m Durchmesser und Rauchofen. Windrichtungsanzeiger in Flugzeugform auf dem Verwaltungsgebäude. Auf den Hallendächern die Aufschrift „Königsberg". Rollfeldgrenzen durch weiße Kiesstreifen bezeichnet.
Kennzeichen des Flughafens bei Nacht:	Nachtbefeuerung wird vor planmäßigen Starts und Landungen oder auf Anforderung beim Verwalter betätigt. Rotes und weißes Feuer von je 1200 HK. auf dem westlichen und nördlichen der 3 Funktürme in Kalthof. Weißes Blinkfeuer blinkt — · — (K). Rotes Festfeuer von 800 HK. Auf dem Verwaltungsgebäude Windrichtungsanzeiger in Flugzeugform, durch Tiefstrahlungsfeuer beleuchtet. Mast durch Warnungsfeuer gekennzeichnet. Neonfeuer auf den Hallen im Norden und Nordwesten, rotes Neonfeuer in W-Form auf der Kaserne im Nordosten des Rollfeldes. Landefeuer aus grünen, weißen und roten Feuern in Reihe parallel der Windrichtung. Es ist von grün über weiß auf rot hin, rechts der Reihe zu landen. Rollfeldgrenzen durch rote Randfeuer bezeichnet. Im Nordosten wird die Brauerei Königsberg durch rotes Neonfeuer in W-Form gekennzeichnet.
Gelände:	Gute Grasnarbe auf Lehmboden.
Rollänge, kleinste:	In Nordwest- und Südwest-Richtung 620 m.
Hallen:	3 Flugzeughallen. Halle I und II: 54×22 m, Halle III: 50,1×20,35 m. Die Hallen enthalten Laufkräne.

Figure M.4.5 Extract from a Flight Manual for the German Reich - Source: Flughandbuch für das Deutche Reich

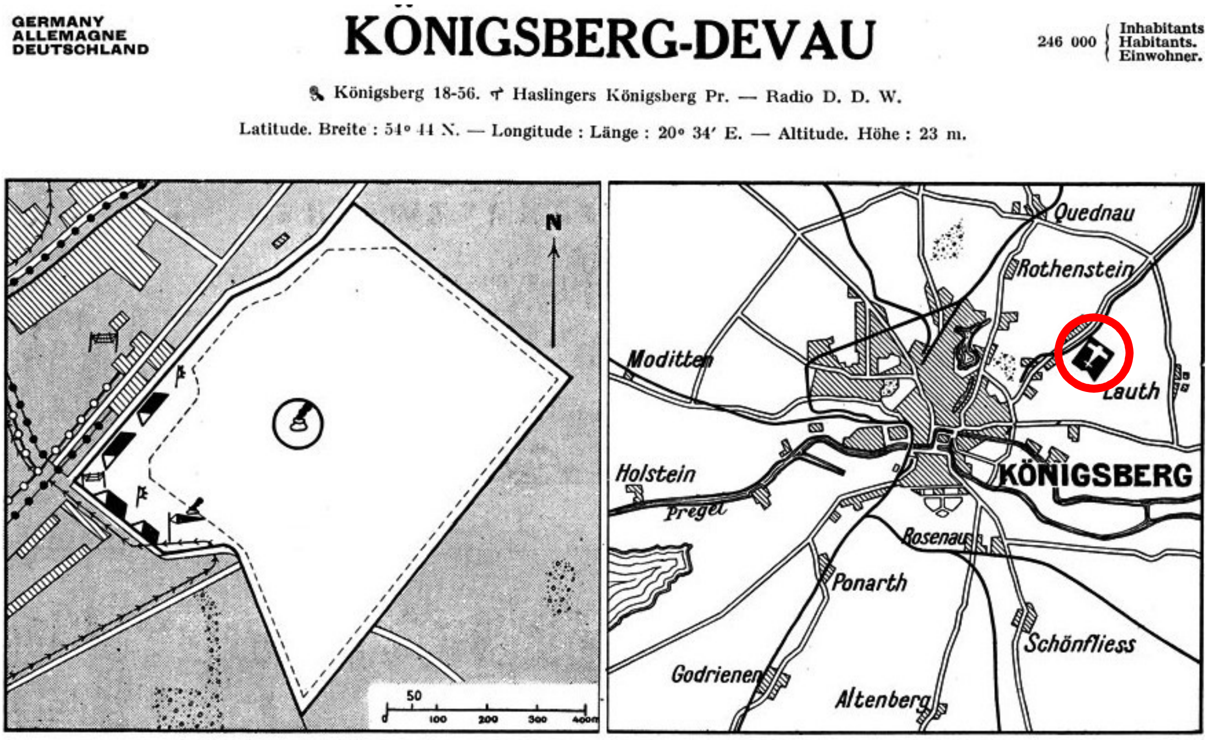


Figure M.4.6 Königsberg site plan and Location Plan – Source: Die Deutschel Luftfart (Treibel, 1992)

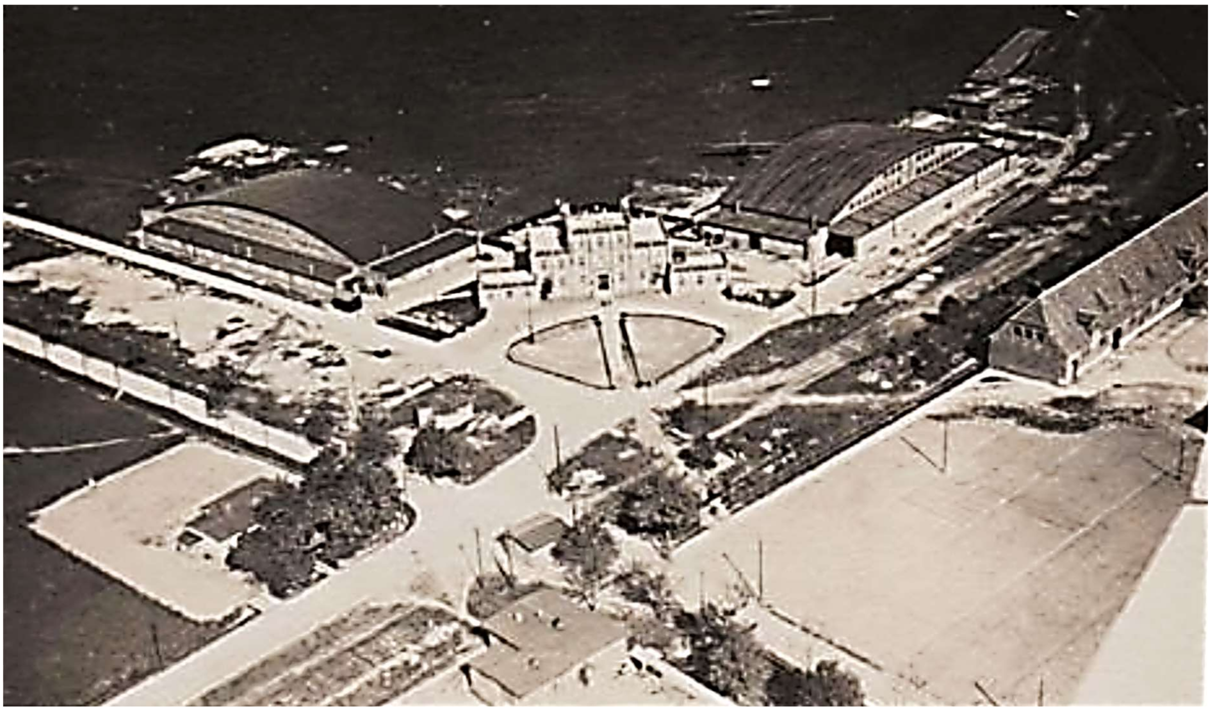


Figure M.4.7 Königsberg Aerial View - Source: Historic Photograph via Pinterest

A concrete apron was later added in front of the terminal which was located so that it was approached diagonally from the south west corner. Roof markings naming the airport as Königsberg and a north point were later painted on the roofs of the hangars (figure 11.4.8).

Figure M.4.8 Königsberg showing spectator facilities – Source: Pinterest.de

The city's tram service was extended to the airport in 1924 soon after the opening of the airport. Line 2 linked the railway station to the airport (figures 11.4.9 & 11.4.10).

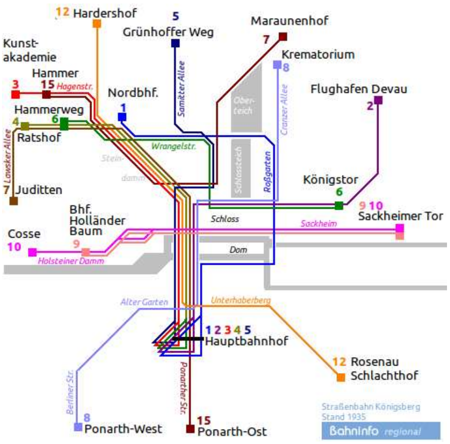


Figure M.4.9 Königsberg tram network – *Figure 11.4.10 Königsberg station (Hauptbahnof)*
Source; http://www.marienburg.pl/files/koenigsberg widok na hansaplatz i nordbahnhof 149.jpg

The terminal was designed by the young Hans Hopp (1890 -1971) who was at the time employed locally in Königsberg, first by the City and then the Königsberg Fair. He was later to become the leading architect in post war East Germany and between 1952 and 1966 he was President of the Deutsche Bauakademie, the national academy of architecture and construction.

His design was essentially neo-classical using a typical Beaux Arts composition of a three bay three storey central section, flanked by two storey two bay wings, and two further single storey three bay outbuildings. The verticality of the composition was emphasised by pilasters that separated the bays (figures M.4.11 & M.4.12) (see also figures 6.15 & 6.16).

Figure M.4.11 Königsberg Terminal landside approach - Source: https://www.bildarchiv-ostpreussen.de/

The roofs of each of the building elements were designed as spectator viewing platforms as became the norm for airport of this period with spectators rather than passengers being the main source of income.

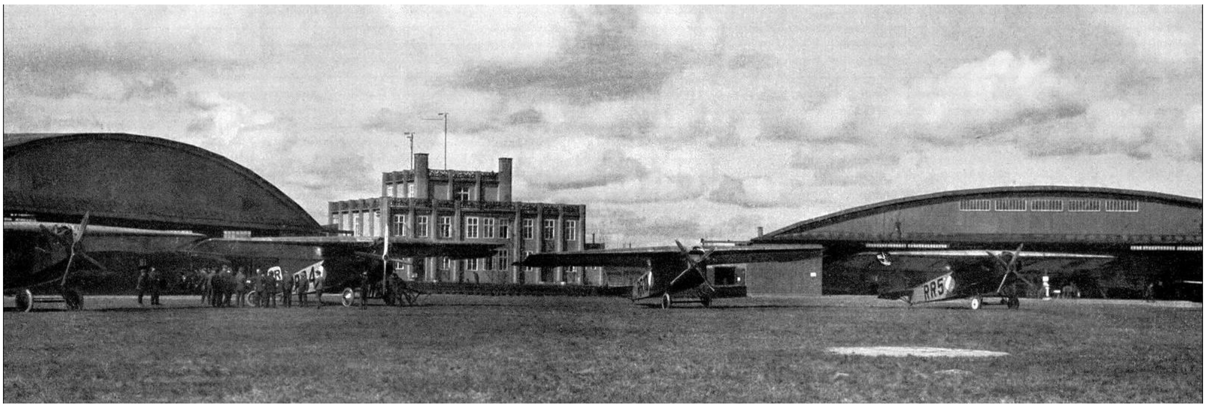


Figure M.4.12 Königsberg seen from the airfield – Source: https://www.bildarchiv-ostpreussen.de/

The terminal contained, a weather station as well as all the necessary passenger processing facilities including customs, immigration and administrative functions of a modern international airport. The requirements for immigration facilities and for passengers to carry passports had only recently been agreed and ratified at the League of Nations, so this would have been one of the first purpose designed immigration facilities.

Lowell Thomas described his experience of flying from Berlin via Danzig and Königsberg en route to Moscow in 1927 in his travelogue - European Skyways:

‘*This Danzig-Königsberg leg of our Berlin-Moscow flight is quite a short one, and in less than an hour we see the outer earthen work forts of the capital of East Prussia, the great military centre where we are to change planes. Königsberg is a city of the plain, built on the north bank of the Pregel. There is not a hill in sight, and the bright red roofs of the houses suggest that modern Königsberg has been built within the course of the past few generations.*

We descend rapidly after we pass over the heart of the city, and at six-thirty-two we drop gently onto the bright green aerodrome a level as a billiard table and one of the largest and finest parking-places for flying-machines that we have ever seen. In war days Königsberg was one of the great mobilisation centres in the campaign against Russia. The Prussians did themselves proud when they made this glorious aerodrome. Lindbergh with his transatlantic plane would have no trouble getting off here with a full load. It is perfectly flat and unobstructed in every direction, pleasantly unlike some of the cow-pasture aerodromes I have come down on in America, and also over here.’ (Thomas, 1927)

The terminal was rebuilt in the 1930s with a more modern style with rounded corners reminiscent of Art Deco (figures M.4.11 & M.4.12).The photograph of the interior shows that the open and welcoming reception/check-in desk (very unlike the small windows to contemporary railway station ticket offices) was central to the interior of the terminal transforming the relationship between the passenger and staff so that they interact on an equal level. The desks were complemented by a discreetly located weighing scale to weigh both passengers and luggage (figure M.4.13).

Figure M.4.13 Königsberg Terminal, rebuilt in the 1930s- Source: https://www.bildarchiv-ostpreussen.de/ Werner Klebusch Collection-- photo: Albert Walsdorf

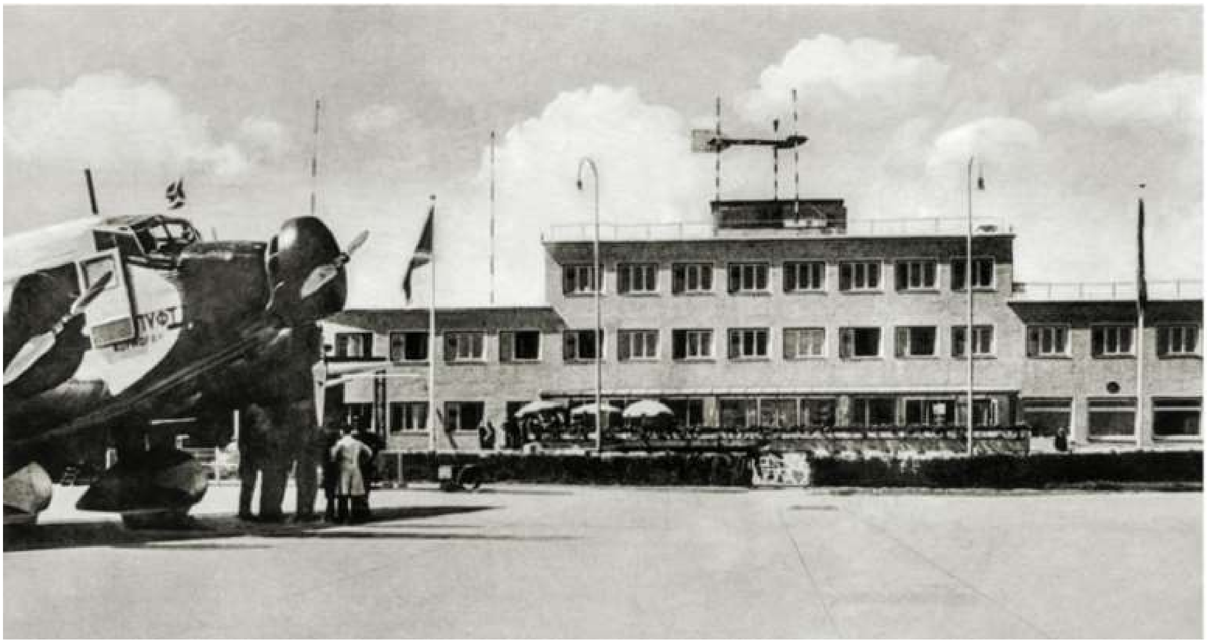


Figure M.4.14 Königsberg Terminal, rebuilt in the 1930s, with a Junkers JU52 in the foreground
Source: https://www.bildarchiv-ostpreussen.de/ Werner Klebusch Collection

Figure M.4.15 Königsberg, Interior View - Source: Museum der Stadt Königsberg (Kalingrad)

5 Berlin Tempelhof (THF) 1928 and 1939

During the 1930s Berlin Tempelhof was by some distance the busiest international airport in the world. In 1939 its timetable showed that it scheduled some 20 aircraft movements an hour between 9 and 10am. All traffic was handled through the original 1928 terminal as the new 1939 terminal, though largely complete, was not yet operational (figure M.5.1).

Figure M.5.1 Berlin Tempelhof 1928 – Source: Deutsch Lufthansa AG

The original masterplan shows the angled hangars on the periphery of the airfield framing the central terminal and embracing the airfield (figure M.5.2). Photographs of the landside and airside of the terminal show its appearance when it was newly completed in 1928 (figure M.5.3). The hangars were designed by Heinrich Kosina and Paul Mahlberg and the terminal by architects Paul and Klaus Engler. The airport and terminal remained in use for civilian flights during the war with the last scheduled flight leaving as late as April 1945.

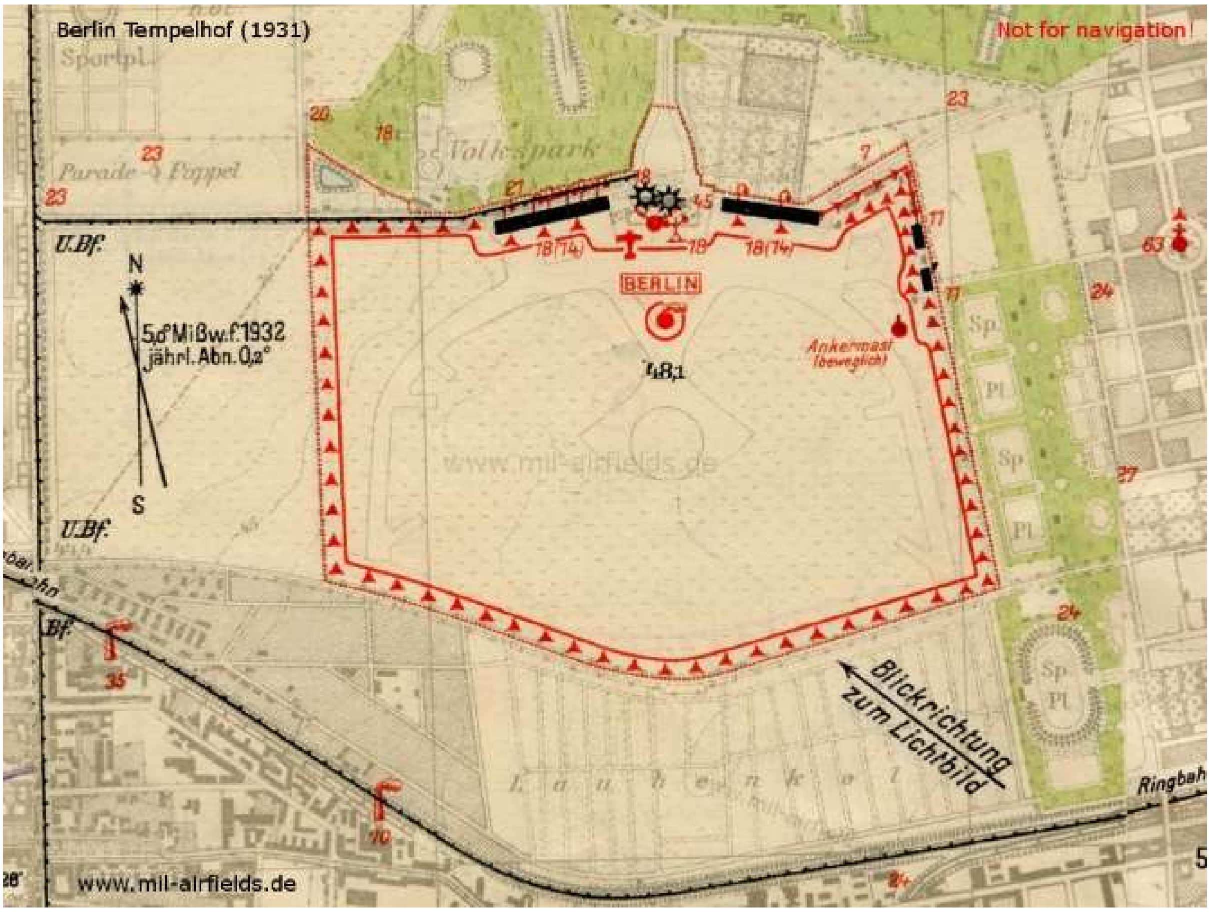


Figure M.5.2 Berlin Tempelhof Site plan 1931 – Source: Military Airfield Directory

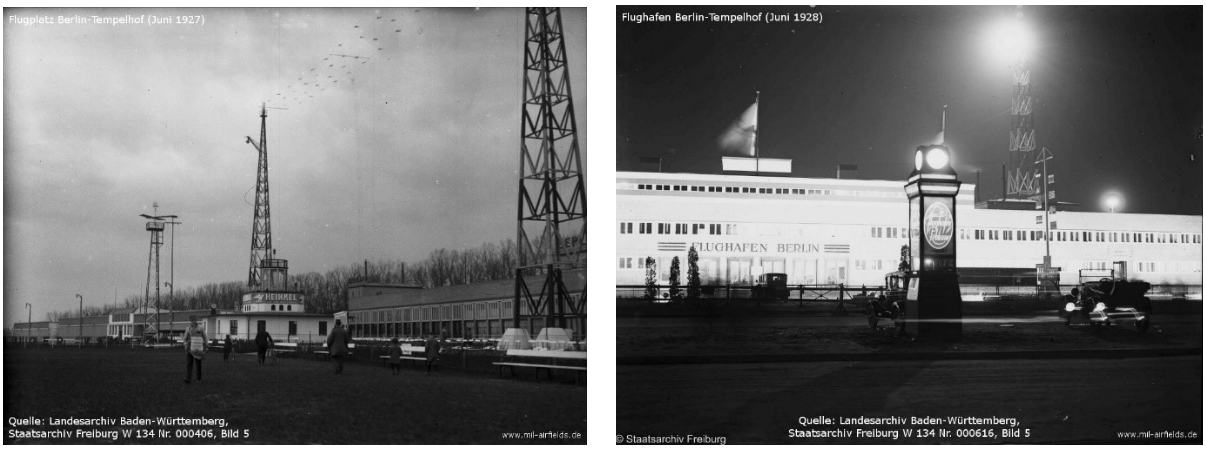


Figure M.5.3 Berlin Tempelhof, airside and landside views of new terminal 1928- Source: Landesarchiv Baden-Württemberg via Military Airfields

When Stedman Hanks described Berlin Tempelhof in 1929 he particularly emphasised the excellent quality of its connectivity to the city centre:

‘*The airport buildings are placed along the northern boundary of the airport and on the main artery of travel between the airport and the city. An underground station and tram line are near enough to the administration building so that transportation facilities are rapid and at frequent intervals’* (see figure 8.34) (Hanks, 1929).

He recognised that the terminal had been designed with extension in mind as can be seen from the Phase 1 and phase 2 photographs (figures M.5.4 & M.5.5) and plan (figure M.5.6) and noted that, unlike Croydon, passenger waiting facilities were airside:

'The main airport administration building, which has been materially extended during the past year, forms the centre structure of the group. Air passengers enter this building for examination by customs officials, and then pass on to the waiting room to wait for the departure of their airplanes' (Hanks, 1929).

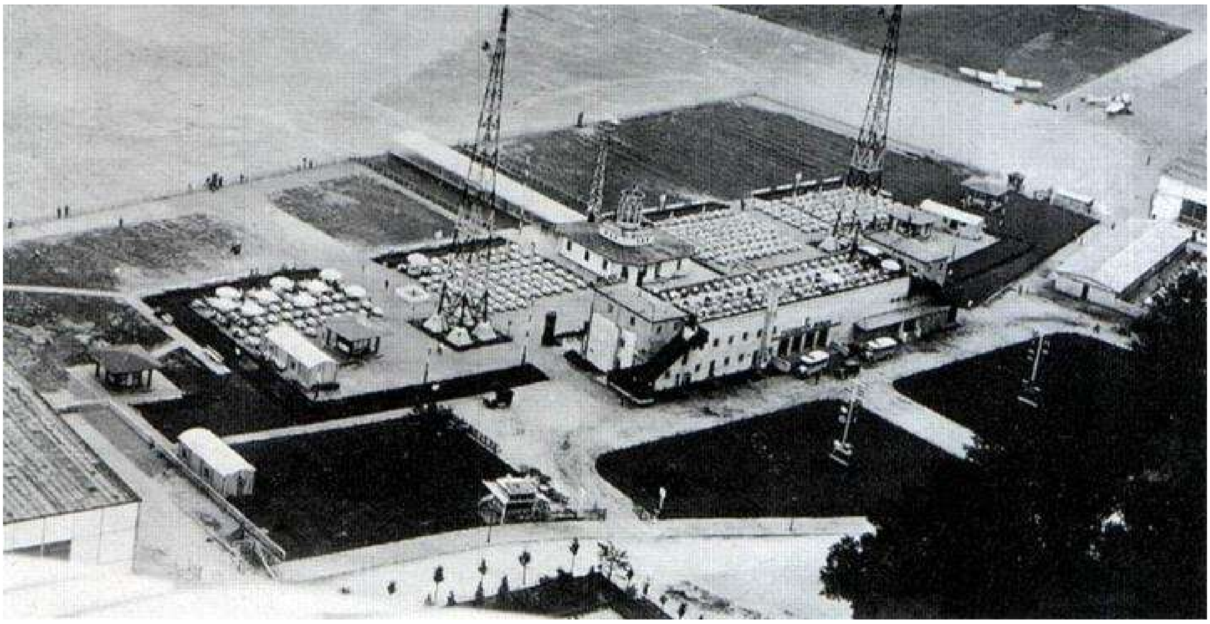


Figure M.5.4 Berlin Tempelhof, Phase 1 of terminal development: Source: dieselpunks.org

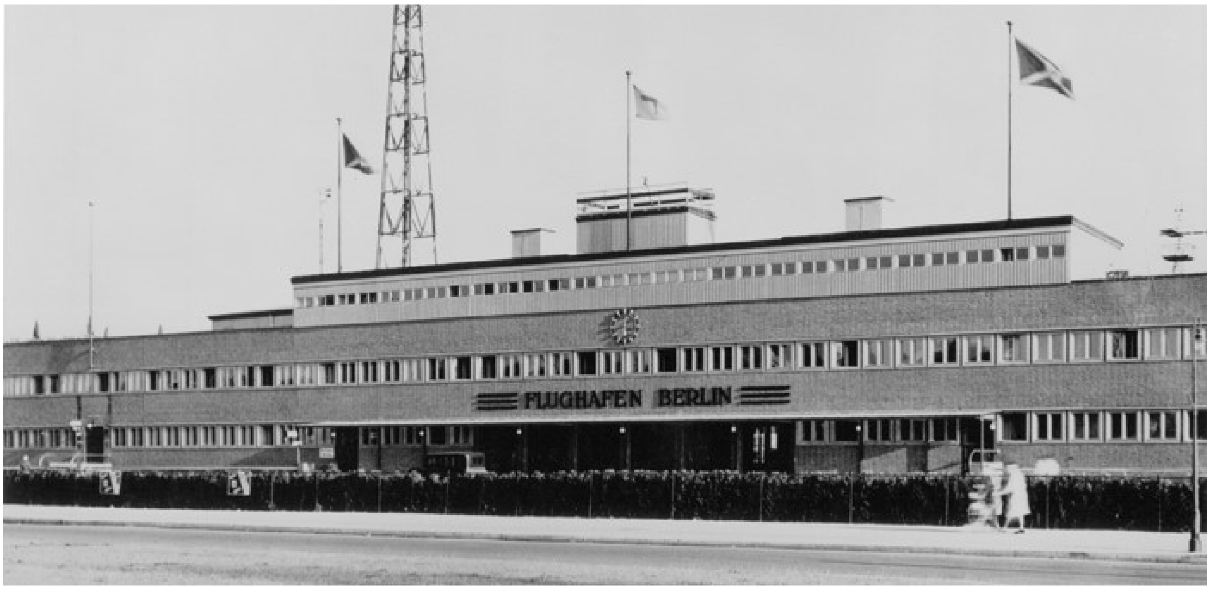


Figure M.5.5 Berlin Tempelhof, Phase 2 of terminal development - Source: thf-berlin.de ©Tempelhof Project

He also recorded the range of facilities that were available:

'In the right wing of this structure is located a modern and well equipped restaurant. The other wing house a branch post office and the offices of air transport companies and airport

officials. The air police use the tower on the administration building. In summer the flat roof is set out with tables and chairs for the use of patrons.' (figure 6.141)

The airport was also used for spectator events such as air shows or Nazi rallies, and had been designed with a slight curve to emphasise the form of an amphitheatre.

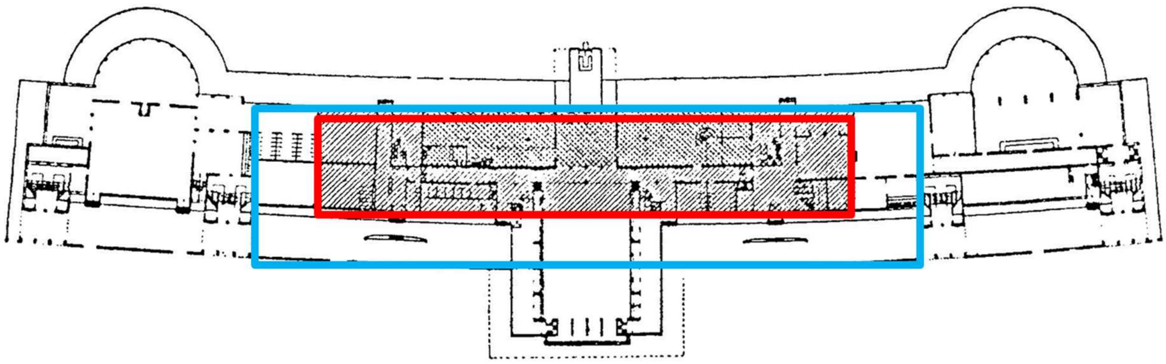


Figure M.5.6 Berlin Tempelhof, floor plan, phase 1 in red, phase 2 blue and unbuilt phase 3 with author's added colour - Source: Die Deutschel Luftfart with author's added colour

Lowell Thomas wrote about his experience of landing there in 1927:

'We make a perfect landing at the finest commercial aerodrome in the world, the Tempelhof Field within the city limits of Berlin…… We taxi up to a concrete platform in front of the spacious main offices of the Deutsche Luft Hansa, where a roomy open car with motor running is waiting to speed us to our hotels.'

On leaving for Moscow they took one of the earliest night flights describing the experience as follows:

'After a midnight supper we taxied to Tempelhof, arriving a half-hour before the time to take off. At ten minutes to two our baggage was weighed and we were weighed. Then we were led across the field to the concrete platform where a mighty three-engined Junkers plane stood ready to whirl us through the night across the hills and forests of Prussia to Danzig, our first stop' (Thomas, 1927).

If the first terminal was modest and extendible, the second terminal was the reverse, a grandiose statement of Nazi ambition over a kilometre long and designed to last sixty years without needing extension. It was planned to be integrated into the master plan for Germania designed by Albert Speer the intended capital of a new empire (see figure 8.37 & 8 38). But as described earlier it was also remarkably innovative and far sighted. For the first time multiple aircraft could be disembarked, turned around and boarded simultaneously from the gate rooms and under the shelter of an enormous canopy (see figure 8.35).

The Reich Air Ministry under the leadership of Hermann Göering undertook the financing and was the builder of the project. In 1935, Ernst Sagebiel, the architect, received the order to design the new airport. Sagebiel, whose work in the Reich Air Ministry began at the end of 1933, made a rapid career there with numerous buildings for the Air Force and especially made his mark because of the planning of the Reich Air Ministry.

The site plan below (figure M.5.7) illustrates the location of the first terminal (1928), shown with a broken outline, and the new terminal and hangar complex in the north-west corner of the site (1939). , ,As can be seen the airfield was extended but was still a grass field while the new terminal was radically larger, and designed to handle traffic that was 30 times greater than the existing demand.

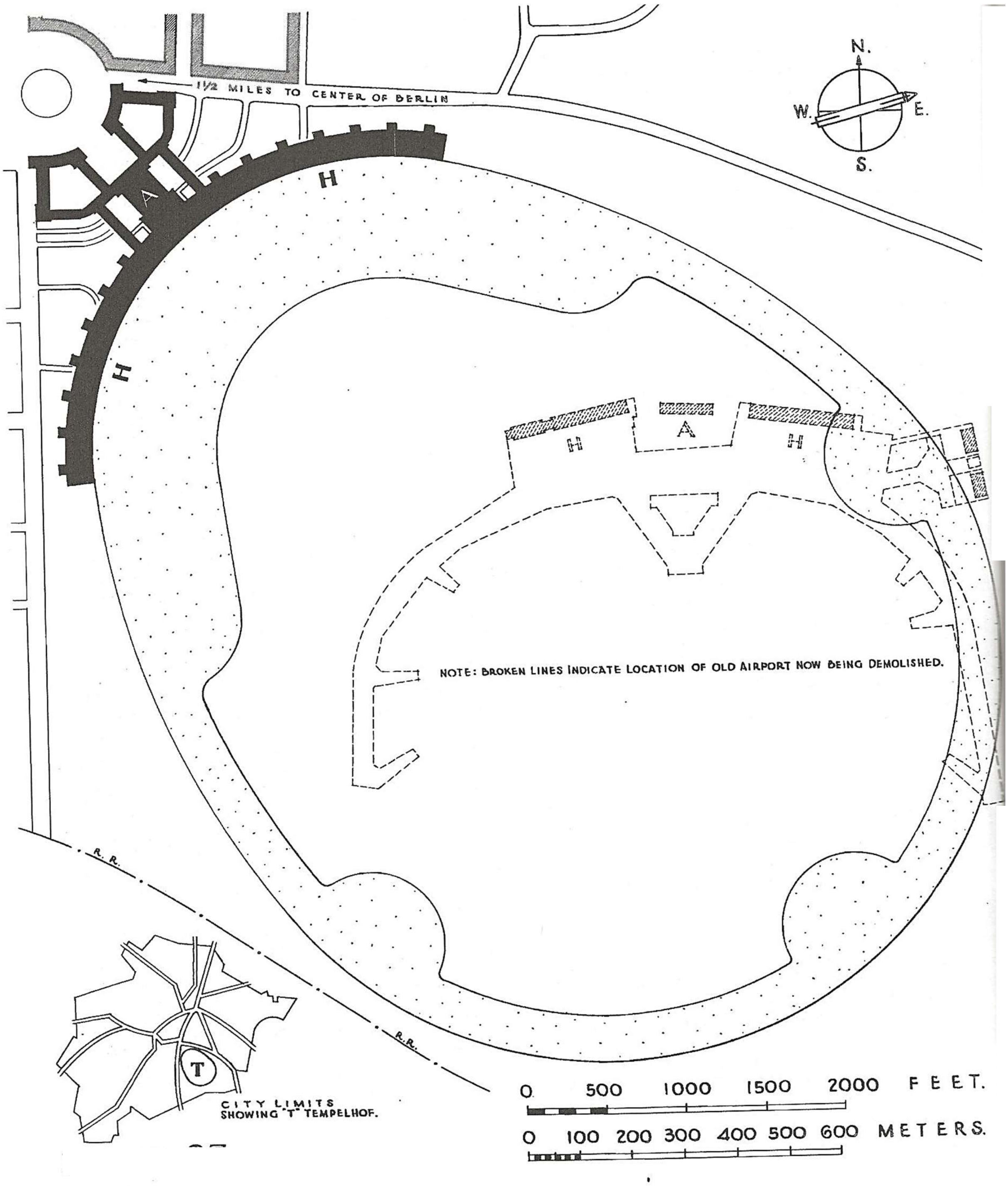


Figure M.5.7 – Berlin Tempelhof site plan showing the relationship between the first and second terminals – Source: Airports, Some Elements of Design and Future Development, John Walter Wood.

In the spring of 1936, the construction for the Airport Tempelhof began. After the initial speedy progress - the first building section was already constructed in the year of the topping-out ceremony 1937 - construction work came to a halt due to the war. The opening intended for 1939 could no longer take place. A number of large scale models, one of which is illustrated below, (figure M.5.8) were prepared by the architect, Ernst Sagebiel, together with drawings that have fortuitously been preserved (figures .5.M9, M.5.10 & M.5.11).

Figure M.5.8 Berlin Tempelhof, model of second terminal building 1937 – Source: thf-berlin.de ©Tempelhof Project

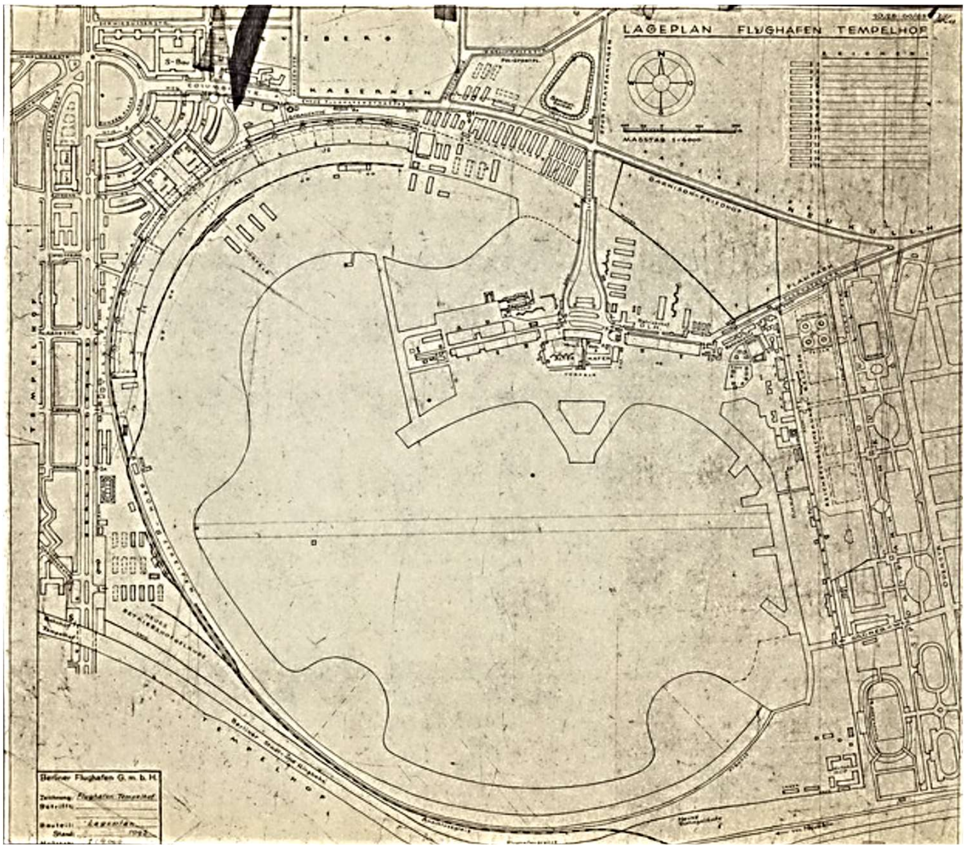


Figure M.5.9 Berlin, Tempelhof Site Plan - Source: Technische Universität Berlin Architekturmuseum

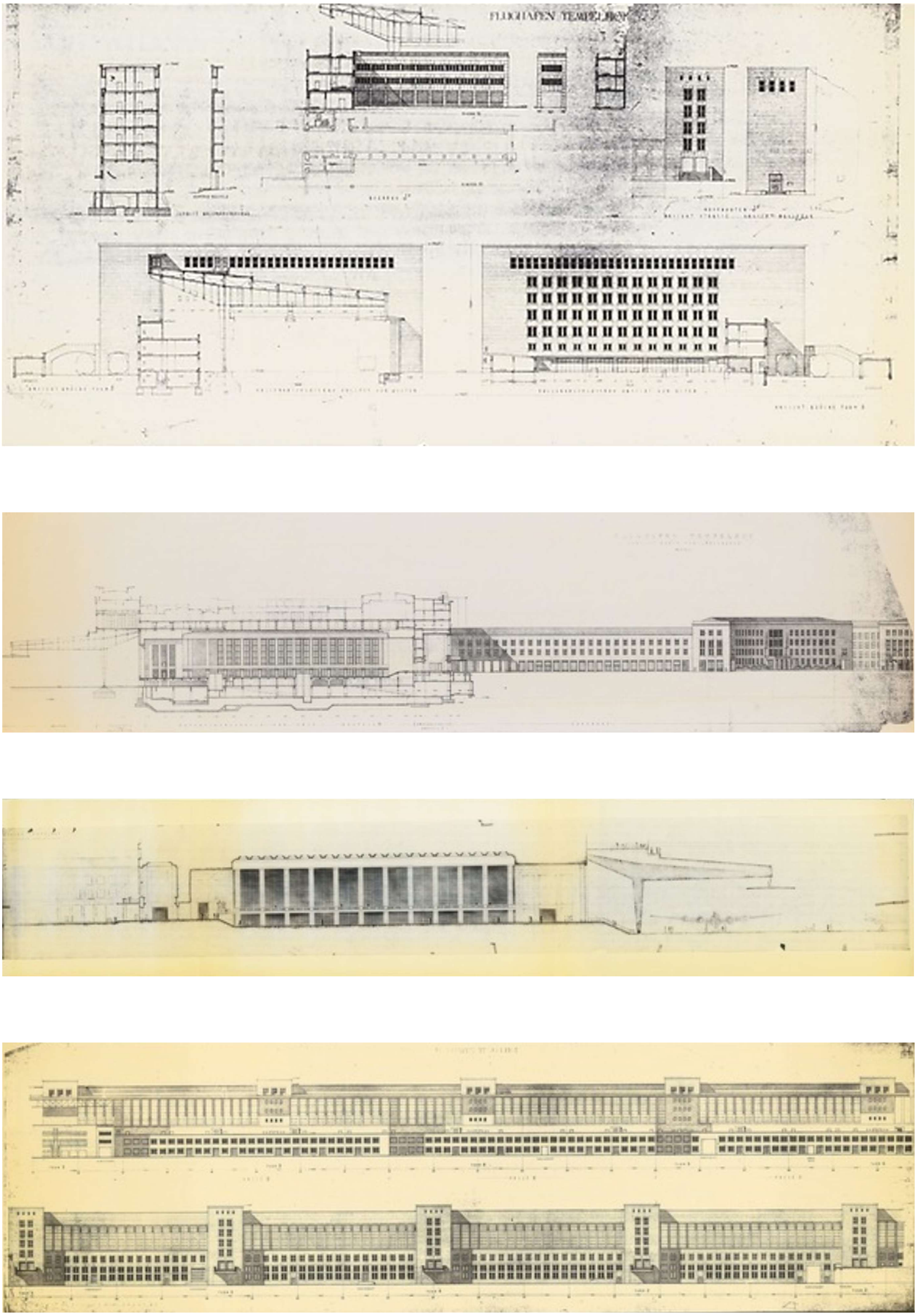


Figure M.5.10 Ernst Sagebiel's drawings for new terminal 1937 - Source: Technische Universität Berlin Architekturmuseum

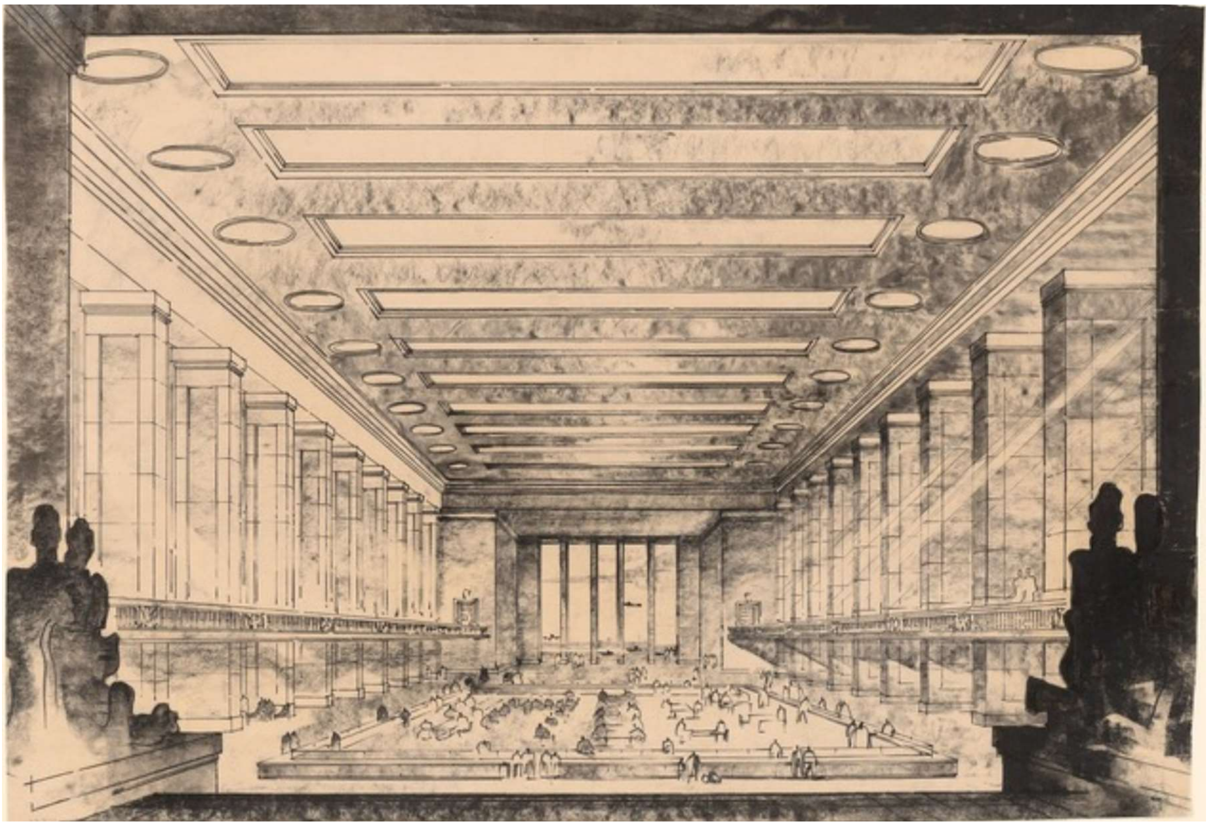


Figure M.5.11 Perspective of check-in hall Source: Technische Universität Berlin Architekturmuseum

The photograh below shows that the main check-in and arrivals hall was preserved with little modificaton until the airport's closure in 2007 (figure M.5.12).

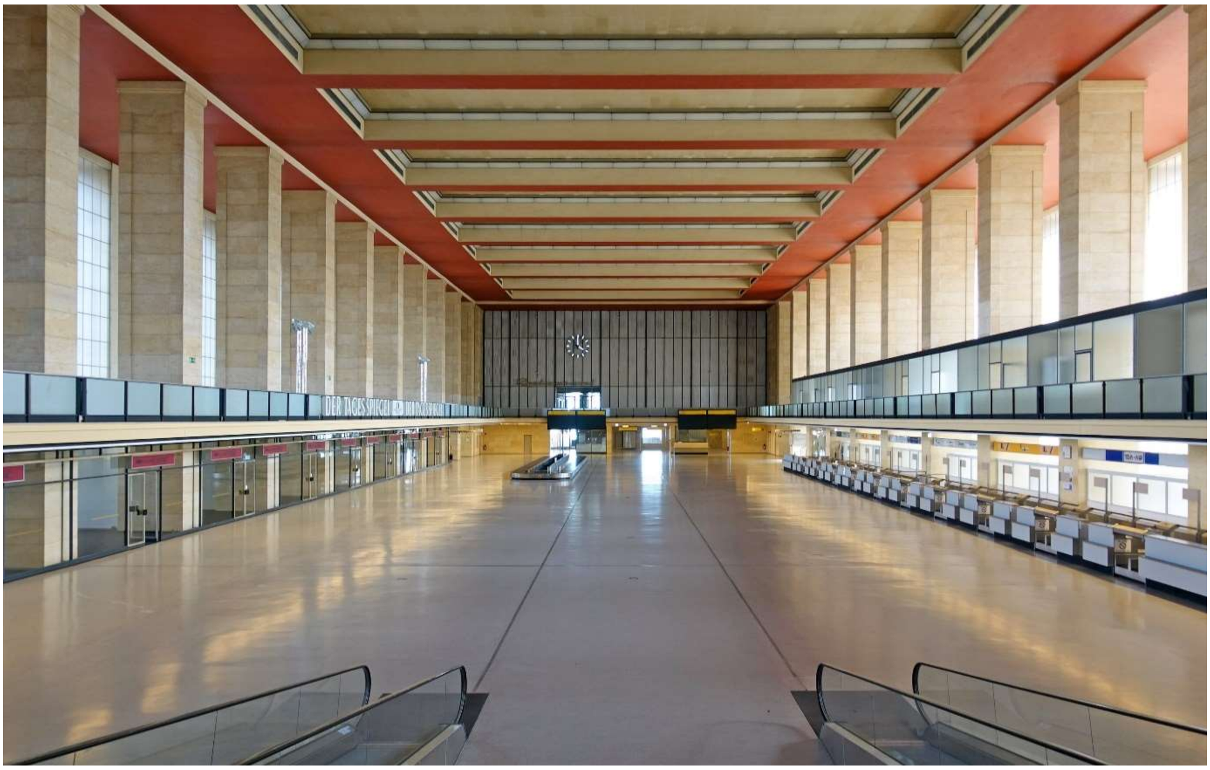


Figure M.5.12 Berlin Tempelhof main check-in hall photographed in 2017 after closure of airport – Source Wikipedia

A new metro station was constructed just outside the main entrance, and a rail network was integrated under the terminal to bring cargo and post directly into the building (see figure 8.36). Aircraft hangars that extended either side from the terminal were designed to make the complex look even larger and more impressive. The terminal continued to be used in post war Germany and was only closed in 2007 due to adverse noise and other environmental impacts. Throughout its life the terminal changed little as it had been built with so much surplus capacity.

Writing in 1940 John Walter Wood identified the two key features that were open to criticism:

'It seems unnecessary and wasteful of space to build vast roof spans to bring large transport planes under cover to the loading platform when a covered passenger platform would accomplish the same purpose at less expense and without limiting the dimensions of planes and their free circulation at the loading points. Similarly, there are obvious disadvantages in bringing the loading platform and the passengers so closely in contact with the hangars. A more complete separation of incoming and outgoing passenger traffic would have been an advantage to airport operation' (Wood, 1940).

His perceptive comments were to become the guidelines for subsequent airport design.

The airfield was less well thought out retaining a grass field when others had begun to adopt concrete runways, though the airport director of the time recognised this feature was obsolescent even before it was completed. After the war the US Air force which used it as a base built a temporary hard surface runway and later on either side two concrete runways (figure M.5.13). The US reorganised the terminal during their occupation (figure M.5.14).

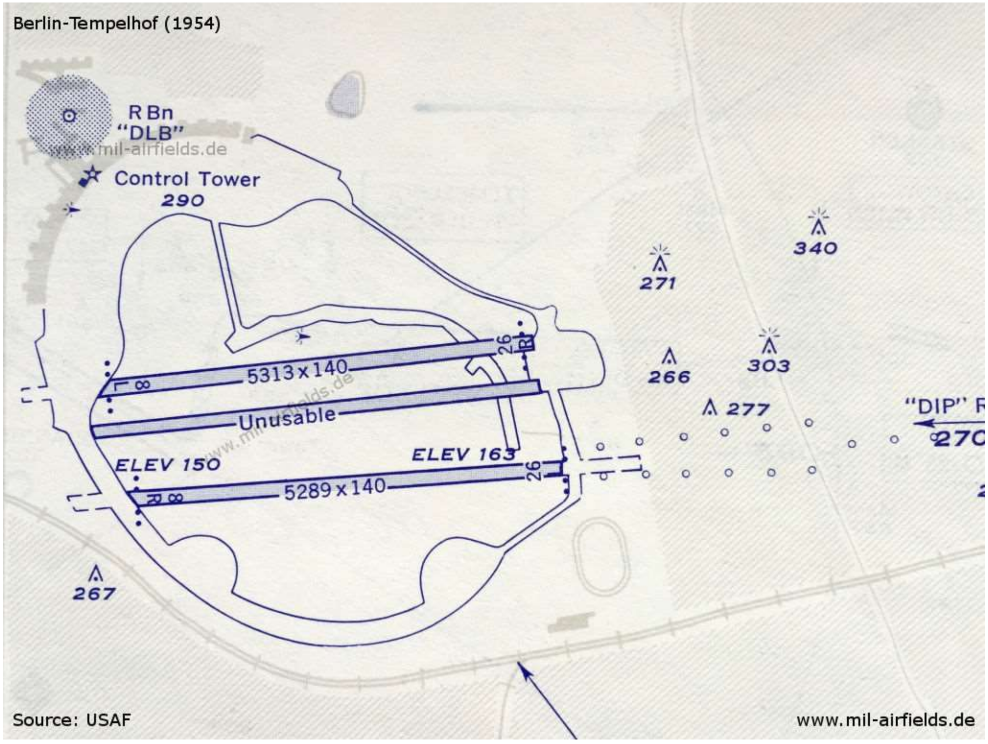


Figure M.5.13 Berlin Tempelhof site plan showing runway layout in 1954 – Source: www. milairfields.de

This enabled to airport to be used in the Berlin Airlift, when the city was blockaded by the Russians, with aircraft taking off and landing only three minutes apart leading, to new strategies in air traffic control which continue to be used today (figure 11.5.15).

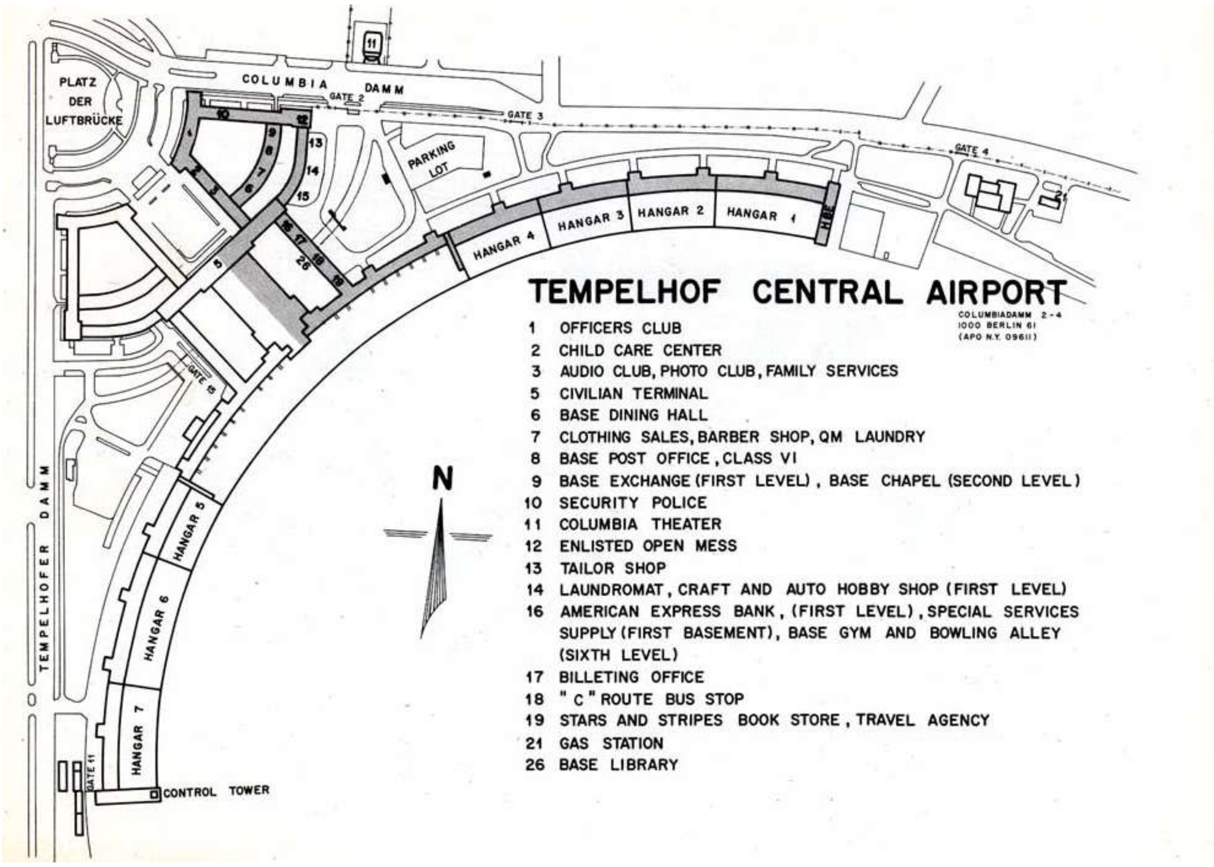


Figure M.5.14 Berlin Tempelhof, terminal layout under American military occupation – Source: usarmygermany.com

The airspace system that we enjoy today was developed and perfected as a result of the Berlin airlift in 1948-9, with modern ground approach control evolving directly from that experience (figure M.5.14). The standardisation of aircraft type to the C-54 Skymaster during the airlift aided the pit stop performance in aircraft turnaround, a factor that would later be rediscovered by the Low Cost Carriers.

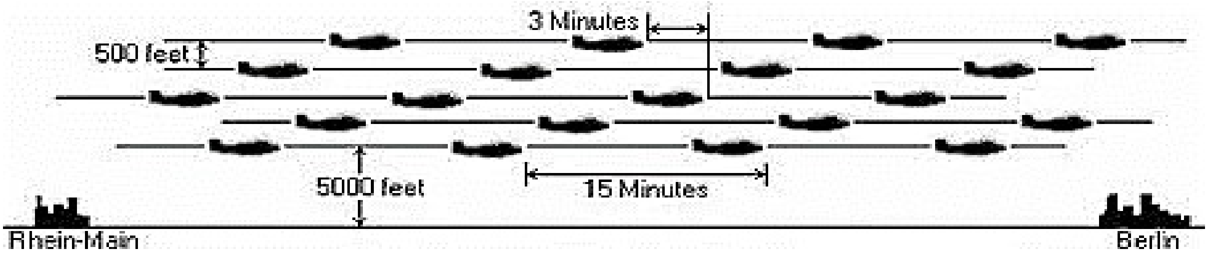


Figure M.5.15 Cross-sectional view of airlift flights into Berlin - Source: AU ECI course 50 page 103

The following images show the flight network that supported the Berlin Airlift (figure M.5.16) and Berliners watching a US Air Force C-54 Skymaster land at Tempelhof (M.5.17). The plane was nicknamed the Rosinenbomber (Candy Bomber) by children as it dropped candy as it came into land. From April 16th 1949 Allied planes landed at the rate of one for every minute.

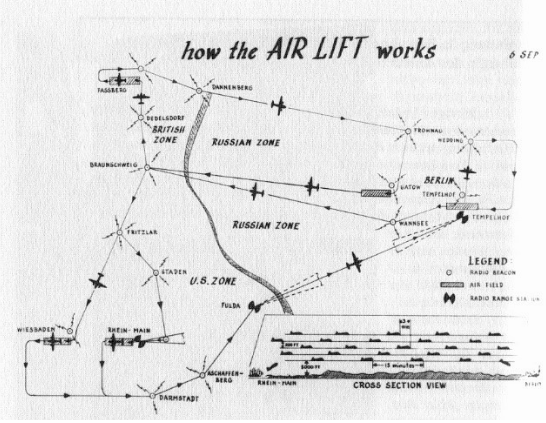


Figure M.5.16 Berlin Airlift airspace layout
Source: weaonsandwarfare.com/

Figure M.5.17.C-54 Skymaster landing at Tempelhof Berlin
'The Candy Bomber' - Source: NATO

Post war civil aviation resumed at Tempelhof, spearheaded by American Overseas Airways, which was later taken over by Pan Am, whose aircraft is in the foreground of the following photograph (figure M.5.18).

Figure M.5.18 Berlin Tempelhof, Arrival of Pan American Airways Flight in 1955 – Source: http://peterpapke.de

The following images show the evolution of the airfield from the war to the present day (figures M.5.19, M.5.20, M.5.21 & M.5.22).

Figure M.5.19 Berlin Tempelhof wartime aerial view with many aircraft dispersed across the airfield 1943 Source: Forgottenairfields.com

Figure M.5.20 Berlin Tempelhof immediate post-war aerial view with single hardened runway – Source: Forgottenairfields.com

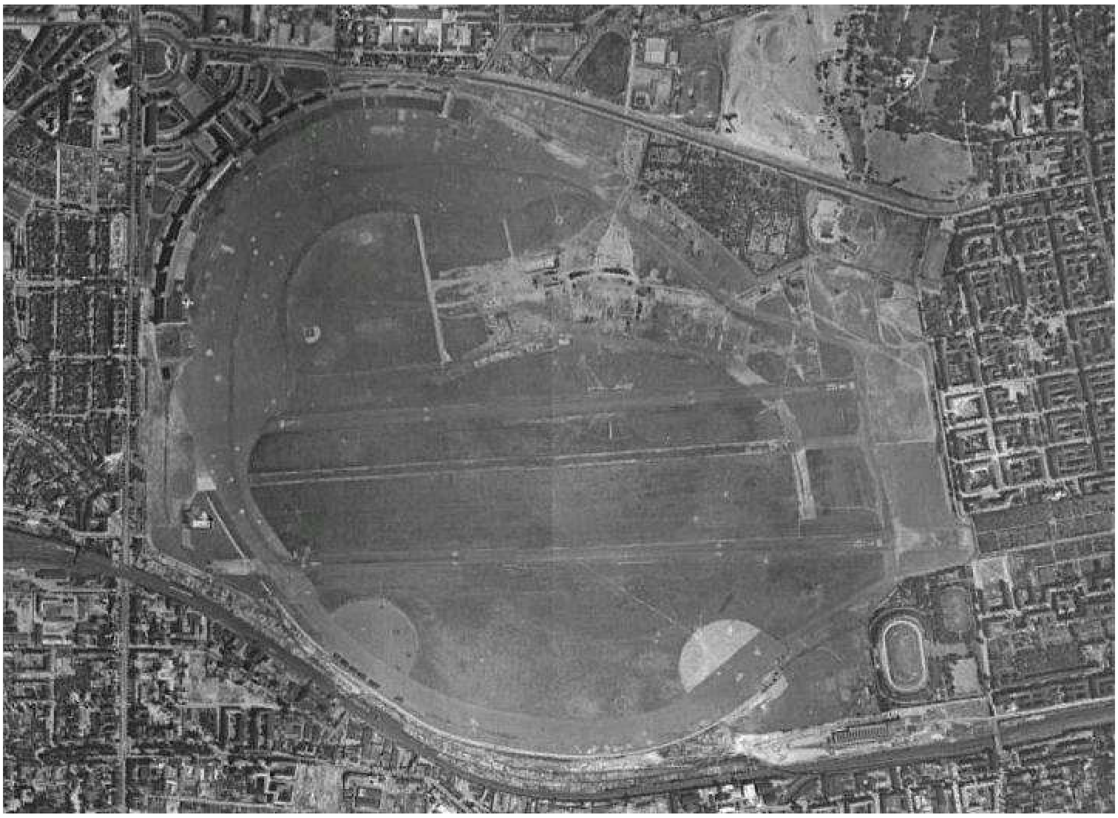


Figure M.5.21 Berlin Tempelhof aerial view with twin runways either side of earlier single runway l953 Source: forgottenairfields.com

Figure M.5.22 Berlin Tempelhof, aerial view of final airport layout with the addition of twin runways – Source: Google Maps

Finally the airport has taken on a new role as a museum and park, following the closure of the airport (figures M.5.23 & M.5.24).

Figure M.5.23 Berlin Tempelhof main entrance in 2019 - Source: maps.google.com

Figure M.5.24 Berlin Tempelhof, Check-in hall re-used as a museum in 2019 - Source:tagesspeigel.de (2019)

6 Gatwick (LGW) 1936 & 1958

Gatwick, is located some 30 miles south of London adjacent to the London-Brighton main line railway (M.6.1). The first innovation was the realisation of the circular form of terminal building which allowed aircraft to park all around it, putting into practice ideas that had earlier been put forward in the Lehigh and Stockholm Bromma competitions (figure M.6.2, M.6.3 & M.6.4). Although its inability to expand was recognised from the outset many subsequent airports have constructed circular satellites. Gatwick was also one of the first to introduce dry boarding as simple retractable canopies.

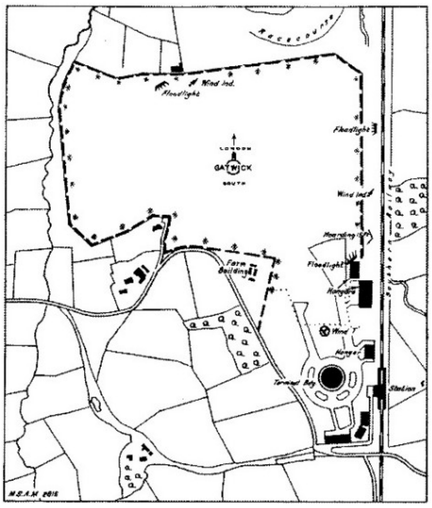


Figure M.6.1 Gatwick 1937, Site plan
Source: UK Airfields and Airports

Figure M.6.2 Gatwick Terminal Model
Source: V&A Museum

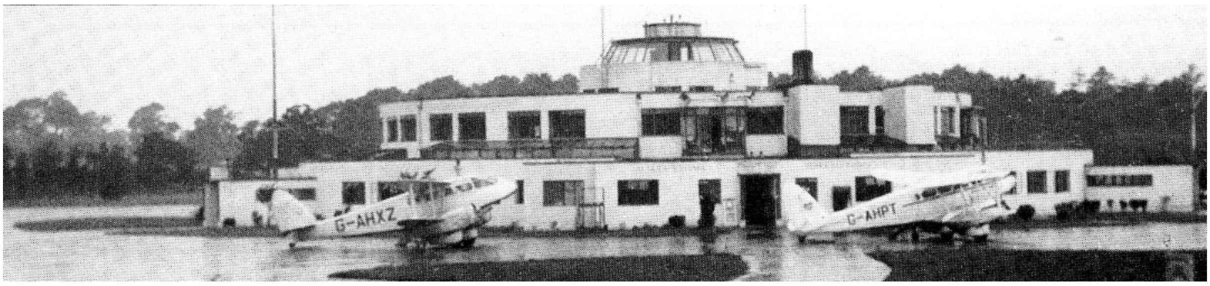


Figure M.6.3 Gatwick Terminal - Source: UK Airfields and Airports

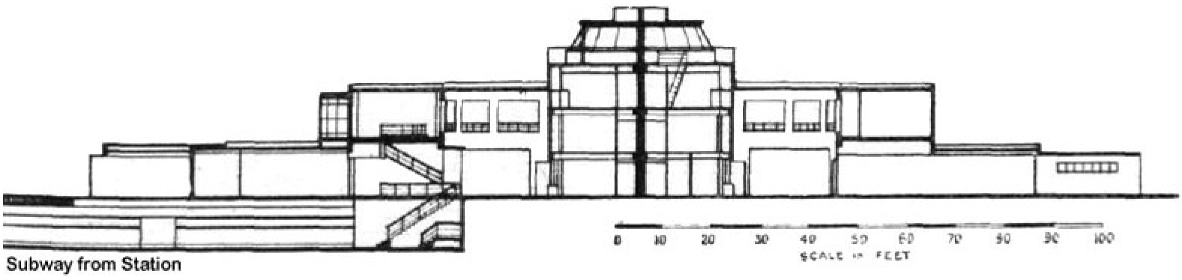


Figure M.6.4 Section through terminal - Source: British Caledonian

The circular terminal was surrounded by six gates, three for arrivals and three for departures, so unlike today the aircraft had to be moved after passengers had dis-embarked and before the next flight could board the aircraft. As John Walter Wood pointed out the circular form meant that internal circulation was not straight forward;

‘The simple lines of the air station as viewed from the air are somewhat misleading and leave one unprepared for the complexity of the interior planning and passenger circulation’ (Wood, 1940, p. 165).

He also criticised the ground movement of aircraft, which involved cross circulation of aircraft and a requirement to circumnavigate the terminal on their way to the hangars and before departing some one and a half times.

Pre-war Gatwick airport was, however, not very successful in part because the airfield was very small by comparison with other airfields of the period (see figure 7.21), restricting the take-off and landing length available, and the ground conditions were very poor, as the airfield lay within in the flood plain of the river Mole leading to frequent closures due to boggy conditions. As a result some of the airlines, including British Airways, moved their operations to Croydon. Gatwick was also the first to have its own dedicated railway station, specially constructed to allow the fastest possible journey time from the city centre. The operators complemented this with offering integrated rail/air tickets that are rare even now. The journey time from London to Paris was better in 1936 than can be achieved today.

The second Gatwick Airport of 1958, went further in integrating rail travel by linking the rail station and air terminal under a single roof (figure M.6.5). It has afforded Gatwick one of the highest proportions of rail travel in the country.

Figure M.6.5 Gatwick 1958 aerial view with railway station in the foreground - Source: ukairfieldguide.net

Gatwick also saw a number of other innovations, the first pier and first transit system in Europe and the first to include a major retail offer. Another aspect where Gatwick has influenced later terminal designs is in the adoption of the modern international style with modular interchangeable components, finding some of the lightness and dynamism that was sought by the Futurists (figure M.6.6).

Figure M.6.6 Gatwick Airport 1958 – Source: Yorke, Rosenberg and Mardall (reproduced with permission from RMJM)

In 1961, a few years after the new airport's opening, G.E. Kidder Smith wrote;

> *'The cleverest feature of this south of London airport is the coalescing of three forms of transport – air, rail, and road under one roof. Rarely has this been accomplished so effectively…….Another admirable feature is its quality of 'airportness': as soon as one arrives one feels that this is an airport and no other transport service. One is architecturally, indeed physically, projected into the field and made a part of the excitement, for no solid wall ever rises between the passenger and his aerial transport'* (Kidder Smith, 1961).

The new Gatwick pioneered a number of aspects of design that we find in terminals today including:

1. The first integrated rail/air interchange under one continuous roof (figure M.6.5).
2. The first pier in Europe (figure M.6.5).
3. The first automated people mover (APM) in Europe (figure M.6.10).
4. The first circular satellite (figure M.6.10).
5. The first post war 'International Style' terminal (figures M.6.6).
6. The first passenger bridge in Europe over a live taxiway linking a pier (figure M.6.10)

Gatwick has been expanded greatly over the years, the first major extension being the doubling of the size of the terminal and the introduction of the north and south piers in 1964.

The relationship between the new 1958 terminal, and the original 1936 'Beehive' circular terminal, can be seen in the following photograph taken after the first extension (figure M.6.8).

Figure M.6.8 Gatwick, showing relationship of 1936 terminal (top right) and new 1958 terminal (top left) – Source: Author's own collection (courtesy of Keith Newton) photographed after the 1964 extension.

In 1970 the central pier was rebuilt on a larger scale with enclosed gaterooms and passenger boarding bridges to provide access to the aircraft. The existing landside forecourt, accessed from the A23, was demolished and the road access was moved to the east of the railway to provide access to the new M23 motorway (figure M.6.9).

Figure M.6.9 Gatwick, South Terminal 1977 with northern and eastern extensions and rebuilt central pier - Source: Gatwick Airport

In 1983 a circular satellite designed to handle wide bodied aircraft replaced the northern pier and was served by the first APM in Europe (figure M.6.10).

Figure M.6.10 Gatwick, South Terminal with the satellite and APM in the foreground, 1983 – Source: Gatwick Airport

Gatwick had planned from the 1970s to build a second parallel runway to the north of the terminal (figure m.6.11),but later decided that terminal expansion took priority and in 1979 signed an agreement with the local planning authority not to seek a second runway for 40 years in exchange for their support for a second terminal.

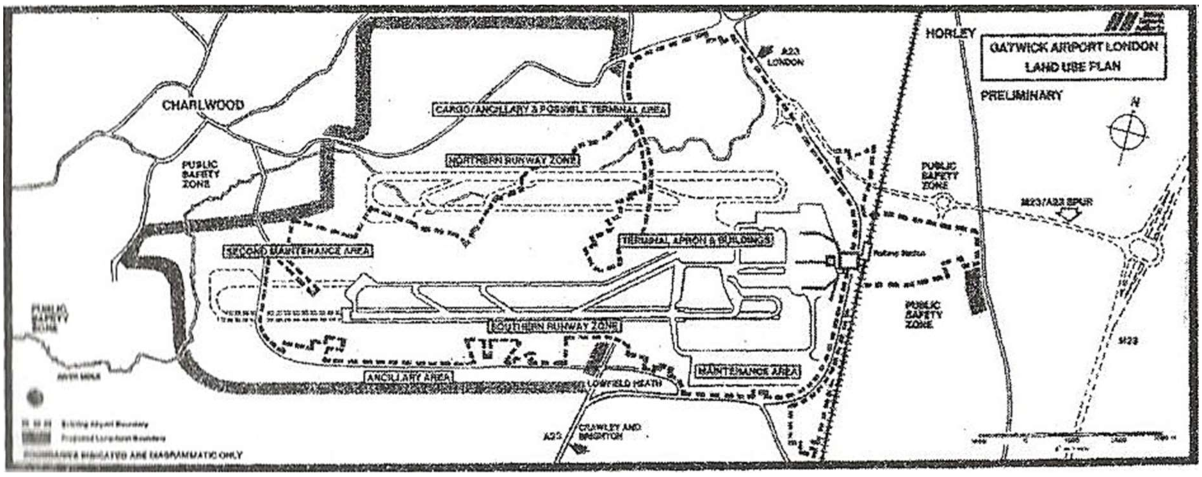


Figure M.6.11 Gatwick, 1970 Land Use Plan showing proposed second runway – Source: BAA (via Dave Welch)

The second terminal, now known as North Terminal, was then designed to occupy the site that had previously been safeguarded for the new runway. The evolution of the terminal facilities between 1958 and 1988 at Gatwick are ilustrated below (figure M.6.12).

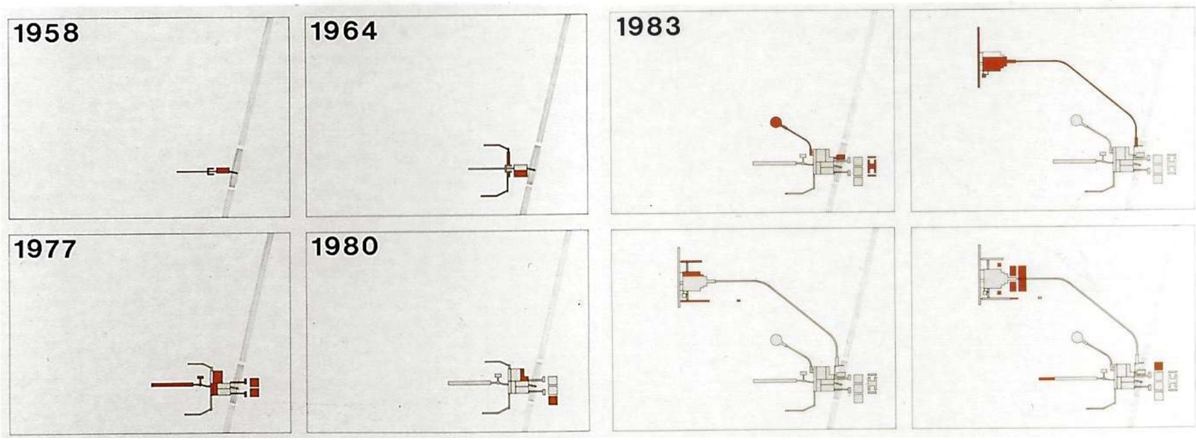


Figure M.6.12 Evolution of Gatwick from 1958 to1988– Source: YRM (reproduced with permission from RMJM)

YRM's second terminal, Gatwick North, is reached from the rail interchange by another transit (blue) and by an extension of the road network (orange) from the South Terminal (figures M.6.13 & M.6.14)).

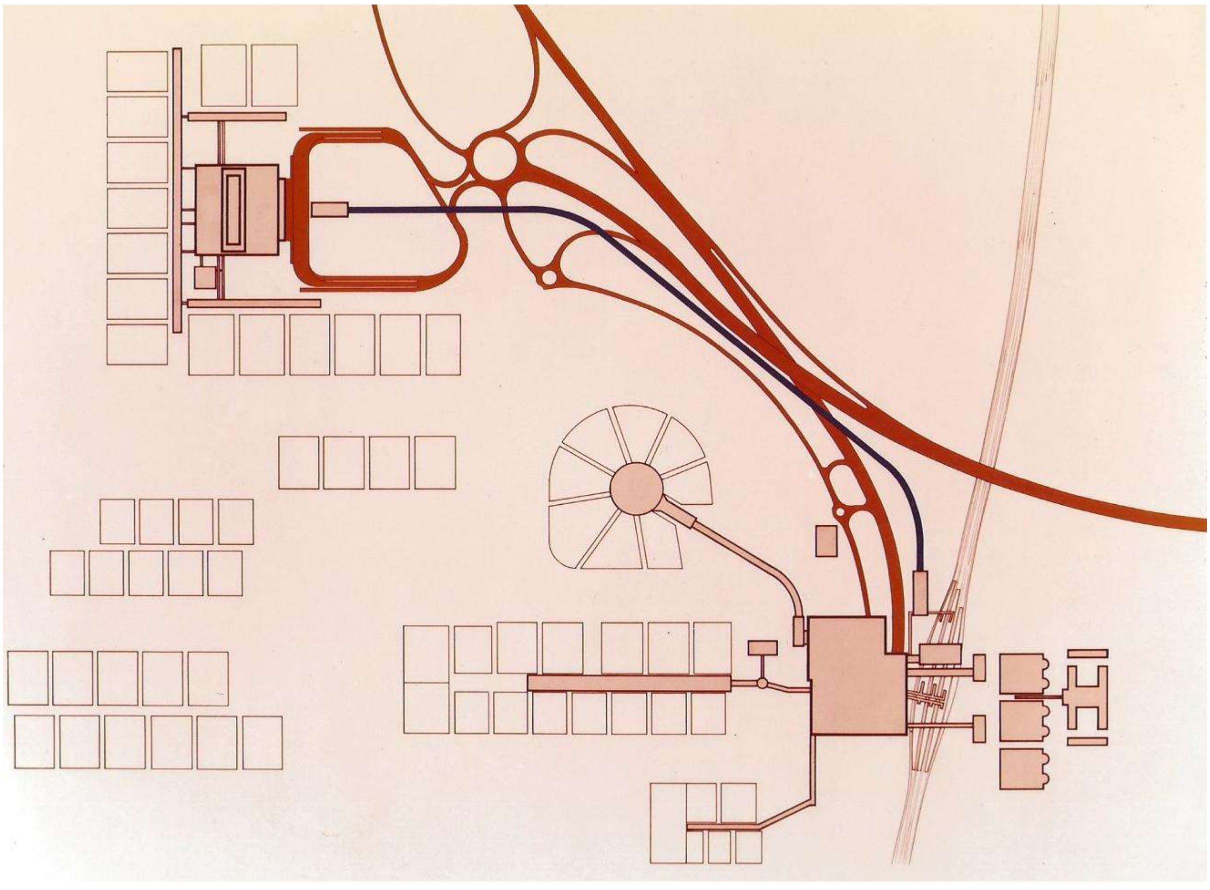


Figure M.6.13 Gatwick, North Terminal Access– Source: YRM (reproduced with permission from RMJM)

YRM's publicity brochure of the time describes the terminal as follows:

> '*the impression of relaxing simplicity, with a total absence of unnecessary detail and varying quality and consistency of design that mars so many airports.'*

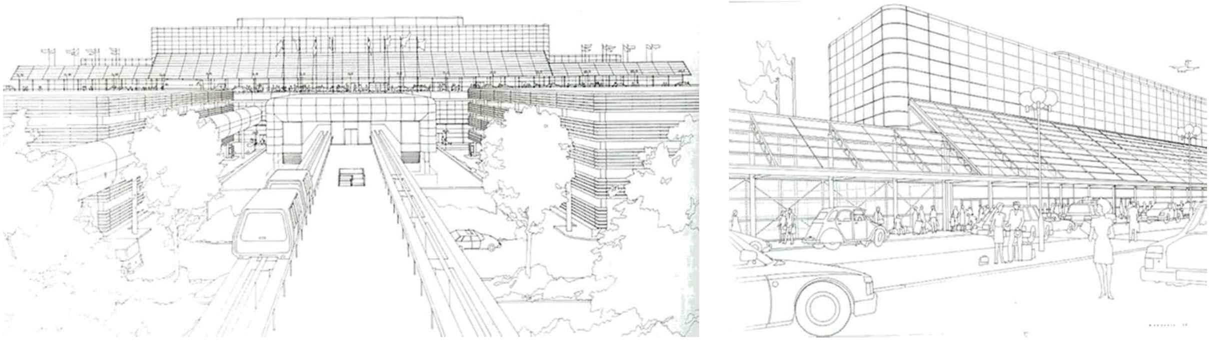


Figure M.6.14 Gatwick, North Terminal landside interchange, transit station and forecourt design sketches Source: YRM (reproduced with permission from RMJM) – Graphics: Bo Mahaddie

The building was designed on three levels as a loose fit (figure M.6.15), almost entirely in dry prefabricated construction, with interchangeable cladding panels inside and out, developed from the system first used by YRM for IBM at Warwick University. That flexibility has allowed the terminal to respond to new trends, with major internal re-organisations, accommodating the growth of retail, stricter security, and the introduction of automated passport control and self-service check-in.

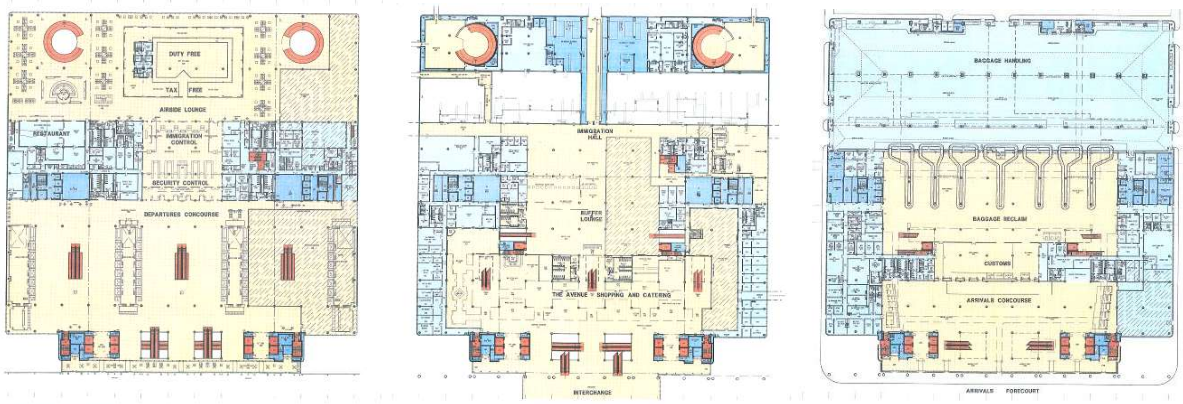


Figure M.6.15 Gatwick, North Terminal, Departures, Commercial and Arrivals Floor Plans, 1988 – Source: YRM (reproduced with permission from RMJM)

Colour plays a major role with the blue of the vitreous enamel panels to the terminal building contrasting with the silver of the pier and white of the link bridges (figures M.6.16, M.6.17 & M.6.18). In writing about YRM in 1992, to accompany an exhibition of their work at the RIBA Heinz Gallery, Alan Powers noted that:

> '*The advantage of YRM's consistency of style and gradual evolution is seen at Gatwick, where the turbulent zeitgeist has been calmed into submission and the architecture benefits from a continuous development of technical understanding.'* (Powers, 1992)

Figure M.6.16 Gatwick, North Terminal, aerial view 1988 - Source: British Airways

Figure M.6.17 Gatwick, North Terminal airside view – Source: YRM (reproduced with permission from RMJM)

Figure M.6.18 Gatwick, North Terminal landside view from transit – Source: BAA

Figure M.6.19 Gatwick aerial view including the North Terminal – Source: BAA

The passenger bridge (figure M.6.20) was designed to link a remote satellite, known as pier 6, with the North Terminal. Early consideration had been given to a tunnel alternative but following a visit to Denver, which had pioneered a bridge link to the first satellite, BAA were convinced that a bridge was both more economical and offered a better passenger experience. Unlike Denver where the bridge was only designed to span over short haul B737 aircraft, the North Terminal Bridge was designed to allow B747 Jumbo aircraft to pass under. Other airports, such as Brussels, have now followed this example.

Figure M.6.20 Gatwick, Bridge over the taxiway from the North Terminal to Pier 6 – Source: ukairfieldguide.net

While much of the simplicity and clarity has been lost as the airport has expanded, full advantage has been taken of the flexibility of the cladding and other components. Many components have been successfully moved from one location and re-used in another as the airport has expanded (figure M.6.19). Gatwick today is the busiest single runway airport in the world.

Looking to the future, the draft Master Plan set out Gatwick Airport Limited's ambitious vision for the future and looks at how the airport could grow across three scenarios, looking ahead to the early 2030s:

- Main runway – using new technology to increase capacity – In the near term, the airport has considered how deploying new technology could increase the capacity of the main runway, offering incremental growth through more efficient operations.
- Standby runway – bringing existing emergency/maintenance "standby" runway into routine use – Under its current planning agreement, Gatwick's existing standby runway is only used when the main runway is closed for maintenance or emergencies. However, the 40-year planning agreement came to an end in 2019. The draft master plan sets out for the first time how Gatwick could potentially bring its existing standby runway into routine use for departing flights, alongside its main runway, by the mid-2020s.
- Additional runway – safeguarding for the future – While Gatwick is not currently actively pursuing the option of building a brand new runway to the south of the airport – as it did through the Airports Commission process (figure M.6.21) – Gatwick believes it is in the national interest to continue to safeguard this land for the future as part of its draft master plan.

Figure M.6.21 Gatwick, Master Plan with second runway and third terminal – Source: Gatwick Airport Ltd

11.7 Le Bourget (LBG) 1919, 1923 & 1937

Paris, Le Bourget, along with London, Hounslow Heath, was the first international airport with passenger services starting in August 1919, using facilities of the former military airfield. In 1923 the facility was rebuilt in the neo-classical style, retaining the layout of the original dispersed administration buildings, set amongst a series of aircraft hangars, and serving a grass airfield (figure M.7.1).

Passengers had to present themselves in turn to several separate buildings before boarding their flight. At this stage Le Bourget missed the opportunity to consolidate all the operational and passenger processing facilities into one integrated terminal which was becoming the norm elsewhere. This separation of services continued until 1937 when the new terminal opened.

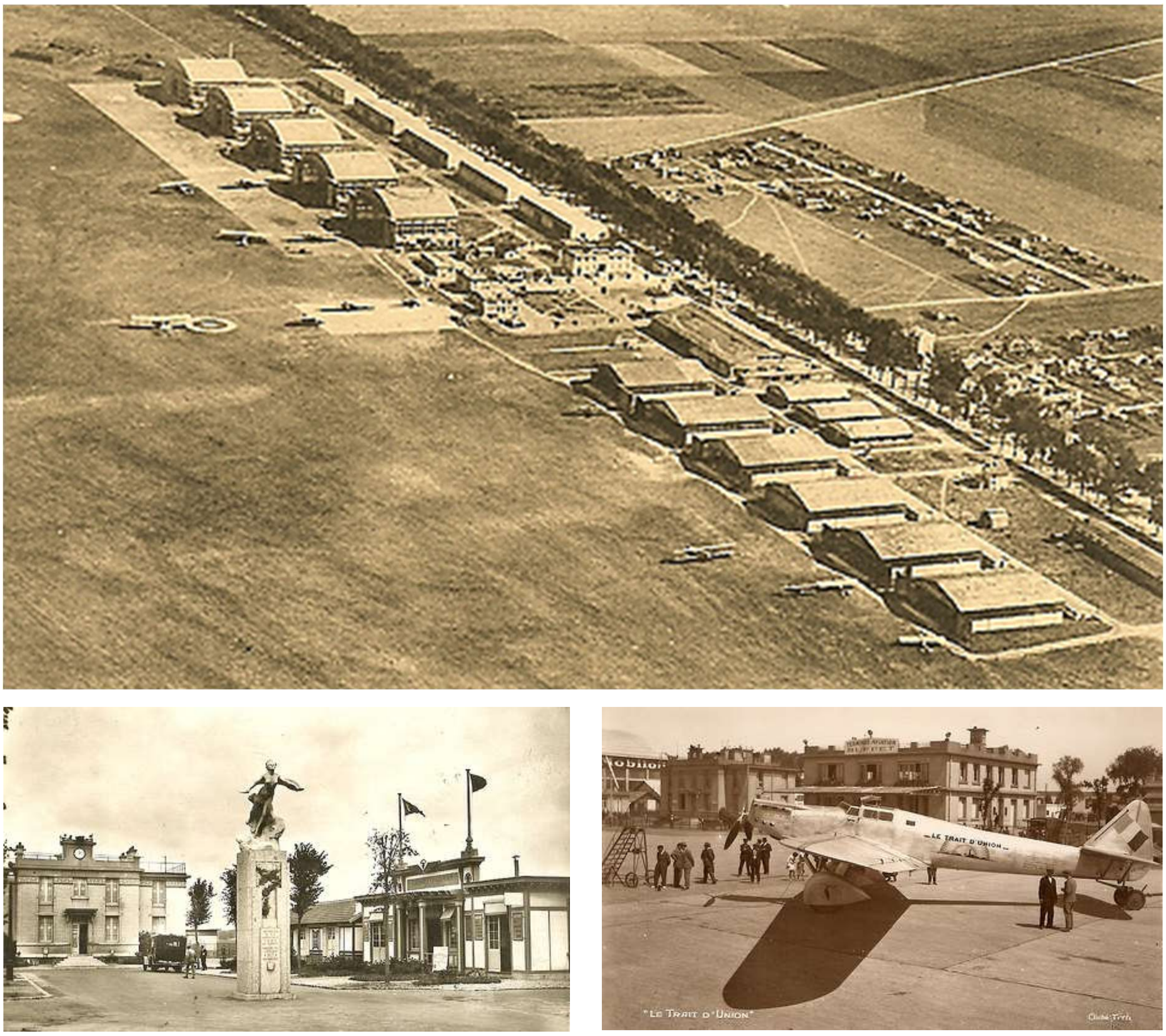


Figure M.7.1 Views of Le Bourget, 1923 - Source: Taylor Empire Airways

The airport became world famous when Charles Lindberg landed there after his first solo transatlantic flight in the Spirit of St. Louis.

The location of the first dispersed passenger complex (1923) is highlighted in green, the hangars in blue, while the replacement new linear terminal (1937) is shown in red in the aiport plan of 1939 below (figure M.7.2).

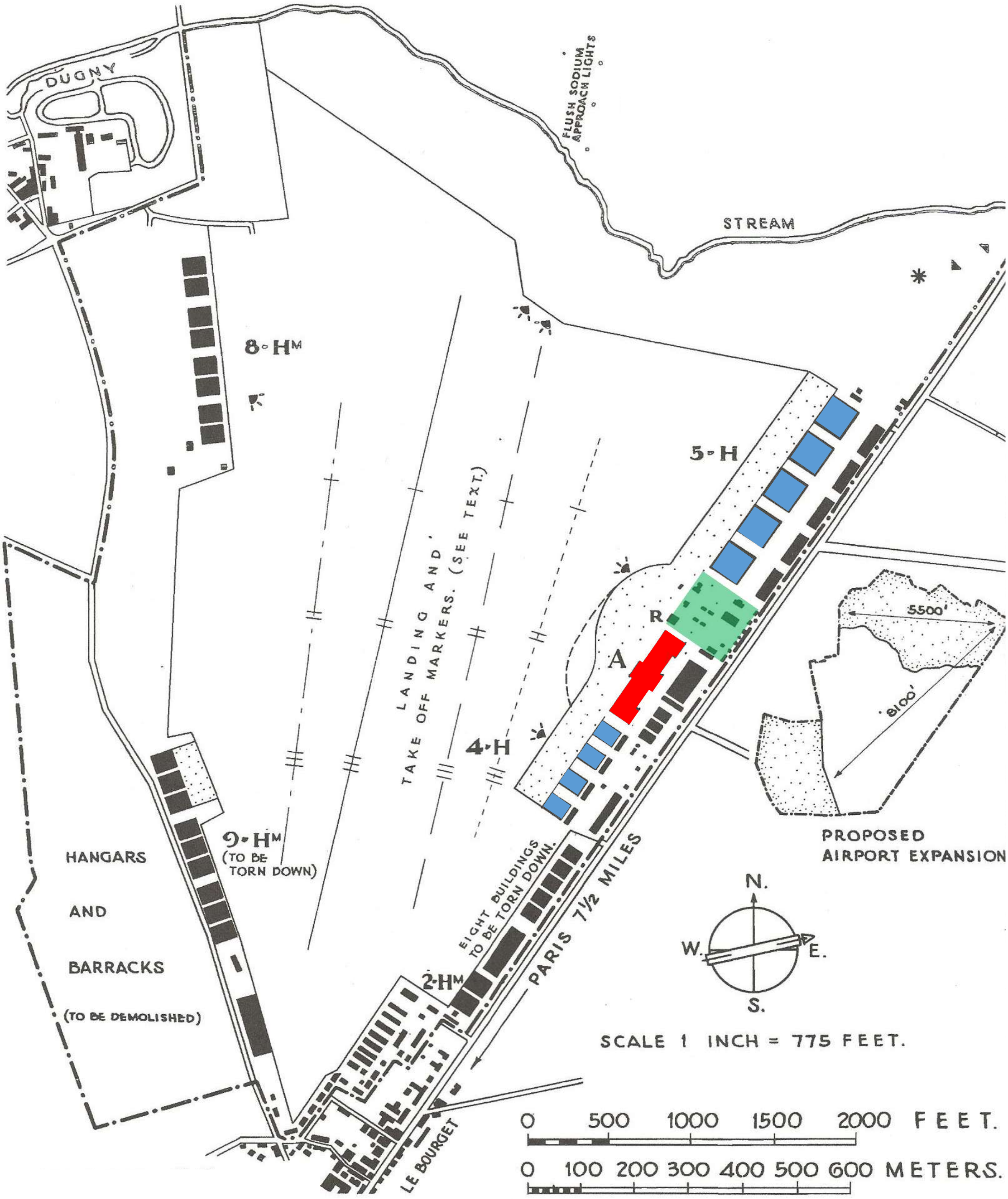


Figure M.7.2 Le Bourget, Site Plan 1939, with author's added colour - Source: Airports, Some Elements of Design and Future Development, John Walter Wood

The new terminal, designed by Georges Labro was due to open in 1936 in time for the June International Exhibition, but was not completed in time and only opened in November 1937. In an article published in L'Architecture in January 1938, Georges Labro described his design as follows (figure M.7.3, M.7.4 & M.7.5):

'My project respected the desire for a simple composition, developing in a straight line slightly in front of the alignment of the hangars, and keeping the depth of the building to a minimum. It also made the most of the heights authorised for the building, the profile of which is intentionally low. In this way I could obtain the largest possible surfaces for the various parts of the terminal, maximising its potential. Furthermore – and this is very important – my design, articulated around a central feature, or if you prefer, around a kind of prow with long wings on each side, allows for the inevitable extensions of the future, with no obstacles placed at the ends of the wings. This makes future changes possible without any fear of compromising the overall order of the composition. As regards the structure, reinforced concrete made rapid construction possible, its simple skeletal framework offering various possibilities for its interior organisation with different and practical combinations of partitions' (Labro, 1938).

Labro's description of his design having a 'prow with a long wing' is compared with the shape of the Farman Goliath Aircraft in figures 6.221 & 6.222 and shows a remarkable similarity of form, but his inspiration was by an aircraft that was by then long obsolete.

While Georges Labro, in theory, embraced the idea of future extension to facilitate growth and change, the terminal was only designed for a single departing and a single arriving flight at one time. However, after the war Labro proposed modifications to the terminal to segregate domestic and international passenger flows and extend the airside face of the building. Further airside extensions were introduced as part of a modernisation programme in 1964 to increase the airside waiting space (figure M.7.6).

Ultimately the building proved inadequate for the growth of traffic and in 1977, Le Bourget was closed to international airline traffic and in 1980 to regional airline traffic, but continued serving both domestic and international business aviation. Since 1975, Le Bourget Airport has hosted the Musée de l'Air et de l'Espace, France's main aviation museum. It also hosts an international air show bi-annually alternating with Farnborough in the UK.

Jean-Christophe Morisseau, the architect responsible for its restoration, comments: *'that the successive refurbishments and extensions that were carried out from the post-war re-construction onwards had little respect for the architectural coherence of the terminal, and most were carried out as provisional solutions to urgent operational problems……It did not affect the structure of the building , however, in an irreversible way.'* (Hecker, 2005). Restoration work has since been carried out to return it progressively to its 1937 state.

Figure M.7.3 Le Bourget, landside view of entrance to terminal – Source: picclick.fr

Figure M.7.4 Le Bourget, airside view of control tower _ Source: del campe

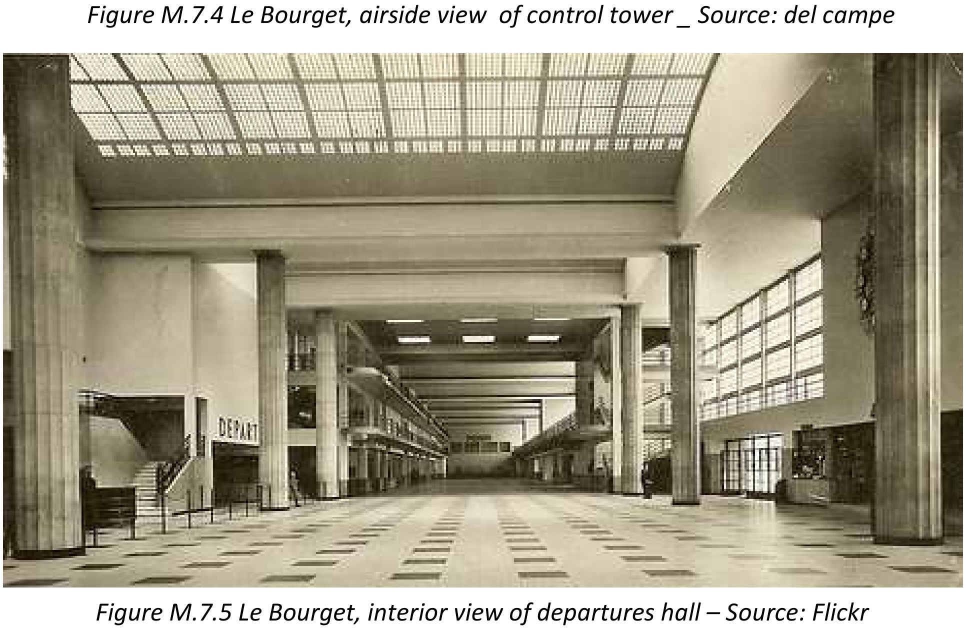


Figure M.7.5 Le Bourget, interior view of departures hall – Source: Flickr

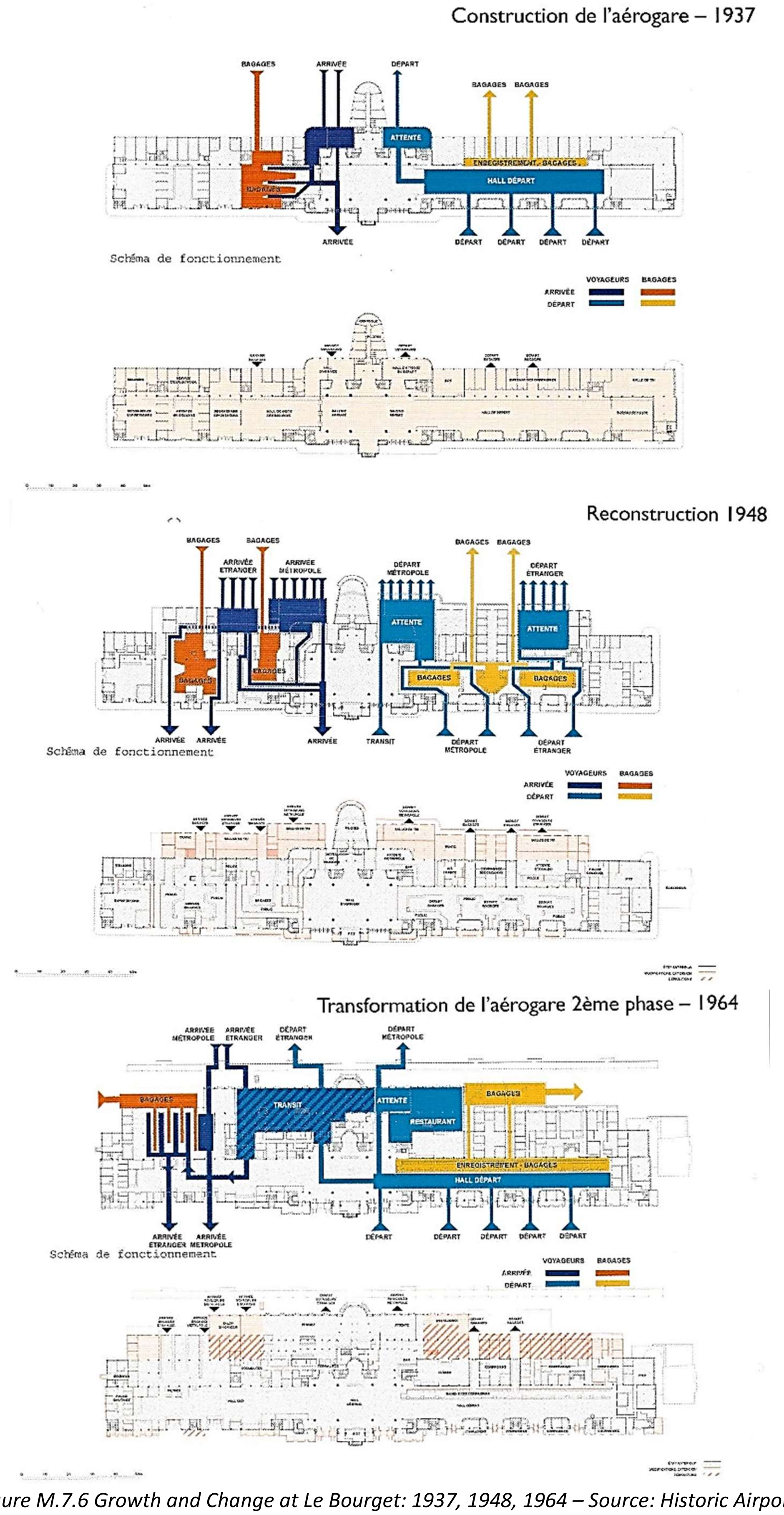


Figure M.7.6 Growth and Change at Le Bourget: 1937, 1948, 1964 – Source: Historic Airports

11.9 New York – LaGuardia (LGA) 1939

LaGuardia is a domestic airport in the northern part of the New York City Borough of Queens. The airport is on the edge of Flushing Bay and Bowery Bay. The Glenn H. Curtiss Airport in 1929 was formerly the site of the Gala Amusement Park, owned by the Steinway family. The park was sold and transformed into the 105-acre private Curtiss Airport, which was later renamed North Beach Airport (M.8.1 & M.8.2).

The initial idea to develop an airport for commercial flights and the selection of the airport's location began as a publicity stunt in 1934. New York Mayor, Fiorello La Guardia, the small-statured man known as 'The Little Flower', threw a tantrum by refusing to deplane from a TWA flight from Pittsburgh to Newark, declaring that his ticket showed his destination as New York. With reporters conveniently already aboard the airplane, the press conference that followed almost immediately made clear that the time had come for a new, modern facility closer to Manhattan. On the day the airport officially opened it was known as the New York Municipal Airport but was later renamed LaGuardia after the mayor. The art deco terminals were designed by Delano and Aldrich and were opened in late 1939.

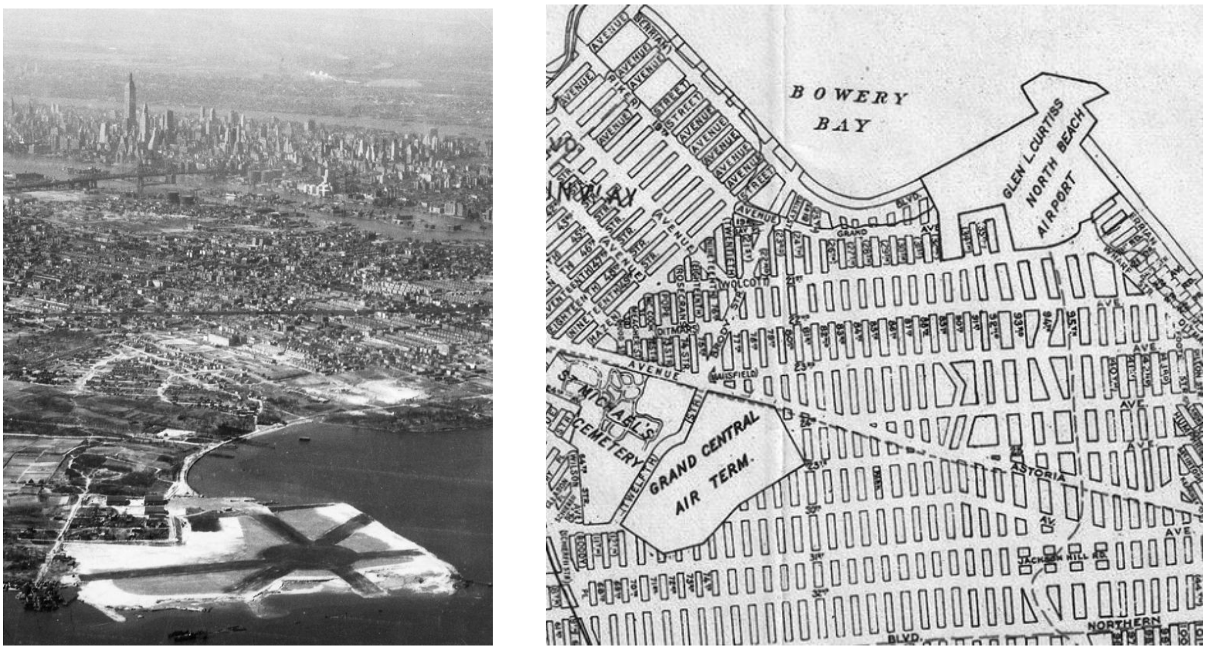


Figure M.8.1 Glen Curtis, North Beach Airport - Source: Abandoned and little-known airfields, New York and Queens

Figure M.8.2 Original masterplan for North Beach airport (later La Guardia) –
Source: Abandoned and little-known airfields, New York and Queens (courtesy of Chris Kennedy)


Figure M.8.3 La Guardia, aerial landside view of landplane terminal and forecourt –
Source: stuckattheairport.com

Figure M.8.4 La Guardia, aerial airside view of landplane terminal and 'skywalk' – Source: Pinterest

Figure M.8.5 La Guardia 1946 showing the basin, which was later filled in, which enabled water taxis to go direct to Wall Street - Source: Airport Journals

Following the war, the Marine Air Terminal became the airport's international departure point for land planes, but larger aircraft and a need for more space prompted other carriers to follow Pan American's lead and move to Idlewild Airport by the end of the decade. In the early 1950s, the Douglas DC-7 and Lockheed 1049 Constellation began flying nonstop across the country but, unable to take off heavily loaded from LaGuardia, they were based at Idlewild instead.

However, the postwar growth in domestic air traffic more than compensated for these losses as LaGuardia cemented its reputation as the city's "close-in" airport of choice for short- to medium-haul domestic flights.

By the 1960s, the main terminal building, located adjacent to the Grand Central Parkway, was outdated and bursting at the seams. A new Central Terminal Building (CTB) replaced it, and is still in use today. Changes to the master plan included lengthening the runways and infilling the original water basin (figure M.8.5). Dedicated on April 17, 1964, the $36 million, 1,300-foot-long structure was completed in time for the 1964-65 World's Fair at nearby Flushing Meadows. With it came a rooftop observation deck running the full length of the terminal. The airport's signature control tower, a circular design 150 feet high, had been completed two years earlier (M.8.6).

The runways have been extended a number of times but are still relatively short at 7,000ft. As a result the airport is equipped with an Engineered Materials Arrestor System (EMAS) at the end of Runways 22 and 13. Created especially for airports like LGA with relatively short runways and water or other surroundings, the arrestor bed's purpose is to safely decelerate aircraft in the event of runway overrun.

The airport has come in for a lot of criticism, mostly due to the condition of the central terminal, with one example being former Vice President Joe Biden's comment that his experiences at LGA make him feel as though he were '*in a third world country*.' Others defend it because of its small size, convenience and historic significance.

However there are now plans put forward by the Mayor of New York to rebuild the entire terminal complex. A rendering of the unified terminal shows dramatic changes from the previously released design, which now has one nearly mile long terminal building with multiple finger piers. A central corridor is connected to independent concourses by bridges that span the aircraft taxiways, an idea that had previously been developed at Denver International (figure M.8.7).

The entire project is set much closer to the Grand Central Parkway in order to create additional space for aircraft operations and movement, in what will still be a very small and congested airport. A people mover is included in the unified terminal design, and a landside 'Airtrain' will connect the airport with the Long Island Rail Road and Ferry Terminal (Jersey, 2020).

M.8.6 Aerial view of airport with rebuilt terminal and added piers - Source: Wikipedia

Figure M.8.7 New York, La Guardia, proposed reconstruction -Source: Architecture Daily, Copyright Governor Andrew Cuomo

9 Chicago O'Hare (ORD) 1947

The City of Chicago appointed Ralph Burke, the City's former chief engineer to plan a future airport on Orchard Field, extending the former Douglas Aircraft Company Factory and Airbase. He prepared a very ambitious master plan for the airport to replace Midway airport. His master plan was formally adopted by the City in December 1947 (figure M.9.1).

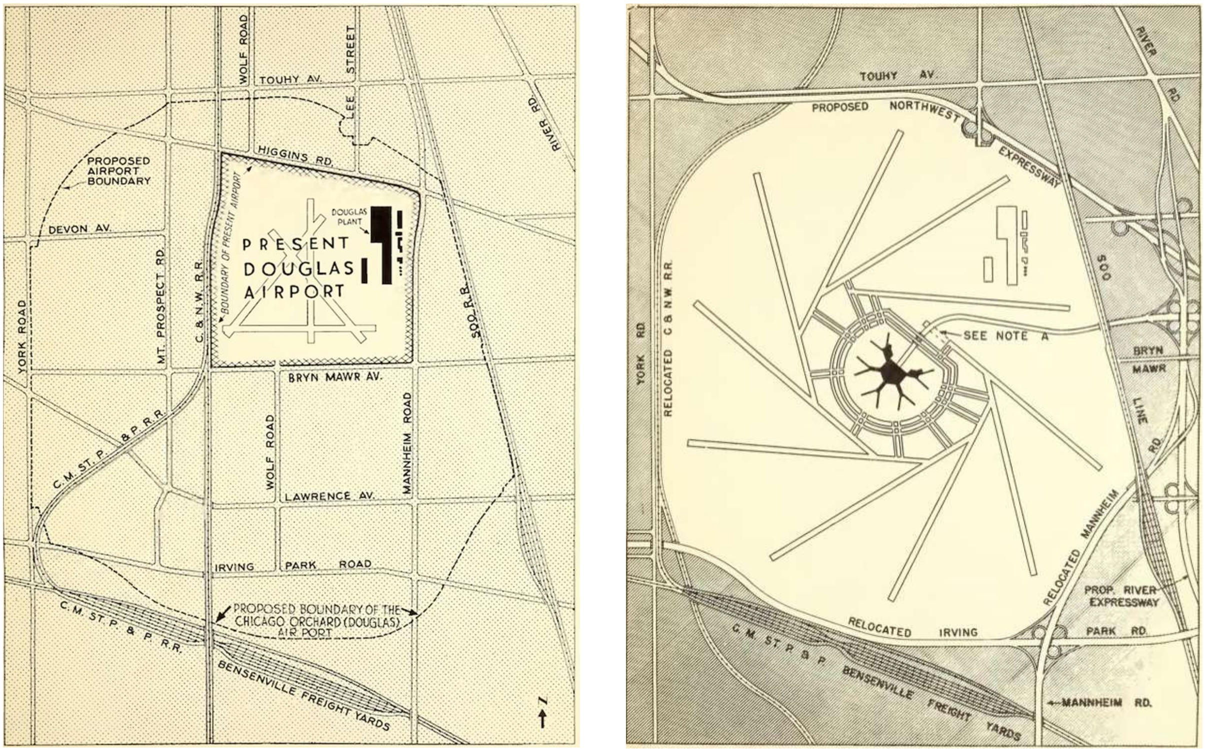


Figure M.9.1 Chicago, O'Hare, Existing Douglas Airbase and Master Plan 1948 – Source: City of Chicago

Burke's plan called for a central terminal around which runways would be arranged tangentially (M.9.3). The terminal itself would consist of a main concourse building with 'fingers' spreading out into the apron area (finger M.9.2). During the design study, two types of terminal designs and two types of runway configurations were considered. Burke examined the feasibility of a 'production line' terminal system where aircraft would be moved by mechanical means to separate areas for unloading, servicing, and loading.

This concept was a development of ideas first seen in the competition to both the RIBA and the Lehigh competitions. This plan was eliminated from consideration as *'too radical a departure from present practice and too advanced for adoption at [that] time.'* (Black, 1930) As conceived this concept has never been put into practice, the closest being where an aircraft unloads at one stand, then is towed to a remote stand to park, and later towed back to another stand.

Figure M.9.2 - Chicago O'Hare, Master Plan – Source: Chicago Tribune Graphics

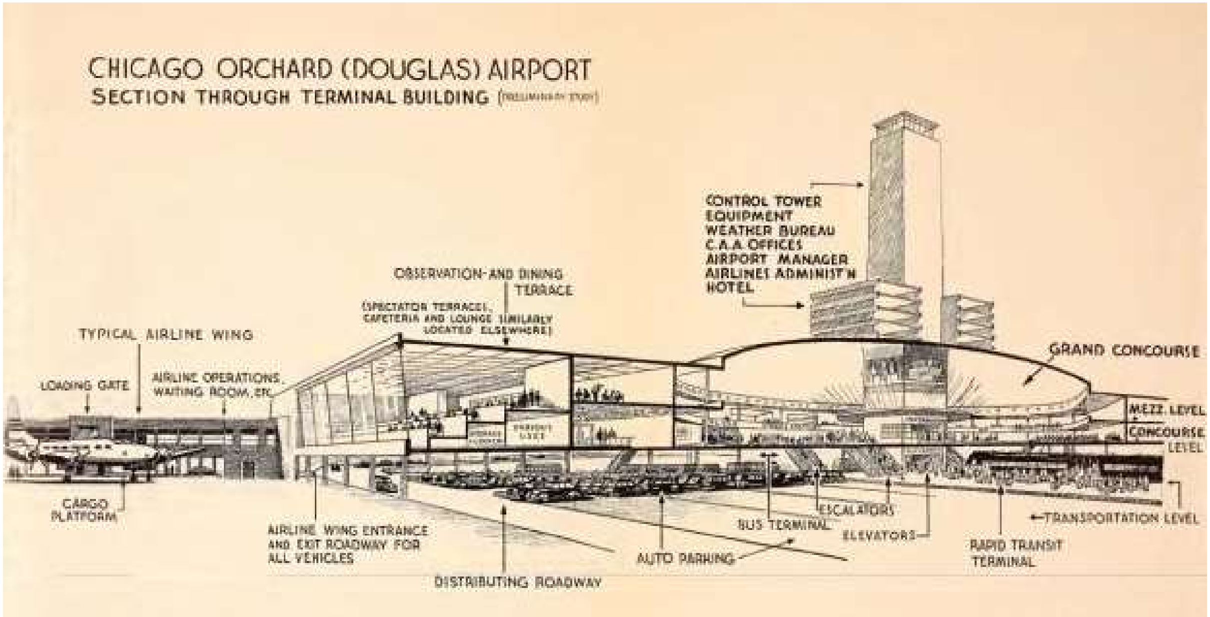


Figure M.9.3 Chicago, O'Hare, original centralised terminal Concept 1948 - Source: City of Chicago

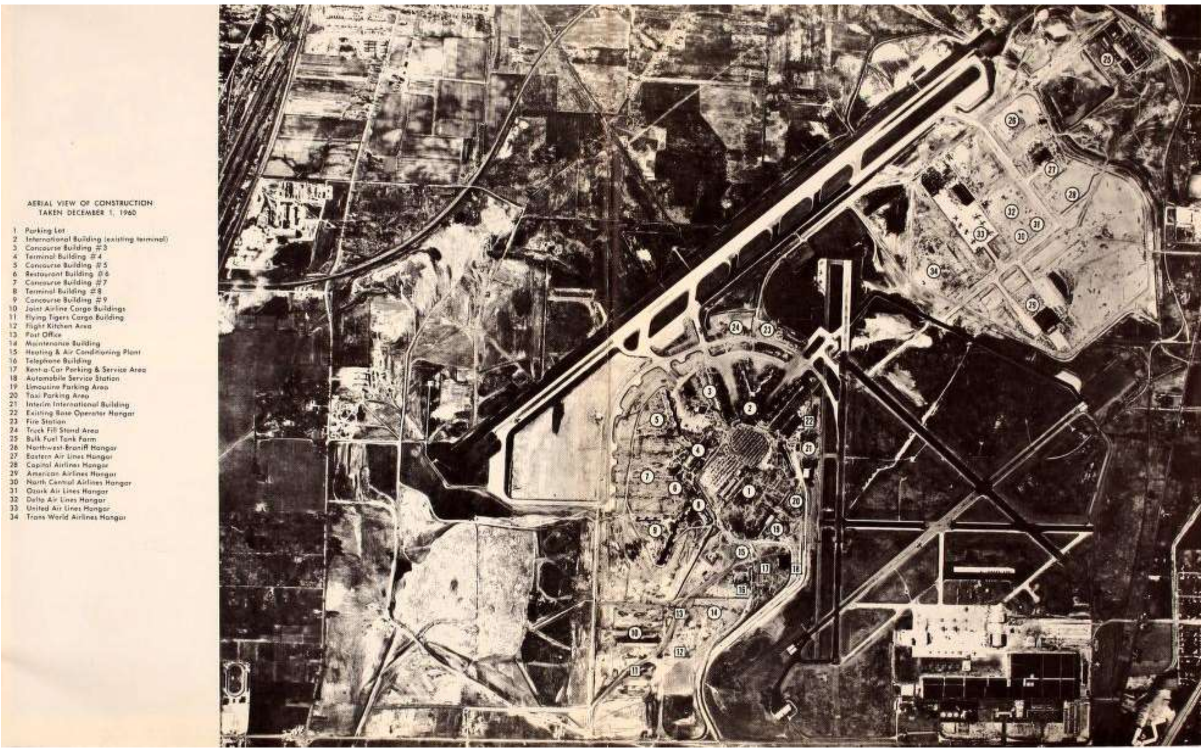


Figure M.9.4 Chicago, O'Hare, Aerial View under construction Dec 1960 – Source: Journal, Chicago City Council

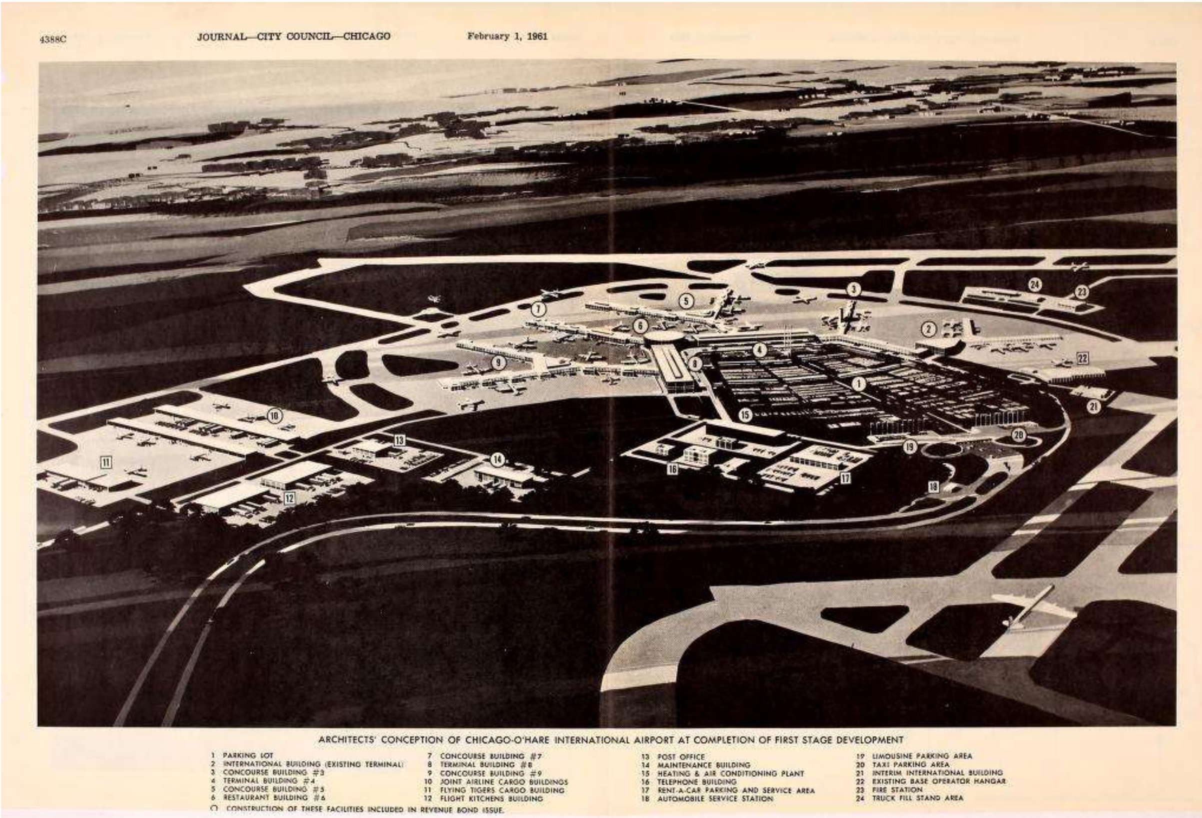


Figure M.9.5 Chicago, O'Hare, Master Plan Update 1961 – Source: City of Chicago, Aviation Department

The first update to the masterplan was published in 1961 (figure M.9.5), with the terminal complex update following in 1963, when the original domestic terminal built in 1955 was renovated to become a new International Terminal. There were 490 people on direct flights between Europe and Chicago in 1953. Just ten years later, over 250,000 passengers used O'Hare to visit an expanded international network including Europe and Mexico. The addition of the dedicated International Terminal allowed Chicago to claim the name Chicago-O'Hare International Airport.

By the late 1960s Chicago was already looking for additional capacity. An additional airport in the Chicago area was being considered, but even if approved it was years away. To alleviate congestion, O'Hare added a new east-west runway, 9R-27L, on the south side of the terminal complex in 1967. In 1971, work was completed on 4R-22L on the south-eastern portion of the airfield. This gave O'Hare three sets of parallel runways, one pair in each direction oriented east-west, north-west-south-east, and north-east-south-west (figure M.9.6).

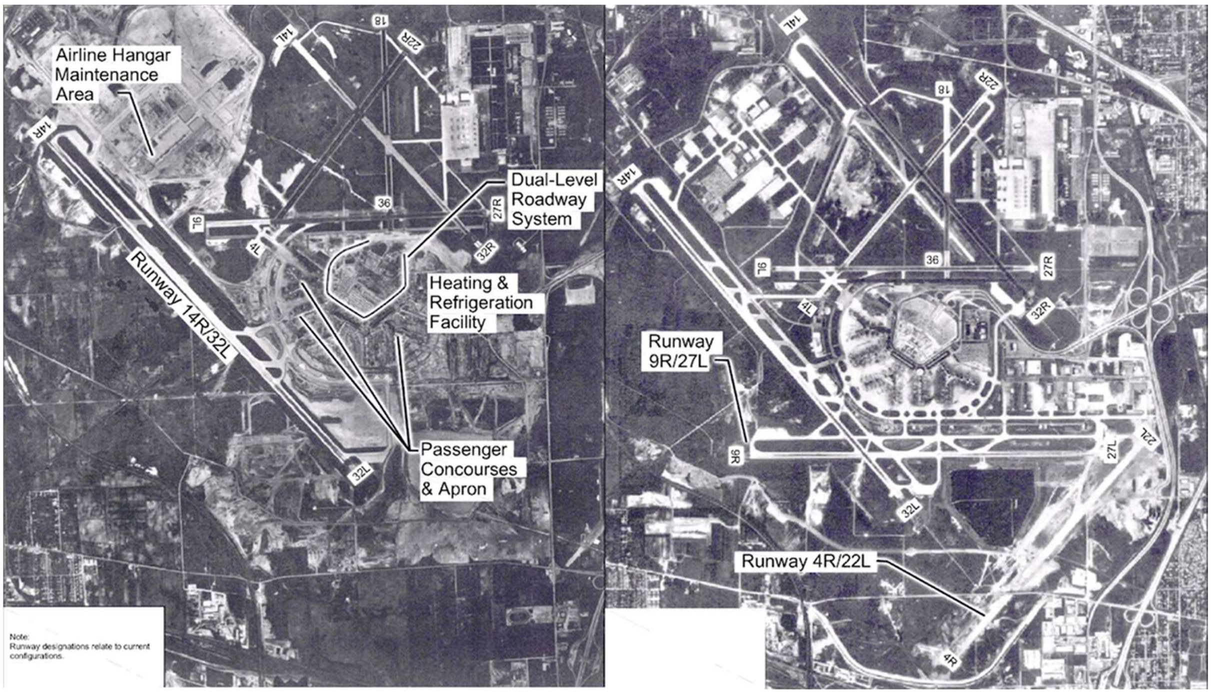


Figure M.9.6 Chicago, O'Hare, showing the 3 pairs of parallel runways - Source: Airways magazine

The Airline Deregulation Act of 1978 had a profound impact on operations at O'Hare. Domestic deregulation led to United Airlines and American Airlines consolidating operations at the airport to form their hubs. O'Hare's terminals were reconfigured to better serve the operations of the hubbing airlines as other airlines, such as TWA and Northwest Airlines, moved their hub operations elsewhere. As United and American's presence at O'Hare became more pronounced, plans were made for a new terminal complex.

Figure M.9.7 Chicago, O'Hare, Development Plan 1990 - Source: Airways magazine

In 1982, Chicago launched the O'Hare Development Program, a new master plan designed to provide the airport with new or rehabilitated terminals and service areas by 1990 (figure M.9.7). The plan called for a new International Terminal on the southeast side of the airfield, a commuter terminal and general aviation terminal located near the new International Terminal, construction of a new Terminal 1—replacing the existing International Terminal—to be used by United, expansion of Terminals 2 and 3, a new air cargo complex on the southwest side of the airfield, a new airport services area with flight kitchens and maintenance facilities, relocation of the existing inner- and outer-taxiway system around the terminal complex, and a people mover to bring passengers between terminals and the remote parking areas.

To accommodate the new larger jets the master plan was modified with the original star shaped piers becoming Y and I concourses.

In 1984, construction began on United's Helmut Jahn-designed 'Terminal for Tomorrow.' Yet, at the time, construction of a new International Terminal was still almost a decade away. To make way for construction of the new Terminal 1, O'Hare constructed a temporary terminal on the ground floor of the main parking garage, creating Terminal 4. Passengers were then bussed directly to their flights from the garage/terminal (figures M.9.8, M.9.9, M.9.10 & M.9.11).

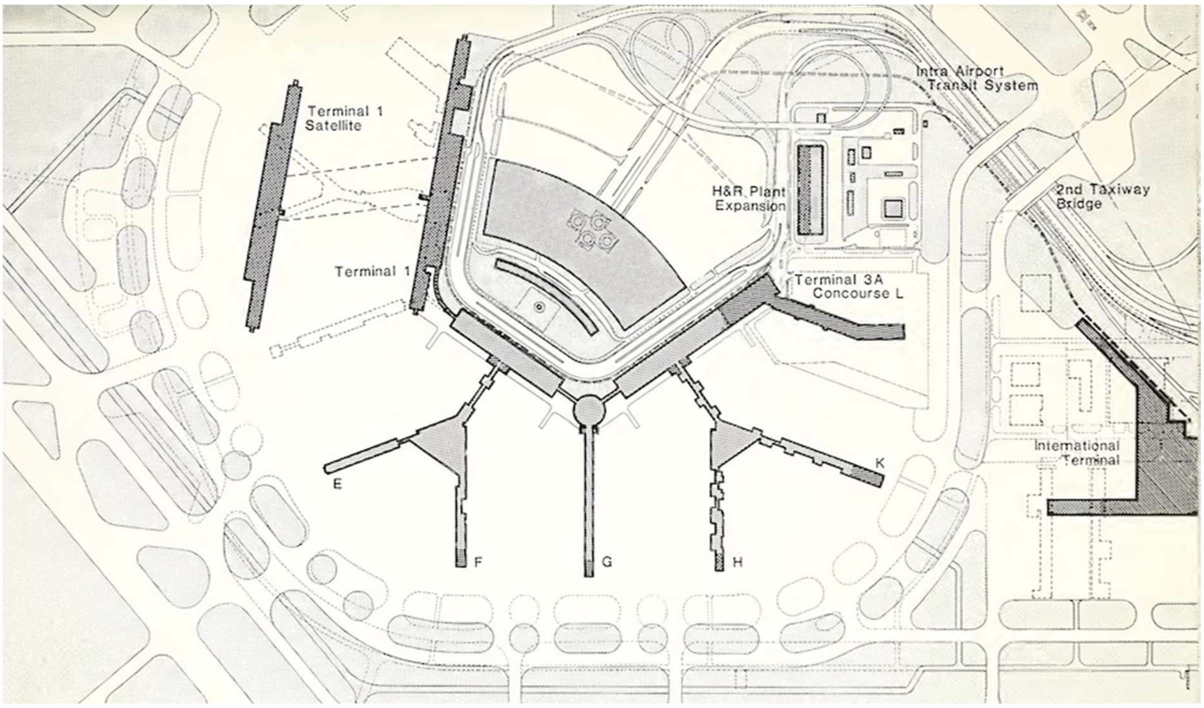


Figure M.9.8 Chicago, O'Hare, International Development Program - Source: City of Chicago

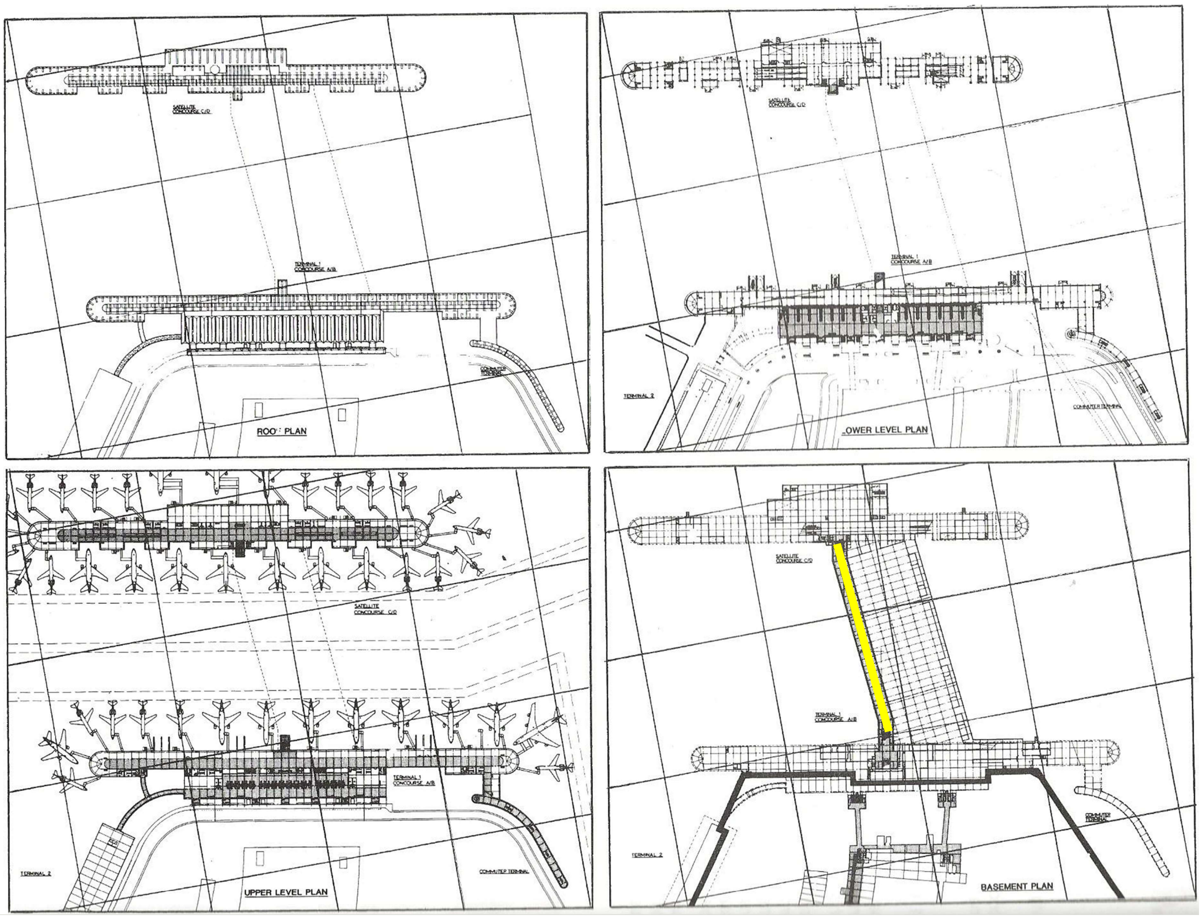


Figure M.9 9 Chicago, O'Hare, United Terminal, with underground walkway highlighted in yellow – Source: Airport Terminals

Construction of the new Terminal 1 lasted until 1987, when the first dozen of more than 40 new gates opened. Jahn described his design as drawing inspiration from the Kew Gardens glass houses and London Bridge and Liverpool Street railway stations, with open floor space and lots of natural light. Concourse B was built next to the roadway, similar to the location of the other terminals, but Concourse C was constructed in the middle of the airfield, connected to Concourse B by an 850 ft tunnel.

That same year, Chicago completed its long-planned extension of the CTA Blue Line train to O'Hare from downtown. A direct rail connection to the airport had been planned since the early 1950s but had never been completed. Before the completion of the rail link, passengers who wanted to reach O'Hare via public transportation had to take an express bus from the Jefferson Park station. The train runs in the median space of the Kennedy Expressway and I-190 near the airport before heading into a short subway stretch. It terminates underneath the main multi-storey car park (figure M.9.12).

O'Hare is still evolving and future master plans show the opportunities created for terminal expansion by simplification of the runway network while staying largely within the existing airport boundary (figure M.9.13) (CDA, 2019).

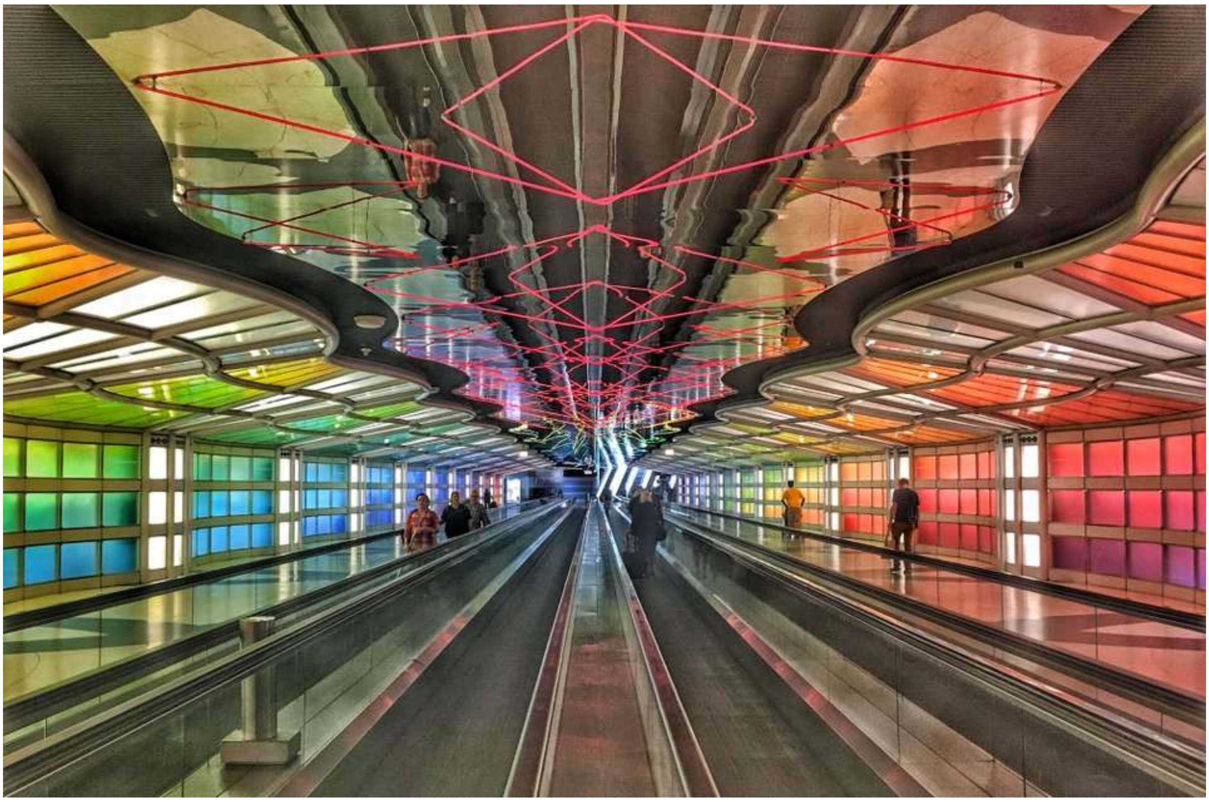


Figure M.9.10 Chicago, O'Hare underground walkway between the terminal and satellite (Concourse B) - Source: Reddit

Figure M.9.11 Chicago O'Hare, Concourse B – Source: Wikipedia

Figure M.9.12 Chicago, O'Hare, Rail Terminus under the main multi-storey car park – Source: Wikimedia

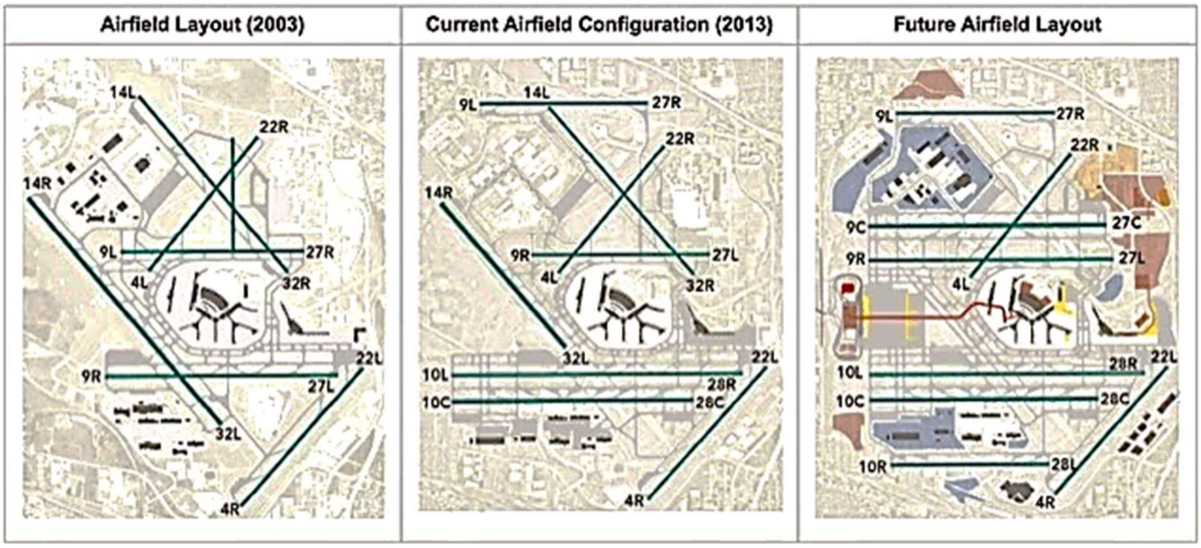


Figure M.9.13 Chicago, O'Hare, Master plan Evolution - Source: City of Chicago Aviation Department

First, two satellite terminals would be built to the west of Terminal 1, connected to the main terminals via walkways and tunnels. Terminal 1 now is used by United, O'Hare's largest carrier.

Second, the existing Terminal 2 used both by American and United for domestic flights would be demolished and replaced by an expanded international terminal, with customs and border-protection facilities.

Third, doing both would allow United and American and their international partners to shift operations out of the existing international terminal, Terminal 5. The new T-5, which is already getting nine new wide-bodied gates under a previously announced deal, would house all operations of Delta Air Lines and its partners, as well as become the new home of discount carriers Spirit, JetBlue, Alaska/Virgin and Frontier. It appears the latter would get a net gain of five to 10 new gates, with some of that already underway via a gate swap with American (figures M.9.14 & M.9.15).

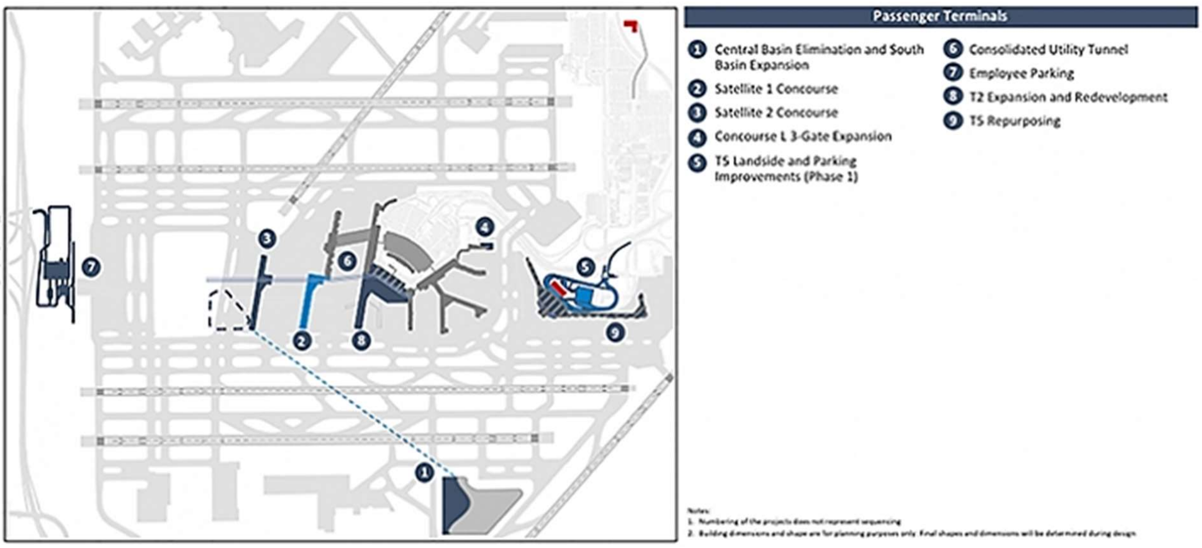


Figure M.9.14 Chicago, O'Hare, Future expansion plans – Source: www.chicagobusiness.com

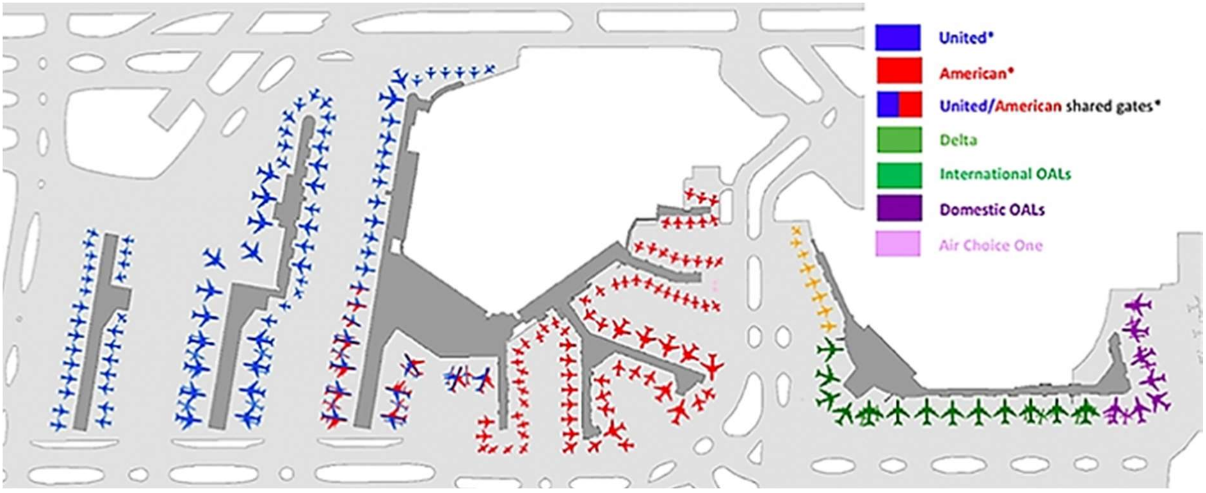


Figure M.9.15 Chicago, O'Hare, Future expansion plans – Source: www.chicagobusiness.com

11.10 St Louis Lambert (STL) 1956

The airport is named after Albert Bond Lambert (1875 -1946). He learned to fly with the Wright Brothers, received his pilot's licence in 1911, and served in the U.S. Army in World War I, reaching the rank of Major. He acquired the Lambert Field and started to create an airport on the site.

Figure M.10.1 St. Louis Lambert 1920 --Source: www.flystl.com

In 1925 the Post Office awarded a contract for airmail service between Chicago and St. Louis, and Charles Lindbergh was hired as the chief pilot. This mail route is the earliest predecessor of American Airlines. While flying the mail Lindbergh decided to seek the Orteig Prize for the first non-stop flight between New York and Paris, with support from the airport's owner. His successful flight aroused worldwide interest in aviation (flystl, 2019), and helped the development of St Louis Lambert airport.

In 1939 James S. McDonnell formed the McDonnell Aircraft Company at Lambert, and with the outbreak of WWII in Europe, the Curtiss-Wright plant at Lambert underwent a $10 million expansion for military production. A new 6,000ft runway was constructed to handle military requirements, and the United States Navy constructed a Naval Air Station.

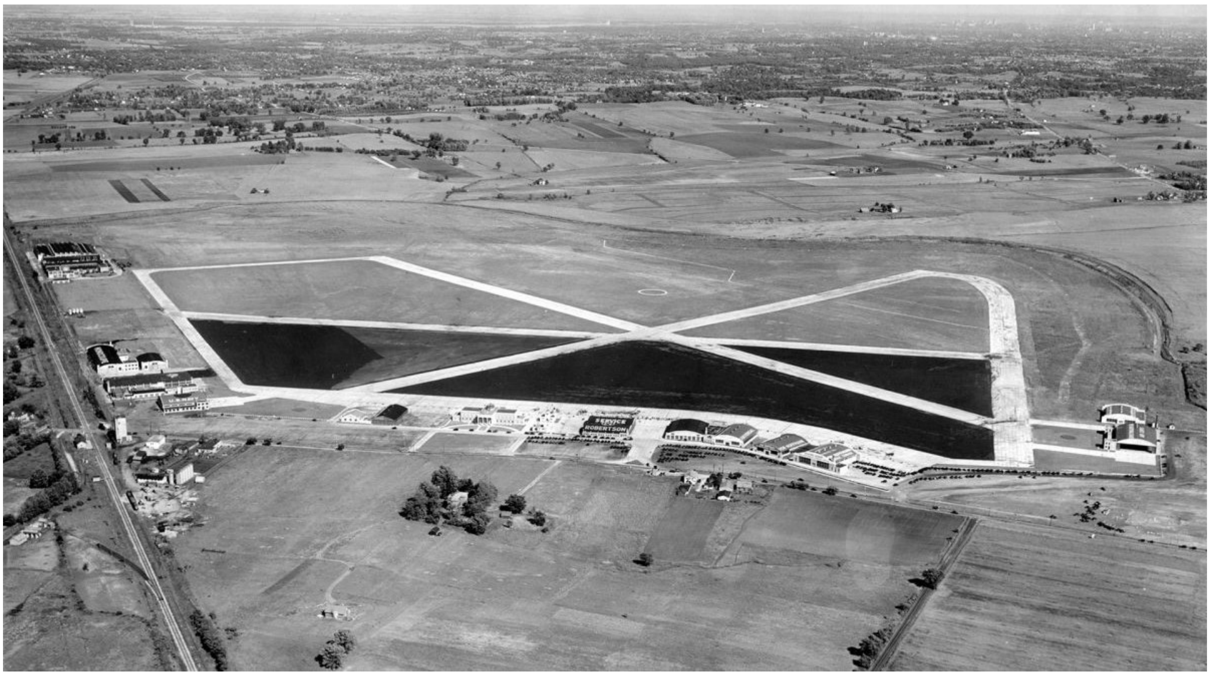


Figure M.10.2 St Louis Lambert Source: www.flystl.com

Although military activity dominated during the war at Lambert, the St. Louis voters passed a new $4.5 million bond issue for airport expansion in 1942 to meet anticipated post-war requirements (figure M.10.2). Post war a number of improvements were driven by military requirements including extending the runway to 10,000ft, but in the early 1950s the architectural practice of Hellmuth, Yamasaki & Leinwerer, and engineers Landrum & Brown were appointed to prepare a masterplan for the airport and design a new terminal (figures M.10.3 & M.10.4 for which the airport is now best known.

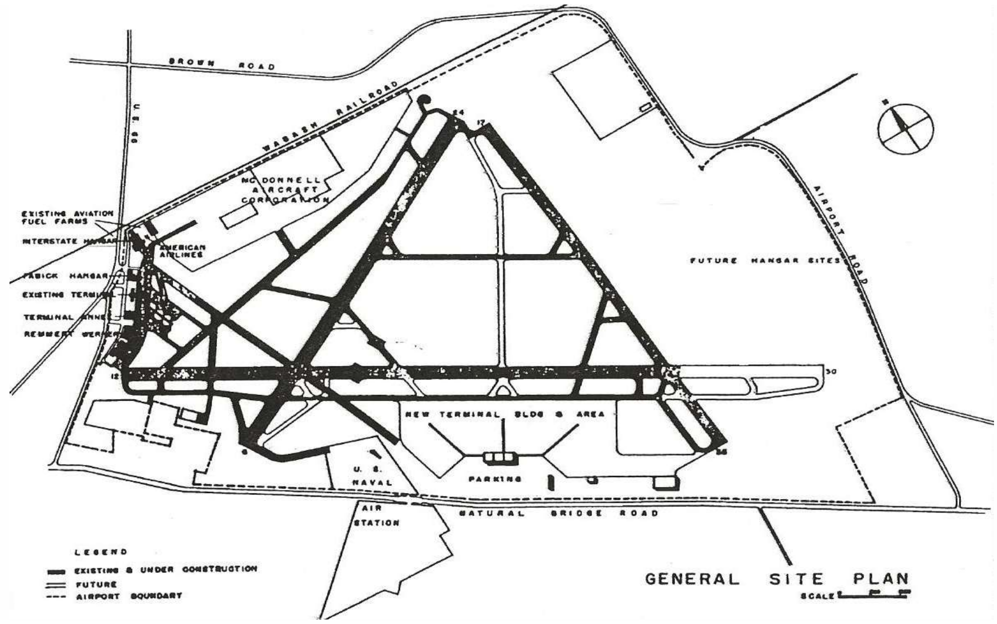


Figure M.10.3 St. Louis, Lambert, Original Master Plan, c.1951 Source: St Louis Municipal Airport, Economic Studies

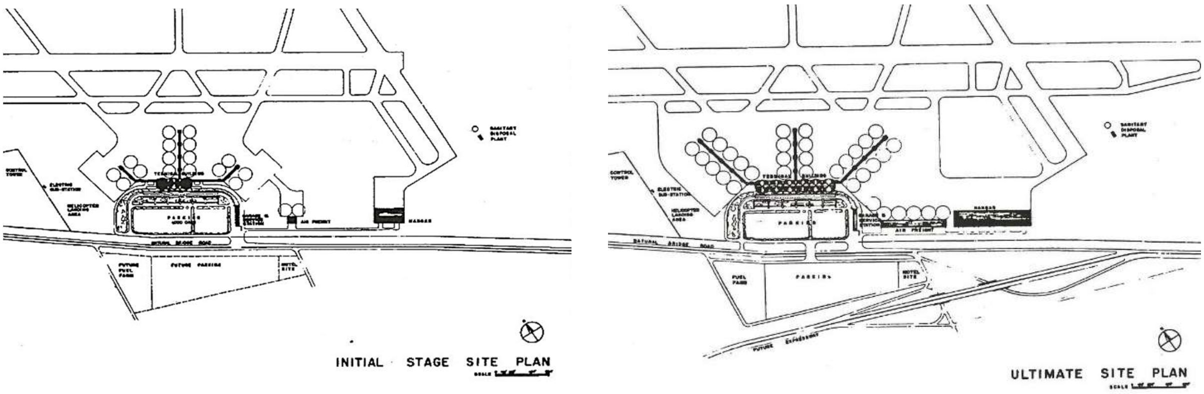


Figure M.10.4 St. Louis, Lambert, initial and ultimate site plans c.1951 –
Source: St Louis Municipal Airport, Economic Studies

Designed by Minoru Yamasaki in the early 1950s, the building and its copper roof has inspired the design of other terminals, such as the TWA terminal at John F. Kennedy International Airport in New York. It is regarded as an icon among airports worldwide (figure M.10.5, M.10.6 & 7).

Figure M.10.5 St Louis Lambert Aerial View – Source: Smart Union

But as Lambert grew busier, ad hoc additions eroded its elegance. The original terminal building had three vaulted sections, each 120ft square, and 32ft tall. An identical fourth section, architecturally in keeping with the rest, was added to the east in 1965.

The real aesthetic problem was inside: The clean lines and sense of spaciousness of the Yamasaki design became cluttered by a chaotic jumble of ticket counters, baggage checks, and food outlets. Fortunately, in recent years, renovations have followed Yamasaki's original intent (figures M.10.8 & M.10.9) (flystl, 2019)

Figure M.10.6 St Louis, Lambert, aerial view showing extended 4th terminal module and truncated finger pier - Source: CMJ

The future masterplan shows that Yamasaki's original terminal concept is planned to be retained but with additional piers, that involve some very long walking distances, to increase capacity (figure M.10.7).

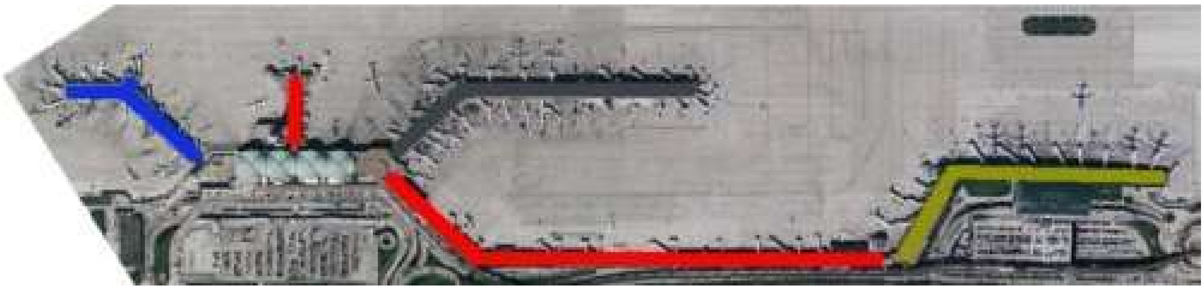


Figure M.10.7 St Louis Lambert, Future Configuration Source: flystl.com

Figure M.10.8 St. Louis Lambert, Departures Concourse - Source: Postcard, The Landmarks Association of St Louis, The St. Louis Mercantile Library at the University of Missouri, St. Louis, The library of Congress' Harris and Ewing Collection

Figure M.10.9 St Louis Lambert, Departures Concourse after 2014 refurbishment –
Source: James Steinkamp Photography

11 New York, Idlewild (JFK) 1948 & 1962

The Airport was proposed in the early 1940s when it became apparent that La Guardia would not have enough capacity in the long term.

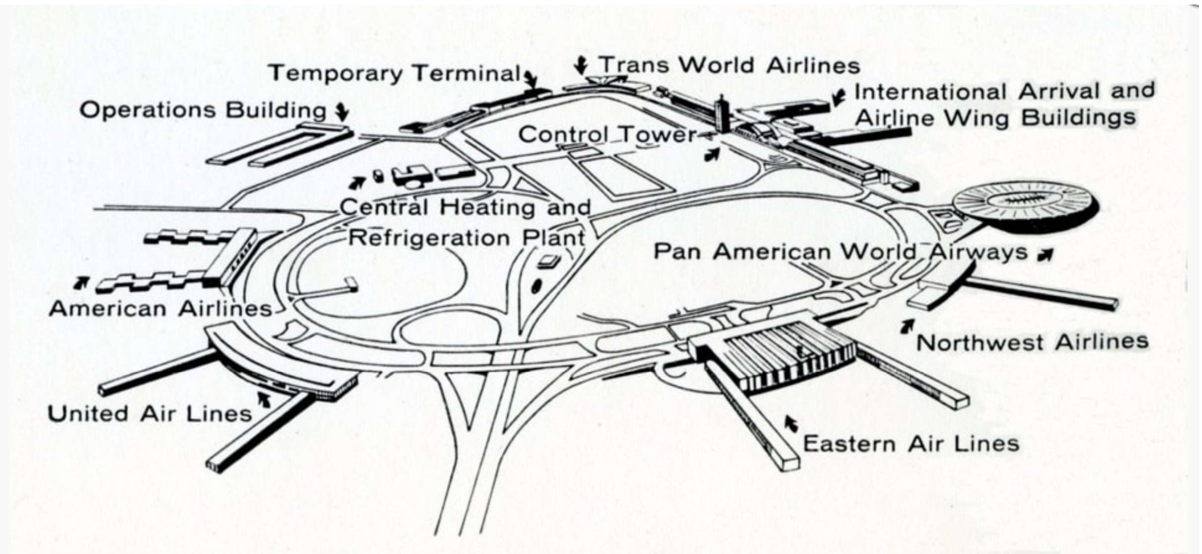


Figure M.11.1 Idlewild, the terminal city concept with multiple airline terminals – Source: Architecture USA

An early master plan prepared by Delano and Aldrich and published in Popular Science in 1943 looked backwards to the third prize proposal in the Lehigh Airports Competition and the Chicago Midway layout with its cruciform runways and terminal on the periphery. (figures M.11.2 & M.11.3)).

The original layout also had some similarities with La Guardia with a large seaplane base and aircraft maintenance complex. It did, however, foresee much larger aircraft and incorporated 2 runways of 10,000 feet (3,048 metres).

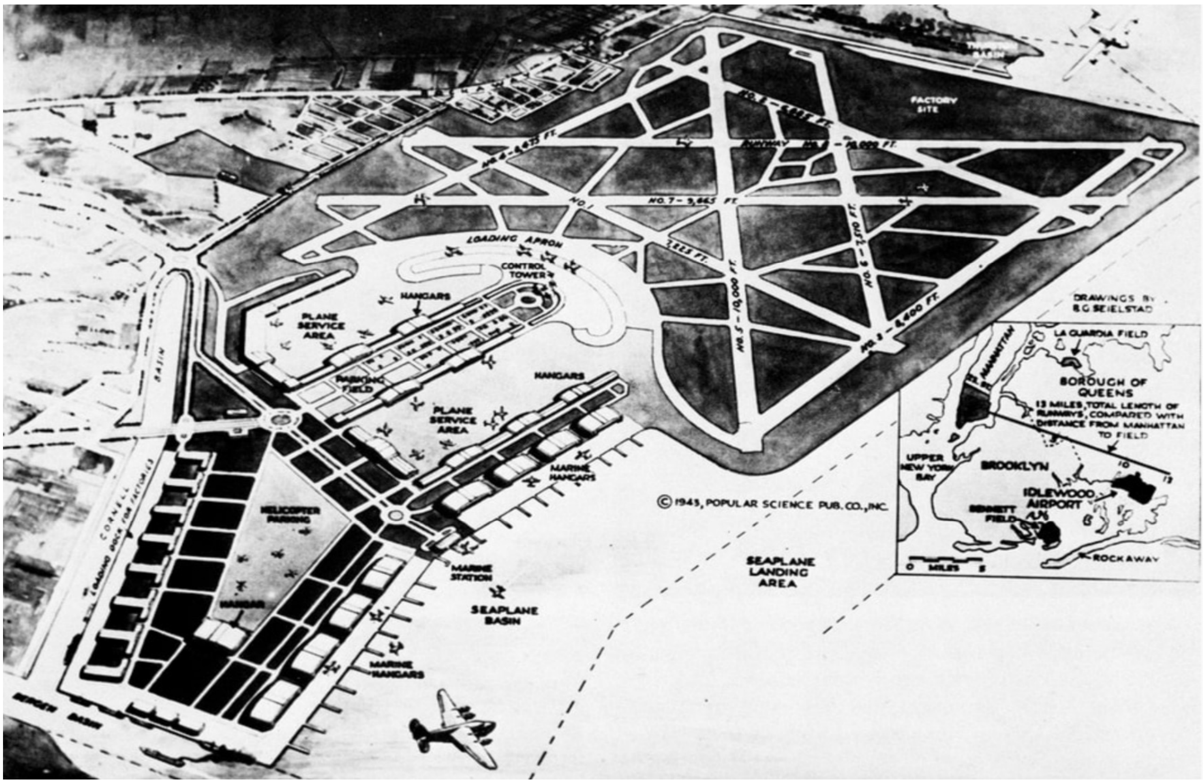


Figure M.11.2 Idlewood (later Idlewild) Airport 1943 – Source: Popular Science Pub. Co. Inc.

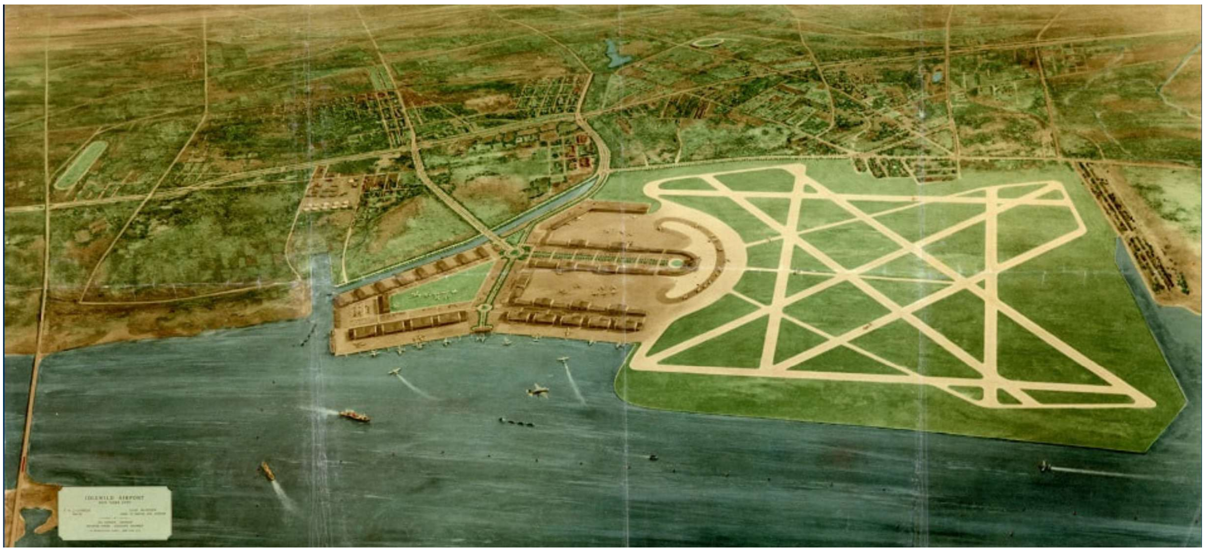


Figure M.11.3 Artists Impression of Idlewild Airport - Source: Cradle of Aviation Museum via Airporthistory.org

Feedback from the airlines was that with the development of long range, land based aircraft facilities for seaplanes were no longer needed, so subsequent master plans focussed on land aircraft only.

However, a series of more ambitious master plans soon evolved (see Figure 6.119) with mid –field terminal concepts and multiple radiating runways. One of the early 1945 centralised concepts promoted by American Airlines is shown on the following page (figure M.11.4).

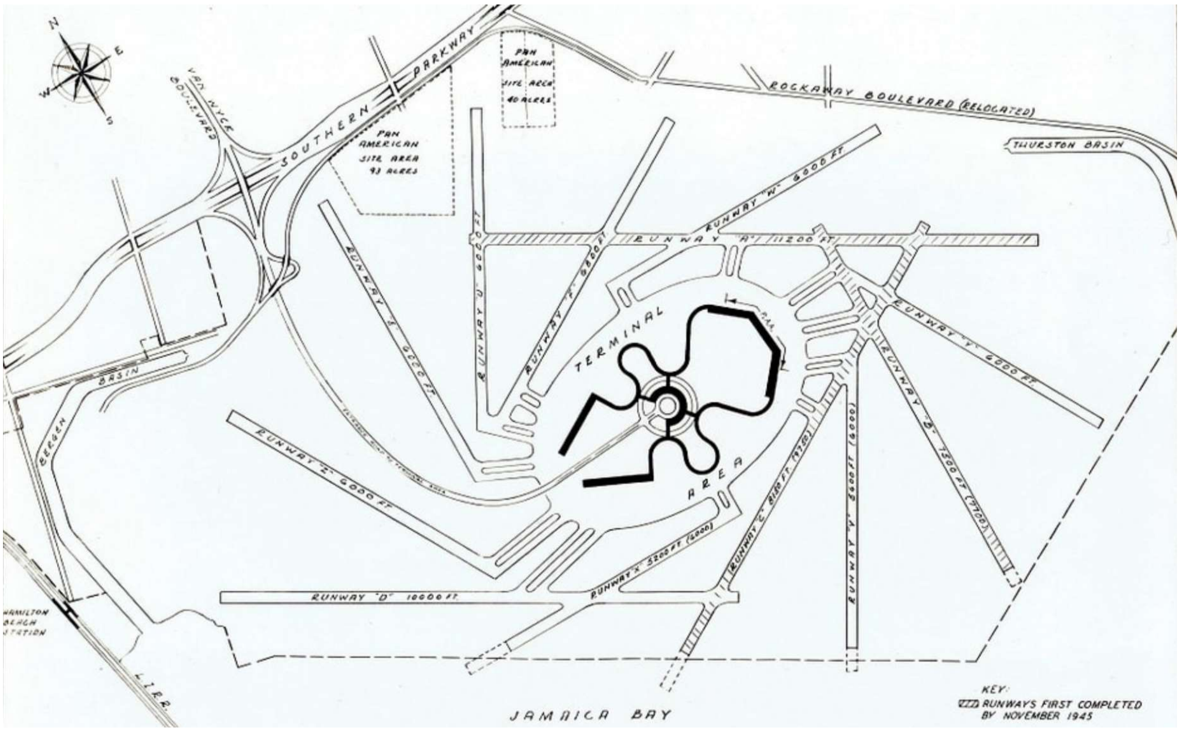


Figure M.11.4 Idlewild Airport 1945 Master Plan - Source: Cradle of Aviation Museum via airporthistory.org

Many concepts were considered and dismissed after that; the initial centralised perimeter development gave way to a unit terminal concept (1947), and a centralised scheme with finger piers (1948) (figure M.11.5).

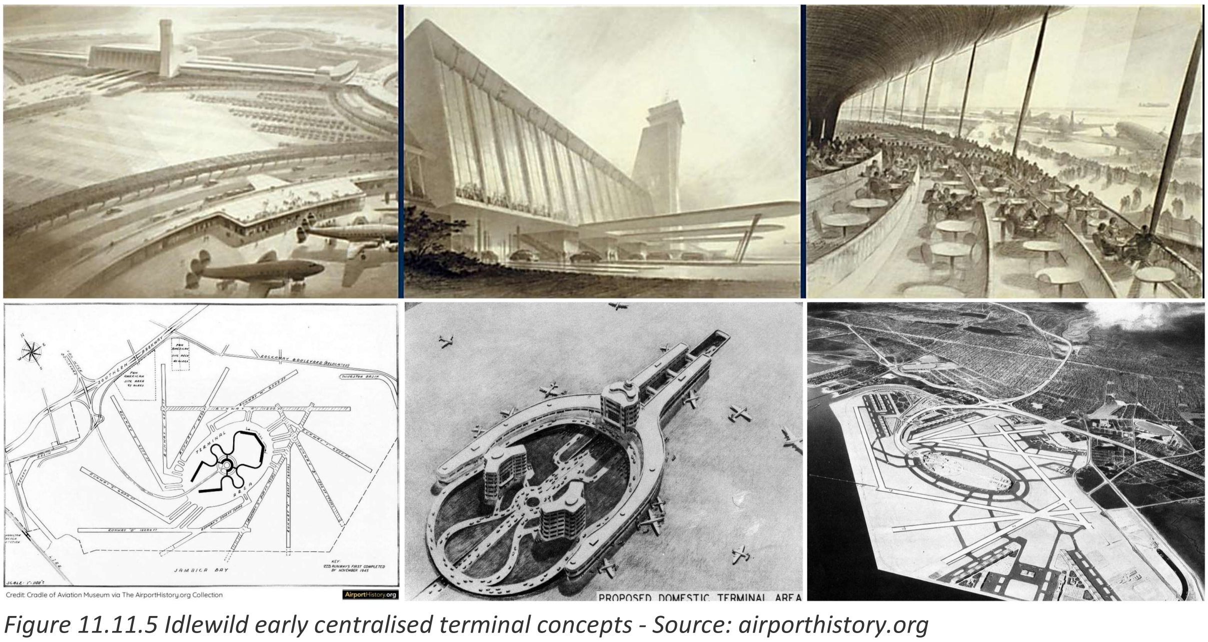


Figure 11.11.5 Idlewild early centralised terminal concepts - Source: airporthistory.org

The airport originally opened in 1948 as New York International Airport but was commonly known as Idlewild Airport. In the early years it featured a series of temporary terminals (figure M.11.6).

Figure M.11.6 Idlewild, temporary terminal, 1947, prior to opening – Source: Airporthistory.org

In parallel with the evolution of the terminals, the runway system was simplified with the improvement in aircraft performance in cross winds resulting in fewer but longer runways, but critically this evolution was centrally planned by the Port Authority and FAA rather than the free for all of individual terminal designs (figure M.11.7).

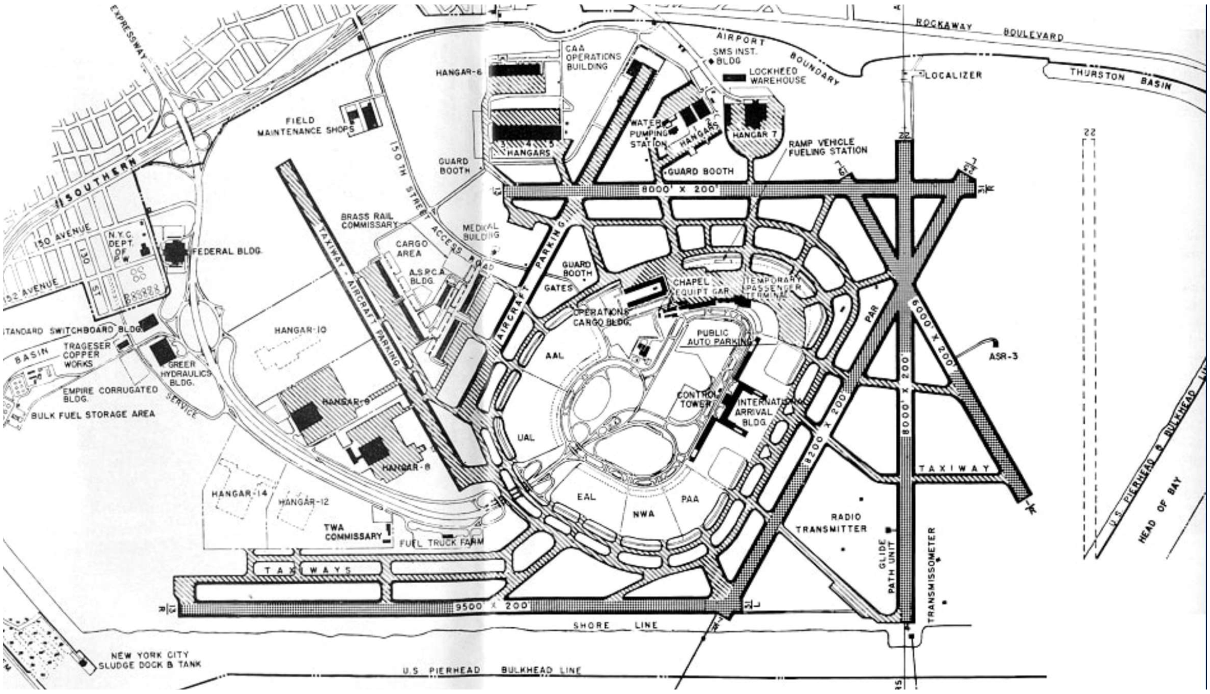


Figure M.11.7 Idlewild masterplan showing the location of the International Arrivals Building and the simplified runway layout – Source: airporthistory.org

The International Arrivals Building, or IAB, was the first new permanent terminal at the airport, opening in December 1957 and was the first to be planned to receive jet aircraft. The building was designed by Skidmore, Owings and Merrill (figure 11.11.7). The terminal stretched nearly 700 metres (2,300ft) and was parallel to runway 7R. The terminal had 'finger' piers at right-angles to the main building allowing more aircraft to park, an innovation at the time (figure M.11.8).

Figure M.11.8 Artists Impression of the International Arrivals Building – Source: airporthistory.org

The building was expanded in 1970 to accommodate passenger boarding bridges. However, by the 1990s the overcrowded building was showing its age and it did not provide adequate space for security checkpoints. It was demolished in 2000 and replaced with Terminal 4. United Airlines and Delta Air Lines opened Terminal 7 (later renumbered Terminal 9), a Skidmore design similar to the IAB.

Pan American World Airways opened the Worldport (later Terminal 3) in 1960. It featured a large, elliptical roof suspended by 32 sets of radial posts and cables; the roof extended 114 feet (35m) beyond the base of the terminal to cover the passenger loading area (figures M.11.9 & M.11.10). The Worldport Terminal was demolished in 2013.

Figure M.11.9 New York, Idlewild (JFK) Pan American Airways Terminal aerial view – Source: Life

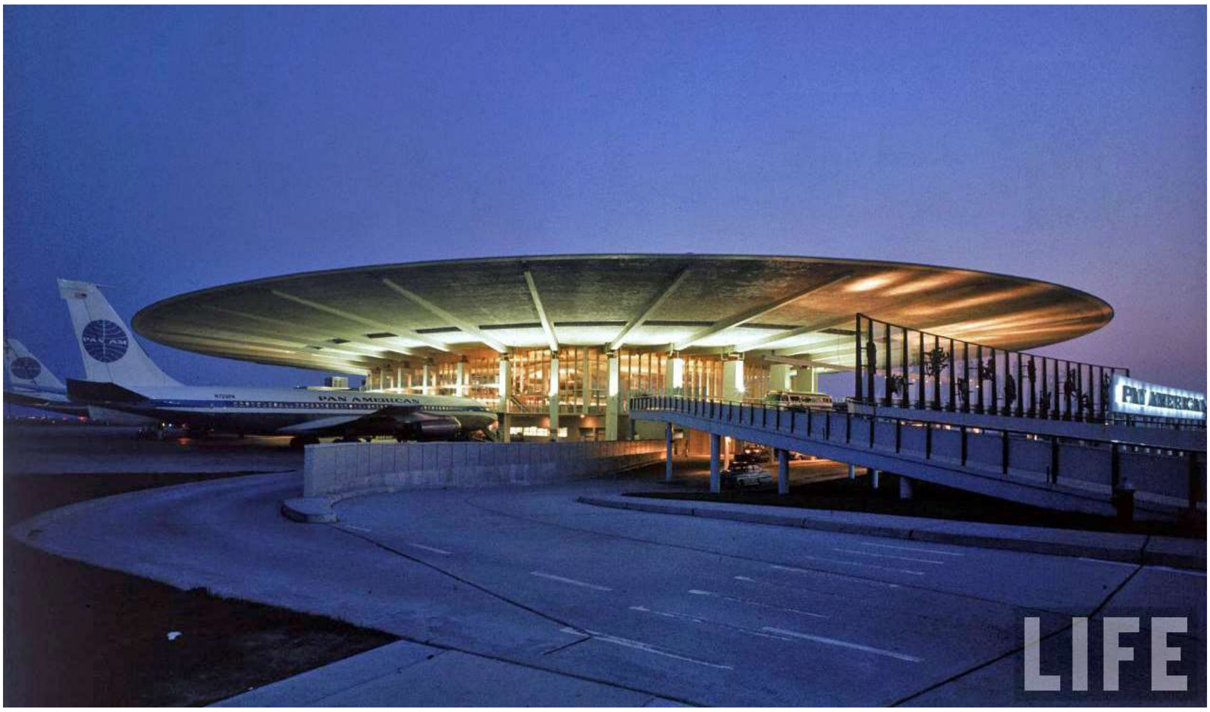


Figure M.11.10 New York, Idlewild (JFK) Pan American Airways Terminal view – Source: Life

The limitations of the elliptical shape are clearly seen in the following image which shows the extended terminal designed to accommodate the larger Boeing 747 aircraft, while the original terminal, originally designed to serve the first generation of jets the Boeing 707, now handled the new generation of short haul jets the Boeing 727 and 737 (figure 11.11.11).

Figure M.11.11 Aerial view of the Pan Am terminal after extension - Source: Pinterest – ipinmg.com

Trans World Airlines opened the TWA Flight Center in 1962, designed by Eero Saarinen with a distinctive winged-bird shape and flowing futuristic curvilinear interior. The preliminary sketch below was presented to TWA by Eero Saarinen (figure M.11.12). The following terminal plan (figure 11.11.13), and images illustrate the design (figures M.11.14. M.11.15, M.11.16, M.11.17 and M.11.18).

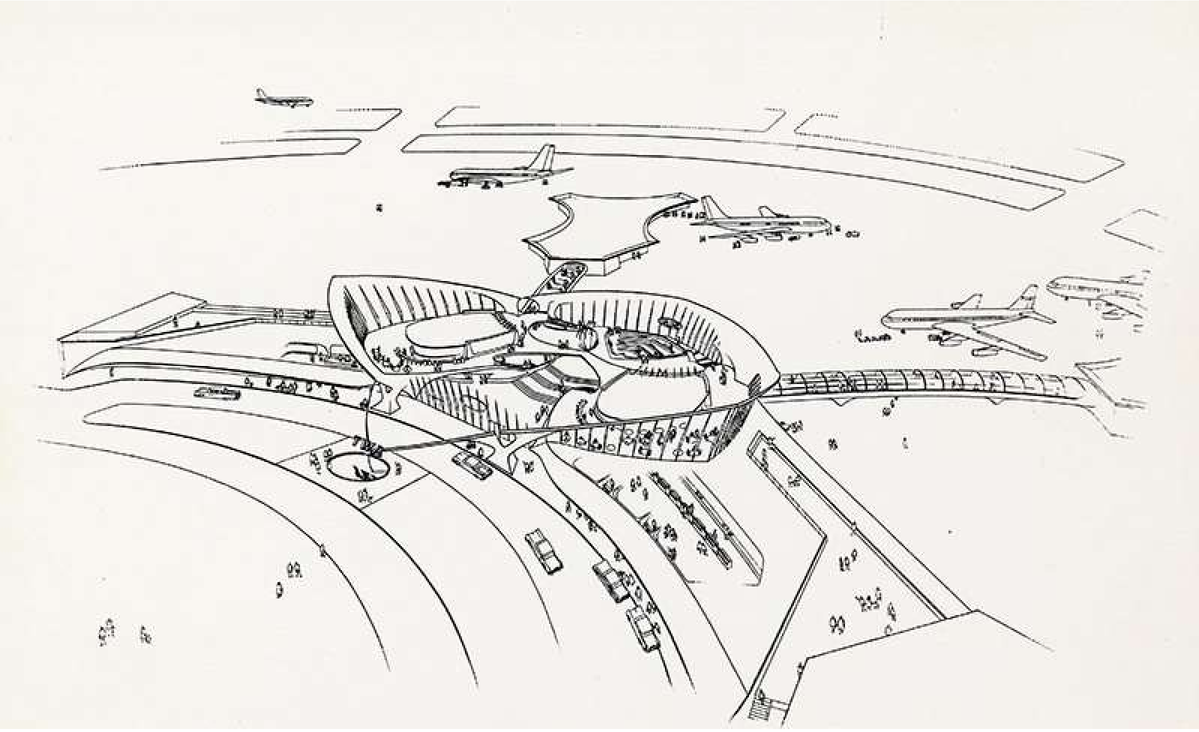


Figure M.11.12 Preliminary sketch of the TWA Flight Center - Source: Photo: © Eero Saarinen Collection (MS 593)/Manuscripts and Archives, Yale University Library

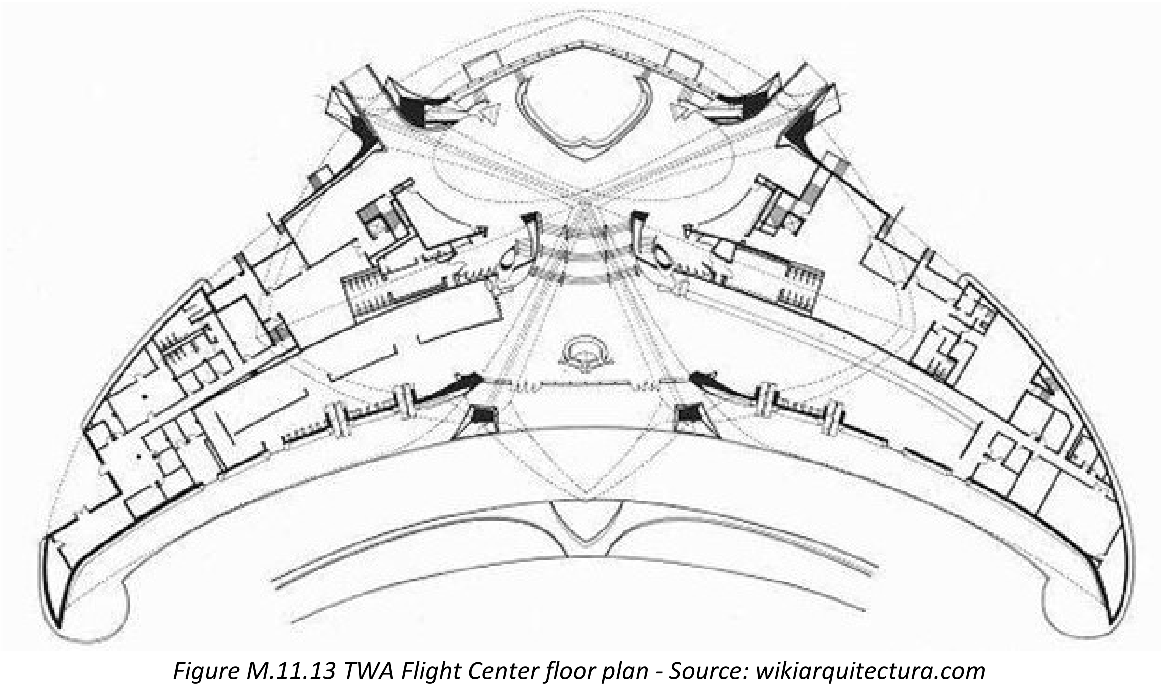


Figure M.11.13 TWA Flight Center floor plan - Source: wikiarquitectura.com

Figure M.11.14 The TWA Flight Center - Source: www.if its hip its here.com

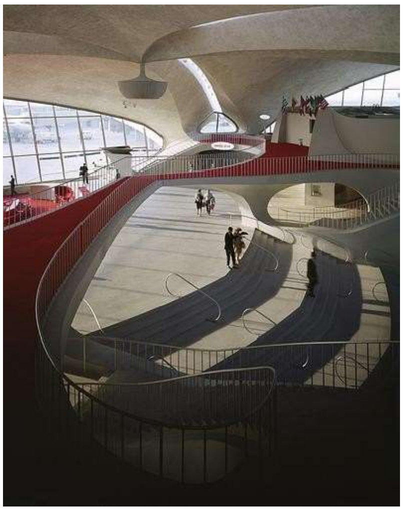


Figure M.11.15 TWA interior
Source: AD Classics

Figure M.11.16 TWA lounge area -Source: Wikimedia, -
Photographer: Brett Weinstein

Figure M.11.17 TWA, Flight Information –
Source: Wired

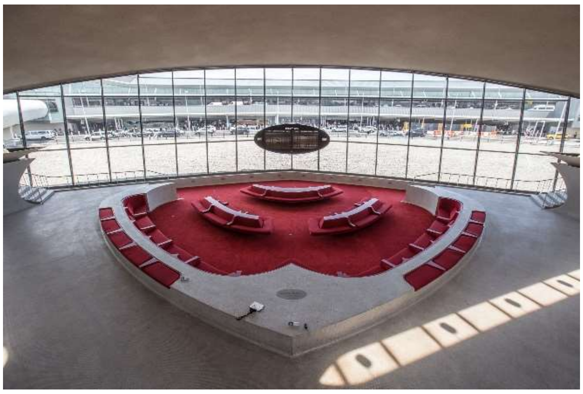


Figure M.11.18 TWA Seating Area
Source: Wired

The planning and design was so specifically geared to the TWA operation of the day, and although a second much larger satellite was added, it proved inflexible and incapable of long term adaptation to changed circumstance. The TWA Flight Center is now preserved on the National Register of Historic Places (figure M.11.19).

Figure M.11.19 – View of the TWA terminal after restoration – Source: Pinterest

The high point of development at JFK was reached in the 1962 when most of the airlines had completed their own terminals, but traffic hadn't grown beyond their capabilities. In December 1963 Idlewild airport was renamed John Fitzgerald Kennedy Airport (JFK) in memory of the late president who had been assassinated earlier in the year. A table below (figure M.11.20) summarises the characteristics of the airline terminals that formed the Airport City (Groot, 2020). The Airport City Master Plan of 1961 and aerial image of the Airport in 1962 can be seen overleaf (figures M.11.21 & M.11.22) (Hunt, 1961).

Open	Terminal	No	Close	Size	Cost	Stands	Architect	Key Characteristics
1957	IAB	T4	2001	55,742m^2	$30M	24	SOM	All international arrivals First finger pier at JFK
1959	Eastern	T1	1995	33,564m^2	$20M	16	Chester L Churchill	Ramps instead of stairs, Two single level piers
1959	United	T9	2000	23,226m^2	$14.5M	16	SOM	First boarding bridges International style
1960	American	T8	2000	17,326m^2	$14M	16	Kahn & Jacobs	First nose in stands Stained glass facade
1960	Pan Am + Worldport	T3	2013	9,446m^2	$12M	8 +8 in ph2	TAMS	Oval Cantilever Roof Extension for B747s
1962	Braniff, NE/NW	T2	2022 *	23,226m^2	$10M	10	White & Mariani	Simplest & longest lived Gates around terminal
1962	TWA	T5	2001	13,995m^2	$15.2M	14	Eero Saarinen	Seminal expression of flight, only satellites
1970	National Sundrome	T6	2008			12	I M Pei	All glass mullions Diagrid ceiling
1970	BOAC	T7	2022 *				GMW	Brutalist architecture Rooftop helipad
1983	Tower		2000			3		Converted Hangar

Figure M.11.20 Summary of JFK Terminals - Source: AirportHistory.org **projected closure*

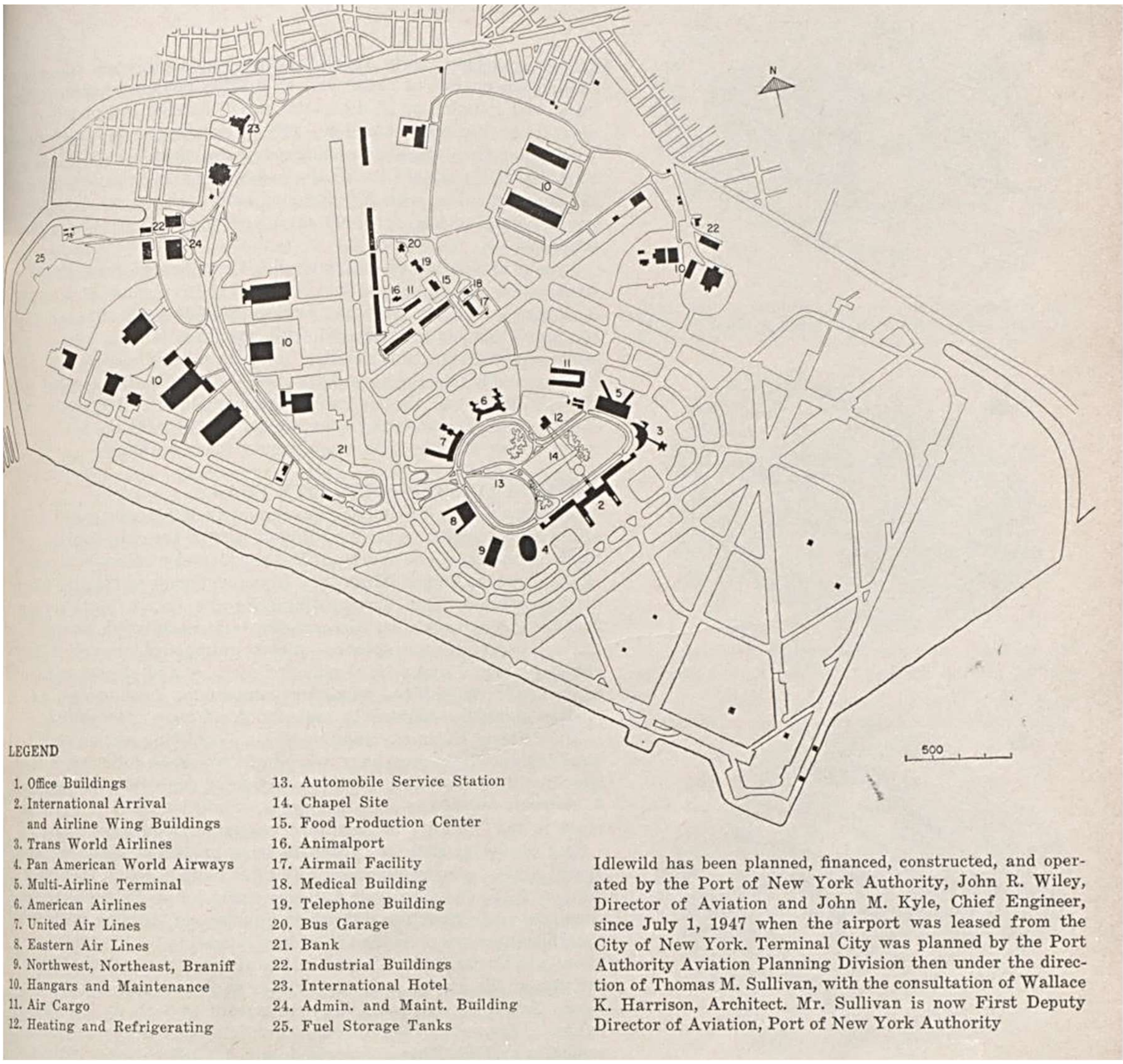


Figure M.18.21 New York, Idlewild (JFK) Master Plan 1961 - Source Architectural Record, September 1961

Figure M.11.22 New York, Idlewild (JFK) Aerial view of the original Airport City 1962 – Source: airporthistory.org

With the demise of TWA in 2001, the terminal remained vacant until 2005 when JetBlue Airways and the Port Authority of New York and New Jersey (PANYNJ) financed the construction of a new 26-gate terminal partly encircling the Saarinen building (figure M.11.23). Called Terminal 5 (Now T5), the new terminal opened on October 22, 2008. T5 is connected to the Saarinen central building through the original passenger departure-arrival tubes that connected the building to the outlying gates. The original Saarinen terminal, also known as the head house, has since been converted into the TWA Hotel (figure M.11.24).

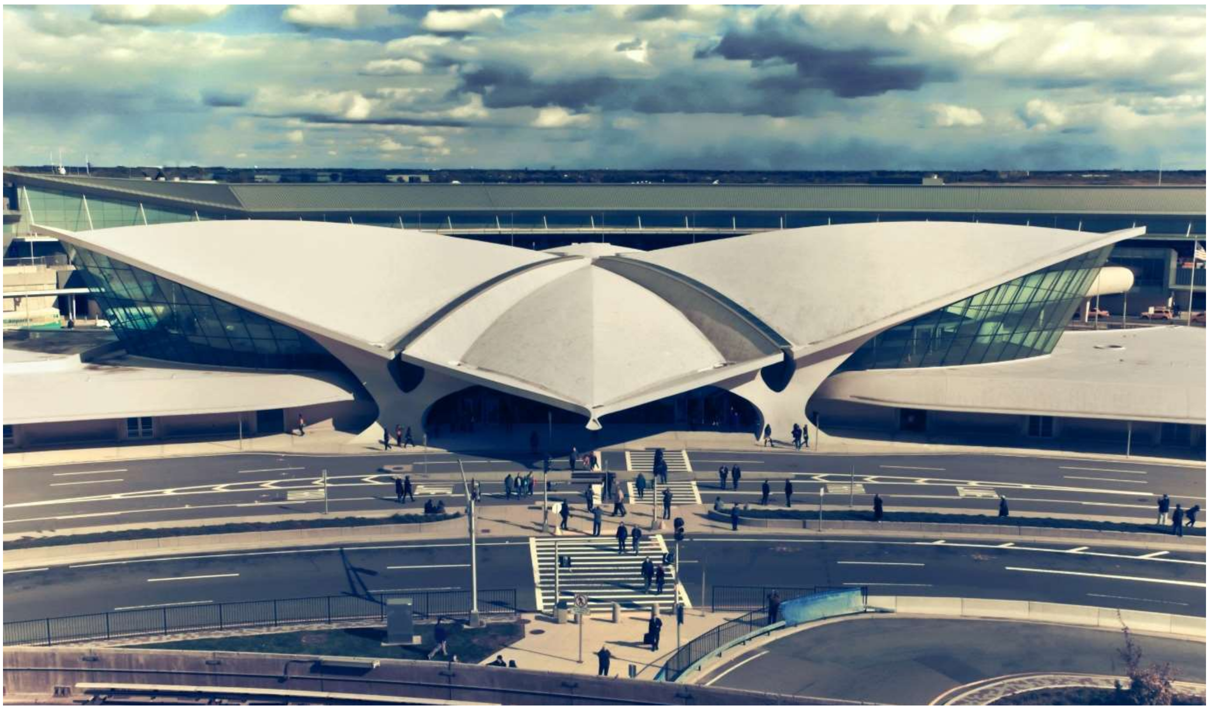


Figure M.11.23 Aerial view of the TWA terminal with the later Jet Blue terminal in the background – Source: Architectural Digest

Figure 11.11.24 The TWA terminal after conversion to a hotel – Source: TWA Hotel

An aerial view of the terminal zone before the demolition of the Pan Am terminal (was T3 in the bottom right foreground) and the current terminal area configuration are shown below (figures M.11.25 & M.11.26).

Figure M.11.25 New York, JFK, Aerial view - Source Architecture Daily Photo: Jeffrey Millstein

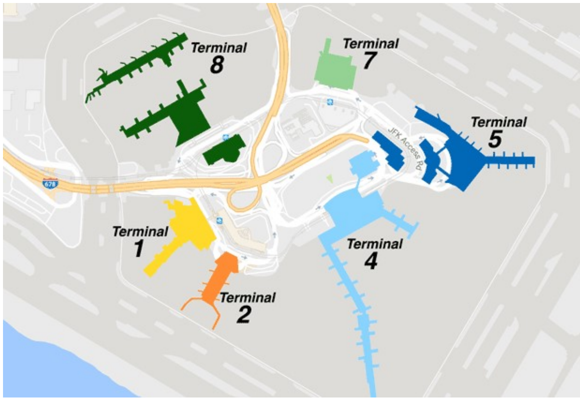


Figure M.11.26 New York, JFK Terminal area plan Source: JFK Airport

JFK is currently spilt across six separate terminals, constructed in stages since 1948, and connected by the AirTrain light rail that was retro-fitted and by various complex access roads Future plans involve the creation of fewer and larger unified terminals that would allow easier transfers for passengers with flight connections. To improve transport links, the congested Van Wyck Expressway and Kew Gardens Interchange that leads to the airport will be widened. Roadways on the site will be reconfigured into a "ring road" to allow easier access to terminals for taxis and ride-sharing vehicles, while extra carriages will be added to the AirTrain to double its capacity. Boosts to security technology, including facial recognition and video-tracking software, are also planned to help speed up passenger movement (figures 11.11.27 & 11.11.28) (NJ, 2020).

Figure M.11.27 Image of the future Terminal 2 - Source: New York Governor's Office


Figure M.11.28 Aerial view of the redeveloped airport – Source: New York Governor's Office

12 Washington, Dulles (IAD) 1962

The innovative and influential mid-field hub concept (figure M 12.1) and toast rack apron layout introduced at Washington Dulles is discussed in Chapter 6.7 and the surface access planning is described in Chapter 8.2.

Washington Dulles was designed to allow growth that could not be accommodated at Washington National Airport and can be regarded as the first airport that was designed specifically for jet aircraft.

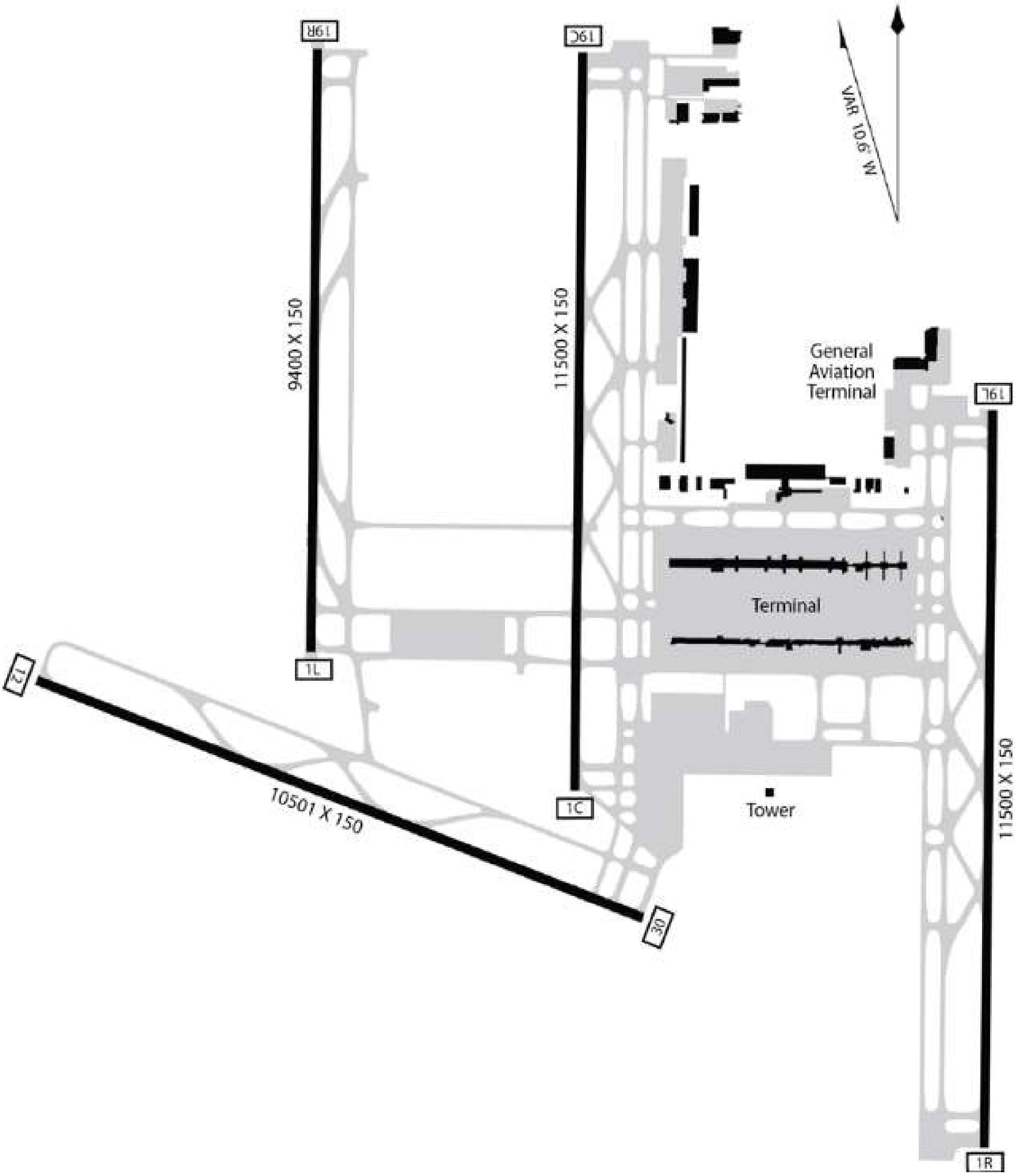


Figure M.12.1 Washington Dulles, Masterplan -Source: FAA

The terminal building, with dramatic upswept clear span roof (M.12.2), although constructed in concrete can be seen as the forerunner of the modern long span steel structures that are an integral part of contemporary airport design. The interior incorporated freestanding cabins, reminiscent of exhibition stands, accepting that the interior has become a flexible stage set (figure M.12.3). The terminal also introduced the concept of an indeterminate architecture, that looked complete and resolved whether in its original size or when extended (figures M.12.4, M.12.5 & M.12.6). These ideas predate Norman Foster's claims to have originated the ideas by thirty years.

The one feature that was to prove a wrong move was the proposal to use mobile lounges to access aircraft (figures M.12.7 & M.12.8). Saarinen enlisted the help of Charles Eames to produce one of the most compelling cartoons promoting an airport concept of operation, as can be seen in this film strip: https://youtu.be/FL-mjc1sgX4.

For a time, mobile lounges were popular and several new airport designs were developed following these principles, including the ill-fated Montreal, Mirabel airport. Mobile Lounges proved to be slow, unreliable and expensive and ultimately were not able to carry sufficient numbers of passengers, as aircraft sizes grew and volumes of passengers increased. Washington Dulles' greatest virtue has been its ability to accommodate growth and change without losing either its simplicity of layout or integrity of form because expansion was planned from the outset.

Figure M.12.2 - Washington, Dulles – Source: Eater Washington DC

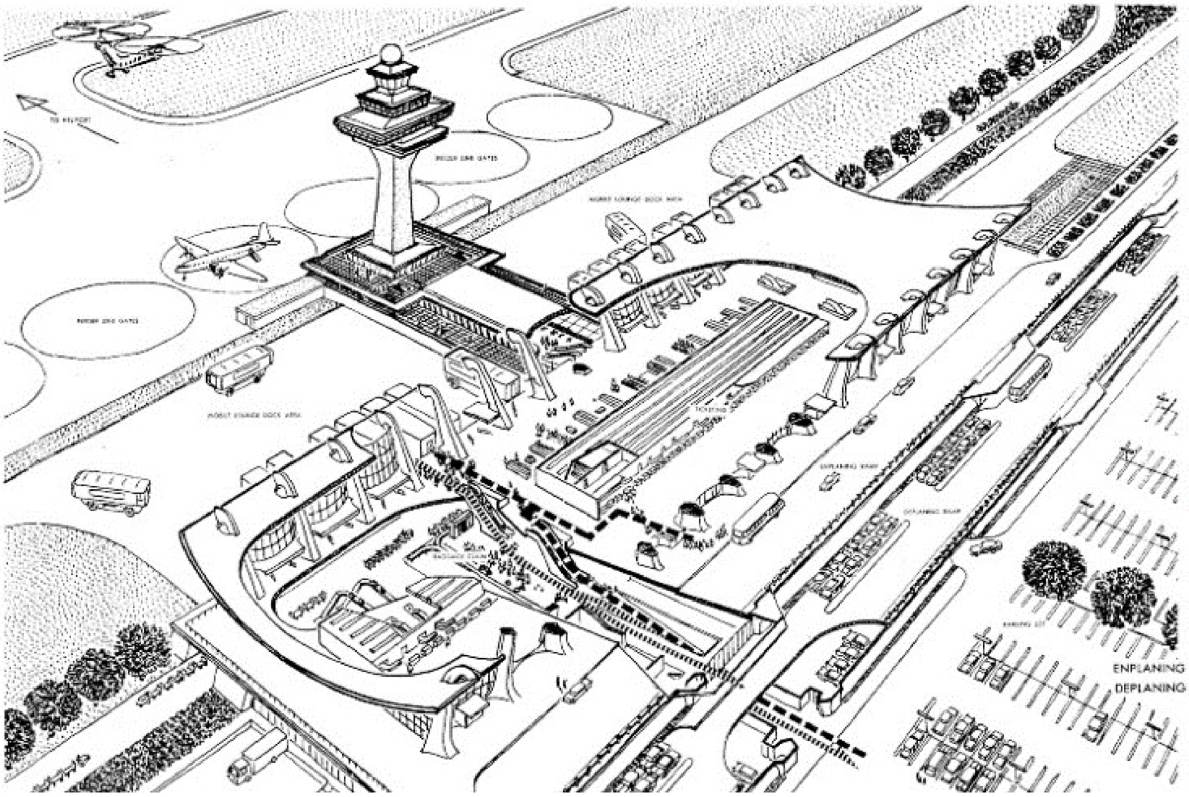


Figure M.12.3 Washington, Dulles, cut away perspective of terminal - Source: FAA

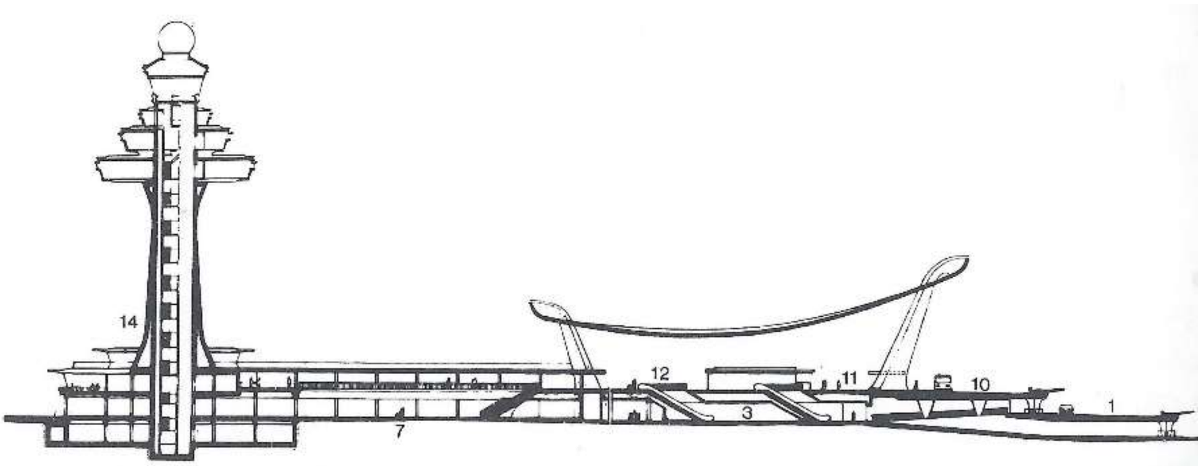


Figure M.12.4 Washington, Dulles section through terminal and control tower Source: FAA

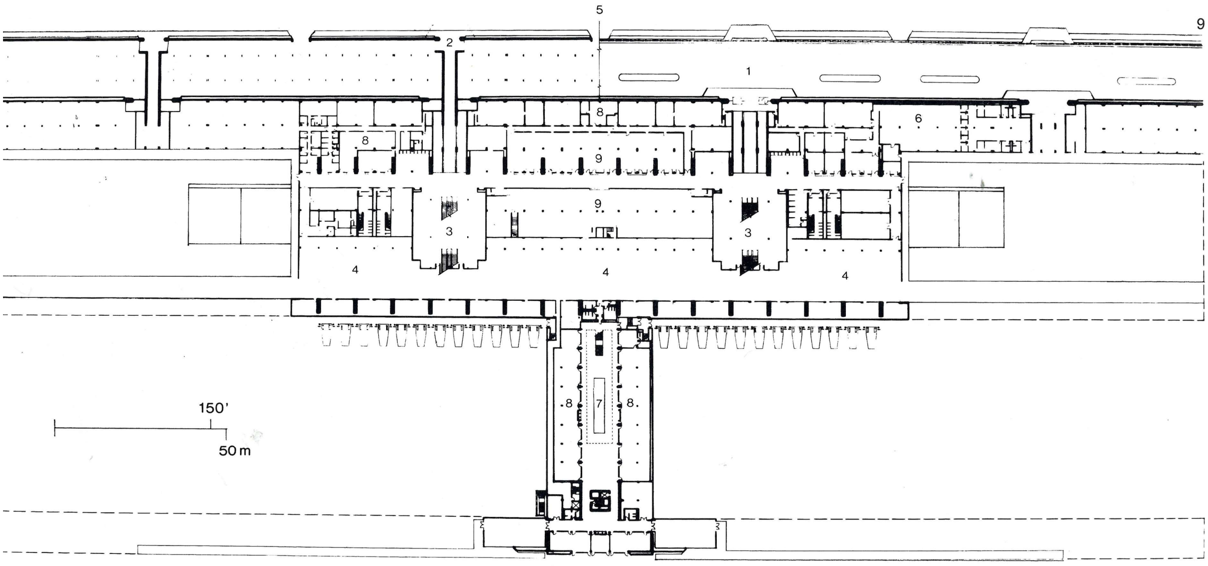


Figure M.12.5 Washington, Dulles, lower level arrivals plan of terminal Source: FAA

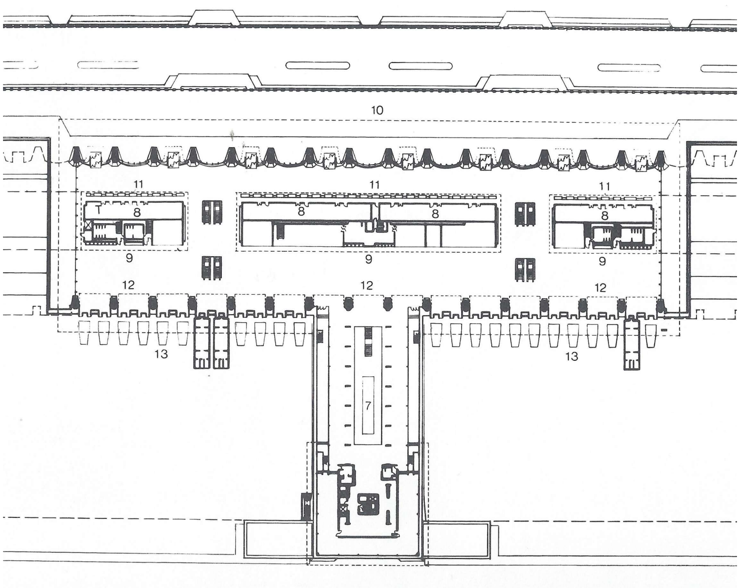


Figure M.12.6 Washington, Dulles upper level check-in plan – Source: FAA

Figure M.12.7 Washington, Dulles, view of 'Planemate' mobile lounge loading aircraft – Source: Pinterest

Figure M.12.8 Washington Dulles interim update with remote satellites still served by mobile lounges – Source: Library of Congress

Figure M.12.9 Washington Dulles, view of check-in concourse at opening - Source: FAA

Figure M.12.10 Washington, Dulles, view of check-in concourse after extension - Source: Architecture Daily - Photo: Rick Latoff

Figure M.12.11 Washington, Dulles, Aerial View - Source: Architecture Daily

Figure M.12.12 Washington Dulles, aerial view of extended terminal area (lighter coloured roof) and added linear satellites - Source: Architecture Daily

13 Los Angeles (LAX) 1962

Los Angeles Airport was originally known as Mines Field and began operations in 1928 (figure M.13.1). It was originally secondary to Burbank's Lockheed Field (today, Bob Hope Airport), becoming Los Angeles’ principal airport in the 1940s (figure M.11.2). By the end of 1946 the new runways, passenger terminals, hangars, control tower, and maintenance sheds were ready, and American, Trans World, United, and Western moved from Burbank, followed by Pan Am shortly after (figure M.13.3).

Figure M.13.1 Aerial view of Mines Field circa 1931. Source: Los Angeles Times Photographic Archive, Young Research Library, UCLA, used under a Creative Commons license.

Figure M.13.2 Aerial view of Mines Field in 1939 before its transformation into Los Angeles Airport. Source: Herald-Examiner Collection, Los Angeles Public Library

Figure M.13.3 Aerial view of Los Angeles International Airport shortly after its post-war renovations. Source: Los Angeles Area Chamber of Commerce Collection, USC Libraries.

During the 1950s Robert Pereira prepared a number of radical, circular, mid-field terminal and satellite concepts (see figures 6.71 & 6.72) that had re-imagined the airport as a leisure experience based on their experience of working with Disney (see figure 6.18).

This evolved into a new concept (figure M.13.4) which had seven simple linear terminals linked by underground walkways to lozenge shaped satellites, some parallel to the terminal and some at right angles. These surrounded a central zone with a large landside car park and commercial and leisure buildings.

The landside element was eventually reduced and simplified to the iconic theme restaurant that can still be seen today, although it is no longer in use (figures M.13.5 and M.13.8) (Luckman, 1988).

Figure M.13.4 Los Angles Aerial View of early masterplan - Source: i.pinimg.com

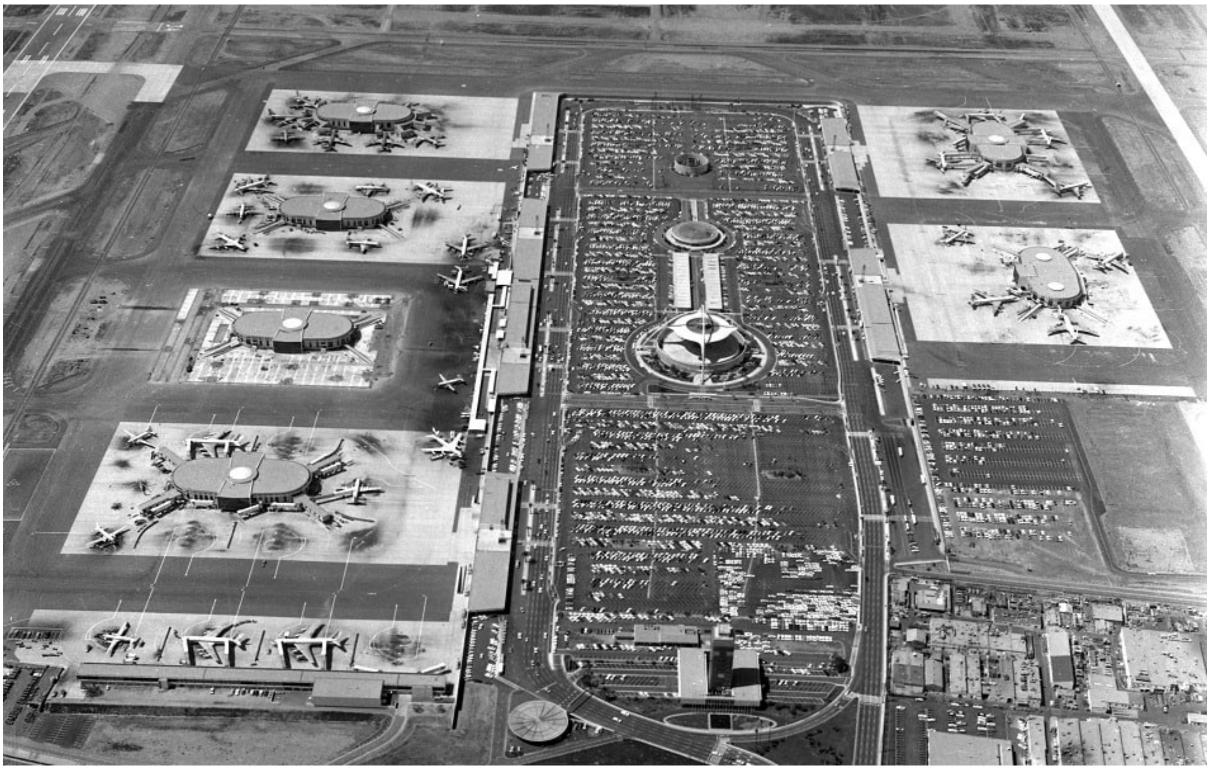


Figure M.13. 5 Los Angeles International aerial view 1963 – Source: airporthistory.org

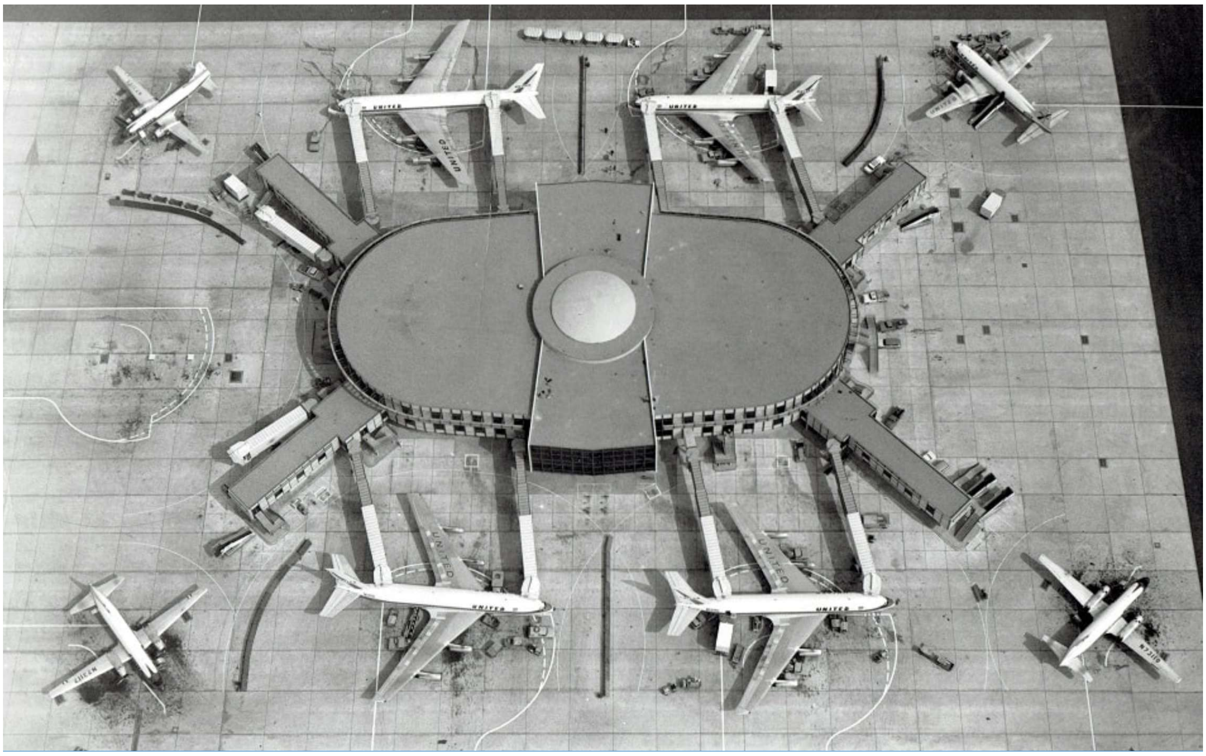


Figure M.13.6 Los Angeles International, aerial view of satellite with aircraft parallel parking and front and rear door boarding Source: www.airporthistory.org

Figure M.13.7 Los Angeles (LAX) Theme Building – Source: California Historical Society Collection, USC Libraries

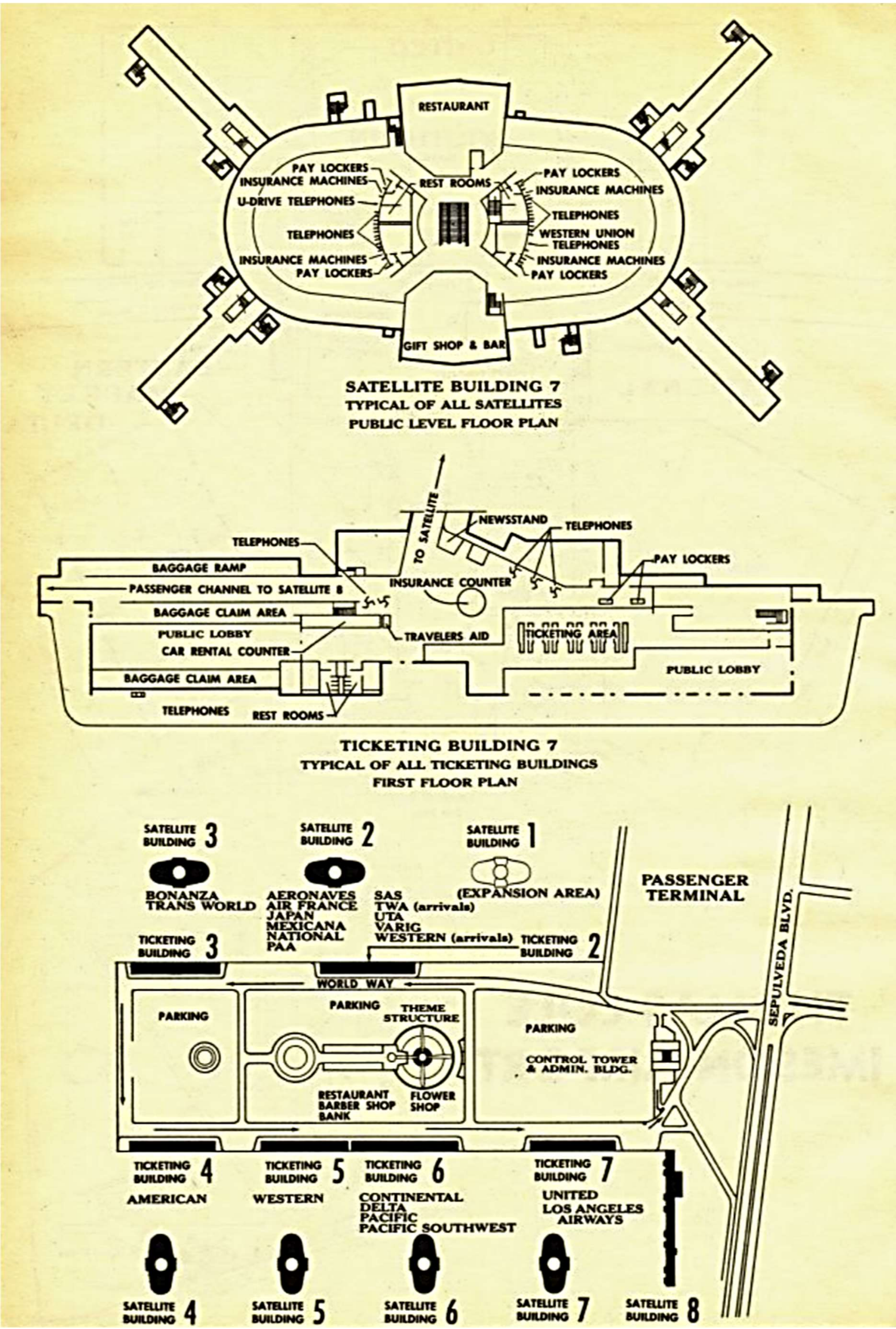


Figure M.13.8 Los Angeles International, terminal and satellite conceptual plans - Source: Pinterest

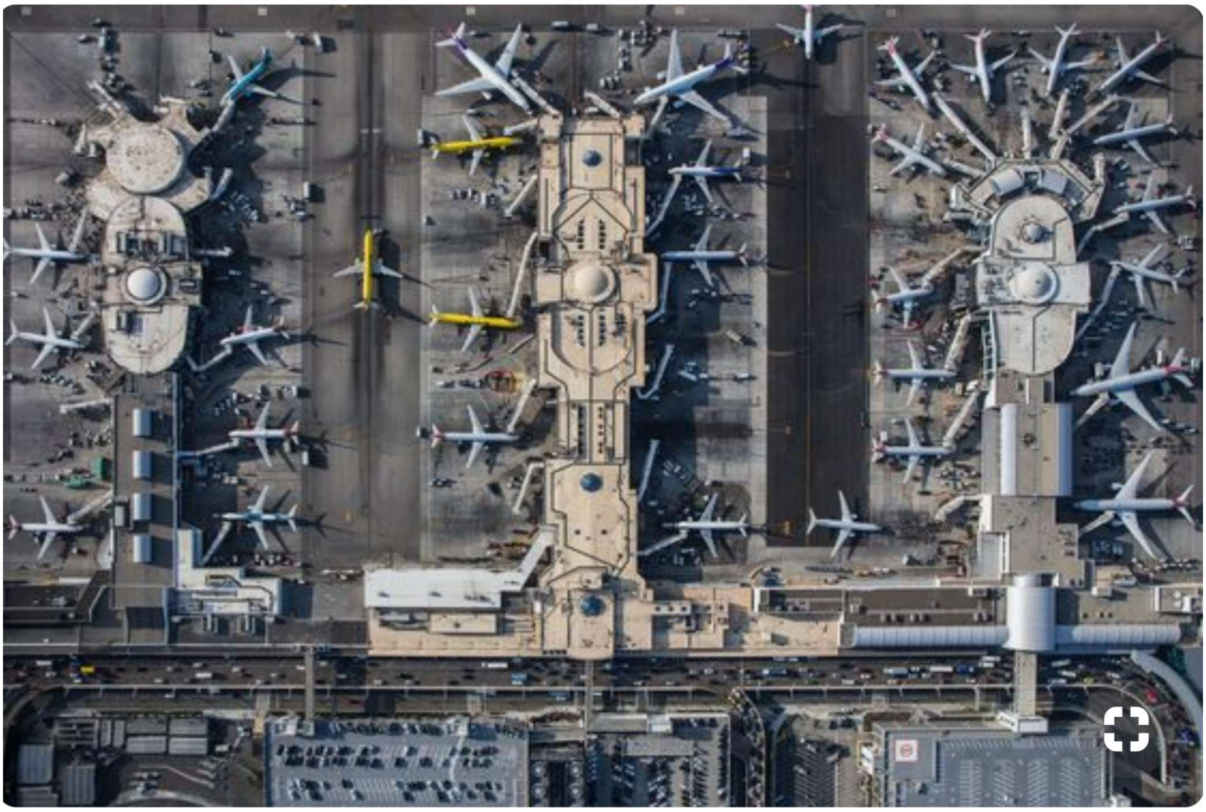


Figure M.13.9 Los Angeles International, Aerial view of satellites updated and reconnected with the terminal to form piers, now with nose-in aircraft parking, and front door boarding only, to use available site area more effectively – Source: Pinterest – from Wired

Originally the satellites had parallel parking for aircraft (figure M.13.6), but this changed to nose-in parking to increase the number of stands available. Later to increase even further the number of stands available for aircraft parking the satellites were reconnected with the head house terminal to create a series of finger piers (figure M.13.9).

The resultant cul-de-sacs has resulted in less convenient aircraft circulation and increased the likelihood of delays to aircraft movement but the original satellite concept imposed unacceptable limits on the capacity of the airport.

11.14 Dallas Fort Worth (DFW) 1973

The original 1966 plans show how the new airport was located half way between Dallas and Fort Worth with a terminal zone between the two pairs of north/south parallel runways (figure M.14.1).

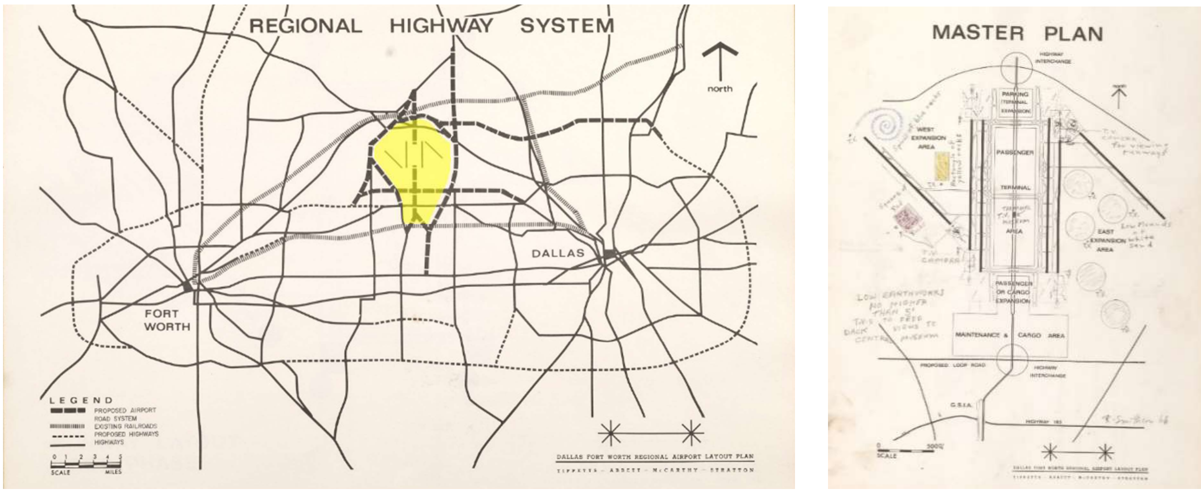


Figure M.14.1 Dallas Fort Worth Regional Plan and Master Plan 1966 _ Source: Smithsonian Institution

Originally a central spine of terminal buildings with finger piers was proposed by master planners, Tippetts - Abbett - McCarthy - Stone (figures: M.14.2 & 3), with integrated multi-storey car parks similar to the design that had previously been developed for Houston Intercontinental (figure 6.114).

This concept produced phasing challenges as both the elevated and basement roads would have had to be constructed the full length of the airport even though there would not have been demand for the same level of terminal space.

Figure M.14.2 Dallas Fort Worth – Aerial Perspective- Source: Smithsonian Institution

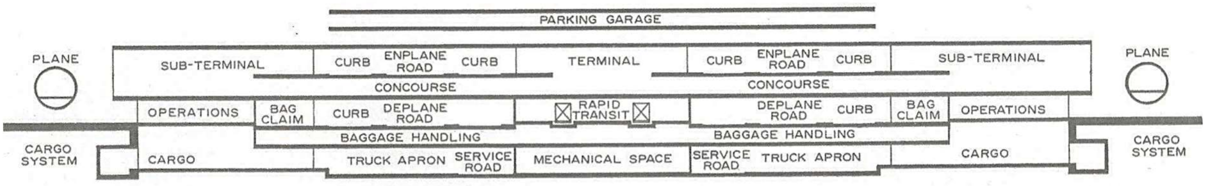


Figure M.14.2 Dallas Fort Worth, cross section through terminal complex – Source: Smithsonian Institution

A much simpler and more economical horseshoe shaped series of unit terminals was then developed in conjunction with architects Hellmuth, Obata, Kassabaum and Brodsky (HOK), with semi-circular surface parking areas in front of each of the terminal zones. The ultimate design of thirteen terminals would have provided 234 aircraft-boarding gates.

Figure M.14.3 Dallas Fort Worth – Future aerial view of airport in 2001 Source: Tippetts Abbett McCarthy Stone

The Unit Terminal concept is described in chapter 6.4. The following section drawing, which is very simple compared with the original proposals above, illustrates the concept which focuses on short walking distances by decentralising all the processing (M.14.4).

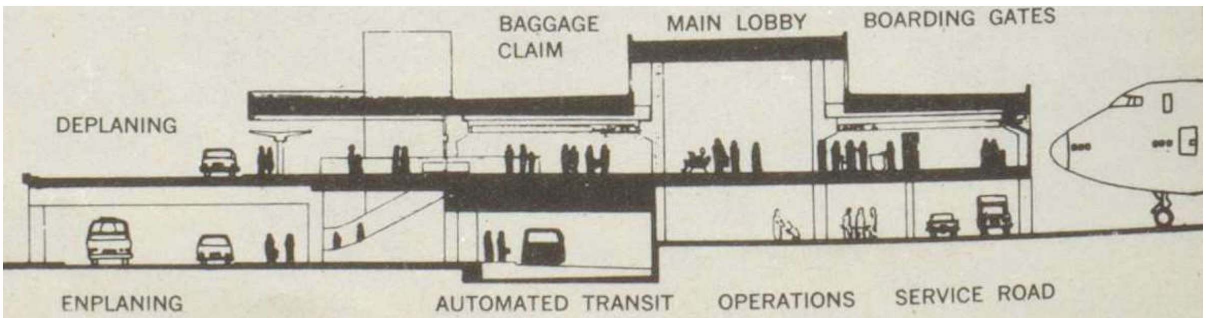


Figure M.14.4 Dallas Fort Worth, Unit Terminal Section - Source: Architectural Design

Each of the four initial terminals contained 790,000 ft^2 of covered space and could accommodate eighteen Boeing 747s (figure M.14.5).

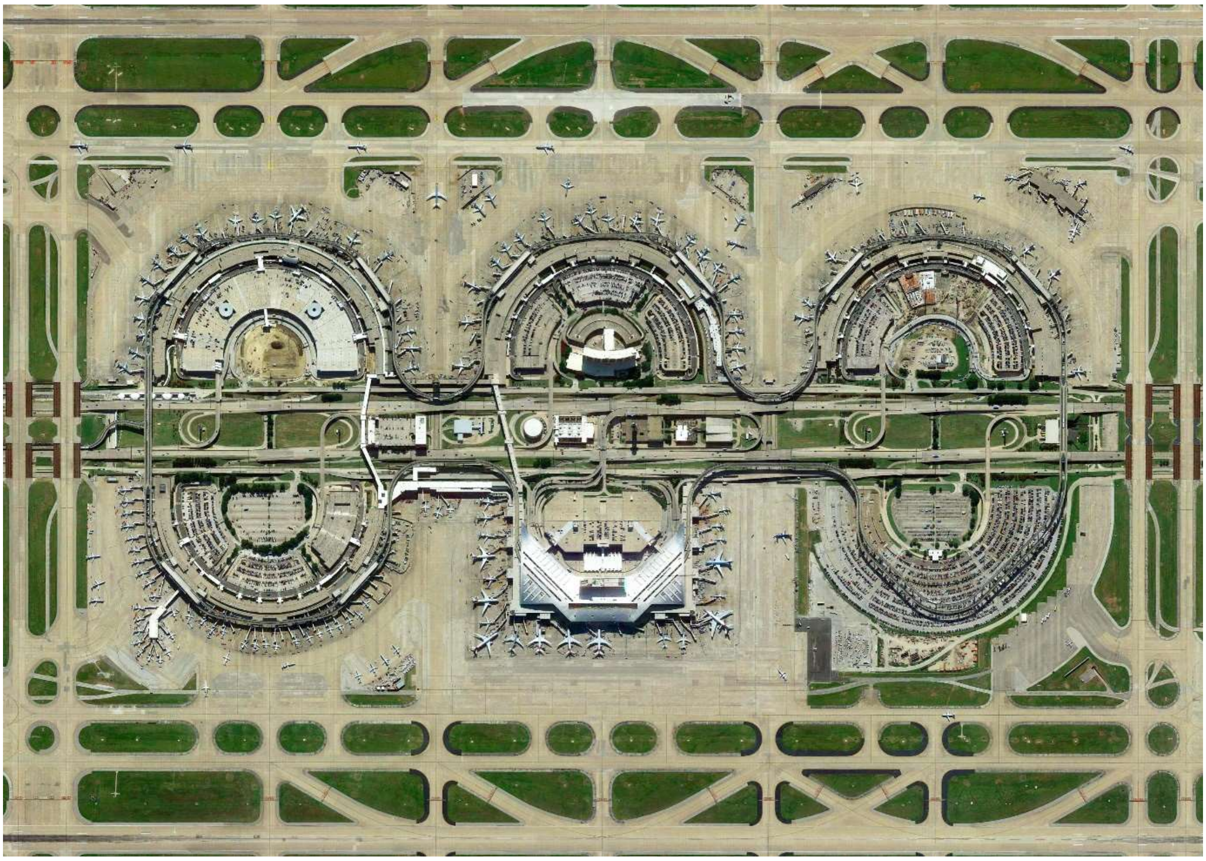


Figure M.14.5 – Dallas Fort Worth Terminal Zone- International terminal at the centre bottom is a later addition – Source: fromabove.altavista.org

Dallas Fort Worth was one of the key exponents of the Unit Terminal concept (figures 6.36 - 6.39 inclusive) and morphed into a major transfer hub by virtue of its transit system that linked the terminals. The later international terminal abandoned the unit terminal concept in favour of a more conventional centralised terminal with the benefits of consolidated security and a compact retail layout that maximised footfall.

The terminals were connected by one of the world's first automated transit systems, called Airtrans. It was designed to move 9,000 people, 6,000 bags, and 70,000 pounds of mail each hour (Figures 8.80 – 8.81). The original people mover train (Airtrans APM) was notoriously slow (17mph (27km/h)), uni-directional (running only in a counter-clockwise direction) and was located outside the secured area thus requiring travellers to go through security again.

It was replaced by 'Skylink' in April 2005 after serving approximately 250 million passengers. Skylink serves all five terminals at a considerably higher speed (up to 35mph (56km/h)), is bi-directional, and is located airside providing the transfer passenger with panoramic views of the airfield (figure M.14.6).

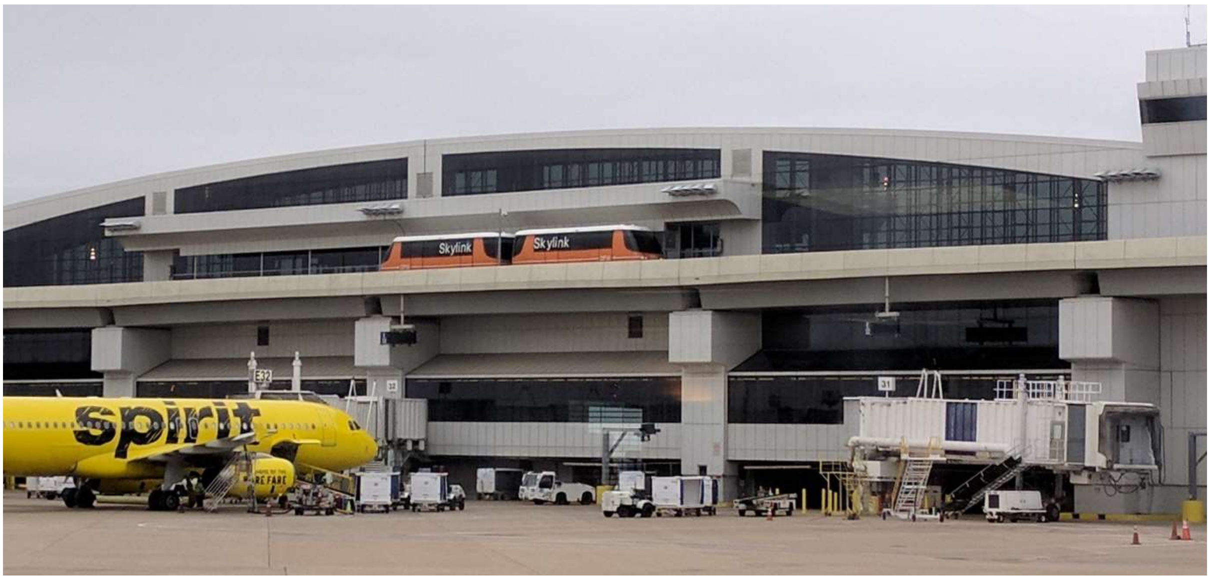


Figure M.14.6 Dallas Fort Worth International Terminal with Skylink Transit in the foreground – Source: Wikipedia

The airport's history has been tied up with the success of the airlines that use it. In its early years the airport was dependent on Braniff Airways which made it one of their key hubs but they ceased operations in 1982. The mantle was picked up by American Airlines who made it their first hub in 1981 and remains the main operator. For a time Delta Airways also operated the airport as a hub but reduced and then closed its operation in 2004 (Texas, 2019). Dallas Fort Worth has not expanded as much as had been originally envisaged as, following deregulation, Southwest Airlines, the original low cost carrier, chose to operate from Dallas Love airport rather than relocate to Dallas Fort Worth (Airways, 2014).

In 2018 Dallas Forth Worth handled 69mppa while Dallas Love handled 16mppa.The airfield has continued to expand and its long term masterplan envisages additional widely spaced parallel runways accessed via end around taxiways (EATs), as pioneered by Atlanta, to avoid aircraft having to cross the main runways (figure 7.41).

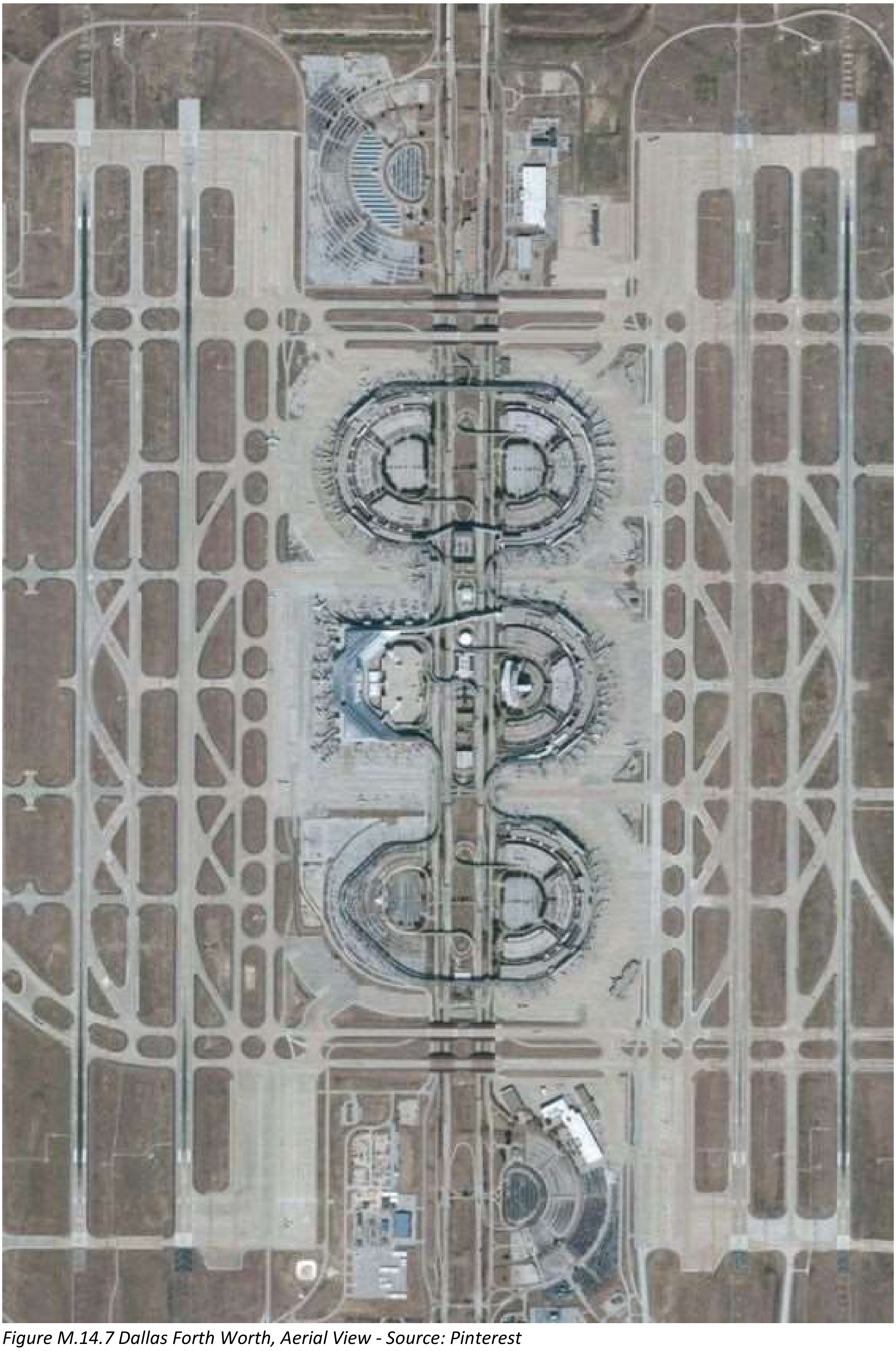


Figure M.14.7 Dallas Forth Worth, Aerial View - Source: Pinterest

11.15 Paris, Charles de Gaulle (CDG) 1974

In the late 1950s, Paris Orly and Le Bourget were reaching capacity so it was realised another airport was needed and the search for a suitable location began. By 1964 that location had been found: a site positioned 15.5 miles (25 kilometres) north-east of Paris. Construction work on the then-named 'Aéroport de Paris Nord' started in 1966. Renamed 'Charles de Gaulle', the new Paris airport was officially opened on 8 March 1974. The airport's initial passenger capacity was set at 10 million per annum.

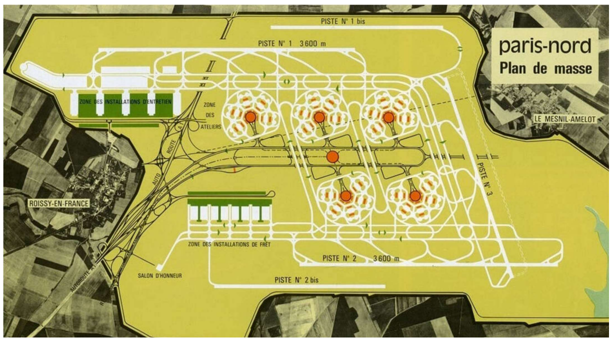


Figure M.15.1 Paris, Charles de Gaulle
Charles de Gaulle Master Plan 1965
Source: Sideshare.net Jeanmarie-Chevallier ADP

Figure M.15.2 Paris, Charles de Gaulle
Master Plan 2015
Source: Wikipedia- By CellarDoor85 – 52031981

Terminal 1

Terminal 1 was the first to be completed with the opening of the airport in 1974. Comprising a main central building and seven surrounding structures, it resembles an octopus when viewed from above. Each of Terminal 1's 10 storeys was originally given a particular purpose: for example, its second floor consisted of retail and food/drink outlets, while storeys three and four predominantly handled check-in and duty free/border control, respectively. It was given the nickname 'Camembert' because of its round shape. CDG was then the most modern airport in Europe and the only one outside the USA to adopt a masterplan with two pairs of close parallel runways.

Terminal 1 layout was driven by a desire to minimise walking distances by developing the American linear terminal concept into a wrap-around circular configuration, but the compact layout resulted in many level changes. Passengers move from level to level on escalators located in Plexiglas tubes within a central circular light well. This created an imagery that exhibited some of the dynamic characteristics of Futurism, but the layout was unfortunately accompanied by feelings of disorientation.

The top three levels were dedicated to car parking, below that were an office floor, the main passenger processing floors and below that again baggage and support areas (figures M.15.3 & M.15.4). There are seven satellites, accessed from the terminal by underground walkways, each with departure lounges on the 3rd level. Many travellers have commented that the layout results in very confusing wayfinding, and in practice it has proved very inflexible and difficult to change (figures M.15.5 & M.15.6).

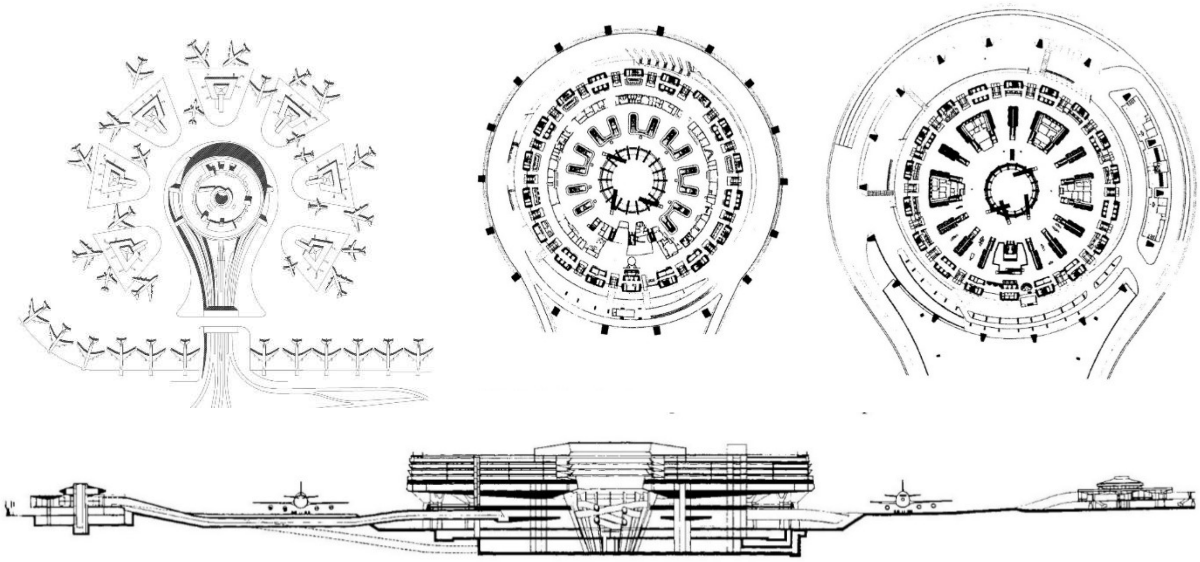


Figure M.15.3 Paris, Charles de Gaulle, Terminal 1 plans & section – Source: The Airport 1974

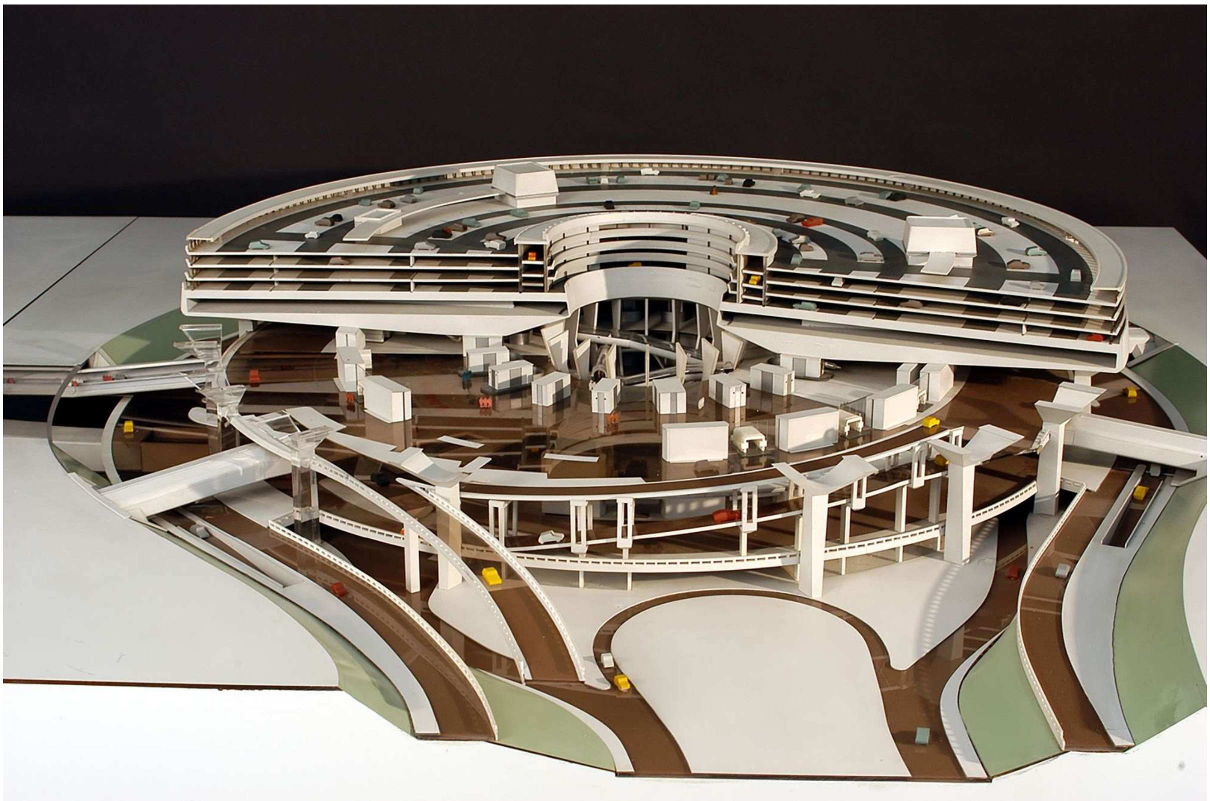


Figure M.15.4 Paris, Charles de Gaulle model of terminal with car park over Source: i.pinimg.com

Figure M.15.5 Paris, Charles de Gaulle, Terminal 1 aerial view – Source: fromabove.altervista.org

Figure M.15.6 Paris, Charles de Gaulle, Terminal 1, central void with criss-crossing passenger conveyors in glazed tubes - Source: Architecture Daily - Photographer; Paul Maurer

A recent project has started replacing three of the remote satellites, that each handled seven aircraft, with a single much larger, curved structure that accommodated 10 much larger aircraft including five A380 gates. This is an investment of doubtful value, now that the A380 aircraft is ceasing production, but it shows the inflexibility and limitations of the original concept (figures M.157, 11.15.8 & M.15.9).

Figure M.15.7 Paris Charles de Gaulle, photomontage of proposed replacement satellite – Source: Paris, Charles de Gaulle

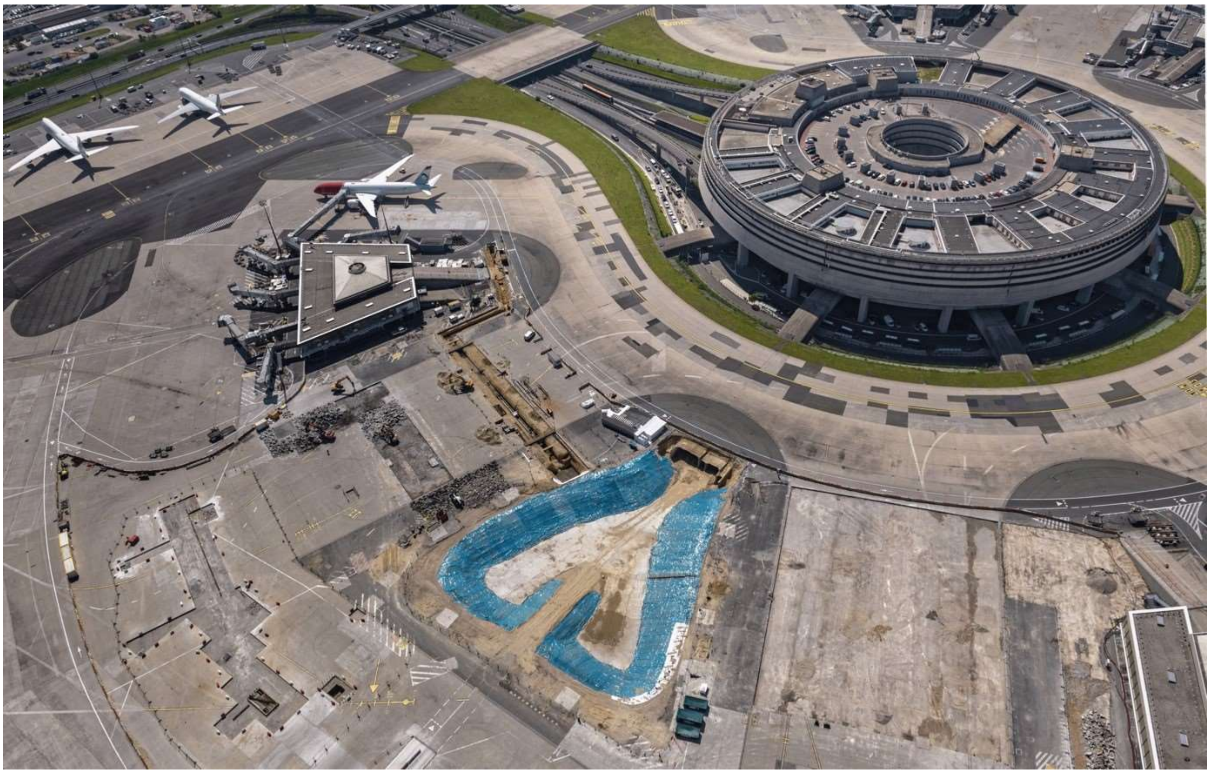


Figure M.15.8 Paris, Charles de Gaulle, aerial view showing demolition of satellite – Source: Paris, Charles de Gaulle

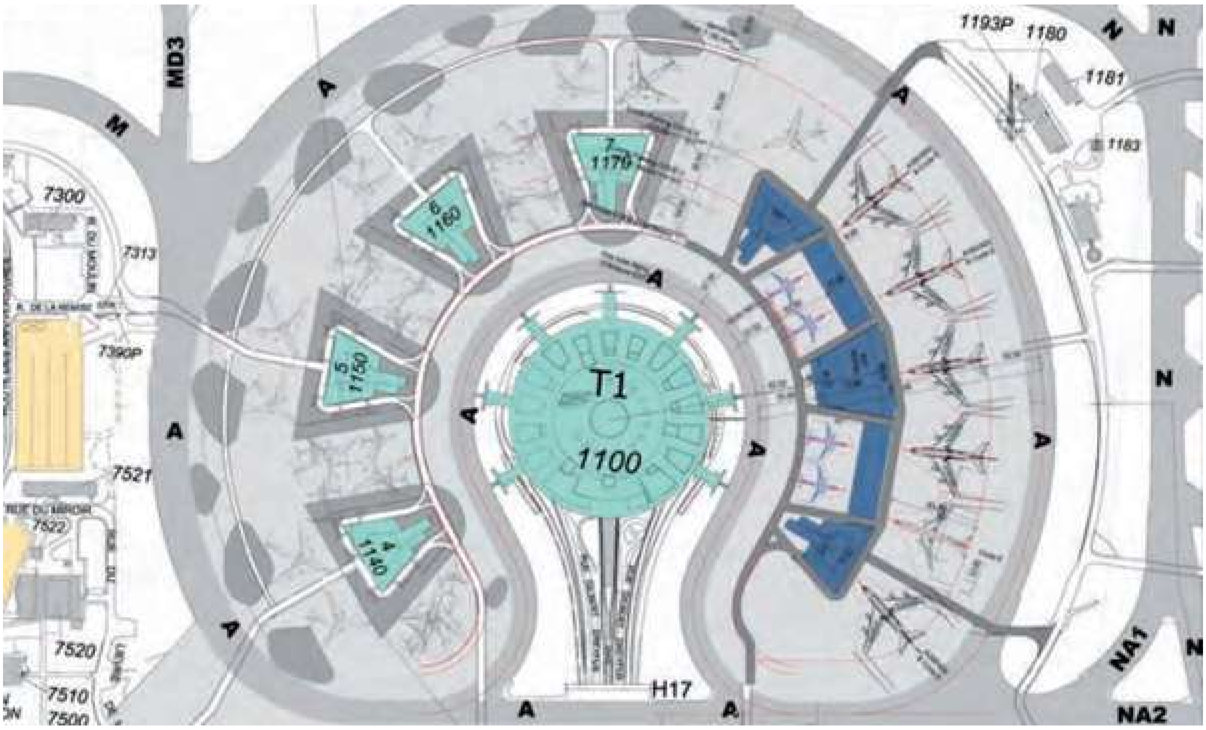


Figure M.15.9 Paris, Charles de Gaulle, aerial view showing proposed reconfiguration of satellites - Source: Paris, Charles de Gaulle

Terminal 2

Terminal 2 was conceived as an expandable linear terminal, solely for Air France's use, but is now much more widely used. It's made up of seven sub-terminals which are lettered 'A' through to 'G'. The latter subsequently suffered a partial collapse on 23 May 2004, causing four fatalities. Construction issues were later blamed for this incident. A reconfigured Terminal 2E was opened on 30 March 2008. The original linear terminals are now supplemented by two satellites L and M, and a more remote satellite G to the east all accessed by an underground transit system (figures M.15.10, M.15.11, M.15.12 &.M.15.13)

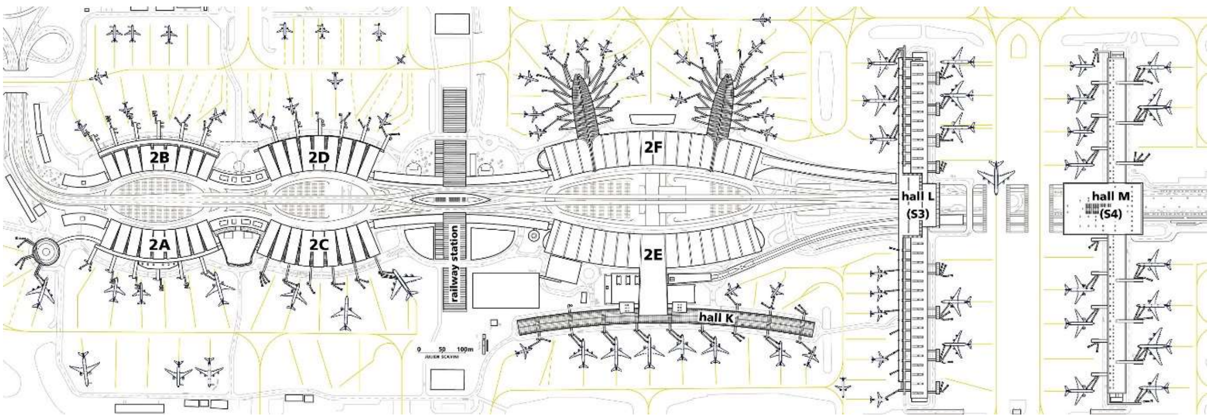


Figure M.15.10 Paris Charles de Gaulle Terminal 2 -Source: Wikipedia by Julien.Scavini - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76322670

Figure M.15.11 Paris, Charles de Gaulle, aerial view of terminal 2B – Source: ADP

Figure M.15.12 Paris Charles de Gaulle, landside view of terminal 2 – Source: ADP

Figure M.15.13 Paris, Charles de Gaulle, aerial view of expanded T2 with satellites in the foreground – Source: copybook.com

Rail Air Interchange

One area where the airport has excelled is in the provision of rail services and an associated public transport interchange. This facility is integrated with terminal 2 between Terminal 2 A&B and Terminal 2 C &D. It links the airport directly with the French TGV international rail network.

Figure M.15.14 Paris, Charles de Gaulle Rail/Air Interchange - Source: ADP

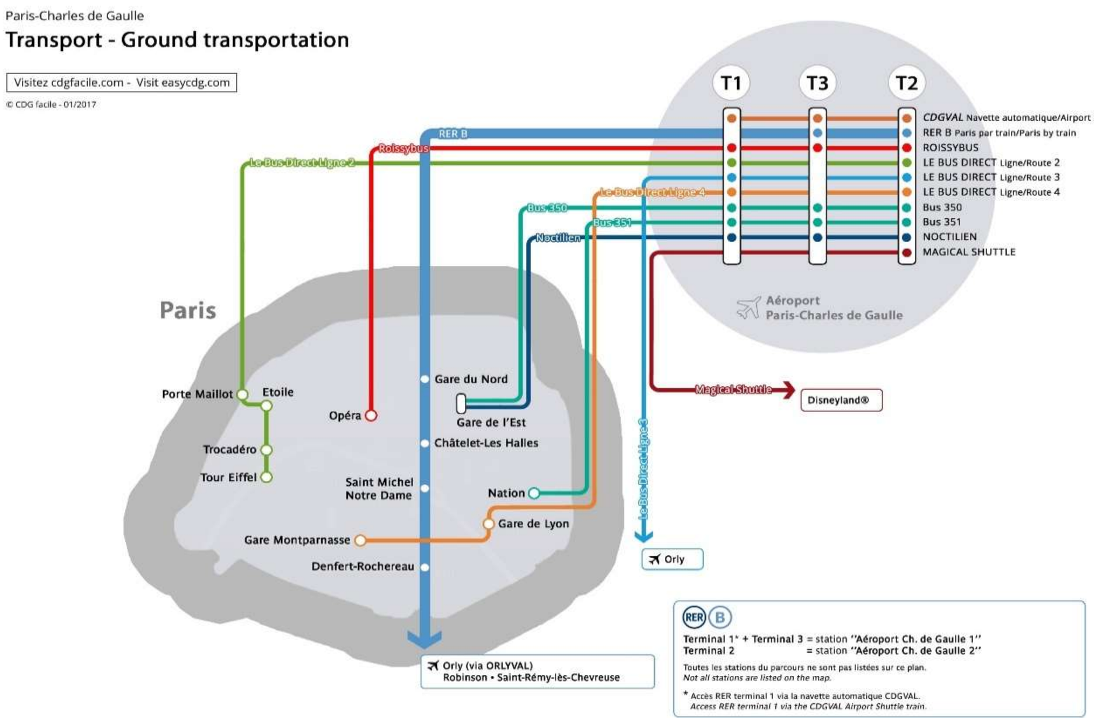


Figure M.15.15 Paris, Charles de Gaulle Rail/Air Interchange - Source: ADP

Terminal T3

Terminal T3 handles Charles de Gaulle's budget carriers/low-cost airlines and charter fights. It opened in 1990 with five gates. The transit between Charles de Gaulle's terminals takes place via the airport's CDGVAL light-rail shuttle service. Charles de Gaulle airport's annual passenger capacity is now set at 80 million per annum (figure M.15.16).

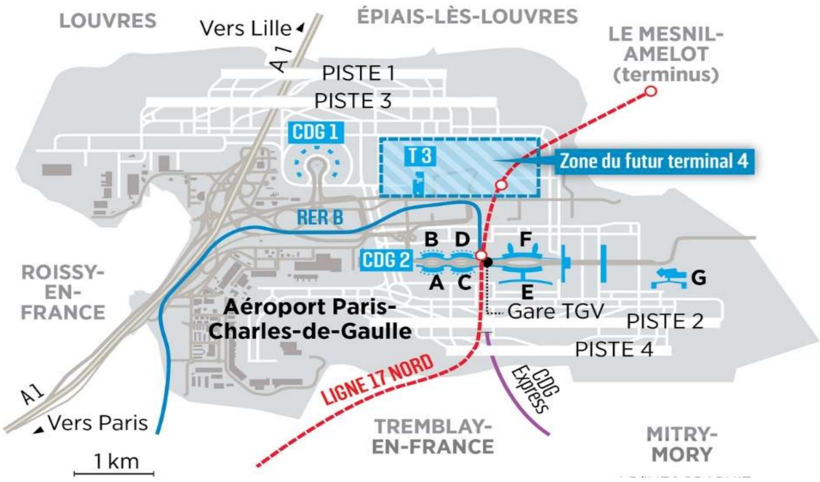


Figure M.15.16 Paris Charles de Gaulle, future rail network - Source: Le Parisien

Terminal 4

Terminal 4 is the airport's most recent project. It aims to increase the terminal processing capacity from the current declared capacity by 50%, from 80mppa to 120mppa. The runway capacity is however declared as only increasing from 480,000 movements per annum to 680,000 movements, or 42% per annum. No new runways are proposed so the airport is relying on a significant increase in aircraft size and improvements to air traffic control to achieve that growth (figure M.15.17) (Paris, 2020).

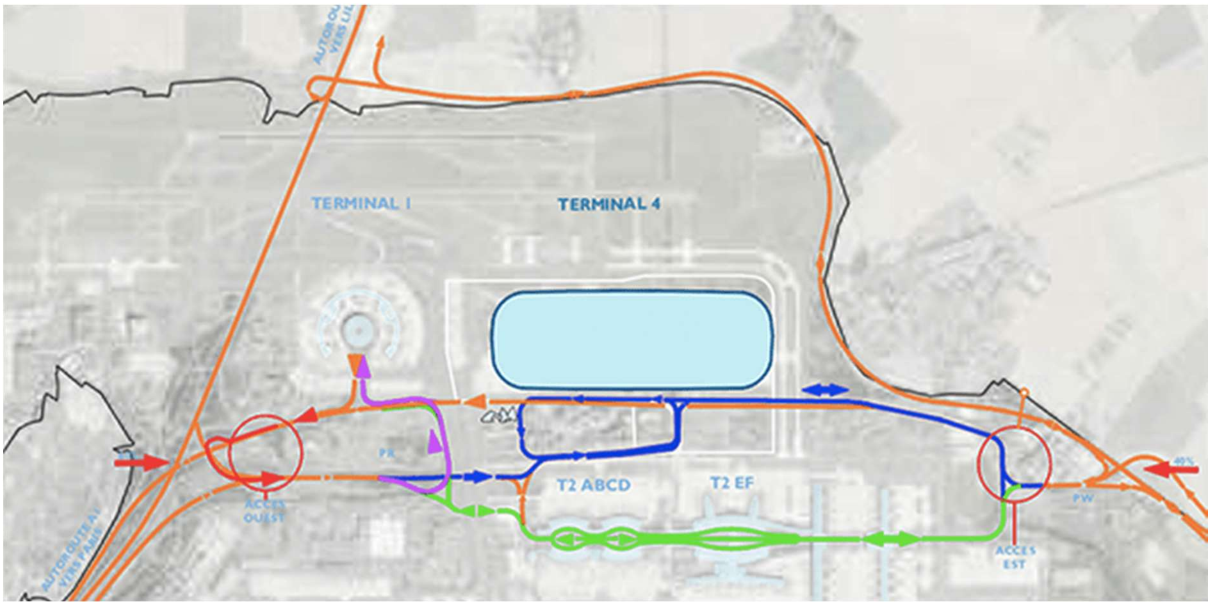


Figure M.15.17 Charles de Gaulle – Location of future T4 Source: aerobuzz.fr

Figure M.15.18 Paris, Charles de Gaulle Future Terminal 4, with T2 in the foreground – Source: cdg.parisaeroport.fr

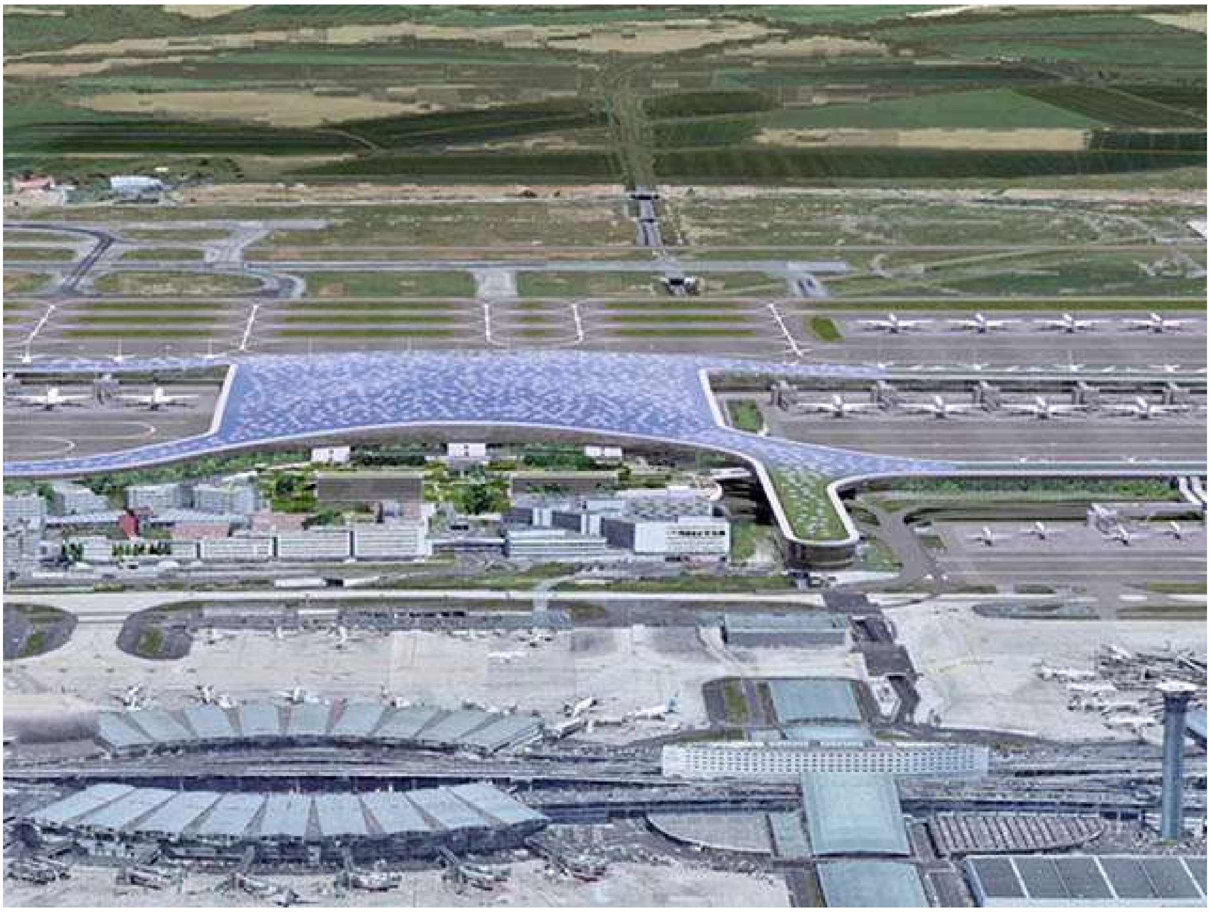


Figure M.15.19 Paris, Charles de Gaulle, proposed T4 - Source: fozoh.com

11.16 Atlanta, Hartsfield (ATL) 1980

Atlanta, Hartsfield-Jackson was originally known as Candler Field. The airfield was created out of a former motor racing speedway circuit, whose oval shape can be recognised in the map below (figure M.16.1). The first scheduled airline service from Atlanta occurred on September 15th, 1926 when a Florida Airways plane departed for Jacksonville and Miami. Charles Lindbergh visited Atlanta Airport on October 11th, 1927 during a cross-country tour following his solo flight across the Atlantic. His visit to Atlanta was a major catalyst for the rapid expansion of Candler Field in the 1930s.

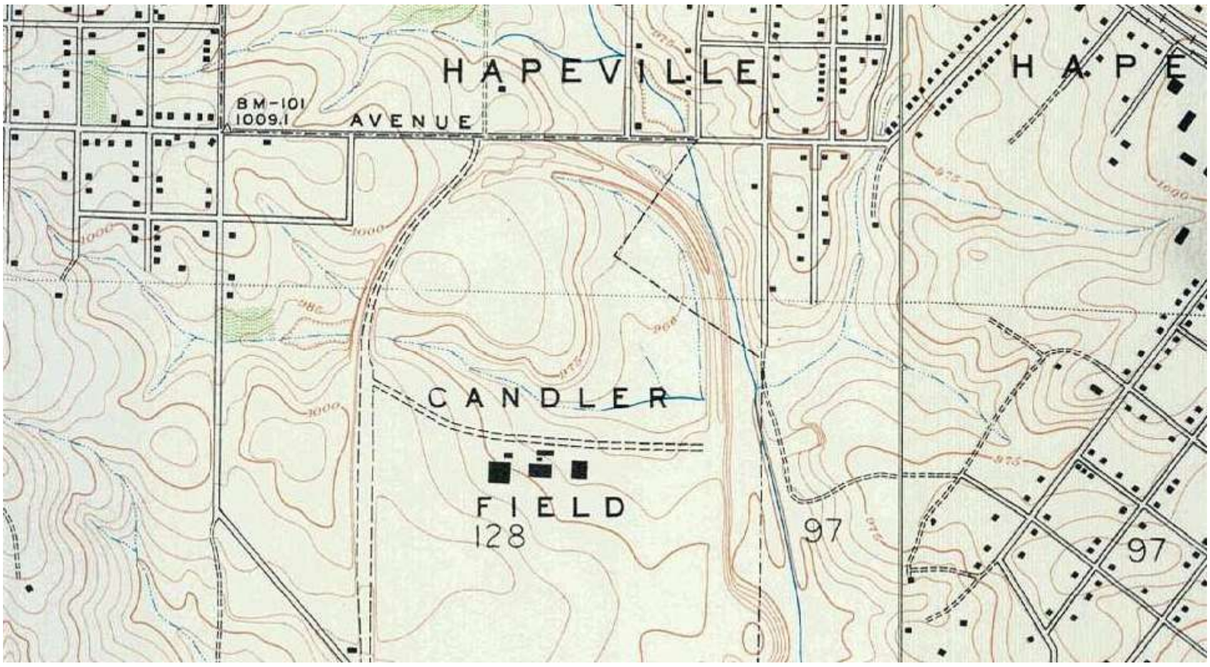


Figure M.16.1 Atlanta, Candler Field, oval racetrack converted to airfield (hangars in black) – Source: sunshineskies.com

The original lean to terminal building, and hangars can be seen overleaf (figure M.16.2).

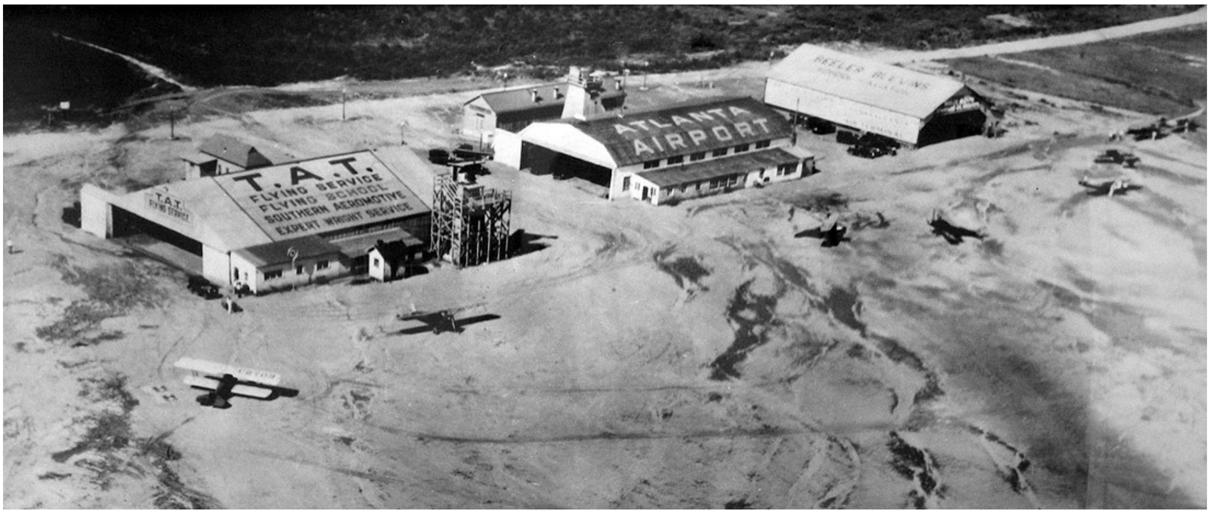


Figure M.16.2 Atlanta, Candler Field - A 1929 view of the airport showing T.A.T. Flying Service, Pitcairn Aviation (with Atlanta Airport on the roof), and the Beeler Blevins hangar. T.A.T. was a predecessor of American Airlines. Source – sunshineskies.com

A mid-1930s postcard (figure M.16.3) shows an Eastern Air Lines Douglas DC-2 at the passenger terminal which opened in 1932. Eastern began flying DC-2s in late 1934.

Figure M.16.3 Atlanta, Candler Field, postcard showing first terminal building 1931, for Eastern Airlines – Source: sunshineskies.com

The 2nd terminal building and control tower shown in the postcard (figure M.16.4) opened in 1932.

Figure M.16.4 Atlanta, Candler Field – Second terminal and new control tower 1932 – Source: sunshineskies.com

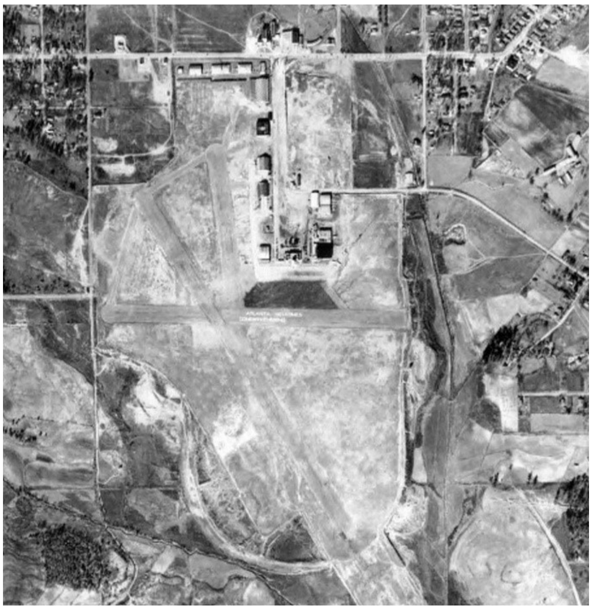


Figure M.16.5 Atlanta, Candler Field
Aerial view –
Source: sunshineskies.com

Figure M.16.6 Atlanta, Candler Field
Third temporary terminal with linear pier 1948
Source: sunshineskies.com

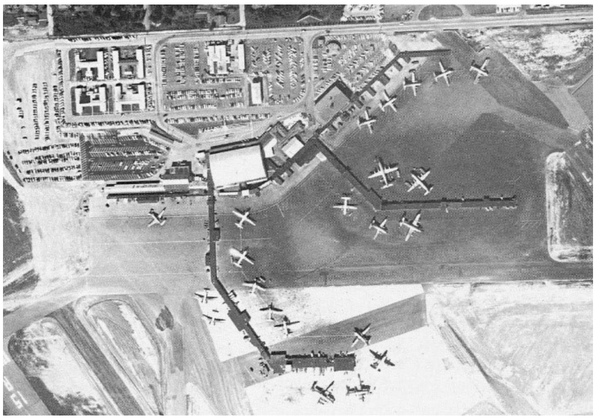


Figure M.16.7 Atlanta, Candler Field
Third temporary terminal with finger pier extensions
Source: sunshineskies.com

Figure M.16.9 Atlanta, Candler Field (Hartsfield)
Fourth Jet Age terminal 1961
Source: sunshineskies.com

Figure M.16.10 Atlanta Hartsfield evolution, a view of the first four terminals – A. Eastern Terminal, 1931, B. Terminal, 1932 to 1948, C. Temporary Terminal, 1948-1961, D, Jet Age terminal 1961 to 1980, E. Delta hangars 1940, F. Air Host Inn, G. Virginia Avenue Entry

Figure M.16.11 Atlanta, Hartsfield, Jet Age terminal with second parallel runway – Source: sunshineskies.com

After nearly a decade of planning and several years of construction, Atlanta's new Jet Age terminal opened on May 3, 1961 (figure M.16.11). The complex is claimed to be the first in the world to be built specifically for jet aircraft. At the time, it was the largest passenger terminal in the country covering sixty acres, with nearly a mile of concourses and 48 gates with parking for 52 aircraft. The enormous light-filled lobby and modern architecture was a considerable improvement on the cramped and dreary temporary terminal that preceded it.

The layout was fairly typical of large airports of the early '60s, similar to Miami or Chicago O'Hare. The central 2-storey terminal featured a 500ft long ticketing lobby upstairs and baggage claim downstairs with long concourses extending from the main building. The turquoise panelled administration building and control tower was one of Atlanta's most identifiable landmarks during the following two decades (figures M.16.12 & 13) (Henderson, 2020).

Figure M.16.12 Atlanta, Hartsfield 1976 Aerial View – Source: Sunshine Skies – Photo: Jim Doane

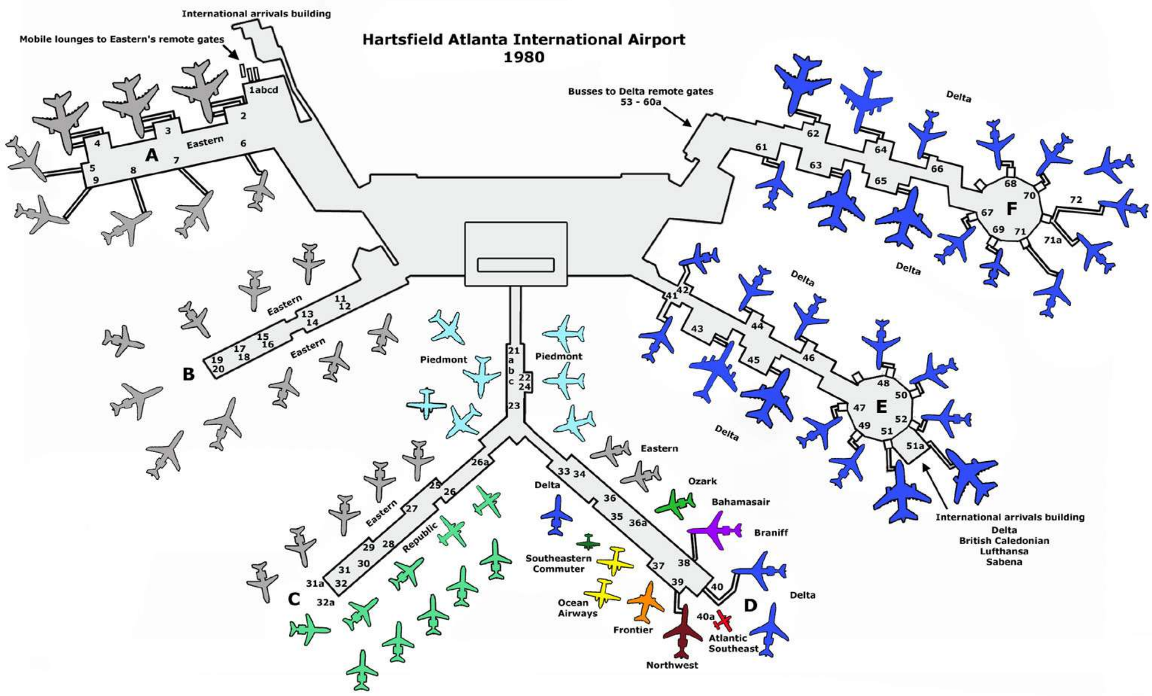


Figure M.16.13 Atlanta, Hartsfield Terminal Layout in early 1980 – Source: www.sunshineskies.com

A third close parallel runway was added to increase the capacity of the airfield as shown on the following site plan (figure M.16.14).

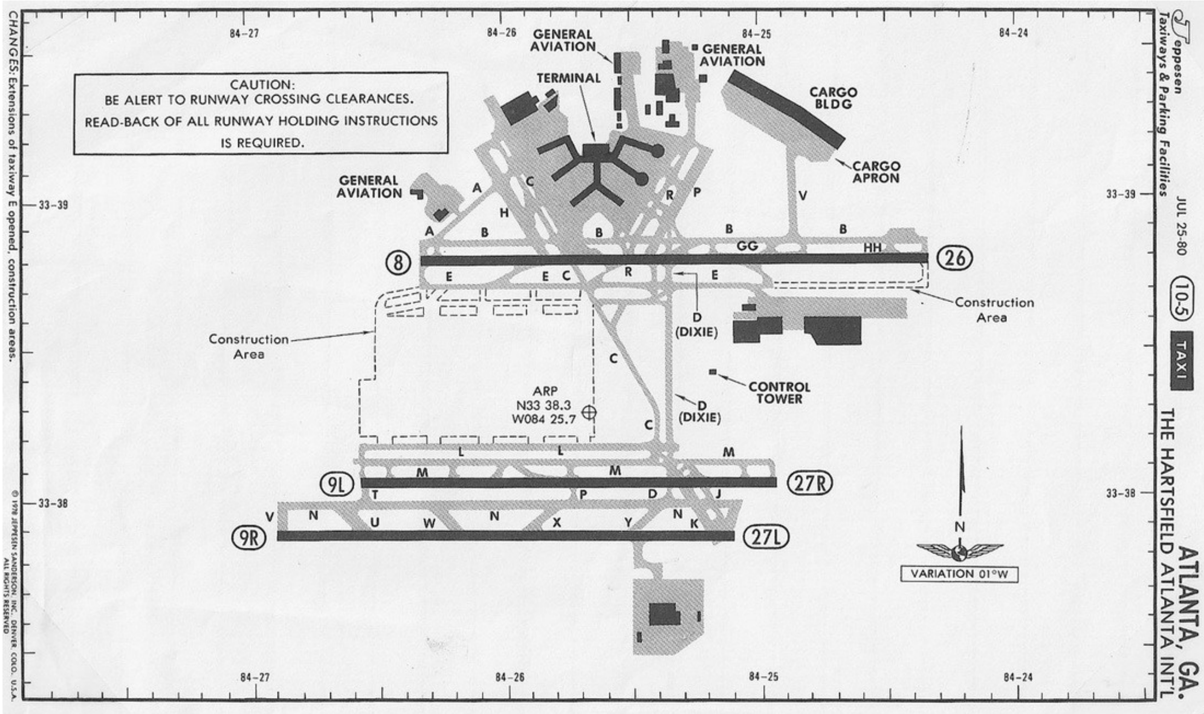


Figure M.16.14 Atlanta Hartsfield Airfield Layout in early 1980 during construction of the midfield terminal– Source: Sunshine skies.com

Figure M.16.15 - Atlanta Hartsfield, Aerial View of Mid-Field Terminal & Satellites 1980– Source: sunshineskies.com, Photo: Jim Doane

The ‘Toast Rack’ master plan of 1980 has served the airport well ever since and allowed it to expand progressively with additional runways and terminal capacity (figure M.16.15, M.16.16, M.16.17, M.16.18 & M.16.19).

Figure M.16.16 Atlanta Hartsfield 1981 Aerial View – Source: Sunshine Skies

Figure M.16.17 Atlanta Hartsfield 1993 Aerial View with 4th runway on the site of the former jet age terminal – Source: Sunshine Skies

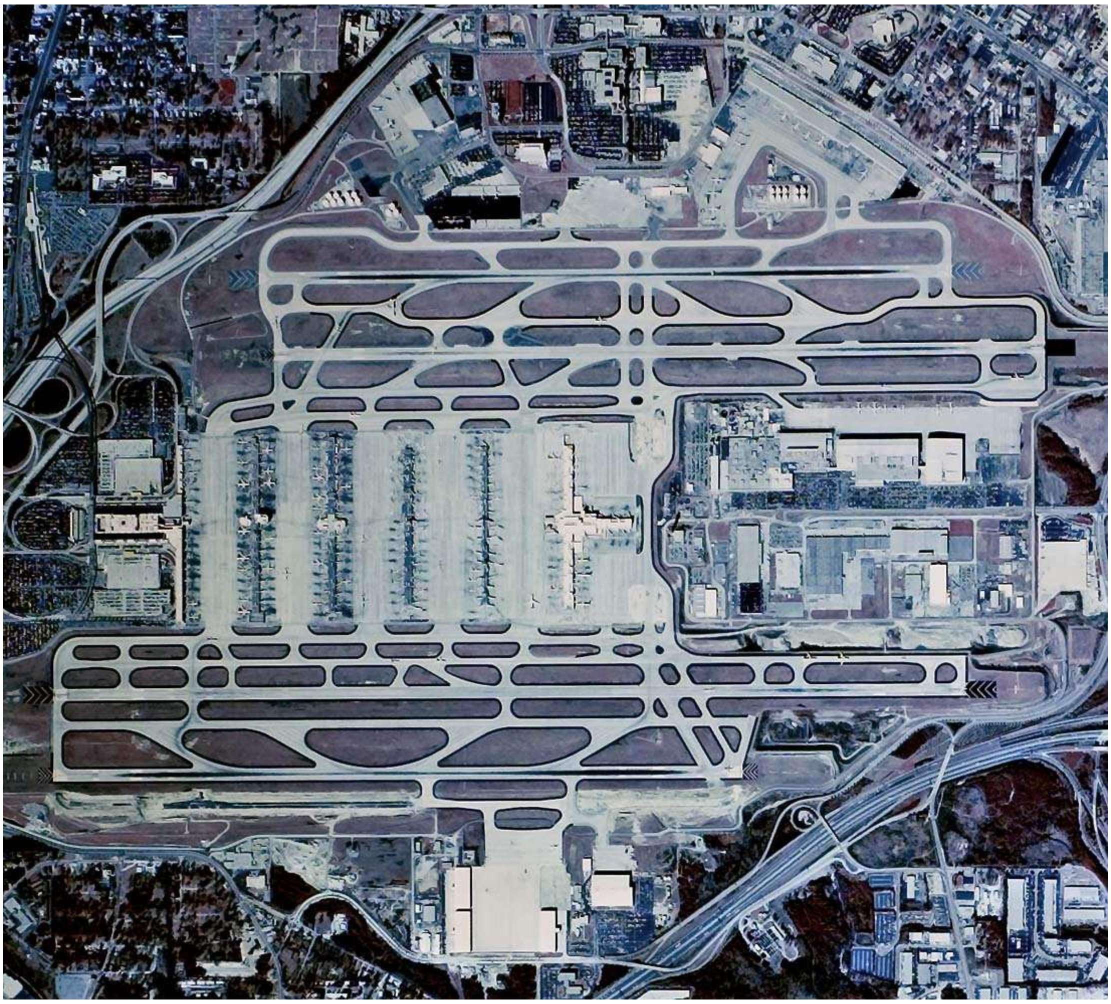


Figure M.16.18 Atlanta Hartsfield 1999, Aerial View with second eastern terminal – Source: Sunshine Skies

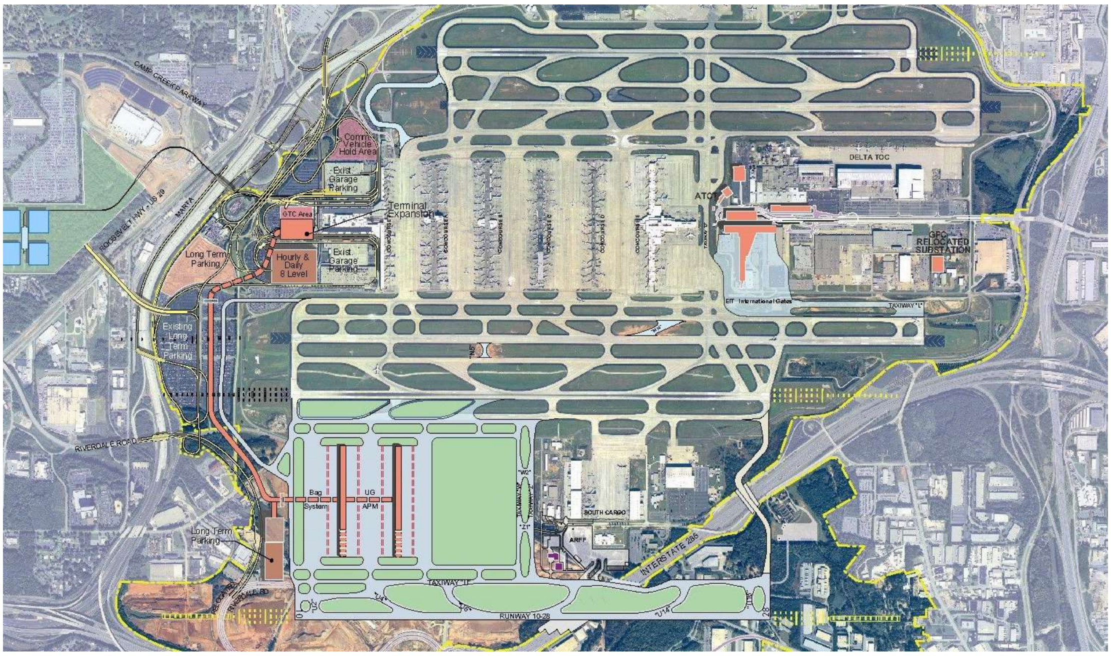


Figure M.16.19 Atlanta Hartsfield Long Term Master Plan with 5th parallel runway to the south and new mid-field terminal area – Source: Art Papers: The possibility of an airport

18 London, Stansted (STN) 1991

Stansted is London's third international airport. It is located some 42 miles (68Km) north-east of London, and is currently the base for a number of low cost carriers. In 2008 a planning application was submitted for a second runway and second terminal but this was later withdrawn, and Stansted continues to operate with a single runway and single terminal.

While some of these ideas can be seen in earlier designs such as St Louis Lambert and Washington Dulles, these were concrete buildings that couldn't offer the same level of flexibility as the tubular steel frame of Stansted. In practice Stansted has other limitations: the service modules and roof structure at 36m intervals limits some of the opportunities to re-configure the interior and the pressures of increased security and retail growth mean that passengers do not walk in straight lines towards the daylight so that wayfinding has become confused.

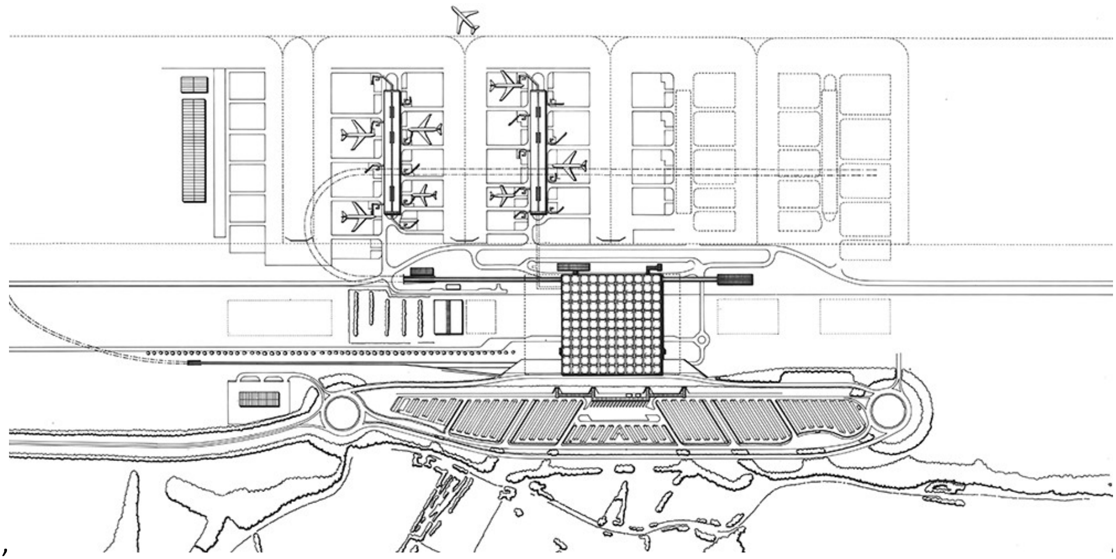


Figure M.17. 1 London, Stansted Site Plan Source: Foster & Partners

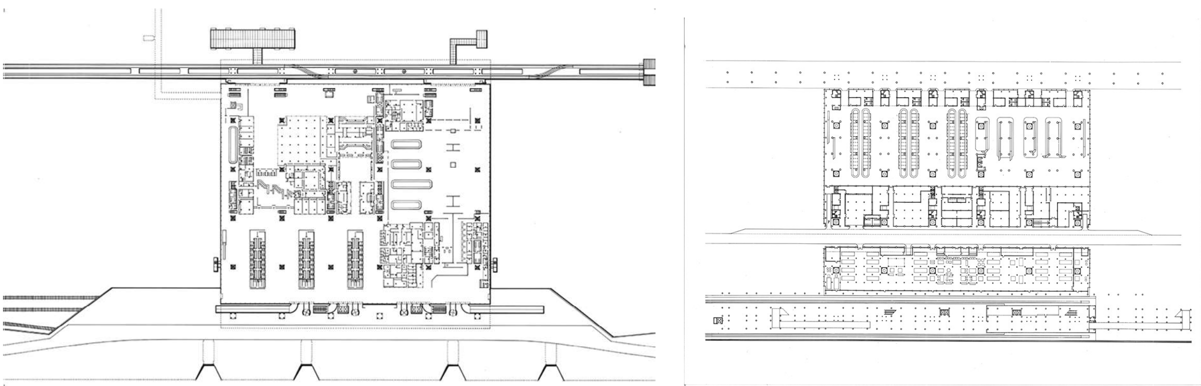


Figure M.17.2 London, Stansted, First (passenger level) and Ground (baggage & support level) plans- Source: Foster & Partners

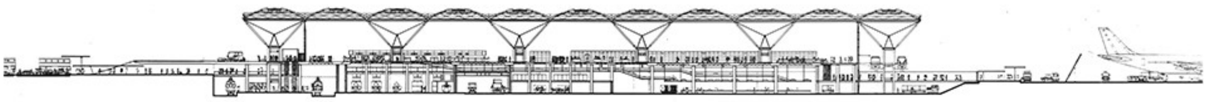


Figure M.17.3 London, Stansted cross section through terminal - Source: Foster & Partners

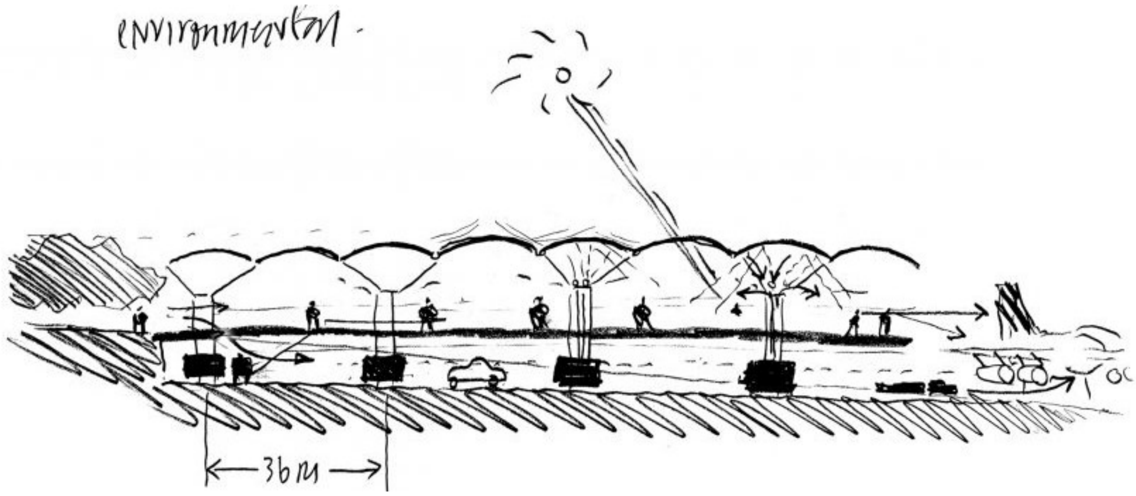


Figure M.17.4 London Stansted, cross section concept - Source: Foster & Partners

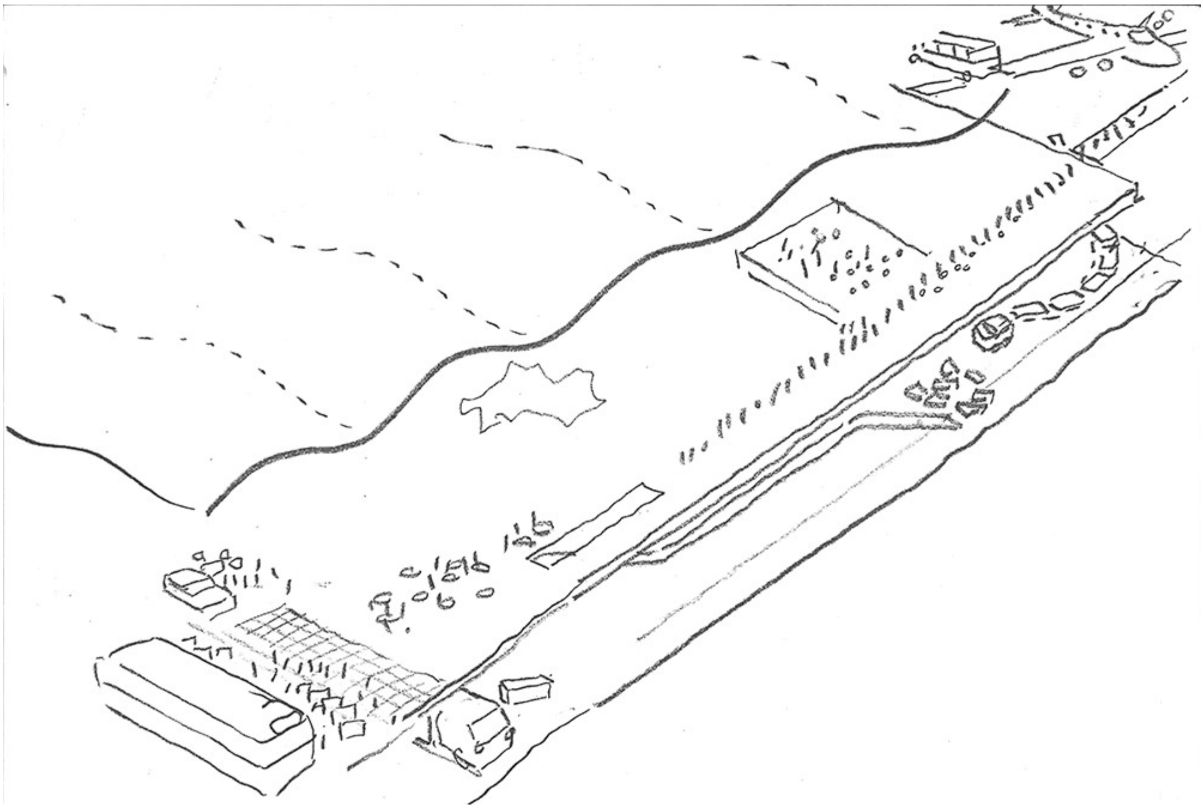


Figure M.17.5 London, Stansted, Direct Passenger Flow Concept Source: Foster & Partners


Figure M.17.6 London, Stansted, terminal and forecourt - Source: Foster & Partners

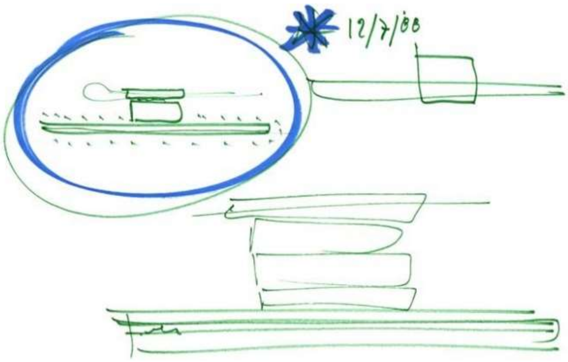

Figure M.17.7 London Stansted, stage 1 expansion of terminal - Source: New Civil Engineer

Figure M.17.8 London, Stansted, stage 2 expansion new arrivals building – Source New Civil Engineer

18 Osaka, Kansai (KIX) 1994

The offshore artificial island site presented new engineering challenges to overcome the sinking of the infrastructure into the soft sea bed which were addressed by constructing the terminal on piles which could be extended. The island had been predicted to sink 5.7 metres (19ft), by the most optimistic estimate, as the weight of the material used for construction compressed the seabed silts. However, by 1999, the island had sunk 8.2 metres (27ft) – much more than predicted (figure M.18.1). The airport was also designed to withstand earthquakes and typhoons which it has already successfully resisted.

Figure M.18.1 Osaka, Kansai Aerial view of original artificial island - Source: ADPI



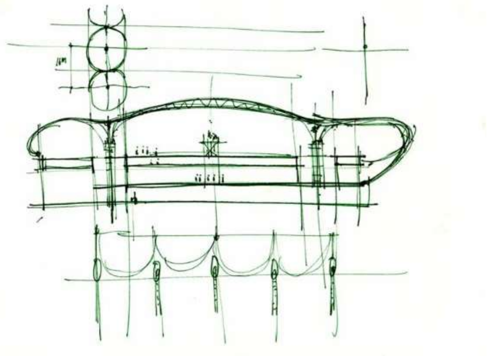


Figure M.18.2 Renzo Piano's initial concept diagrams 1988 - Source: Fondazione Renzo Piano

The terminal is 1.7 kilometres in length making it the longest linear terminal in the world. It has a sophisticated people mover system called the Wing Shuttle, which moves passengers from one end of the pier to the other. Renzo Piano describes his design as follows:

'Kansai airport rests upon the island like a glider seen in plan – the main body of the airport forming its fuselage, and the boarding gates positioned in its wings.

A notable feature, and one of primary importance in the organisation of the airport, is the unobstructed visibility of the planes themselves thanks to the uninterrupted lines of vision through the open departures level Main Terminal Building. The departure level is covered by a large, clear-span, undulating roof of asymmetrical form. It is perhaps this shape that is the project's main innovation.

In the main terminal building the geometry of the roof's undulating cross-section is formed of a series of arcs of different radii connected at tangent points. Three-dimensional beams spanning 80m follow the cross-sectional asymmetrical form of the roof, supported at their extremities by pairs of inclined columns.

The 42 boarding gates are housed within the "wings" of the glider. Their glazed facades address the runway, while their opaque, curved roof sweeps down to turn its back on the distant coastline. The height of the "wings" decreases to the buildings' extremities, with the roofs following an almost imperceptible curve, just sufficient to ensure the control tower's lateral line of vision

The shape of the roof of the terminal arises from a long work on the dynamic lines of the air flows circulating in the building. It has been designed to convey air from the passenger side to the track side without requiring the use of closed conduits. Blade-like baffles guide the airflow along the ceiling and reflect the light coming from above. This eliminates all the elements that would have prevented the structure from being seen. Even the curves of the "wings" of the building are the result of the application of a strict law: they have been defined on the basis of a toroidal geometry. The curvature is almost imperceptible, but it was necessary to favour the side view from the control tower.' (Renzo Piano, 2020)

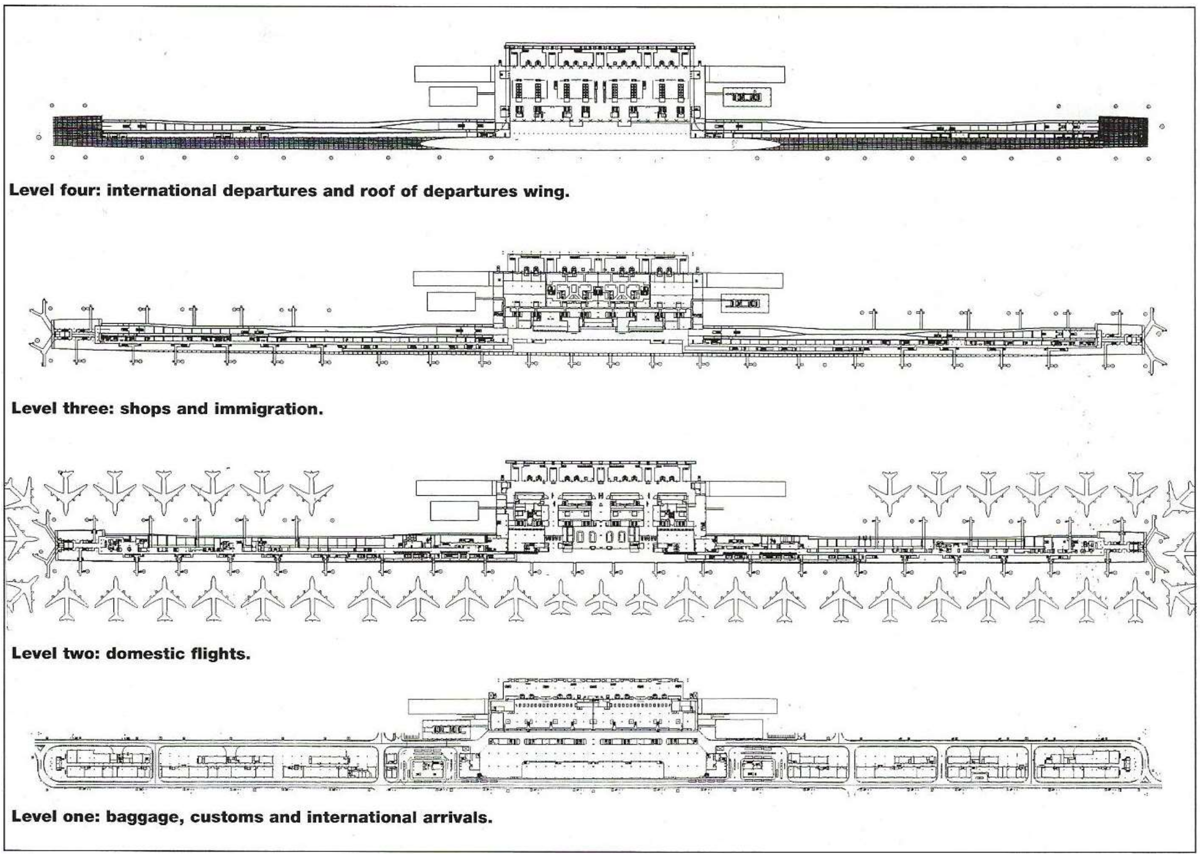


Figure M.18.3 Osaka, Kansai Floor Plans – Source: RIBA Journal

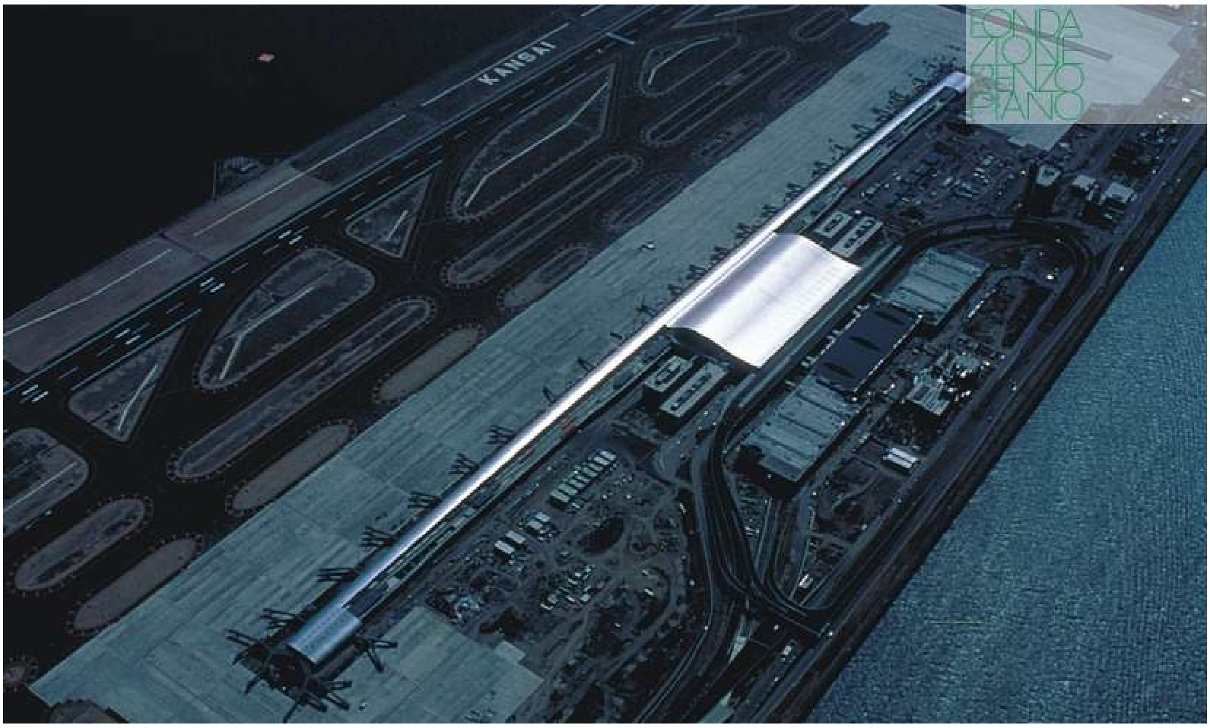


Figure M.18.4 Osaka, Kansai, Aerial view of Terminal - Source: Fondazione Renzo Piano

The terminal's roof is shaped like an airfoil. This shape is used to promote air circulation through the building; giant air conditioning ducts blow air upwards at one side of the terminal, circulate the air across the curvature of the ceiling, and collect the air through intakes at the other side (figure M.18.5).

Figure M.18.5 Osaka, Kansai, showing airfoil roof Source: Fondazione Renzo Piano

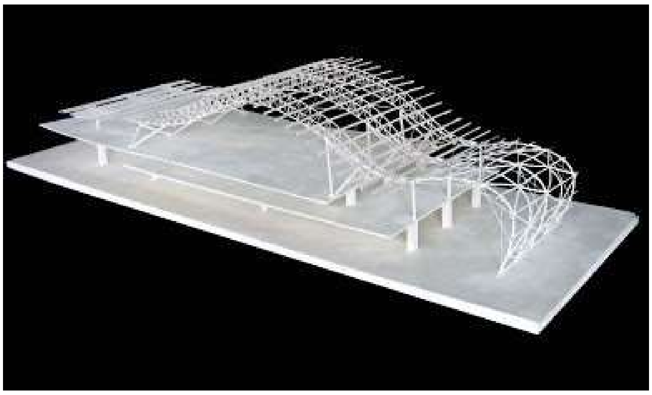


Figure M.18.6 model of roof structure – Source: Fondazione Renzo Piano

The roof spans 82.8 metres using a Warren based triangular three dimensional type primary truss. It is asymmetrically arched tracing the shape of the curvilinear roof above with 18 trusses placed 14.4 meters apart. A continuous secondary structure spans across the primary trusses and is built out of standard I-sections with traditional cross bracing. It is designed to absorb lateral forces generated by earthquakes and helps restrict potential buckling of the primary trusses (figure M.18.6). The gable ends of main terminal are double bow trusses, used to avoid complexity of joining a truss and glazing (figure M.17.7).

Figure M.18.7 Osaka, Kansai roof structure – Source: Fondazione Renzo Piano

Figure M.18.8 Osaka, Kansai interior
Landside 'Canyon' Concourse-
Source: Phot Fondazione Renzo Piano

Figure M.18.9 Osaka, Kansai, interior
Airside Gatelounges
Chris McGuire / Masterfile / Corbis

Kansai has now been expanded to include a second runway and second terminal to increase capacity and provide resilience (figure M.18.10 & 11).

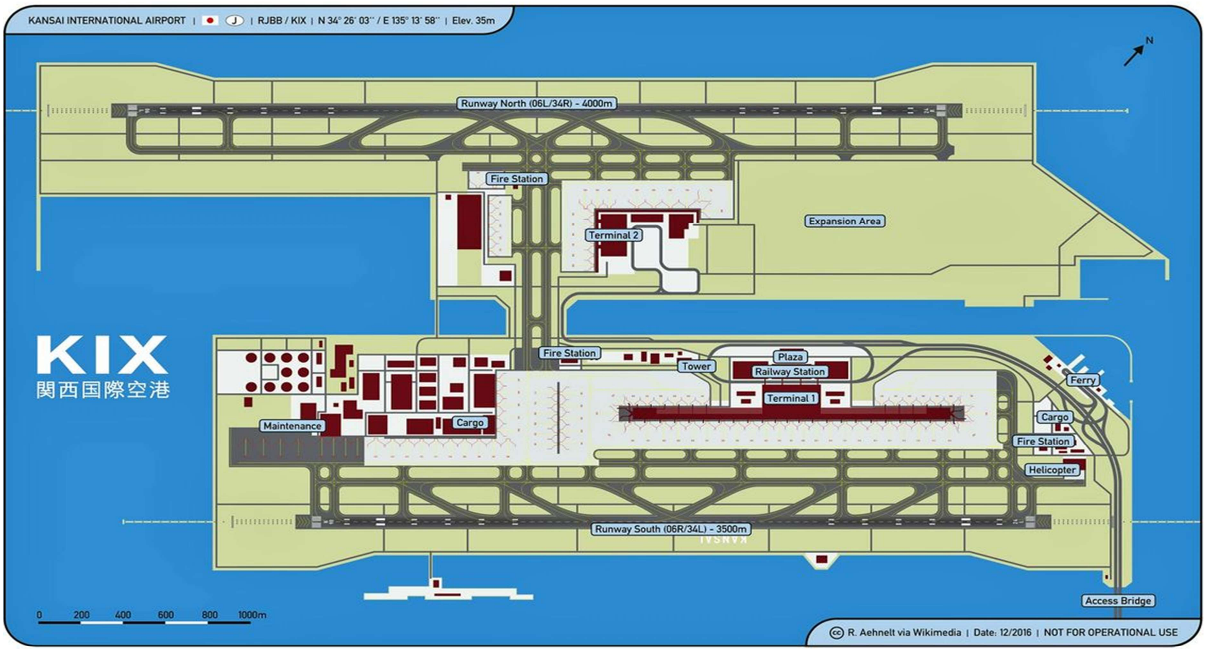


Figure M.18.10 Osaka, Kansai, Masterplan showing second runway and proposed terminal 2 –
Source: Wikimedia

Figure M.18.11 Osaka, Kansai aerial view showing second runway - Source: Pinterest i.pinimg.com

19 Hong Kong, Chek Lap Kok (HKG) 1998

Chek Lap Kok Airport was designed as a replacement for the former Hong Kong International Airport (commonly known as Kai Tak Airport) built in 1925. Hong Kong International Airport was built on a large artificial island formed by flattening and levelling Chek Lap Kok and Lam Chau islands and reclaiming the adjacent seabed, effectively demolishing a mountain and pushing it into the sea to create the airport.

Figure M.19.1 Hong Kong, Chek Lap Kok, Original masterplan - Greiner–Maunsell Consortium – Source: HOK

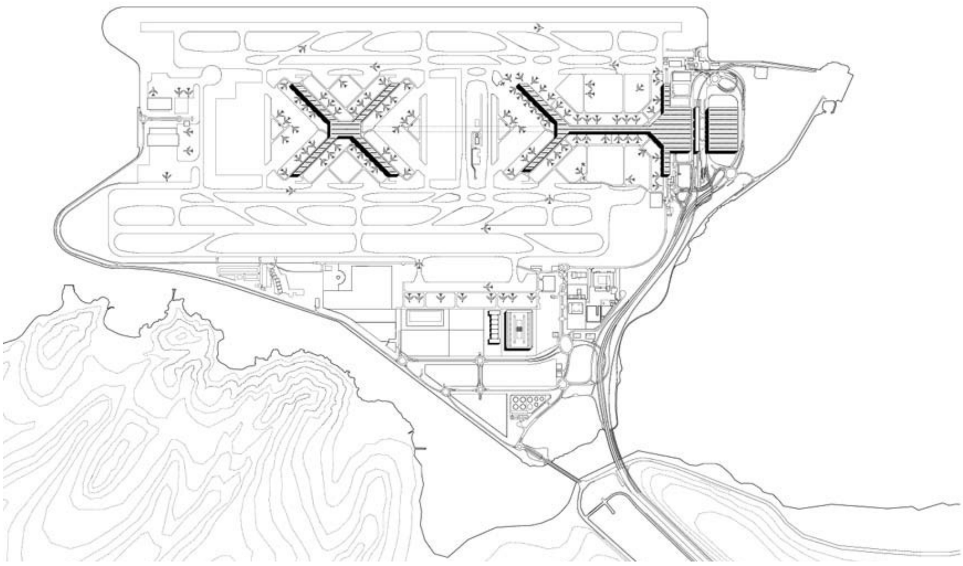


Figure M.19.2 Hong Kong, Chek Lap Kok, winning competition entry, site plan – Source: Foster & Partners

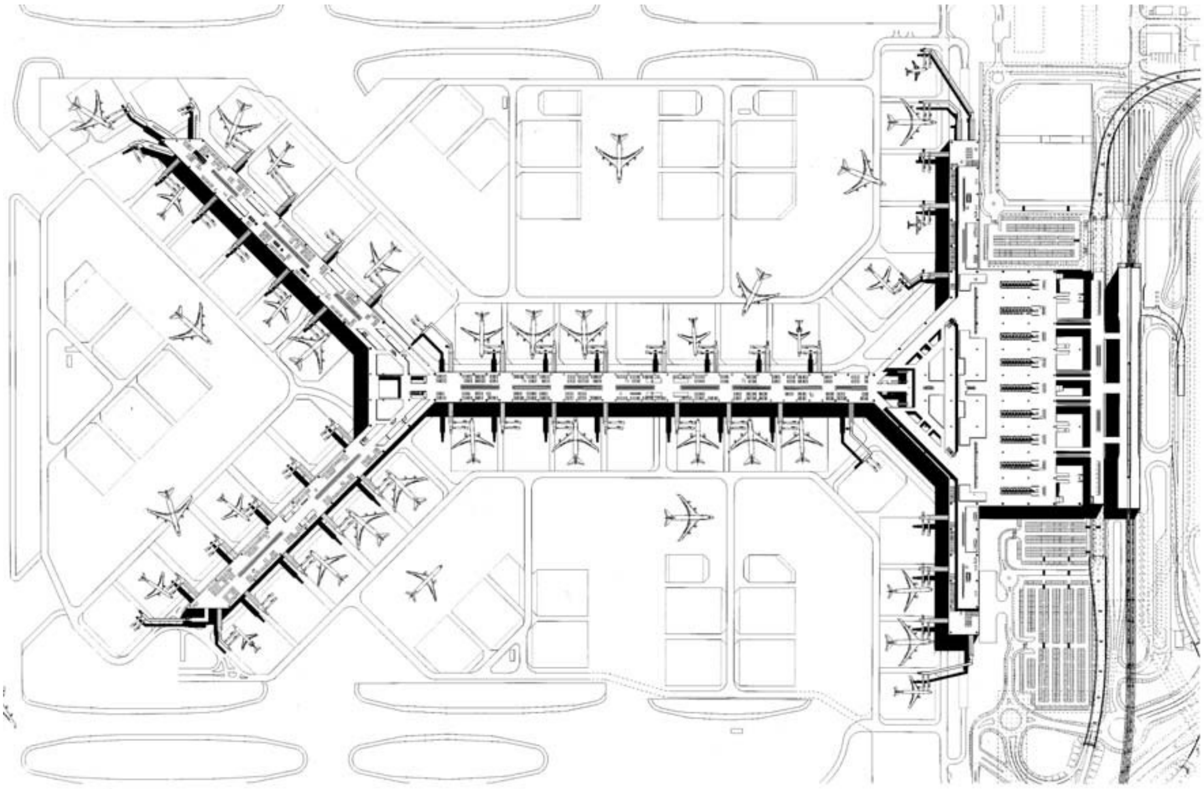


Figure M.19.3 Hong Kong, Chek Lap Kok, winning competition entry, departures level – Source: Foster & Partners

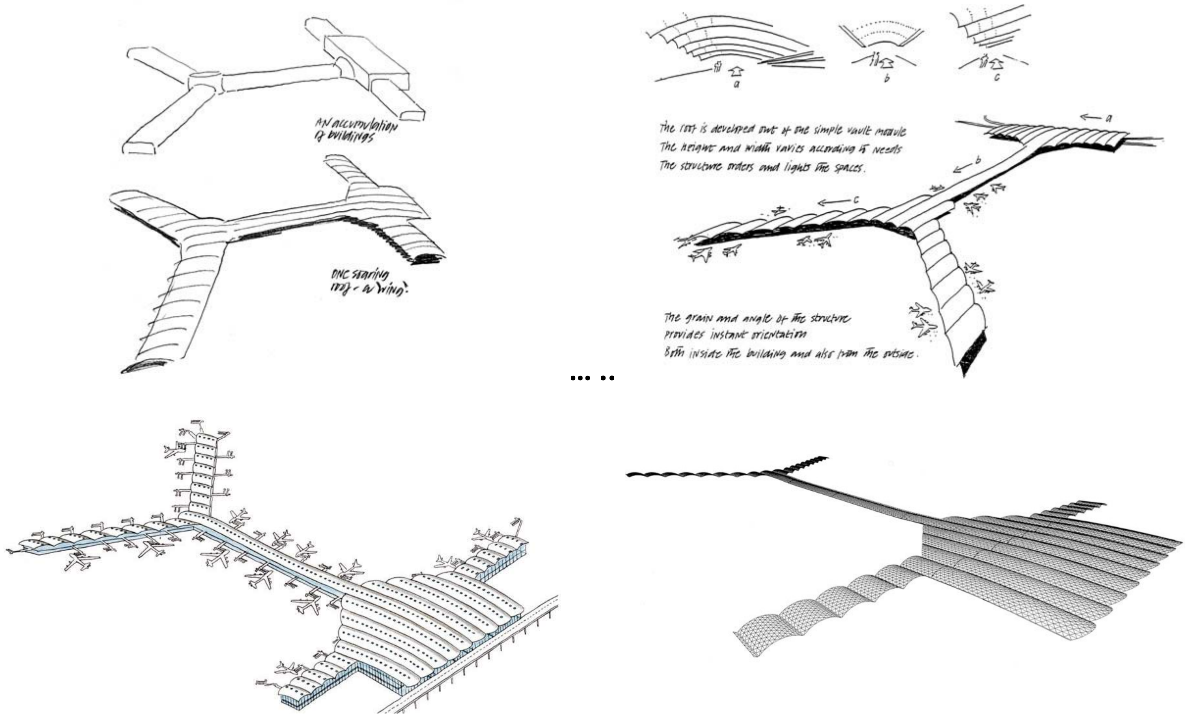
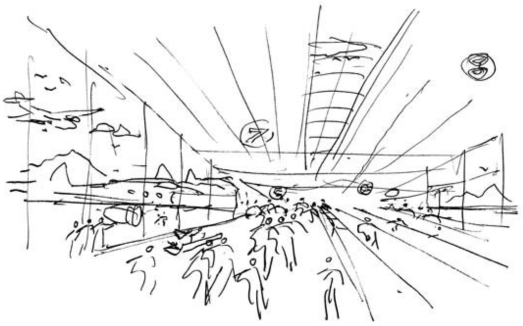


Figure M.19.4 Hong Kong Chek Lap Kok, evolution of roof design – Source Foster & Partners



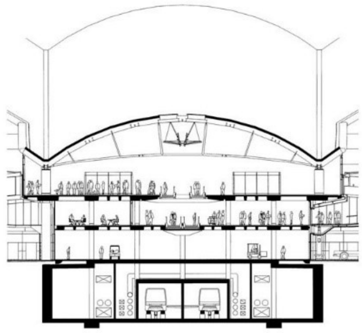


Figure M.19.5 Hong Kong Chek Lap Kok, gatelounge concept and section through pier – Source Foster + Partners

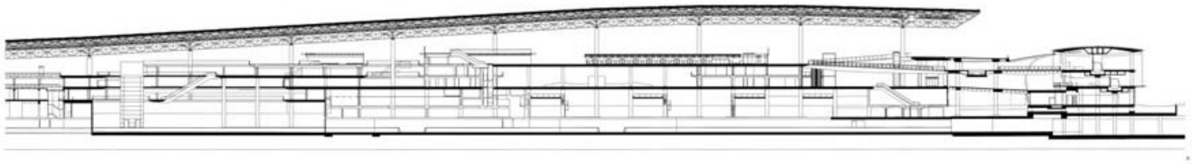


Figure M.19.6 Hong Kong, Chek Lap Kok, long section through terminal and interchange – Source Foster + Partners

Figure M.19.7 - Hong Kong International – Source: YouTube

Figure M.19.8 Hong Kong, Skypier and Sky City land, sea air Interchange Source: SOM.com

For the next stage of development Hong Kong International Airport proposes to construct a third runway on reclaimed land, and re-build terminal 2 to serve a new large remote satellite (figures M.19.9 to 12 inclusive).

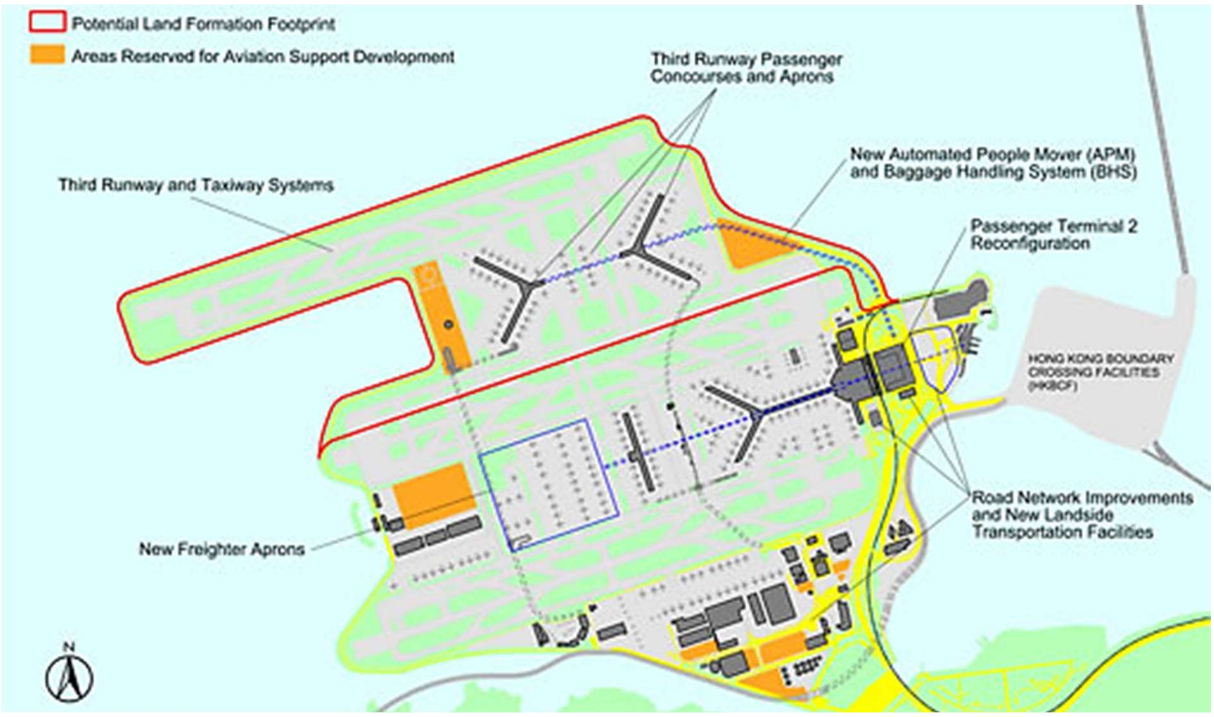


Figure M.19.9 Hong Kong, Chek Lap Kok, 3rd runway masterplan – Source: HKIA

Figure M.19.10 Hong Kong, Chek Lap Kok, initial phase of satellite to terminal 2 - Source: HKIA

Figure M.19.11 Hong Kong, Chek Lap Kok, initial phase of satellite to terminal 2 - Source: HKIA

Figure M.19.12 Hong Kong, Chek Lap Kok, ultimate development of satellite to terminal 2 on the left and the existing terminal to the right - Source: HKIA

20 Kuala Lumpur (KUL) 1999

Kuala Lumpur was designed as a hub airport to replace Subang International Airport.

The satellite acts as a long haul transfer hub, with departing and arriving passengers mixing freely because gate security has been employed and the cruciform shape makes the maximum walking distances exceptionally short at some 250 metres. At the centre of the cruciform satellite is a tropical garden that brings the jungle into the centre of the airport (figures M.20.3 & M.20.4).

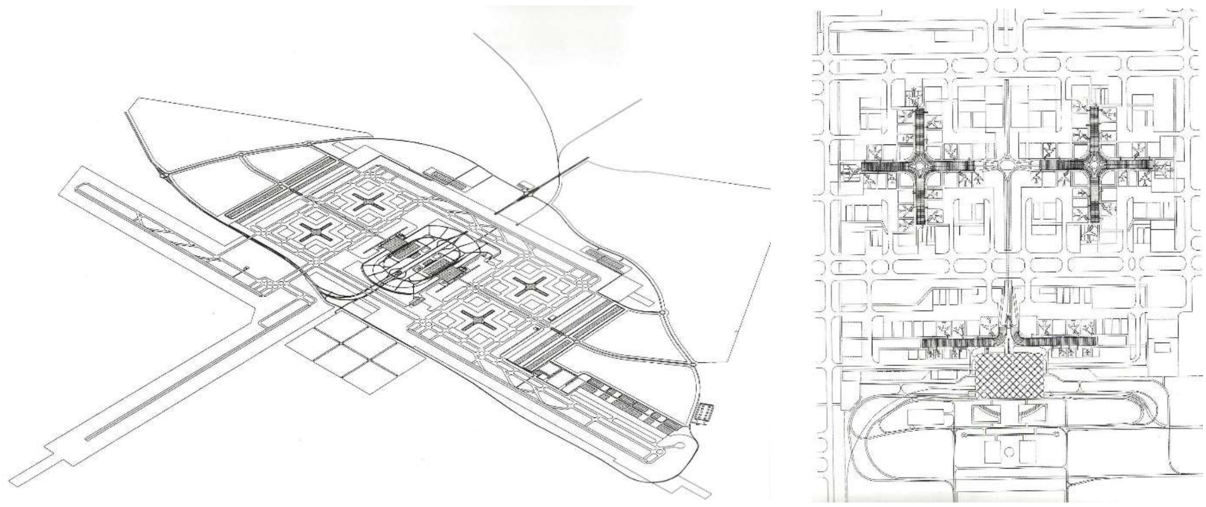


Figure M.20.1 Original KLIA Master Plan - Source: skyscrapercity.com

Figure M.20.2 Kuala Lumpur –
Satellite Transit Station - Source: Wikipedia

Figure M.20.3 Kuala Lumpur –
Satellite Jungle Boardwalk - Source: KLIA

Figure M.20.4 KLIA Jungle Boardwalk Source: kuaby.com

	KLIA	LCCT	KLIA2
Capacity (passengers per year)	25 million	15 million	45 million
Terminal size (sqm)	479,404	64,067	257,000
Retail space (sqm)	19,425	8,898	32,000 (estimated)
Car park (lots)	6,208 (covered lots), 5,509 (uncovered lots)	3,000 (uncovered lots)	6,000
Cost	About RM10 Billion	RM300 Million (terminal cost only)	RM3.6 – 4.0 Billion (latest estimate)
Runway access	Runway 1 and 2 at KLIA	Runway 1 and 2 at KLIA	4Km runway with a 2.2Km separation from Runway 2
Passenger comfort (capacity / floor space)	52 pax per sqm	234 pax per sqm	124 pax per sqm

Figure 11.20.5 Comparison Terminal 1, Interim LCC Terminal and Terminal 2 Source: Malaysia Airports

To address the expanding market for LCCs, KLIA like Singapore Changi built a simple terminal for the market, but later replaced it with a much more ambitious terminal. Unusually the new terminal design aimed at LCCs incorporated airbridges and a transfer baggage facility (figure M.20.6).

Figure M.20.6 Model of KLIA T2 - Source: says.com

Figure M.20.7 Aerial view of KLIA T2 - Source: klia2.info

21 Seoul Incheon (ICN) 2001

Seoul Incheon was designed when the existing international Gimpo airport was reaching capacity. The original masterplan envisaged a mid-field terminal, located between parallel runways, with a terminal with two piers and a remote satellite and was designed to accommodate A380 aircraft from the outset (figure M.21.1). The engineering design of the reclamation built on the experience gained at Kansai and Hong Kong and involved building two sea walls to link the two islands and draining the land behind to form the platform of the airport which, like Schiphol is located below sea level.

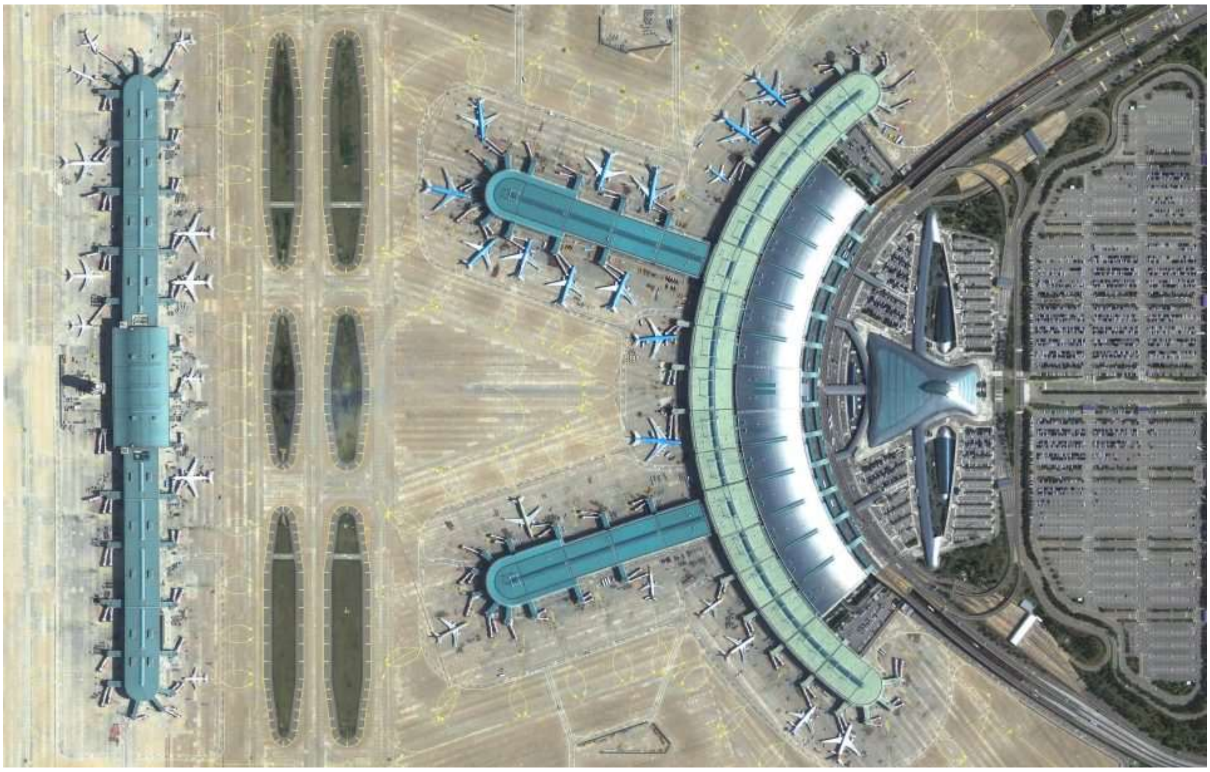


Figure M.21.1 Seoul, Incheon Aerial view of Terminal Source: fromabove.altervista.com

The airport was originally planned to be built in three phases, incrementally increasing airport capacity as the demand grew. This was changed, however, to four phases after the airport was opened. Phase 1 included the main terminal building and two runways while phase 2 extended the airport to include the remote satellite accessed by an underground transit system and added a third runway. Phase 3 includes a fourth runway and a first stage of the second terminal which will be completed in phase 4 along with a fifth, widely spaced runway (Bates, 2011).

The airport is unusual in working in concert with the existing Gimpo airport which is now used for domestic fights only with a fully integrated rail transfer facility between the two airports with through booking of flights permitted, including the rail transfer. Uniquely Seoul quotes inter airport minimum connection times for transfer passengers.

Incheon includes a dramatic rail transfer interchange (figure M.21.2) designed by Terry Farrell which is discussed in Chapter 8.3 and an Aerotropolis which is described in chapter

9.7. The second terminal is a large mid-field design with finger piers, phase 1 of which has been completed as stage 3 of the masterplan (figure M.21.3, 4 &5).

Figure M.21.2 Seoul, Incheon Interchange - Source: Ken Eckert / WikiCommons

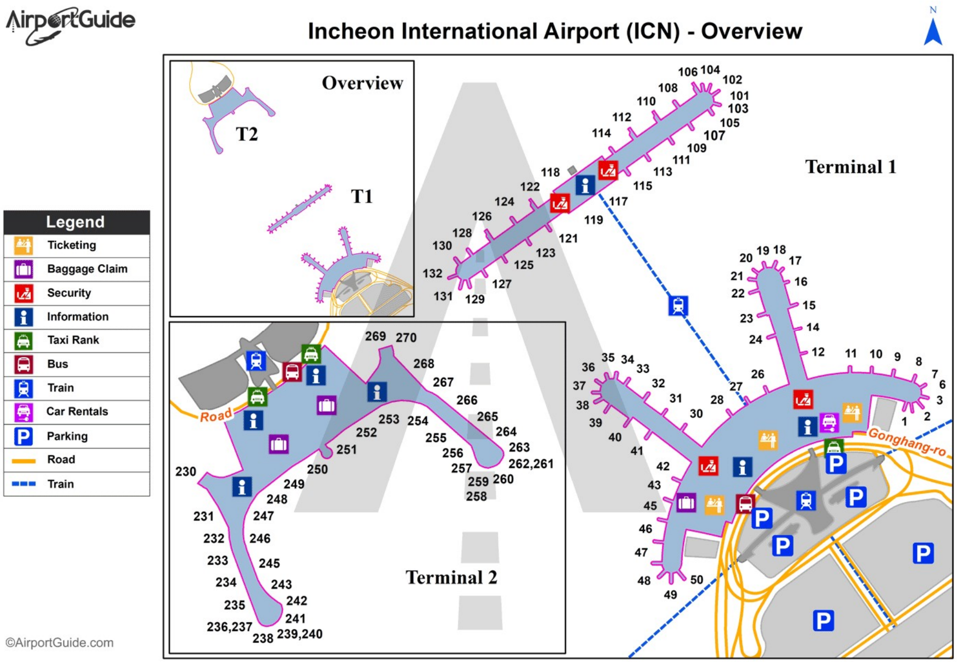


Figure M.21.3 Seoul, Incheon, terminal layout showing gates - Source: Airport Guide.com

Figure M.21.4 Seoul, Incheon, CGI of second terminal - Source: Gensler

Figure M.21.5 Seoul, Incheon, Aerial view of phase 1 of completed second terminal in the foreground and the existing terminal One and remote satellite in the background- Source: IIAC

Figure M.21.6 Seoul, Incheon Terminal 2 Interior - Source: getbybus.com

22 Bangkok Suvarnabhumi (BKK) 2006

Bangkok Suvarnabhumi was designed to replace Don Mueang. The latter continued as a base for a number of LCCs while Suvarnabhumi established itself as a global hub, and rival to Singapore, Kuala Lumpur, Seoul Incheon and Hong Kong for transfer traffic.

The Airport Master Plan

The phase 1 masterplan can be seen below (figure M.22.1).Facilities that were completed in the first phase included:

- a 563,000m² passenger terminal
- two parallel runways, each 60m wide, one 3,700m long and the other 4,000m long with a runway separation distance of 2,200m
- two parallel taxiways to facilitate simultaneous departures and arrivals
- 120 parking bays (51 with contact gates and 69 remote gates) and five of these capable of accommodating the Airbus A380
- 132m air traffic control tower (the tallest in Asia)
- two five-storey parking garages with a capacity for 5,000 cars
- a 190,000m² cargo terminal
- aircraft maintenance facilities: four fully equipped aircraft hangars to service up to 12 aircraft (Bangkok, 2020)
-

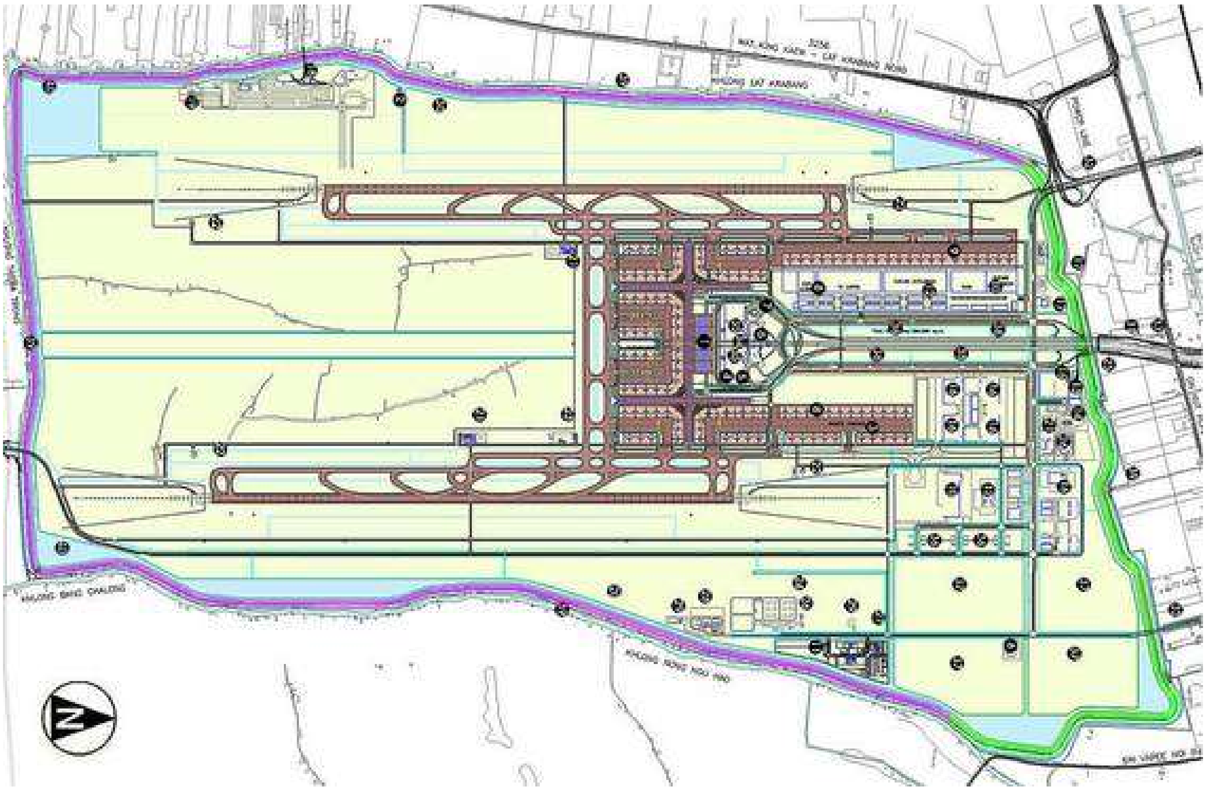


Figure M.22.1 Bangkok, Suvarnabhumi, Original airport master plan - Source: Dorsch.de

The passenger terminal complex

Designed by the MJTA group of consultants, comprising Murphy Jahn Architecture and TAMS consultant (USA) and ACT Engineering consultant (Thailand), the passenger terminal complex (comprising the terminal itself as well as the concourse) covers an area of 182,000m².

Seven floors and a basement gives the terminal a total floor area of over 563,000m², (six million ft²) making it the largest in the world at the time. An innovative roof trellis (one of the largest in the world) designed to shade the building against intense tropical sun and reduce the cost of air conditioning, was also the largest of its kind.

There are 360 check-in counters on ten check-in islands, all with connected baggage belts, and another 100 check-in counters not connected to the baggage belt system.

The domestic and international halls are clearly separated with the second floor as a dedicated arrival hall and the fourth floor as a departure hall. The structure's main materials are steel and glass (figure M.22.2 - 10).

Figure 11.22.2 Bangkok, Suvarnabhumi, Aerial view of terminal - Source: Chukoh Chemical Industries Ltd

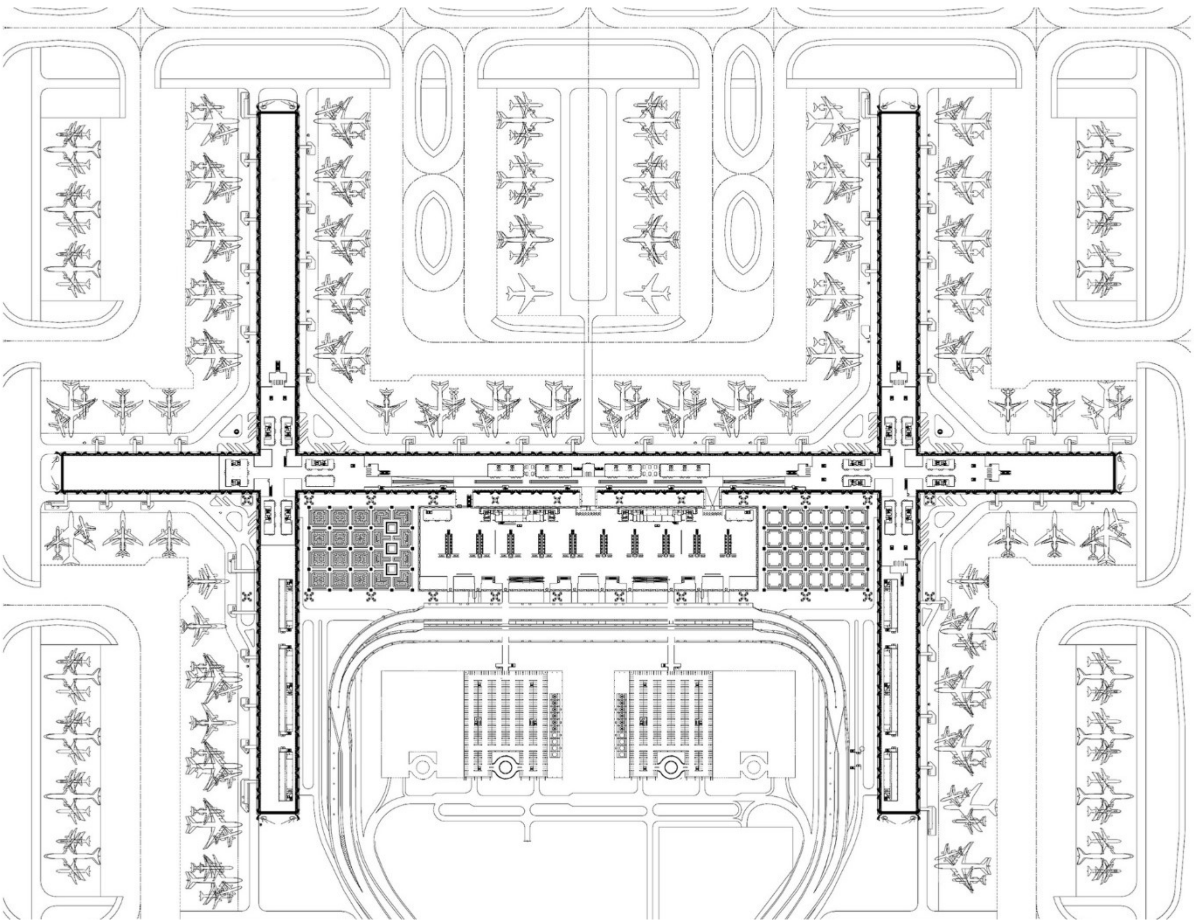


Figure M.22.3 Bangkok, Suvarnabhumi, terminal gate layout - Source: Airport Builders

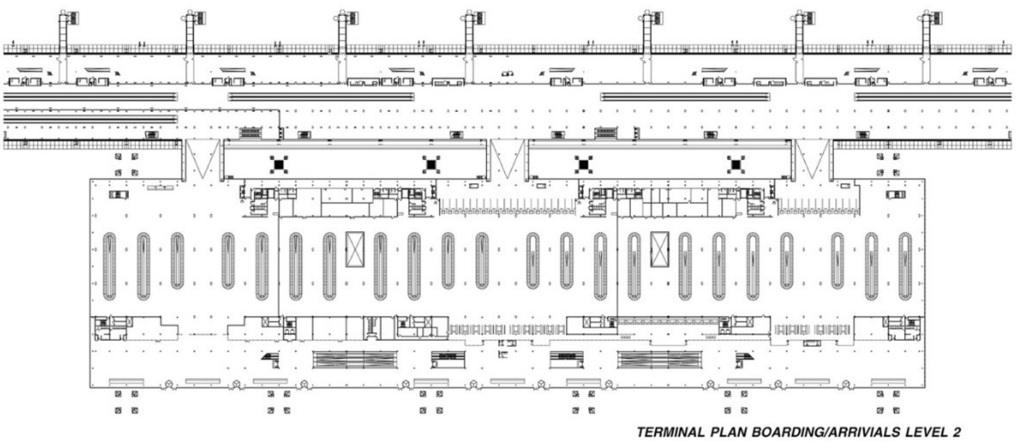


Figure M.22.4 Bangkok, Suvarnabhumi, terminal lower boarding and arrivals level 2 – Source: Airport Builders

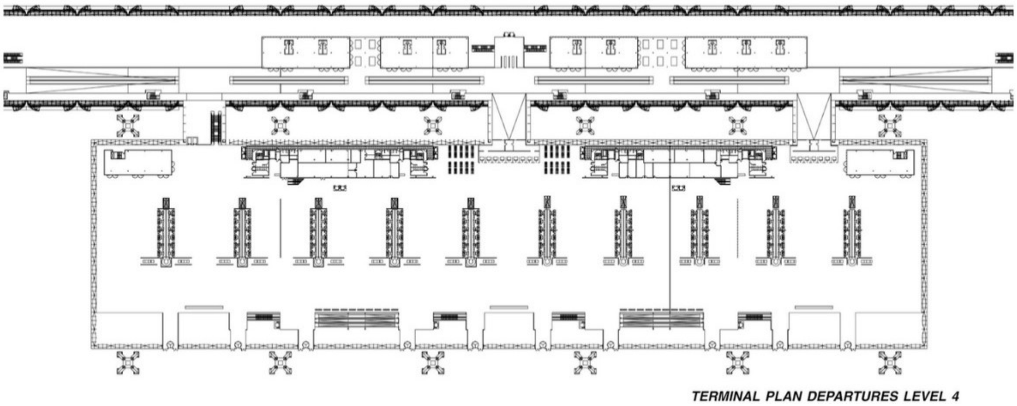


Figure M.22.5 Bangkok, Suvarnabhumi, terminal check-in and departures level 4 – Source: Airport Builders

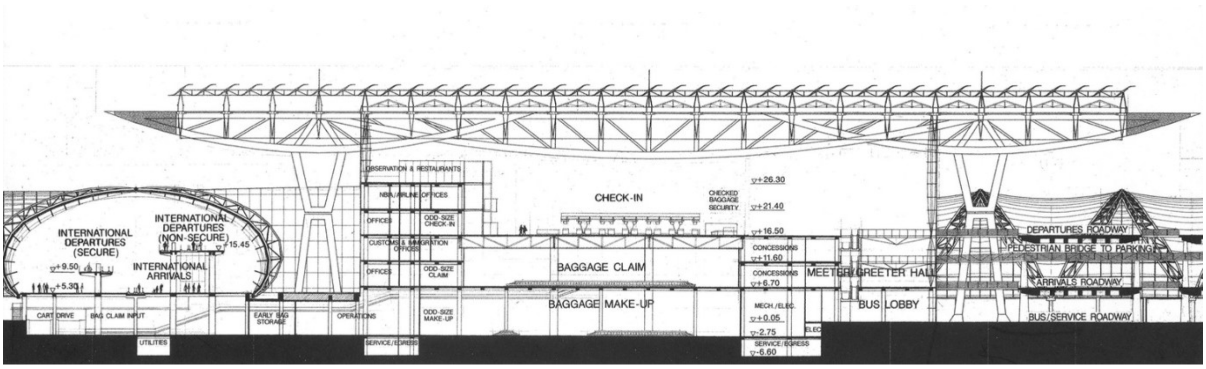


Figure M.22.6 Bangkok, Suvarnabhumi, cross-section through terminal – Source: Airport Builders

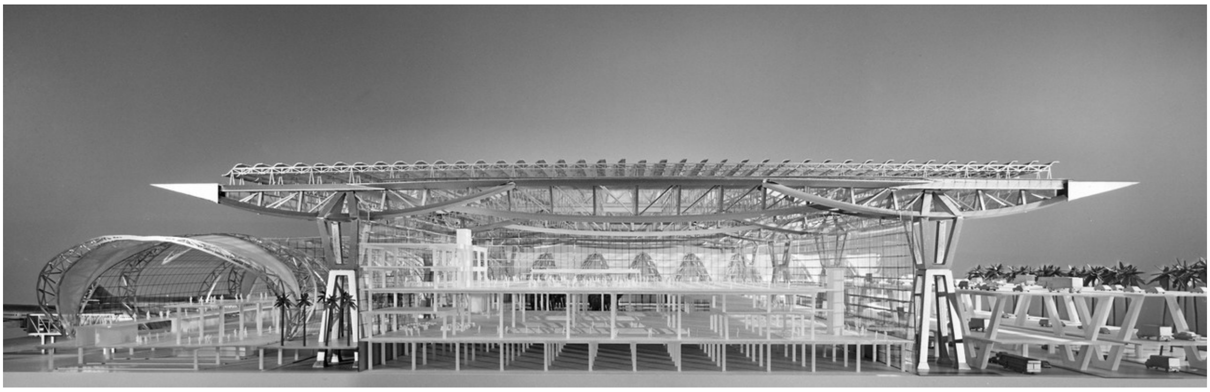


Figure M.22.7 Bangkok, Suvarnabhumi, sectional model of terminal – Source: Airport Builders

Figure M.22.8 Bangkok, Suvarnabhumi, photograph of upper level of the pier –
Source: Architecture Daily – Photographer: Rainer Viertlboeck

Figure M.22.9 Bangkok, Suvarnabhumi, photograph of the pier roof – Source: e-architect.co.uk

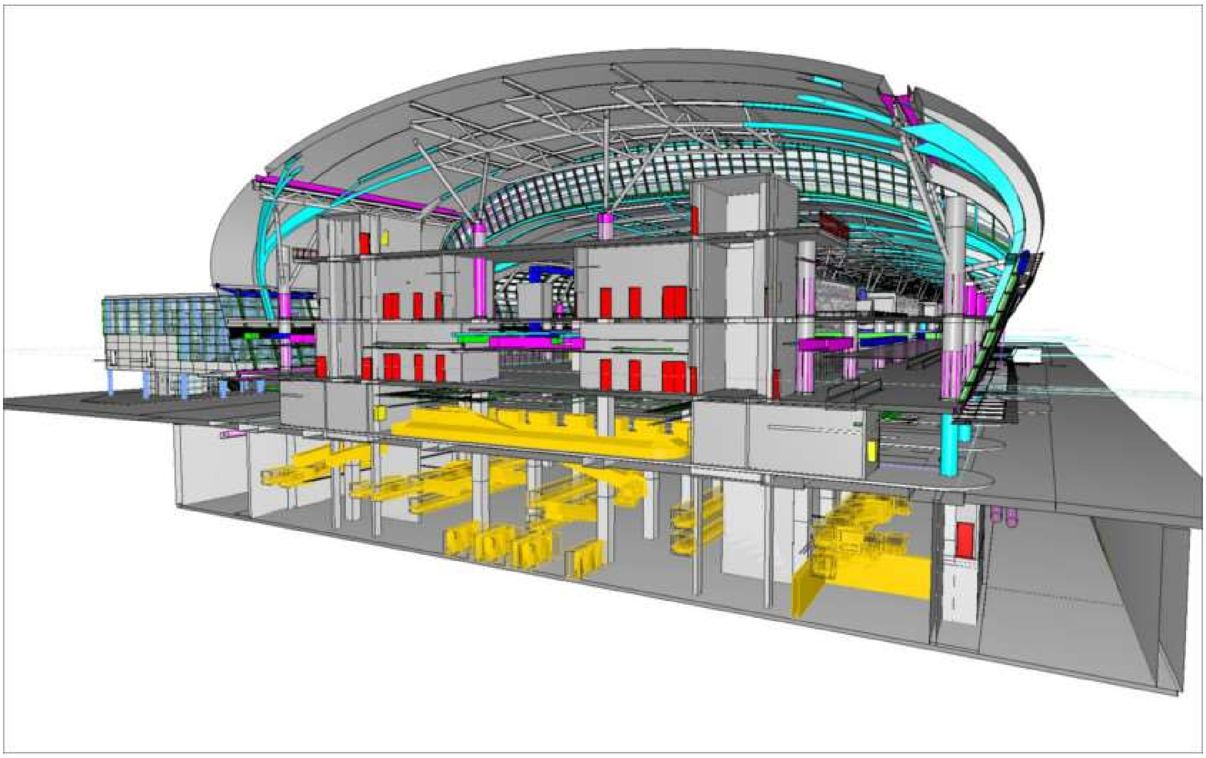


Figure M.22.10 Bangkok, Suvarnabhumi, sectional perspective through pier – Source: MAA Group Consulting Engineering

Figure M.22.11 Bangkok, Suvarnabhumi, CGI of new satellite Source: NACO/HOK

Figure M.22.12 Bangkok, Suvarnabhumi, 2030/2040 Master Plan - Source: Skyscraper City

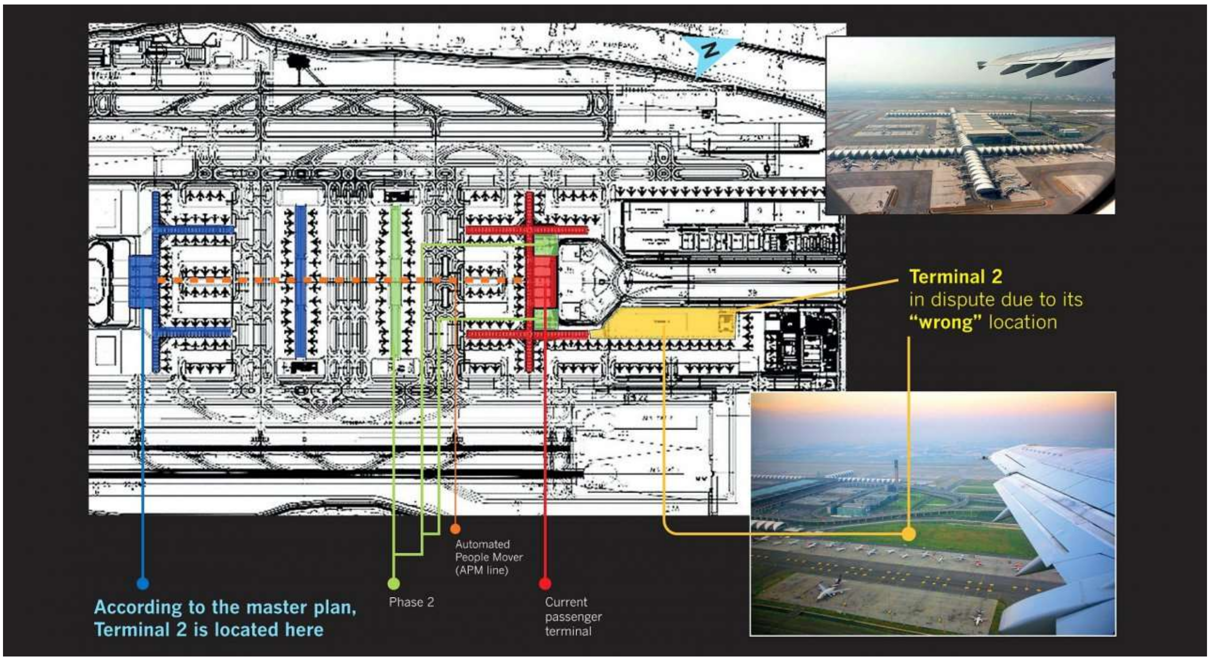


Figure M.22.13 Bangkok, Suvarnabhumi, An alternative but disputed location for a second terminal in yellow- Source: The Nation

The future masterplan includes two satellites (figure 11.22.11) and a second terminal, the location of which is still being debated (figures 11.22. 12 & 13). At this latter stage a transit will become essential to link the buildings together.

11.23 Madrid Barajas (MAD) 2006

Madrid's Terminal 4 was designed as a hub and is mainly used by the One World Alliance, including Iberia and British Airways as complementary to Heathrow. It has a unique masterplan with four widely spaced runways, which are slightly misaligned, with the terminals on the perimeter and a new satellite located mid field (figure M.23.1). Terminal 4.

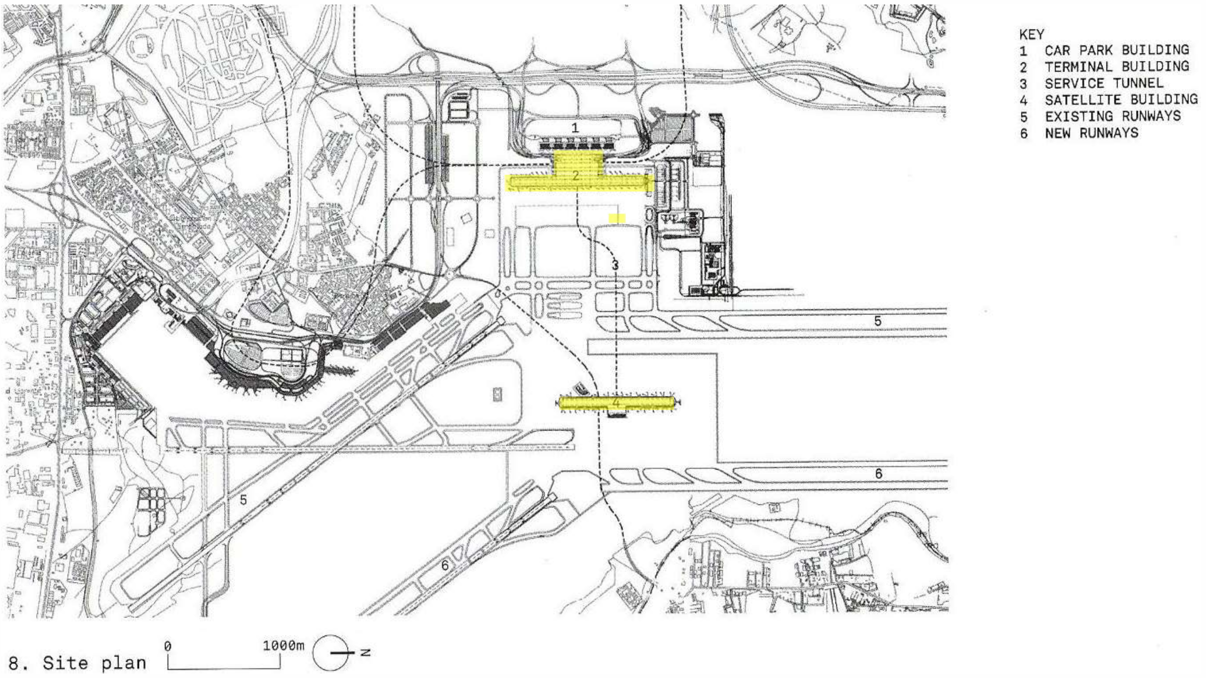


Figure M.23.1 Madrid Barajas, master plan 2006 with Terminal 4 and satellite highlighted in yellow - Source: Rogers, Stirk, Harbour + Partners

In common with many other European Airports, Madrid Barajas is seeking to exploit its generous landholding to create an airport city comprising three elements (figure M .23.2):

1. Logistics Centre
2. Global Business Hub
3. Passenger Service

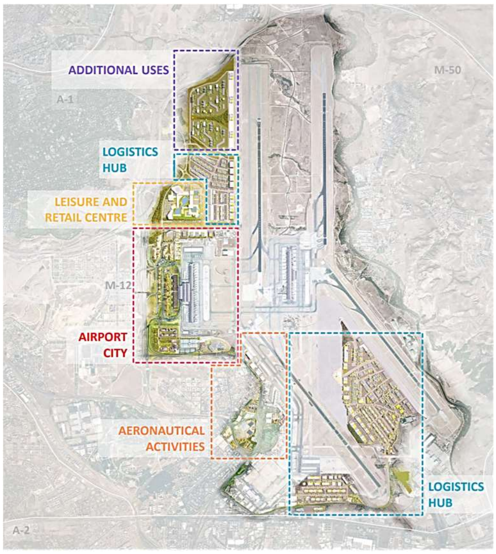


Figure M.23.2 Madrid Barajas, Masterplan Development Strategy 2017 – Source: Aena

Rogers Stirk Harbour, architects for the new terminal, describe the planning and architecture of Madrid Barajas with a particular emphasis on its environmental credentials:

'The terminal, which is the biggest in Spain, was commissioned to enable Barajas International Airport to compete with major hub airports within Europe. The core building comprises a sequence of parallel spaces separated by a linear block allowing daylight to penetrate deep into the interior. The same form is applied to the satellite, which is comprised of two linear blocks, one for passport control and the other containing the gates.' (figure M.23.3). *The bamboo linear roof structure is connected above by a chain of roof lights, permitting maximum flexibility in the arrangement of accommodation on each of the floors* (figure M.23.4). *'This enables the building to be expanded in phases. The new terminal has a metro, rail station and landside transit link to the existing terminals as well as a transit system linking the core terminal with the satellite. Pedestrian circulation to and from the parking area is concentrated along the face of the parking structure, creating an animated façade opposite the terminal. The layout of the arrivals hall creates clear and separate routes to the various modes of ground transportation, giving equal weight to public and private transport. The arrivals and departures forecourts as well as the train and metro station are covered by a standard module of the roof, which thereby encompasses the entire sequence of activities from drop-off to departure gate.' 'Environmental measures, aimed at significantly reducing energy consumption, include a stratified cooling system, displacement ventilation supply to the piers, low level air supply to all other passenger areas, extensive shading to the facades and roof lights, zoned lighting and the collection of rainwater to irrigate the landscape.'* (Harbour, 2020)

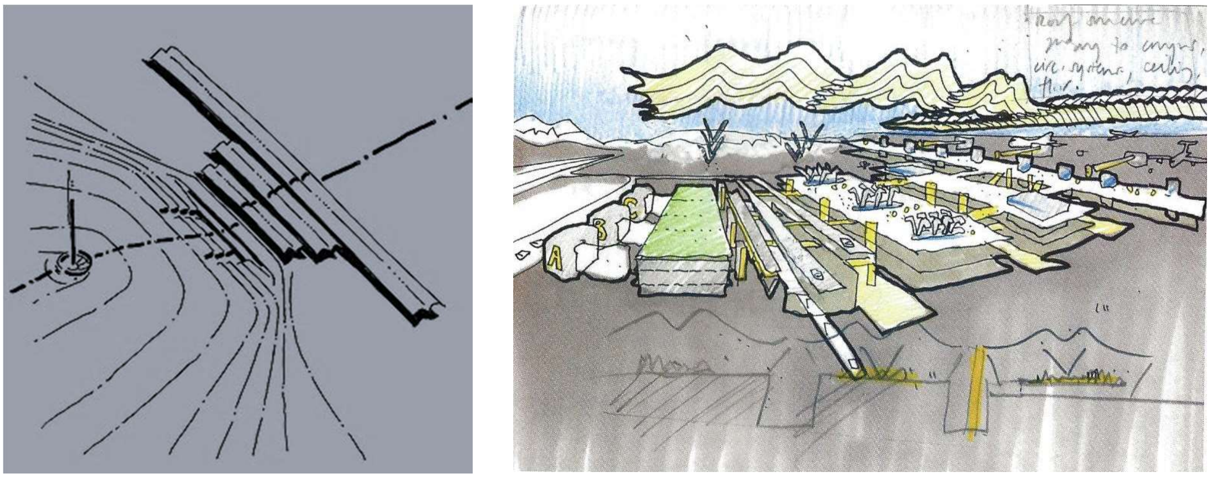


Figure M.23.3 Madrid Barajas, Linear Terminal & 'Magic Carpet' Roof Concept –
Source*: Rogers Stirk Harbour + Partners*

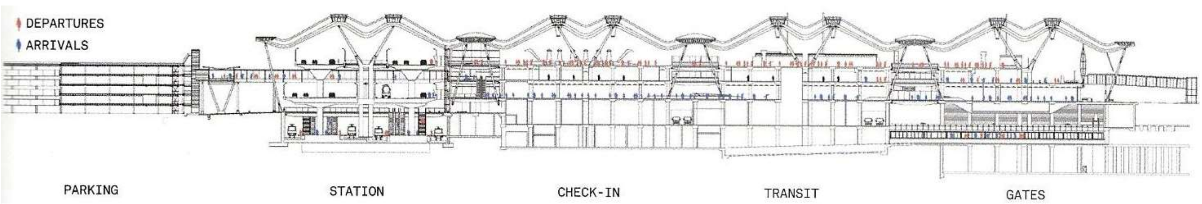


Figure M.23.4 Madrid Barajas, Section through terminal – Source: AJ

'The accommodation is distributed over six floors; three above ground for check-in, security, boarding and baggage reclaim, and three below ground levels for maintenance,

baggage processing and transferring of passengers between buildings. The lower levels, robustly constructed in concrete, contrast strikingly with the light-weight transparency of the passenger areas above.' (figure M.23.5)

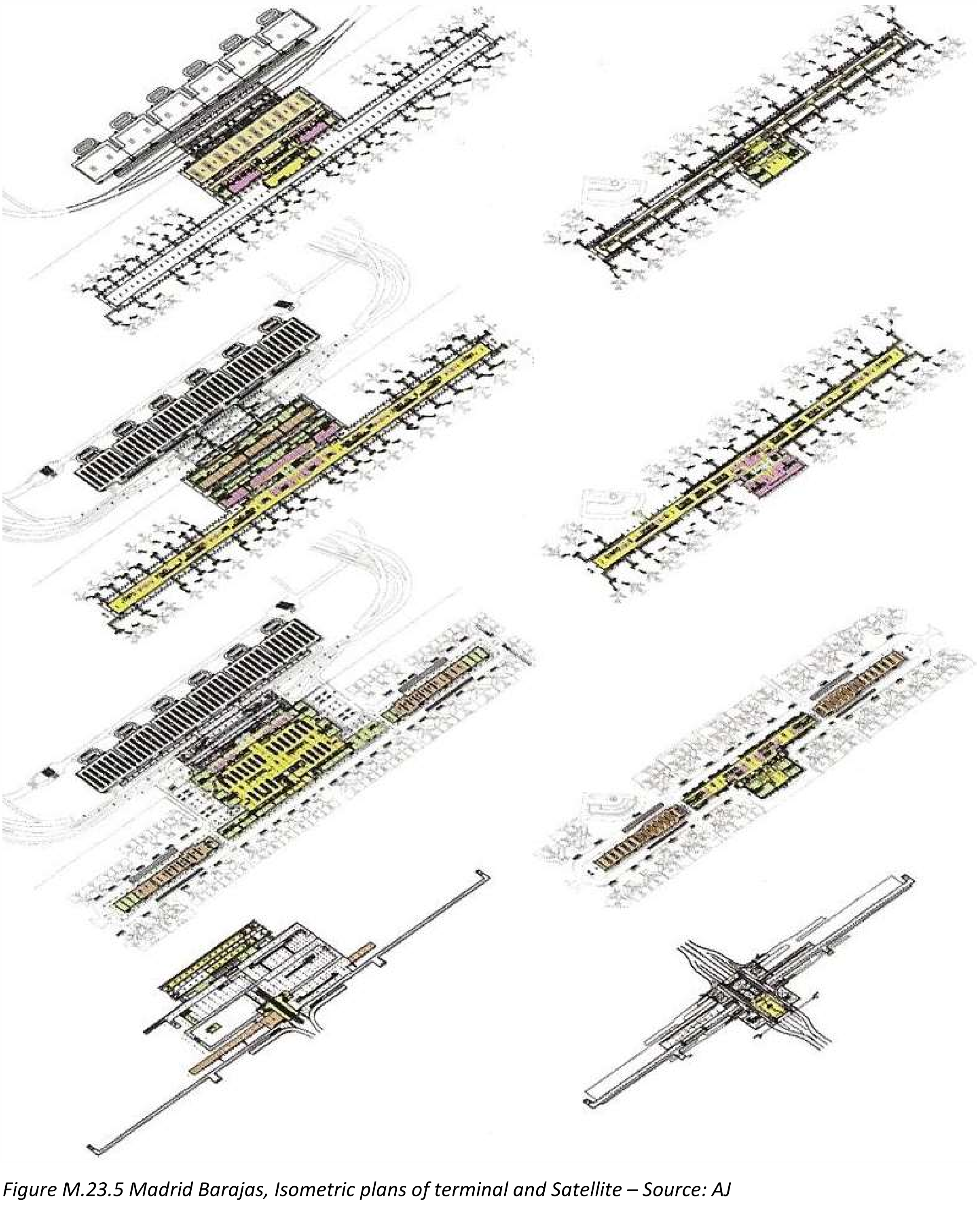


Figure M.23.5 Madrid Barajas, Isometric plans of terminal and Satellite – Source: AJ

Figure M.23.6 Madrid Barajas, Check-In – Source: Rogers Stirk Harbour + Partners

'The building is covered by a wave-shaped roof, supported on central 'trees' and punctuated by roof lights that provide carefully controlled natural light throughout the upper (departures) level of the terminal. The roof then oversails the edge of the building to shade the façades' (figures M.23.6 & M.23.7). *'Given the multi-level section, a strategy was required to bring natural light down into the lower levels. The solution is a series of light-filled 'canyons' that separate the parallel slices of space that demarcate the various stages of transit, from the arrival point to check-in, security and passport control, then on to departure lounges and finally to the aircraft'*.

Figure M.23.7 Madrid Barajas, Magic Carpet Roof – Source: Rogers Stirk Harbour + Partners

'*The canyons are spectacular full-height spaces, spanned by bridges from which arriving and departing passengers, though segregated, can share the drama of the impressive space. The grand scale generates the feeling of a truly significant public space. The canyons also act as locators, underlining the clear sense of direction and legibility that is fundamental to the scheme. Despite the extreme heat of summer in Madrid, the design team were committed to the use of passive environmental systems wherever possible, while maximising transparency and views towards the aircraft and the mountains beyond.*

The building benefits from a north-south orientation with the primary façades facing east and west, the optimum layout for protecting the building against solar gain. The design team set out to maximise natural light to all passenger areas and reduce dependence on artificial light, while providing views out but reducing solar gain with a combination of deep roof overhangs and external shading.

A low-energy displacement ventilation system is used in the pier, and elsewhere in the terminal a more conventional high-velocity system is used' (Harbour, 2020).

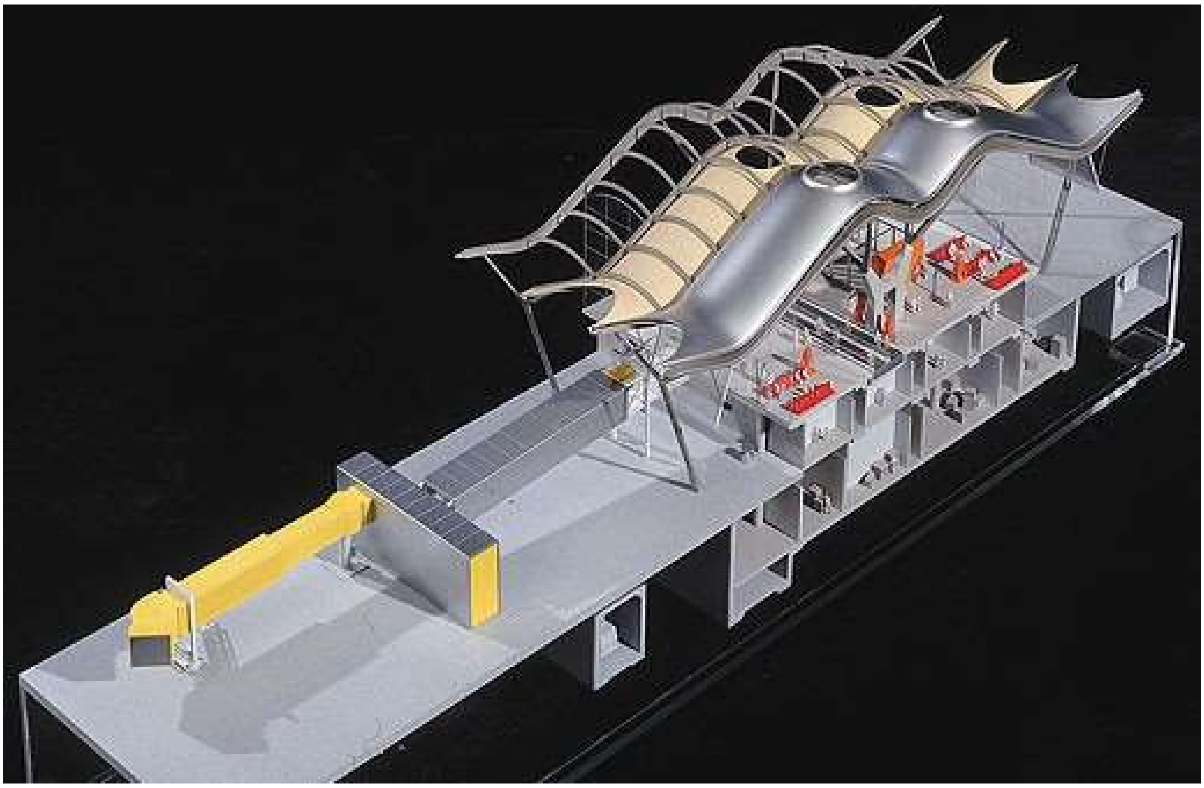


Figure M.23.8 Madrid Barajas, model of satellite – Source: Rogers Stirk Harbour + Partners

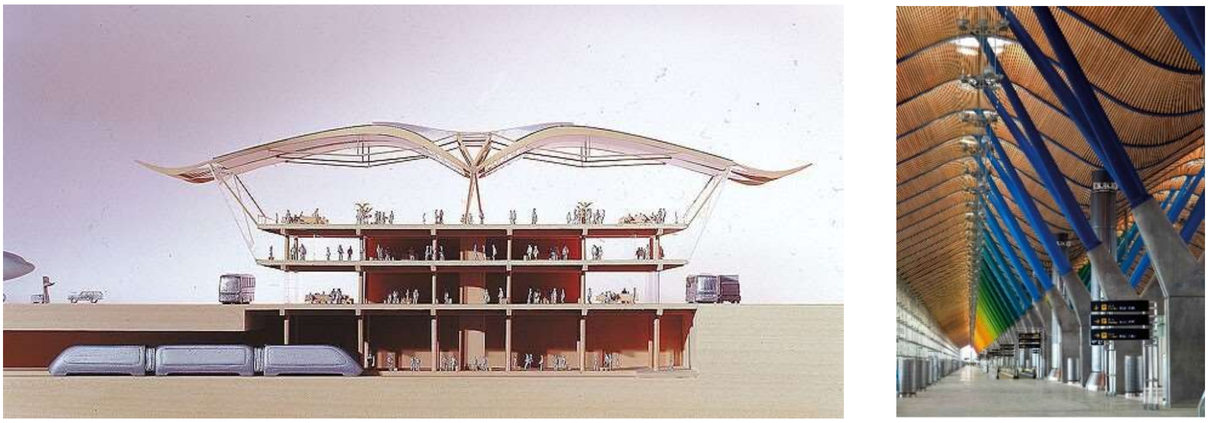


Figure M.23.9 Madrid Barajas, Sectional perspective and image of satellite – Source: Rogers Stirk Harbour + Partners

Figure M.23.10 Madrid Barajas, Aerial view of satellite Source: Pinterest

24 Heathrow (LHR) T5 2008, T2 2014 and the Heathrow Expansion Programme.

The original Heathrow war time master plan has been discussed in chapter 7 (figure 7.23) and its unique underground surface access concept in chapter 8 (figure 8.42). The underground surface access has over time proven to be one of the most intractable constraints to the evolution of the airport around which subsequent upgrades have had to be planned. The drawing below shows the plan of the airport when it opened in 1946 (figure M.24.1). The temporary tented terminal complex was located to the north of Runway No.1 and adjacent to the control tower (figure M.24.2)

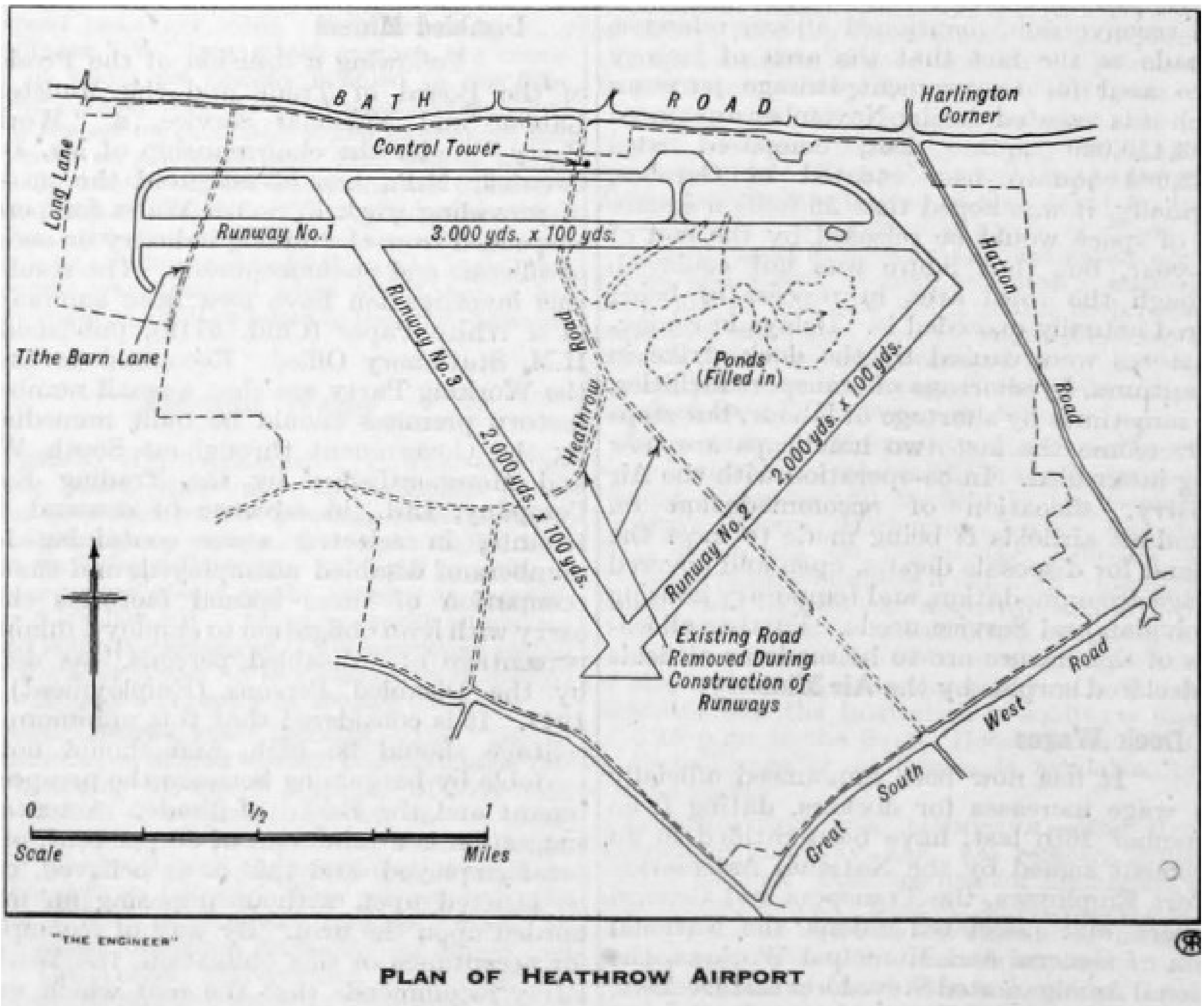


Figure M.24.1 London, Heathrow Plan - Source: The Engineer 11.01.1946

Figure M.24.2 London, Heathrow Temporary Tented Terminal 1946 – Source: BBC News

Chapter 6 included discussion of its first terminal the Europa Building (later Terminal 2) (figure 6.40) and its reversible passenger flow (figure 6.111), and Terminal 4, which introduced the level separation of arrivals and departures (figure 6.113). The following figures show London Airport (Heathrow) when the first terminals (Europa Terminal later renamed T2 and Queens Building) opened in 1955 (figures M.24.3 and M.24.4).

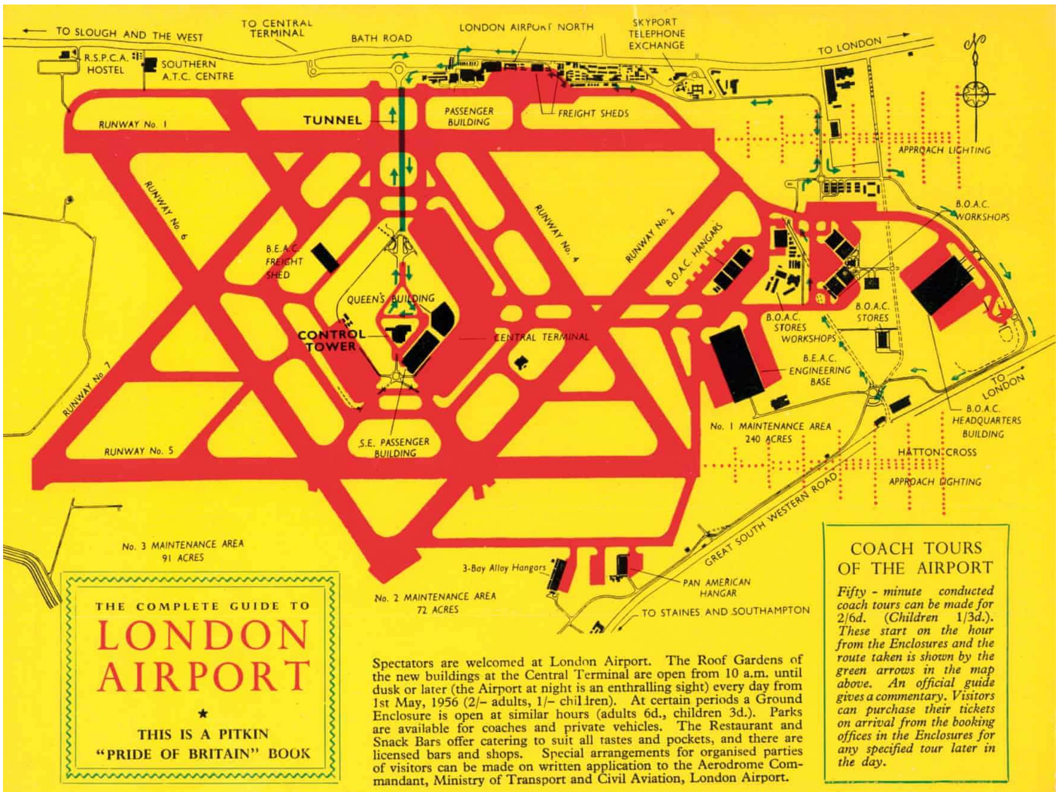


Figure M.24.3 London, Heathrow, 1955 – Source: The Complete Guide to London Airport, Sir Miles Thomas

Figure M.24.4 – London, Heathrow Aerial view of Queens Building, Europa Terminal & Control Tower 1955 Source: The History Press

As Heathrow continued to expand with the construction of Terminal 3 (originally the Oceanic Terminal 1961) and Terminal 1 (1969) the constraints of the Star of David runway layout can be clearly seen (figureM.24.5). The next step was the construction of T4, in the south which opened in 1986 (figures 6.30).The last crosswind runway was only closed to allow the construction of the new Terminal 2 which opened in 2013.

Figure M.24.5 Heathrow Aerial View, showing terminals 1, 2 &3 in the CTA 1977 – Source: airporthistory.org

The concept for Heathrow Terminal 5 evolved over a very long period of time with one of the earliest proposals for a mid-field terminal dating back as far as 1976 (Figure M.24.6). It illustrates the importance of a multi-disciplinary design approach.

Rogers Stirk Harbour + Partners won the competition for Terminal 5 (T5) at Heathrow Airport in 1989. The terminal became operational in March 2008, after being officially opened by Queen Elizabeth II. The original competition scheme evolved during the 1990s, shaped by changing requirements, including a dramatic reduction in site area and more stringent safety requirements.

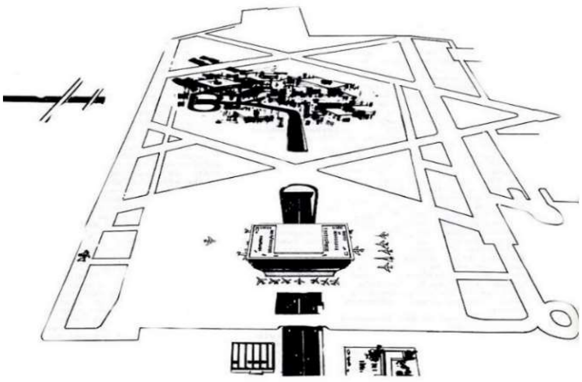


Figure M.24.6 - Early Concept for Heathrow T5 with a motorway under the terminal (1976) Source: BAA

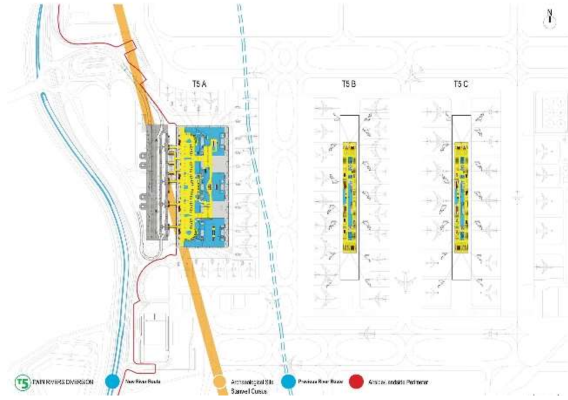


Figure M.24.7 - Heathrow T5 'Toast Rack' Master Plan Source- Rogers, Stirk Harbour + Partners

Serious design began after the design competition in 1989 which saw the Richard Rogers Partnership selected, narrowly winning over YRM with jury votes split 7 to 6 in their favour. The multidisciplinary design at Heathrow T5, with co-located teams of architects and planners was a long and complicated process aggravated by the longest public inquiry process in UK history, but illustrates well many of the contemporary issues associated with multidisciplinary airport design. The masterplan layout was largely based on the 'toast rack' concept (Figure M.24.7), with a mid-field terminal supporting a series of satellites, had been developed for Atlanta airport, as this was shown to the most efficient land use on a uniquely tight site and optimised aircraft movement across the airport.

The architectural team included:

- Rogers, Stirk, Harbour+Partners (formerly the Richard Rogers Partnership) – Concept Architect and Lead Designer.
- YRM – British Airways Architects and responsible to BAA for the campus design guidelines and design of the ancillary buildings.
- HOK – Architect for railway infrastructure
- Chapman Taylor – Retail architect
- Pascall + Watson – Executive architect for the fit out

Several engineering disciplines were also involved, including Arup, Mott MacDonald, DSSR, TPS, WSP and Atkins. At its peak, over 2000 designers were working on the project. Instead of having many different firms spread out across the country, sending drawings and specifications to each other a core multidisciplinary design team was assembled that worked from a single building at Heathrow integrating teams from the airport and the airline with the construction management team. So while design team management to produce a single integrated design concept was demanding it was greatly assisted by co-locating key members of the team together.

The work on design and construction continued for nearly 20 years, the extreme length being partly due to the extended public inquiry process. It was inevitable that over such a long time period there would be significant changes to the brief and design approach. These included major changes to the security regime, retail concept and adjustments to the planning to suit the operation of the main tenant British Airways. The opportunity was also taken by both BAA (now Heathrow Airport Ltd) and British Airways to improve operational processes by housing their operational staff in adjacent spaces and embracing advances in IT and other technology. The terminal concept developed over a long design period as the context and brief evolved.

Concept 1 – 'Magic Carpet'

The first concept was a single level scheme, developed from the winning competition entry between 1989 and 1992 (figures M.24.8, M.24.9 & M.24.10).

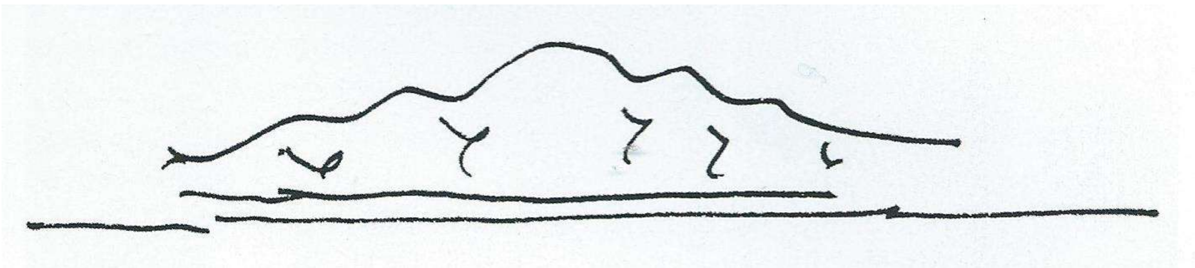


Figure M.24.8 – Heathrow T5 'Magic Carpet' Concept – Source: Rogers Stirk Harbour + Partners

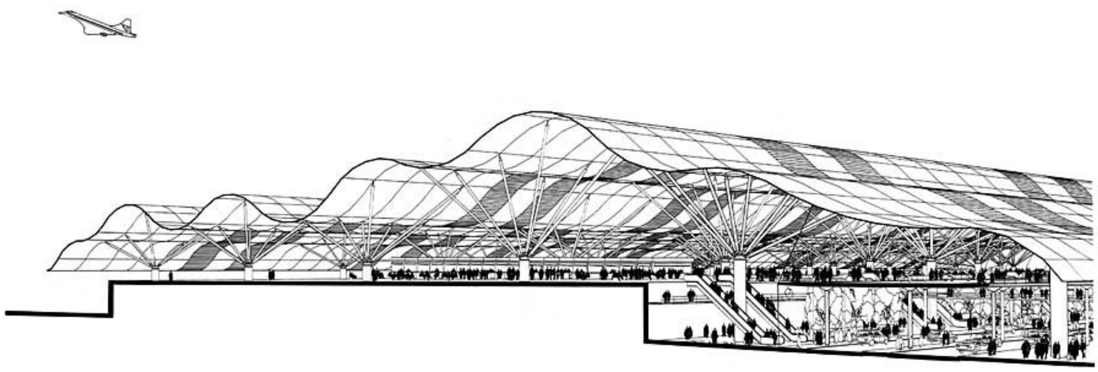


Figure M.24.9 – Heathrow T5 Competition Scheme (June 1989) – Source: Richard Rogers Partnership

Mike Davies, the RSH+P project director explained:

> *'It was built on the concepts which had previously been explored at Stansted including the notion of a building where the arriving and departing passengers were all on one level and would experience the same quality of space. The idea was to create a great room, covered by a flowing wavy roof, which gradually crescendoed in height over the largest hall space. We created multiple waves and the biggest wave sat over the most important public spaces. The roof was deliberately conceived as flowing and tipped up on the outside edge on the airside as a celebration of "up, up and away"…… instead of squeezing passengers through 5-6 metre high spaces, we offered great lofty heights, more like cathedrals, in which people felt they were moving through open and airy spaces with good views – generous architectural spaces'* (Davies, 2008, pp. 73-76).

Figure M.24.10 – Heathrow T5 'Magic Carpet' Model – Source: Rogers Stirk Harbour + Partners

This scheme was abandoned during the public inquiry when legal advice was that building in the green belt was too contentious, requiring the terminal to be redesigned. This led directly to the development of a second more vertically stacked concept, with 5 passenger levels above ground and 3 levels of basement supporting accommodation.

Concept 2 – 'Canyon'

This was a more vertically developed concept resulting in a more compact footprint on a restricted site. It was developed in the period between 1992 and 2000 to address the legal advice that restricted the site. This taller scheme split the floor plate into three with light wells separating them (figure M.24.11 & M.24.12).

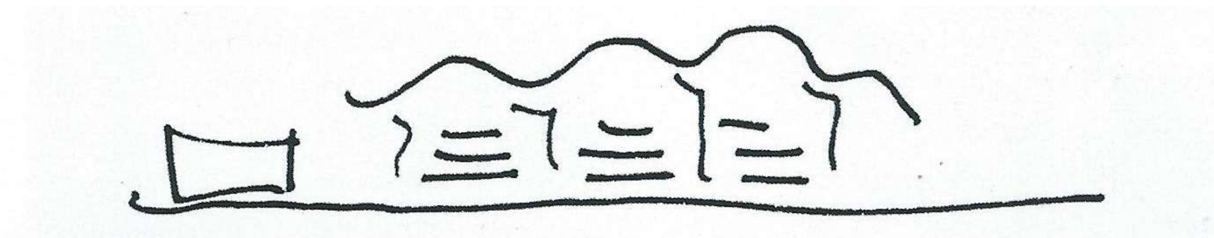


Figure M.24.11 – Heathrow T5 'Canyon' Concept – Source: Rogers Stirk Harbour + Partners

Mike Davies described the design as follows:

'The scheme was characterised by the organisation of the overall plan into a landside plate, a process plate and an airside plate, with all three bands of floor linked by bridges across two canyons, which allowed the light to penetrate down to the lower levels of the building. Essentially the landside processes fitted one plate, the security, customs and immigration processes sat in the middle plate, and the airside plate accommodated the airside dwelling lounges and aircraft gates' (Davies, 2008, pp. 76 -77).

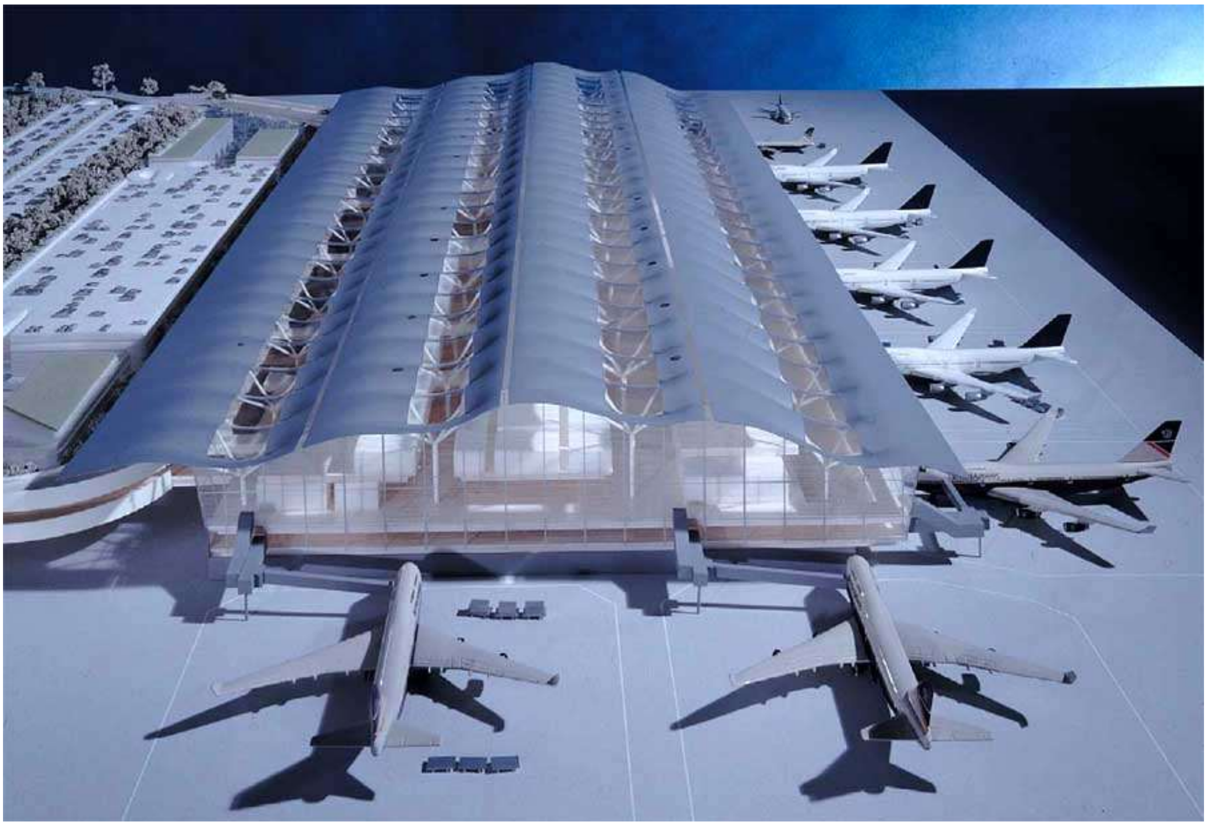


Figure M.24.12 – Heathrow T5 'Canyon' model - Source: Rogers Stirk Harbour + Partners

It was eventually not pursued, in part because of the inherent inflexibility of the floor plates, which did not naturally fit the functional requirements, and in part because during the long delay caused by the public inquiry RSH+P had developed another similar, but more generous and spread out canyon scheme for Barajas Airport in Madrid, on a much less restricted site which also used a "canyons of light" concept. No doubt they did not want to repeat a similar, but compromised, approach on a more difficult and restrictive site.

Concept 3 – 'Tied-Arch'

A long span structure of 144 metres had been proposed by YRM in their T5 completion entry in 1988 in which they came a close second to Richard Rogers. They were by now working for British Airways as a part of the integrated multidisciplinary design team, and co-located with RSH+P at Heathrow. The joint team now saw the flexibility a long span structure could offer in the light of an increasing number of changes to requirements such as more stringent security standards, following Lockerbie and 9/11, imposed by the UK government.

Other new influences, such as the emergence of Global Alliances and in particular the One World Alliance saw an expansion of transfer traffic, differentiated products for premium passengers such as fast track and ever more glamorous airline lounges. Retail concepts had also evolved with a higher proportion of the provision being airside, and when allied to new faster check-in processes it resulted in passengers spending a higher proportion of their dwell time in the shopping mall that the airside lounge had become. The response was the 'Tied Arch' concept (figures M.24.13 & M.24.14).

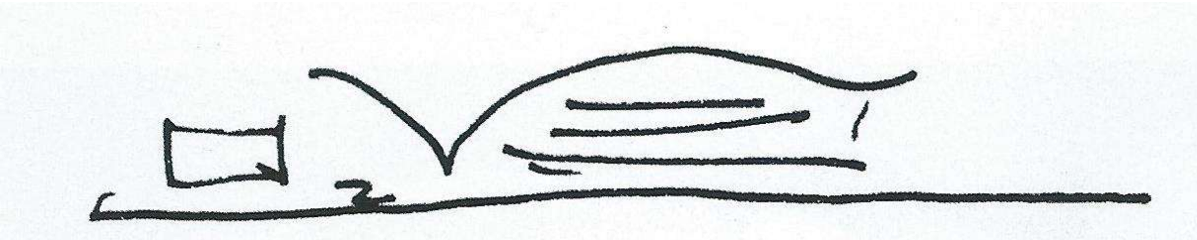


Figure M.24.13 – Heathrow T5 'Tied-Arch' concept - Source: Rogers Stirk Harbour + Partners

Mike Davies continued;

> *'What became clear, in visiting many airports, Stansted included, was that whatever you do the internal column layout becomes a constraint on internal planning. So as a team, BAA and we looked at longer spans, which meant less columns and greater flexibility. We studied several longer spans solutions and created what was called the 'tied arch' scheme. The 'tied arch' scheme had quite an ambitious roof span, around 100 metres, which dramatically reduced the number of internal columns in the building. The tied arch scheme had also incorporated the various rail and underground stations underneath the terminal, directly integrated into the terminal space*' (Davies, 2008, pp. 80-81).

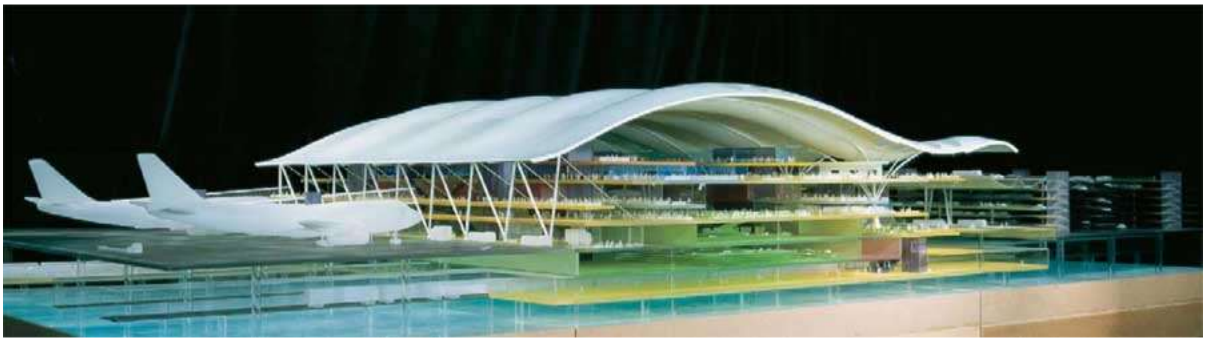


Figure M.24.14 – Heathrow T5 'Tied-Arch' model – Source: Rogers Stirk Harbour + Partners

After a series of detailed studies, that incorporated learning from the Kings Cross Underground Station fire (1987), about separating the terminal from the rail station below to prevent fire from spreading from the station to the terminal, the design team decided that the legislative regime of a station was so different from that of a terminal that the two couldn't be merged into a single space. This was combined with an understanding that the tied arch concept produced a series of new constraints to the interior planning as the ties couldn't be cut or eliminated and so the fourth and final concept was developed.

Concept 4 – 'Great Hall'

The final concept that evolved out of collaborative multidisciplinary working was the interchange concept. YRM had proposed a landscaped zone between the multi-storey car parks and the terminal to create a breathing space on the passenger journey (figure M.24.15). During the design a new directive was issued from the UK DfT that vehicular traffic had to be kept 30 metres away from the terminal. This concept of a green space in front of the terminal that had lain dormant was then revived (figure M.24.16).

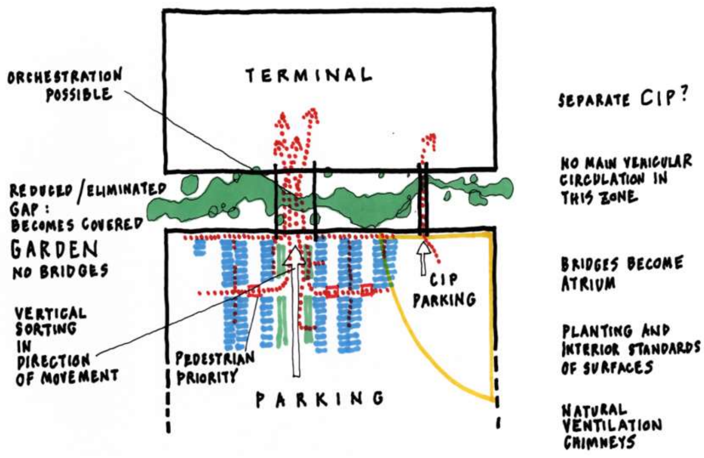


Figure M.24.15 – T5 Landscaping Concept – Source YRM (reproduced with permission from RMJM)

Figure M.24.16 – T5 Photographs - Source: Author's collection

It involved moving the forecourt away from the terminal and relocating it above the car park to create a vehicle free zone in front of the terminal. This allowed the creation of an external light filled piazza planted with trees just outside the terminal, into which the vertical circulation to the rail stations was moved creating an interchange. RSH+P then designed an even longer span structure of 156.6 metres for the terminal removing internal constraints to the departures concourse.

Mike Davies explained the new concept this way:

> *'We ended up with a very clear concept which in some ways returned to the spirit of our earliest competition idea, yielding a very large departures floor plate with no constraints on it at all. Alongside this long span 'Great Hall' concept came the decision to make the interior fabric of the building below the departures levels, an independent, steel frame structure. The external structure is freestanding and does not join with the edges of the external building envelope at any point. You have an external wrapper with a void space all around the edges with an easily adaptable island inside it. As a result, natural light pours into the building at the facades, then beyond this void, you have an internal structure which can be changed at will,*

without any impact whatsoever on the main external envelope.' (Davies, 2008, pp. 81-83)

This concept owed something to the collaboration with YRM, who had previously explored the idea of a very large clear span over the main terminal of 144metres in their competition proposal of 1989 (figure M.24.17).

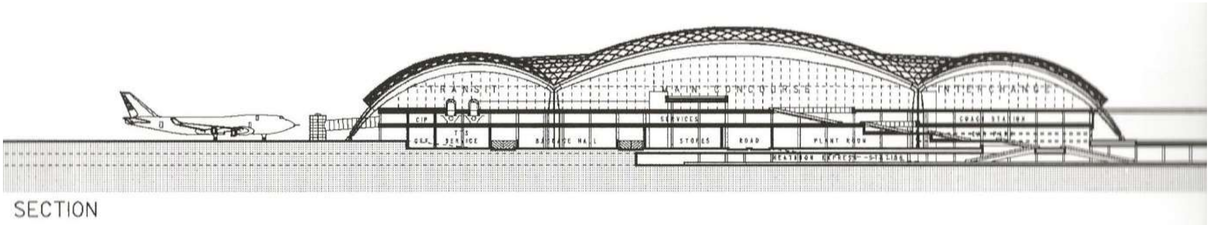


Figure M.24.17 - YRM Heathrow T5 Competition Design *Source - YRM Architects and Planners (reproduced with permission from RMJM)*

The 'Great Hall' concept, which is also reminiscent Piano's Kansai design, on the landside and airside edges, is illustrated below (figures M.24.18, M.24.19 & M.24.20).

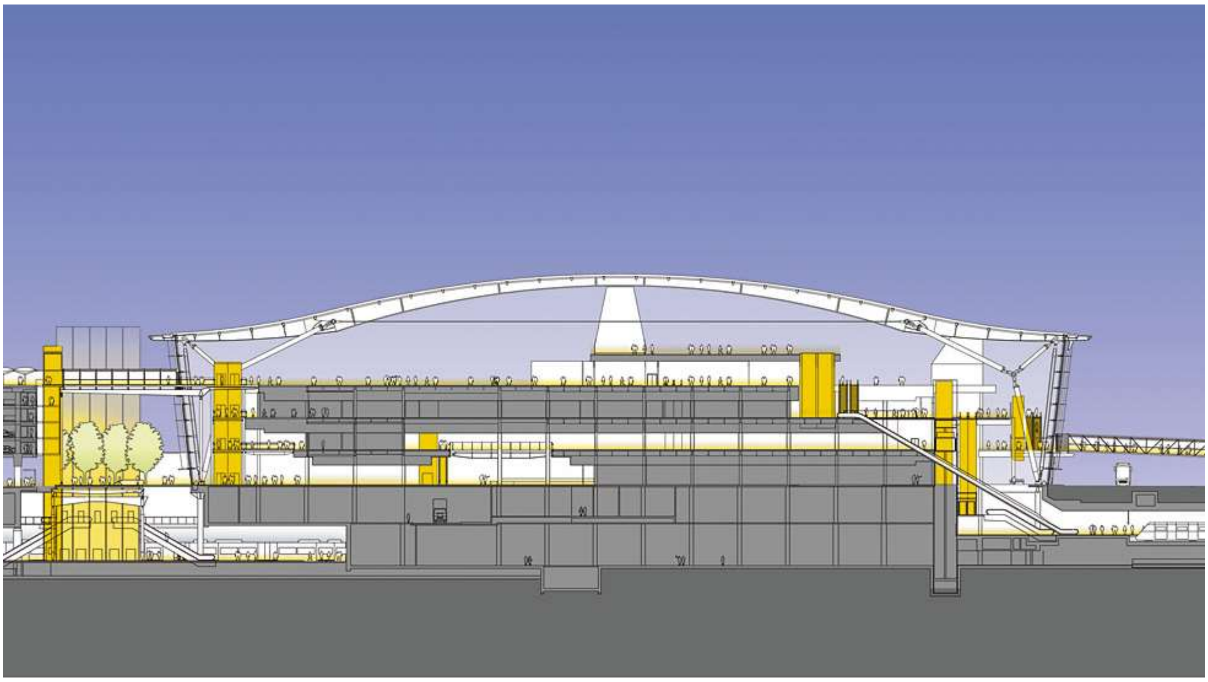


Figure M.24.18 - Heathrow T5 – 'Great Hall' Concept – Source: Rogers Stirk Harbour + Partners

Figure M.24.19 – Heathrow T5—The Great Hall Structure – Source: Rogers Stirk Harbour + Partners

Figure M.24.20 – Heathrow T5—The Great Hall Roof – Source: Rogers Stirk Harbour + Partners

The built scheme for the main terminal offers an unencumbered, long-span 'envelope' – developed with Arup – with a flexible internal space conceptually similar to that of Madrid Barajas or the practice's much earlier design for the Pompidou Centre in Paris.

Departure and arrivals areas, check-in desks, commercial space, retail, offices, passenger lounges, back-up and other facilities are all contained within freestanding steel-framed structures inside the building and can be dismantled and reconfigured as future needs change.

The built, multi-level scheme is contained beneath an elegant, curved floating roof, supported by slim columns at the perimeter edges to provide the required highly flexible and visually dramatic internal space. In this scheme, passengers depart and arrive in a terminal building that offers generous spaces and fine views across the airport (figure M.24.21). The main terminal, its satellite buildings, and the new control tower are all part of a wider T5 campus development that includes a landscaped motorway link from the M25, the creation of two new open rivers from previously culverted channels under the airport, the construction of more than a square kilometre of taxi-ways and aircraft stands, three rail stations (for the Piccadilly line, Heathrow Express, and overland rail), an airside track transit system, and an airside road tunnel connecting directly to Heathrow's central terminal area.

As well as the design of the main terminal building, RSHP was also responsible for the design of two satellites and Heathrow's new control tower (figure 5.05), which became operational in early 2007.

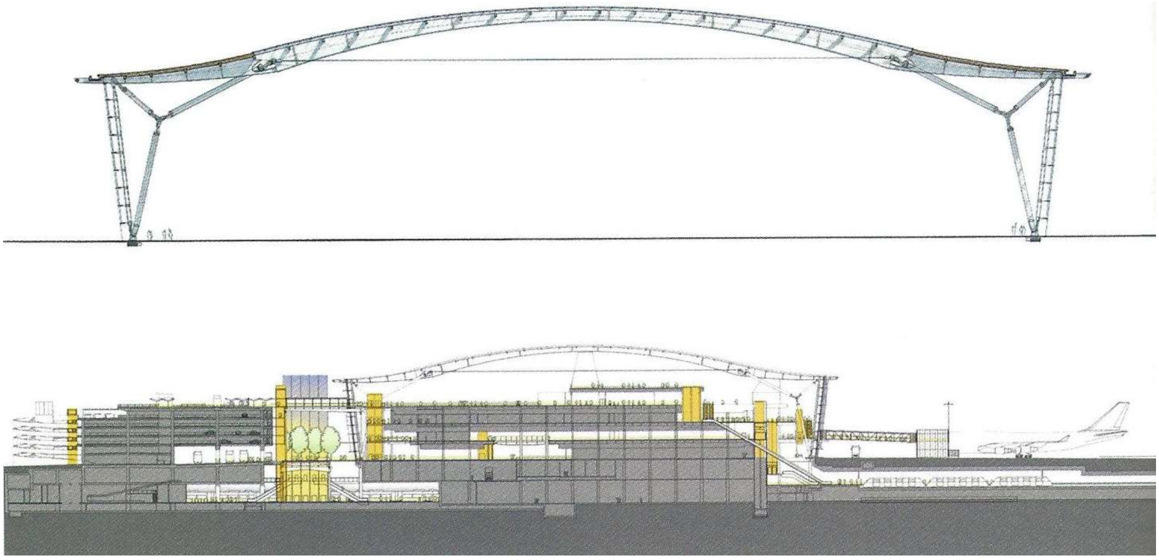


Figure M.24.21 Heathrow Terminal 5 Sections – Source: Architects Journal

The Terminal 5 floor plans are illustrated (figure M.24.22 & M.24.23). Proposals are being developed to increase the capacity of Terminal 5 and modify the layouts of facilities. Constraints to increasing throughput include the government imposed requirement for more rigorous security checks which requires additional space and staffing levels.

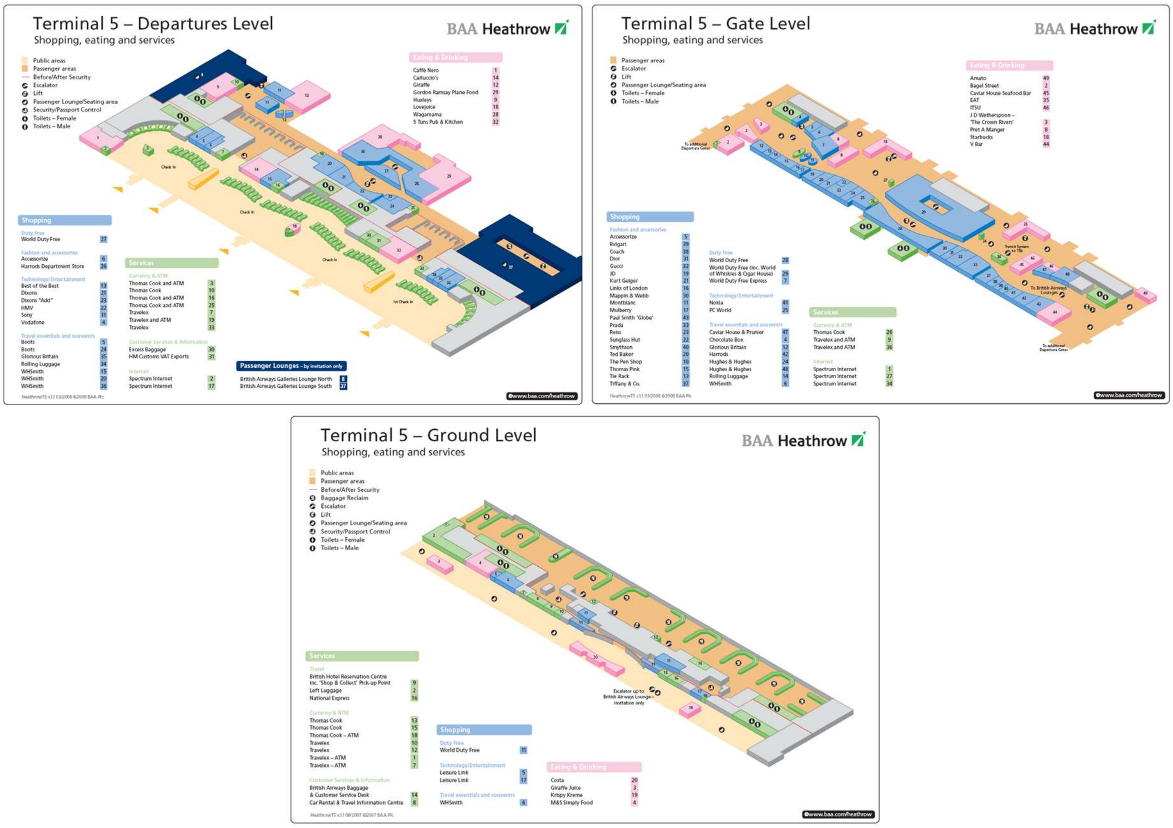
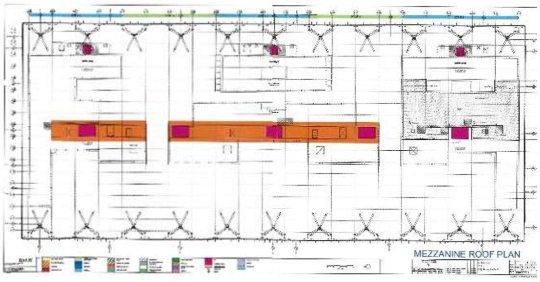
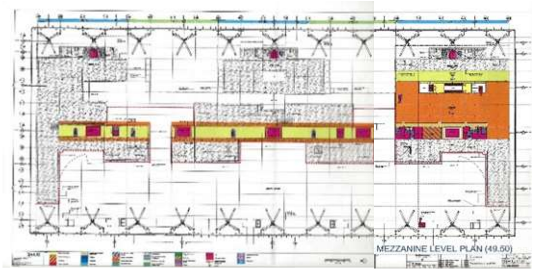


Figure M.24.22 Heathrow Terminal 5, Retail Floor Plans – Source: Heathrow

Heathrow Terminal 5 Floor Plans

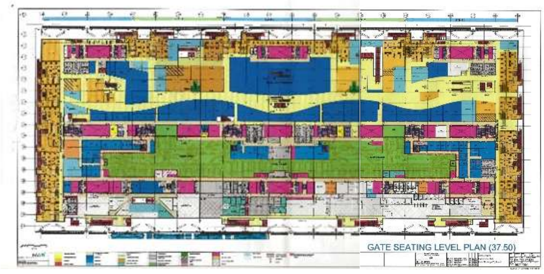


Mezzanine Roof

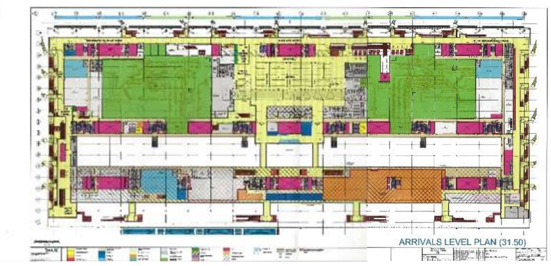


Mezzanine Level

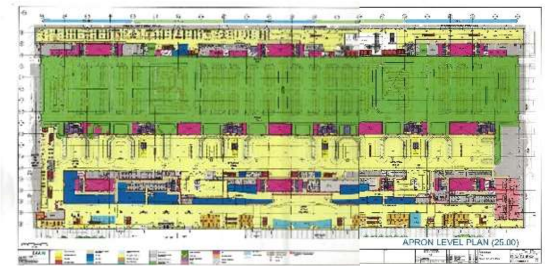
Departures Level



Gate Level



Arrivals Level



Apron Level

Upper Basement Level

Lower Basement Level

Figure M.24.23 Heathrow T5 Floor Plans - Source: Author's own collection

Figure M.24.24 Heathrow Terminal 2, Concept Design - Source: Foster + Partners

Terminal 2 at Heathrow, originally known as Heathrow East, was designed by Foster + Partners to replace the original 1955 Frederick Gibberd Terminal 2 and Queens Building to become the new home for Star Alliance airlines and handle an estimated 20 million passengers every year (Figure M.24.24, M.24.25 & M.24.26). Architect Luis Vidal, was later appointed by Heathrow's Spanish owner Ferrovial to take up the terminal design where the Foster+Partners masterplan left off.

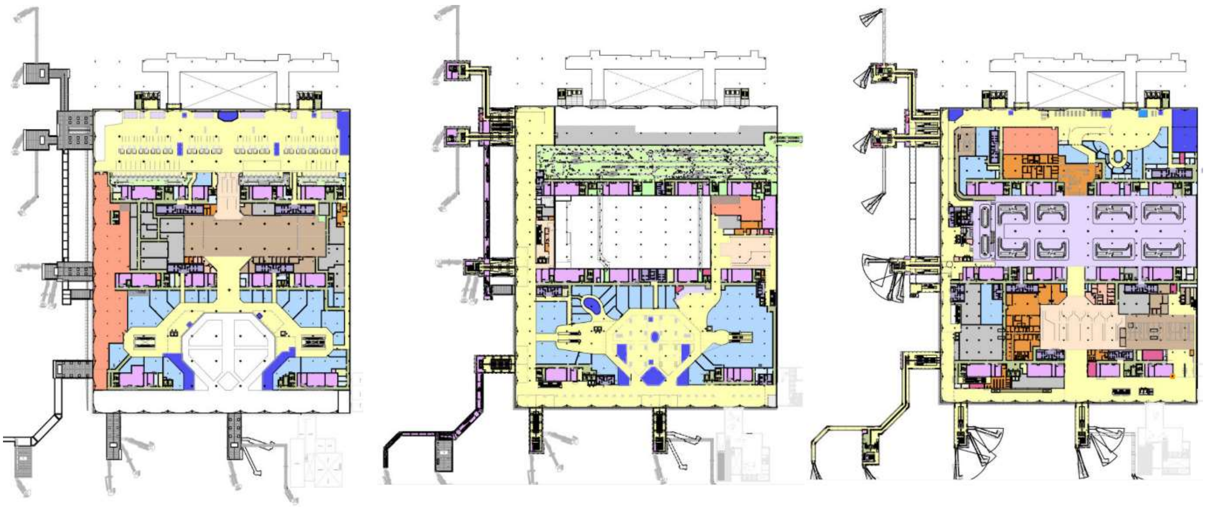


Figure M.24.25 Heathrow Terminal 2, Floor Plans – Source: Architecture Daily

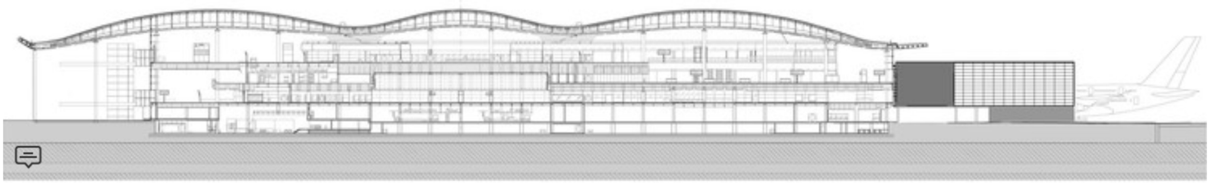


Figure M.24 26 Heathrow Terminal 2, Cross Section Source: Architecture Daily

Heathrow Terminal 2 is unusual in two respects. First the wavy roof incorporated northlights, a feature more usually found in factories, but adopted because it allowed good daylight penetration into the interior without the accompanying heat gain, an important consideration as airports become more environmentally conscious. Second, due to the proximity of the London Underground under the ground floor, it was designed without both a basement and a departures baggage system. It relied instead on reusing the obsolescent baggage system in the adjacent mothballed Terminal 1. This will in turn produce additional challenges as the second phase of the terminal is designed, and will result in additional costs and complications and an extended phasing programme to maintain business continuity.

The Heathrow Expansion Project is planned to increase the capacity of Heathrow from the current 80 million passengers a year to 142 milillion pasengers a year by building a third parallel runway, increasing terminal capacity and providing additional stands and ancillary facilites. Heathrow announced in January 2020 it will launch an eight-week public consultation to finalise its proposals for airport expansion following the recent decision by the UK's aviation regulator, the CAA, to cap early spending on the project (figure M.24.27).

Figure M.24.27 Heathrow Expansion Project – Source: Grimshaw Architects

25 Beijing Capital (PEK) 2008

The airport has three widely spaced runways and three main terminals. Terminal 1, with 60,000m^2 of space, opened on 1 January 1980, and replaced the smaller existing terminal, which had been in operation since 1958. The latter continues as VIP and charter terminal. Terminal 2 opened on 1 November 1999, with a floor area of 336,000m^2. This terminal was used to replace Terminal 1 while the latter was undergoing renovation. It can handle twenty aircraft on stands connecting directly to the terminal building.

The much larger terminal 3, covering approximately 1,300,000m^2 and with 69 passenger boarding bridges, was designed by a consortium of Netherlands Airport Consultants (NACO), UK Architect Foster and Partners, and ARUP and opened for the Olympics in 2008 (Airport Technology, 2020)

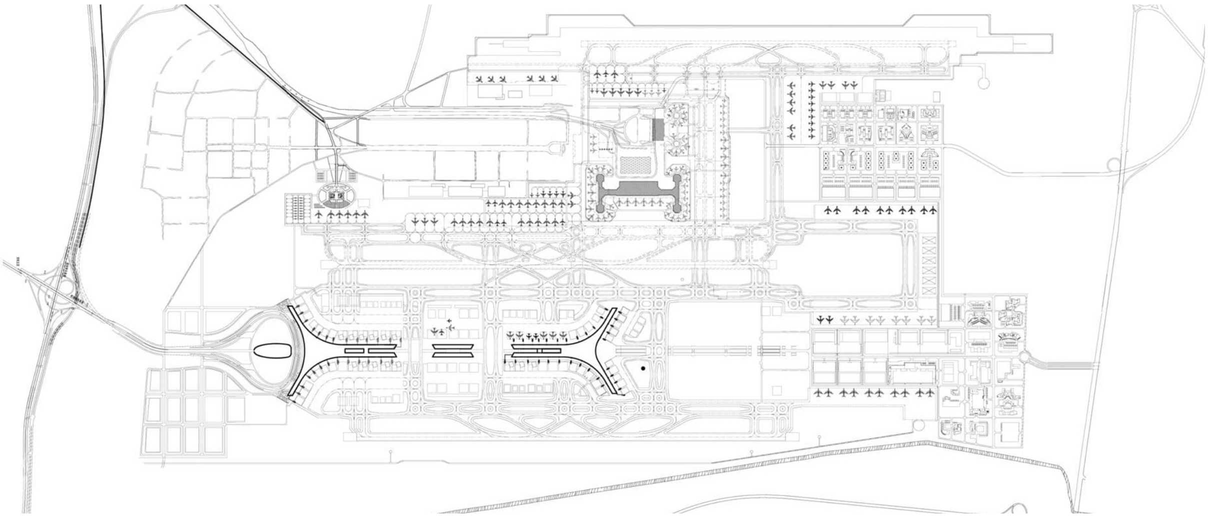


Figure M.25.1 Beijing Capital masterplan _ Source: Foster + Partners

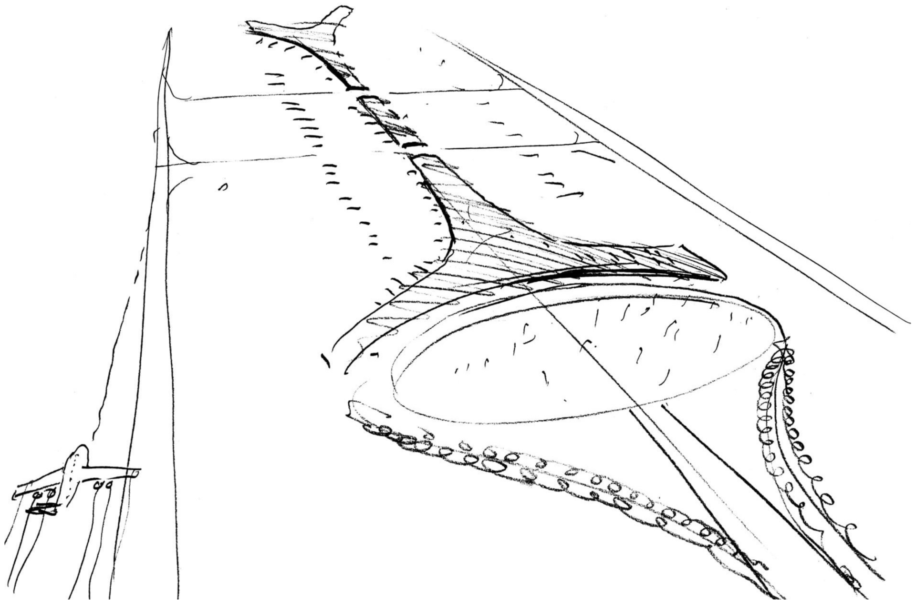


Figure M.25.2 Beijing Capital, Concept Diagram – Source: Foster & Partners

Foster + Partners describe Terminal 3 as follows:

'Located between the existing eastern runway and a planned third runway, the terminal building and Ground Transportation Centre (GTC) together enclose a floor area of 1.3 million square metres and were designed to accommodate 50 million passengers per annum by 2020. Although conceived on an unprecedented scale, the terminal's design expands on the new airport paradigm created by Stansted and Chek Lap Kok. Designed for maximum flexibility to cope with the unpredictable nature of the aviation industry, like its predecessors, it aims to resolve the complexities of modern air travel, combining spatial clarity with high service standards. Transport connections are fully integrated, walking distances for passengers are short, with few level changes, and transfer times between flights are minimised. Like Chek Lap Kok, the terminal is open to views to the outside and planned beneath a unifying roof canopy, whose skylights are both an aid to orientation and sources of daylight − the colour cast changing from red to yellow as passengers progress through the building' (Foster, 2008).

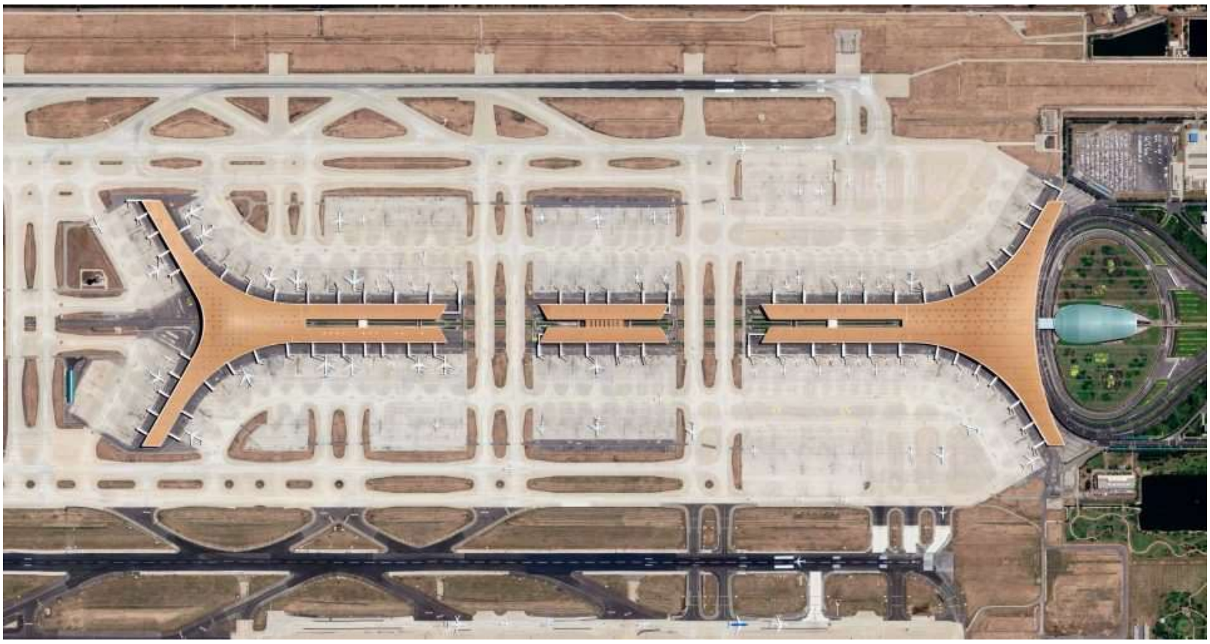


Figure M.25.3 Beijing Capital Terminal 3 Aerial View – Source: Google Earth

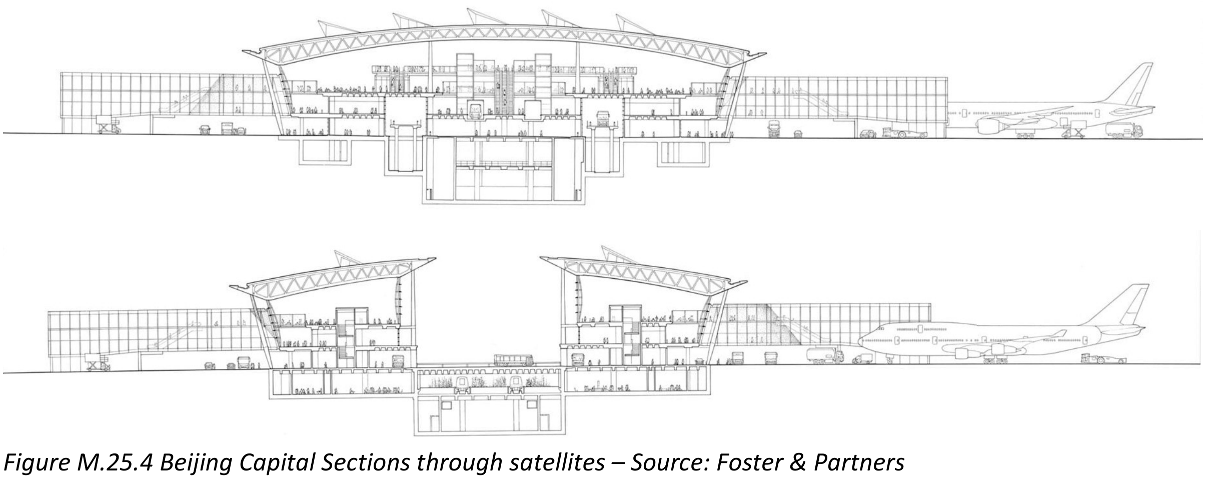


Figure M.25.4 Beijing Capital Sections through satellites – Source: Foster & Partners

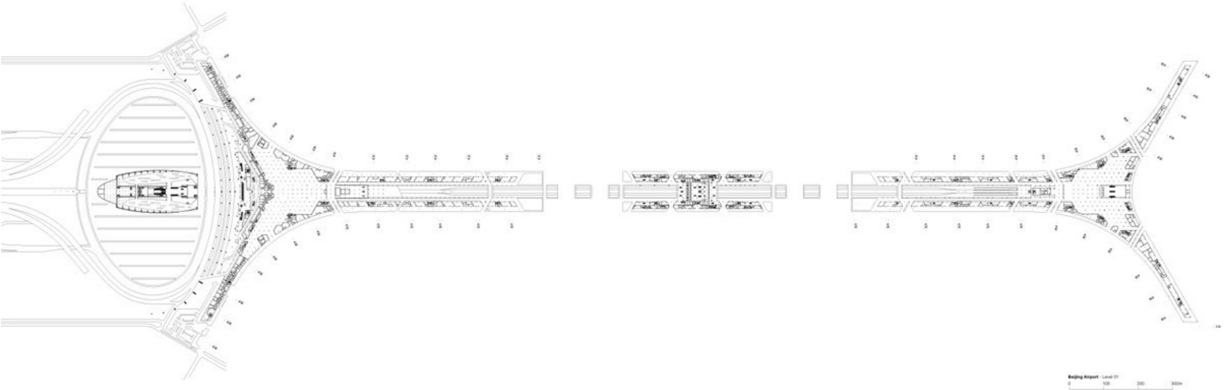


Figure M.25.5 Beijing Capital, Terminal 3, Departures Floor Plan -Source: Foster & Partners

Figure M.25.6 Beijing Capital Terminal 3 Entrance - Source: Voyages-Chine.com

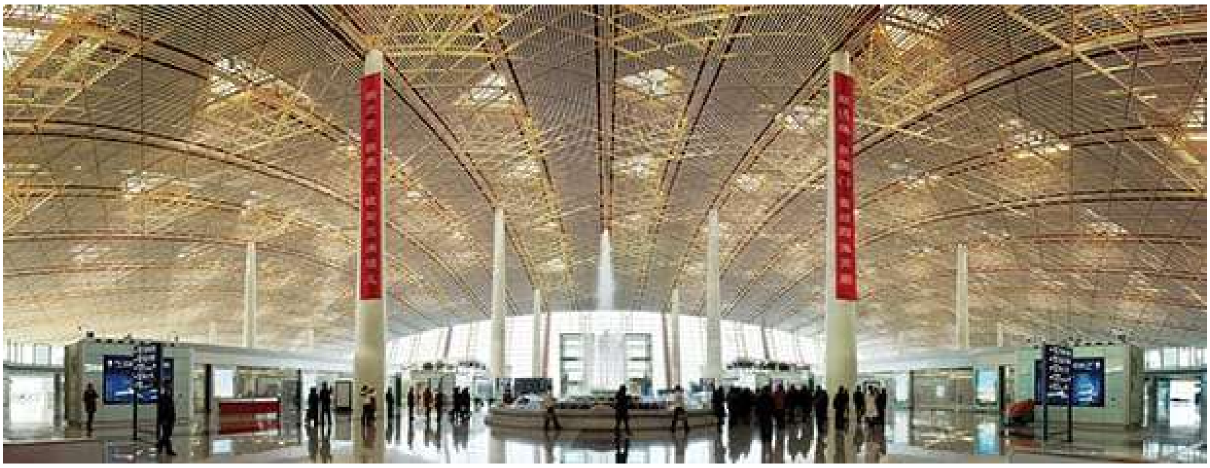


Figure M.25.7 Beijing Capital - Source: Foster & Partners, Photographer: Nigel Young

26 Dubai International (DXB) 2010

Dubai International Airport opened in 1960 with a simple terminal and runway of just 1,800m, after the late Ruler of Dubai, Sheikh Rashid bin Saeed Al Maktoum, ordered its construction. The 1970s saw the construction of a new terminal to accompany the lengthened runway which included unusual externa, spiral ramps to the four boarding gates (figure M.26.1). The expansion of the airport had a new impetus in the 1990s with the growth of Emirates airline which had only been founded in 1985 (DXB, 2018).

Figure M.26.1 Dubai Airport Terminals in the 1960s and 1970s - Source: Dubai Airports

The expansion of Dubai international has been driven by the growth of Emirates Airline which has an all wide body aircraft fleet and operates the largest number of A380 aircraft in the world.

Concourse A is the world's first A380 purpose built facility and also features the world's first multi-level boarding for First and Business Class passengers directly from the respective lounges. The concourse includes one 4 star hotel and one 5 star hotel, First and Business Class Lounges, and duty-free areas. Concourse B is directly connected to Terminal 3, and is dedicated exclusively to Emirates. The terminal has 10 floors (4 basement, ground floor, and 5 above-ground floors). Paul Griffiths, Chief Executive of Dubai Airports, has said of the underground terminal:

'Terminal 3 is unique. Firstly, it's one million square metres – twice the size of Heathrow's Terminal 5. Secondly, the whole terminal has been built underground, yet it feels like a large cathedral. Thirdly, it is the first terminal in the world that has been designed specifically for the A380' (2020 ACI EUROPE Airport Business, 2008).

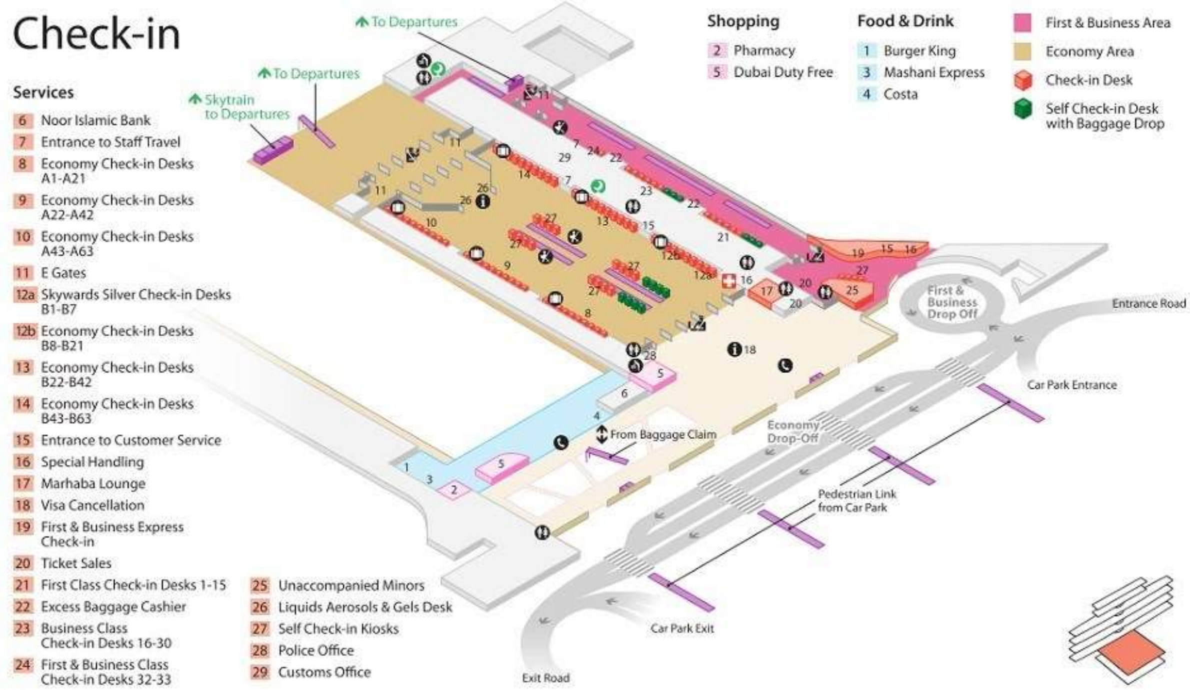


Figure 11.26.2 Departures Layout – Source: Dubai Airports

Figure M.26.3 Arrivals Layout – Source: Dubai Airports

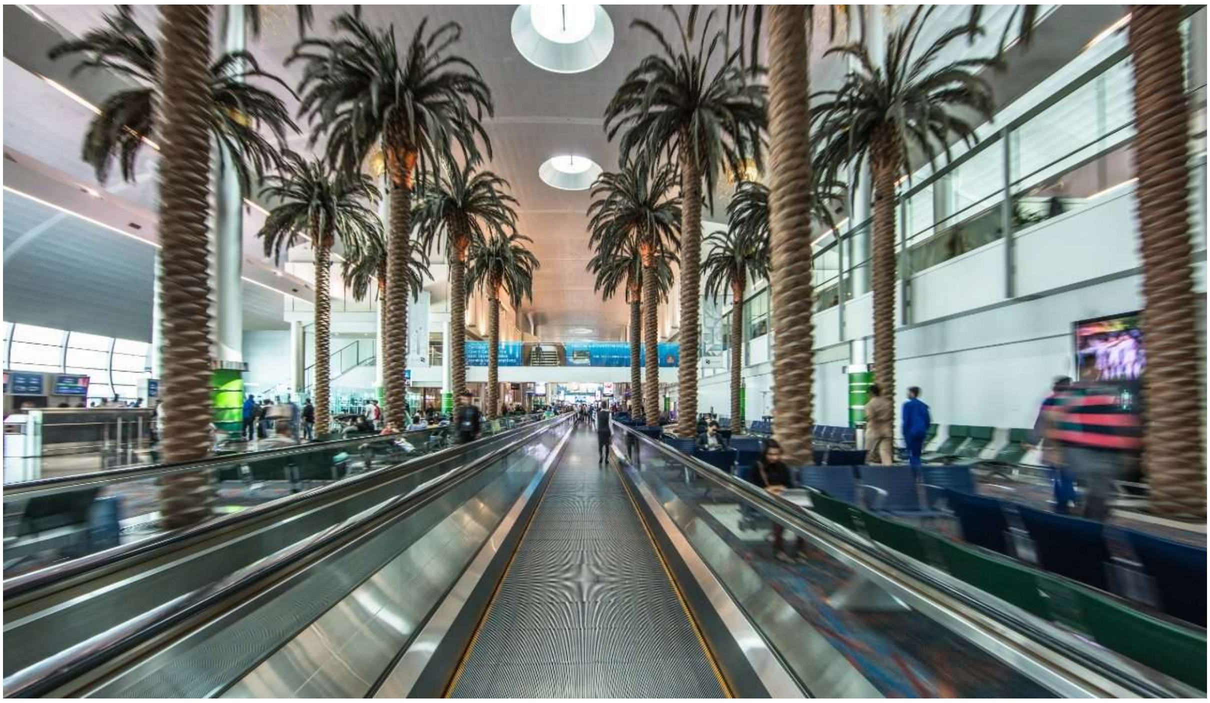


Figure M.26.4 Dubai International underground check-in concourse – Source: Qantas Magazine

Figure M.26.5 Dubai International, Retail Mall in the satellite concourse Source: getbybus.com

27 Istanbul Grand (IST) 2019

Istanbul Grand is a rapidly expanding new hub airport and boasts the largest terminal yet designed without a transit system, at least in phase 1, with 71 passenger boarding bridges accessible from its finger piers, most of which can handle two narrow bodied aircraft. The layout bears comparison with that developed for Bangkok Airport. At a later stage it will be expanded to include a satellite and second terminal. Istanbul Airport City is discussed in chapter 9.8.

Figure M.27.1 Istanbul Grand, Location Plan – Source: Wikipedia

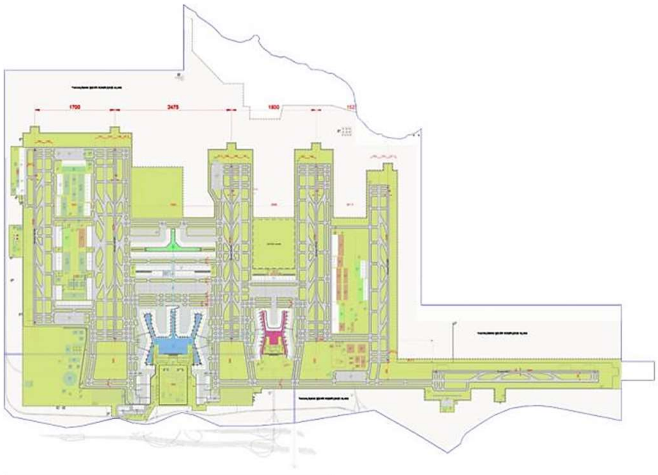


Figure M.27.2 Istanbul Grand – Master Plan Source: Wikimapia

Figure M.27.3 Istanbul Grand Aerial View, Airport under Construction - Source Wikipedia

Figure M.27.4 Istanbul Grand, Aerial CGI – Source: Grimshaw Architects, Haptic Architects & Nordic Office of Architecture

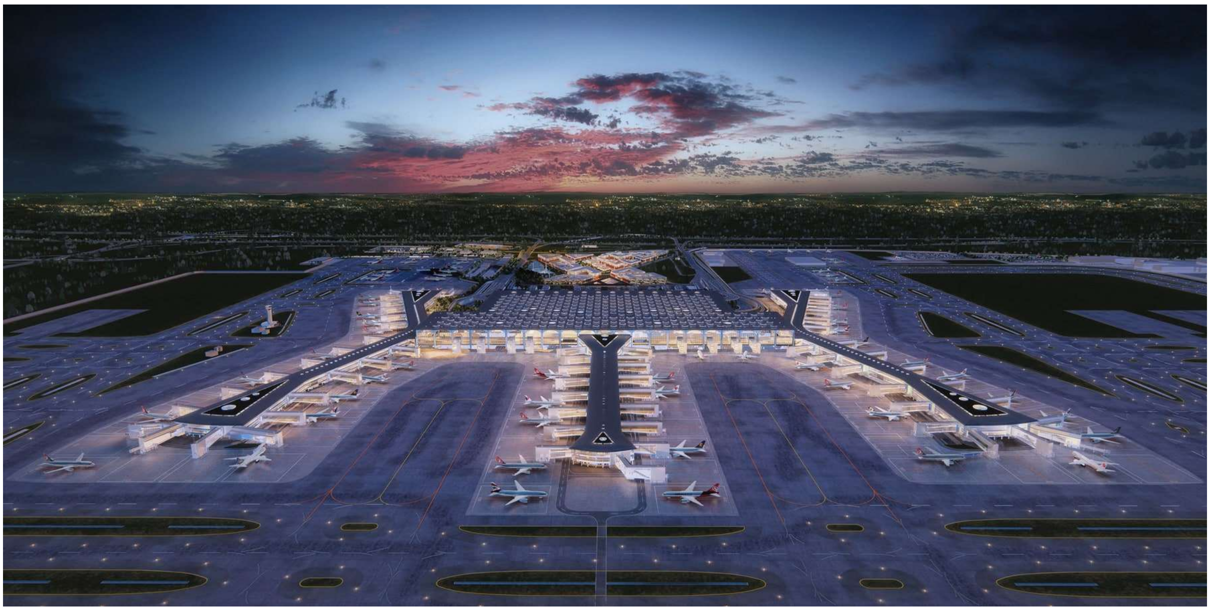


Figure M.27.5 Istanbul Grand, Aerial View - Source: IGA by Havilimani Vaz Aci, via Architectural Digest

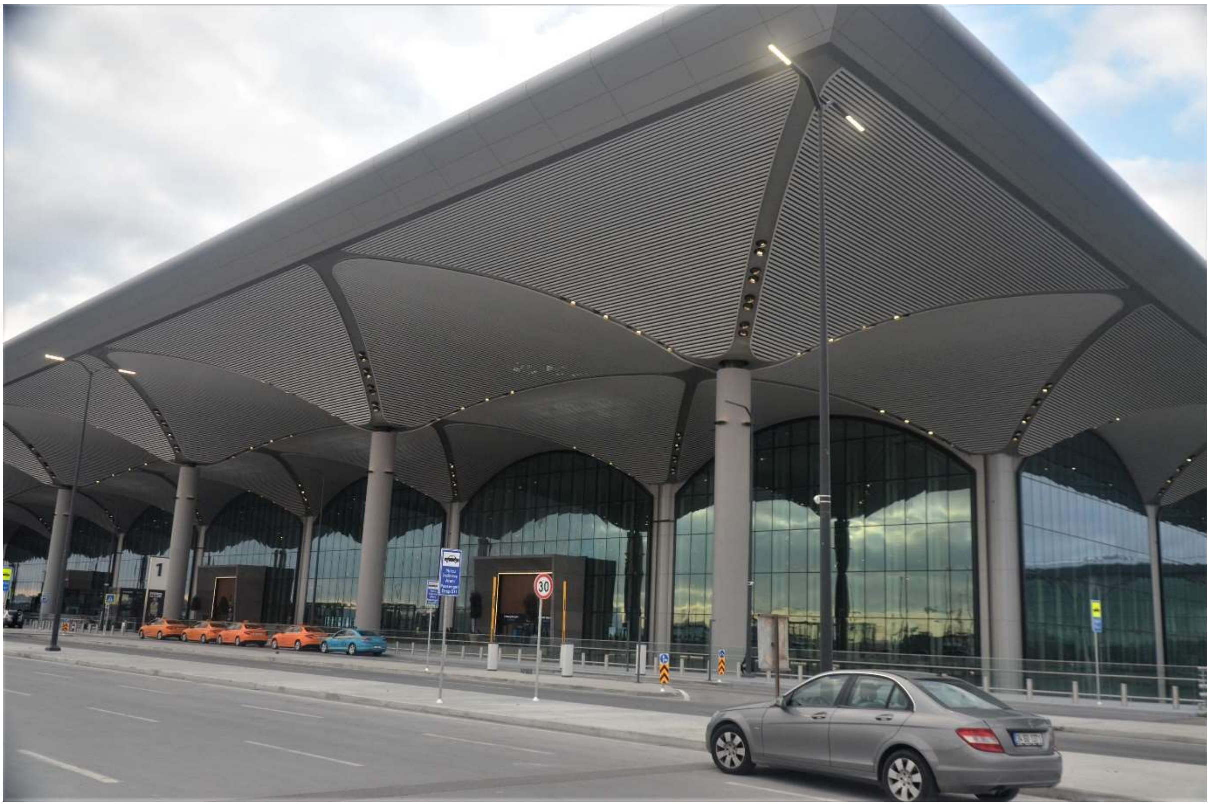


Figure M.27.6 Istanbul Grand – View from Forecourt – Source: Wikipedia

Figure M.27.7 Istanbul Grand – CGI of Departures Concourse – Source: Grimshaw

Grimshaw describe their design approach as follows: *'The design draws on the architectural character of Istanbul – a city rich with colour, pattern and history since its Byzantine origins – and includes vaulted ceilings pierced with skylights that draw in diffuse daylight and create an open, lofty volume with clear lines of sight. Focused beams of sunlight illuminate key areas in the terminal, such as check-in, security, customs and retail areas.'*

Figure M.27.8 Istanbul Grand CGI of Airside Lounge & Retail Mall – Source: Haptic Architects

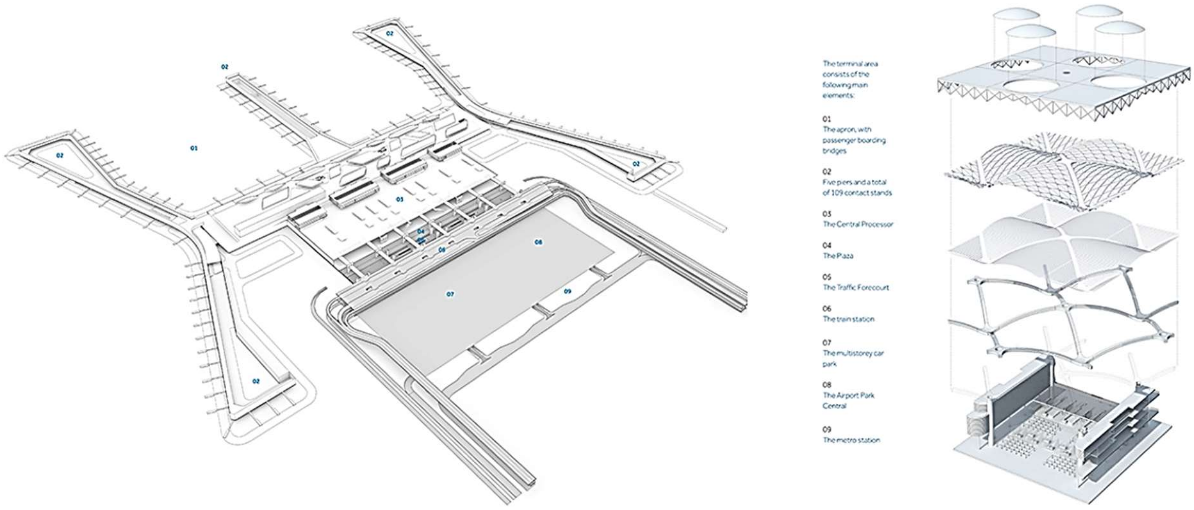


Figure M.27.9 Istanbul Grand – Isometric of Floor Plan and Roof Construction – Source: Haptic Architects

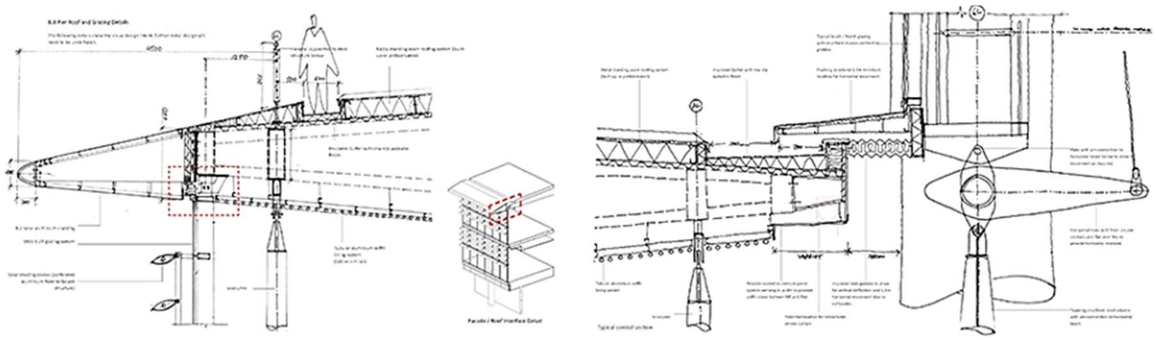


Figure M.27.10 Istanbul Grand – Details of Roof Construction – Source – Haptic Architects

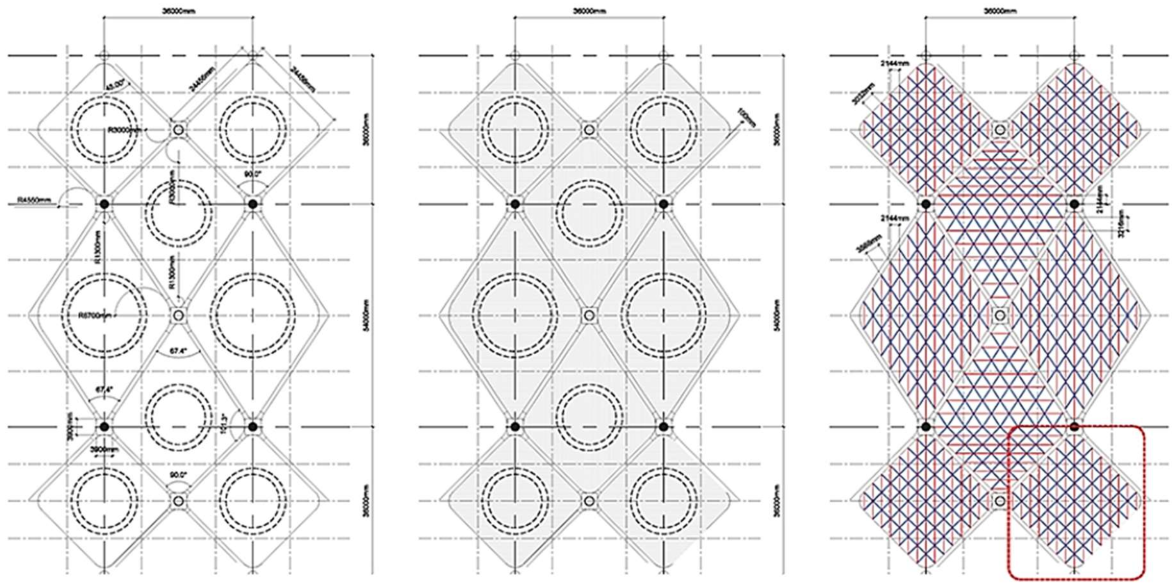


Figure M.27.11 Istanbul Grand, Reflected Ceiling Plans – Source: Haptic Architects

Figure M.27.12 Aerial View of Istanbul, Grand in operation - Source: Daily Sabah

28 Beijing Daxing (PKX) 2019

At the time of opening in September 2019, Daxing Airport has four runways and 79 stands, of which 60 are jetty served. Eventually, the airport will have 7 runways in total and will be able to serve about 620.000 flights annually (Daxing-PKX, 2019). The whole airport is aligned on its north-south axis with the gates that lead to Tianamen Square and the Holy City to become the newest entry point to Beijing. The airport has been named the Phoenix Gate.

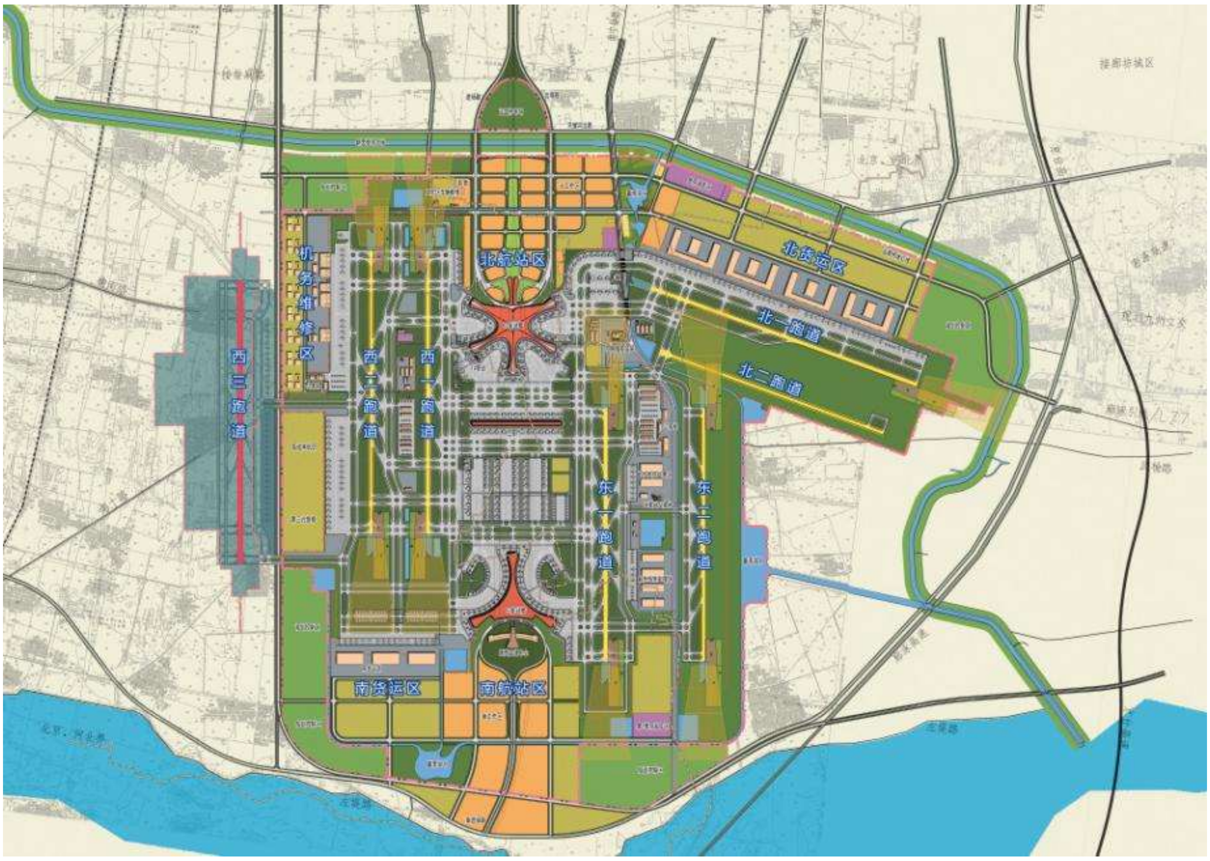


Figure M.28.1 Beijing, Daxing Master Plan - Source: kaskus.co.id

The terminal building design team was led by the late architect Zaha Hadid. Nicknamed The Starfish of Beijing because of its shape, it has a large central space and 6 “tentacles”, resembling a giant “octopus”.
The sectional concept has international check-in at the top level and a mixed domestic departures and arrivals level on the floor below. Below that again is an international airside departures lounge, and the lowest passenger level is international arrivals.
The passengers will have to pass through the central area where all the shops and the leisure facilities are located and then head to their departure gate, situated along one of the arms.

Figure M.28.2 Beijing, Daxing, Aerial View, nearing completion 2019– Source: Wikipedia Photo:王之桐

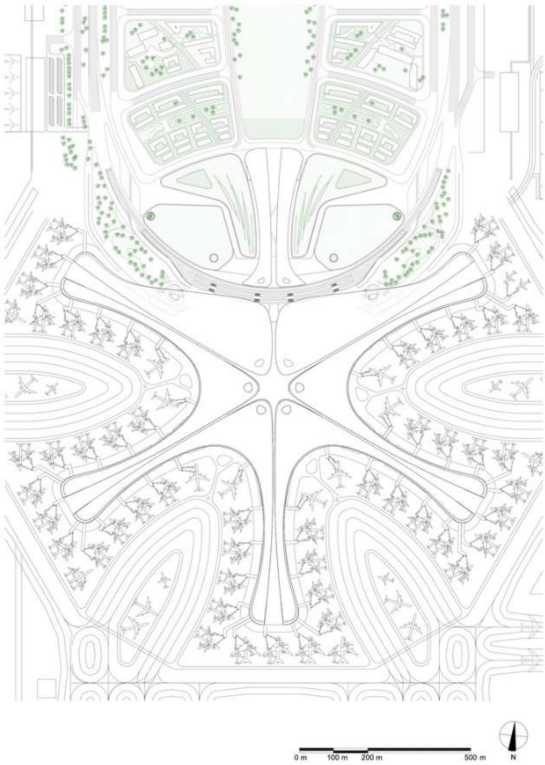


Figure M.28.3 Beijing Daxing,-Roof Plan - Source: Architecture Daily

ZHA's completed scheme conceptually consists of a compact radial design of six sculptural forms within the terminal's vaulted roof (figure M.28.2). The 100m-long structural spans allow flexibility for future reconfiguration.

A benefit of the hexagonal geometry is the walking distance between the centre and each gate has been limited to 600 metres, the maximum recommended by IATA (figures M.28.3, M.28.4, M.28.5, M.28.6, M.28.7, M.28.8 & M.28.9).

Natural light is brought into the building through a network of linear skylights, which also act as a method of wayfinding to guide passengers to and from their departure gates. All passenger amenities are located in a court at the centre of the terminal.

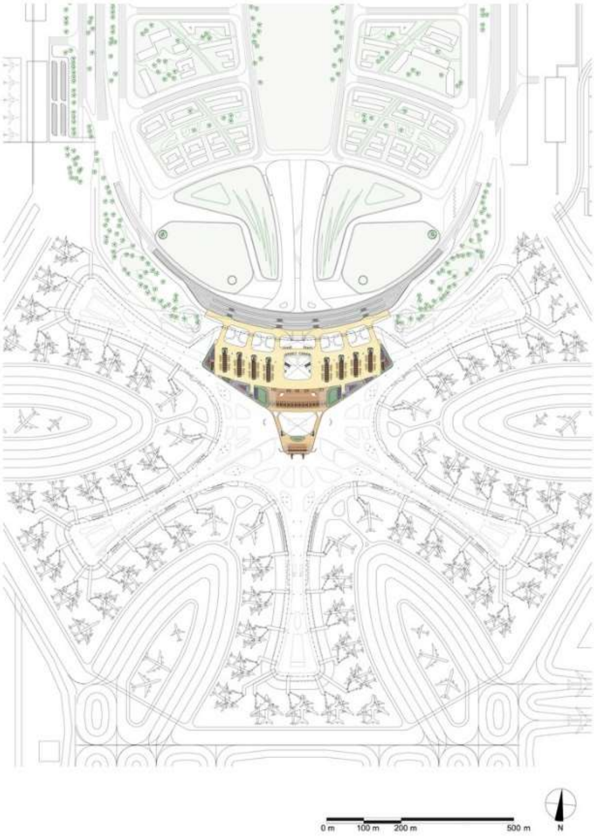


Figure M.28.4 Beijing Daxing, Level 4
Source: Architecture Daily

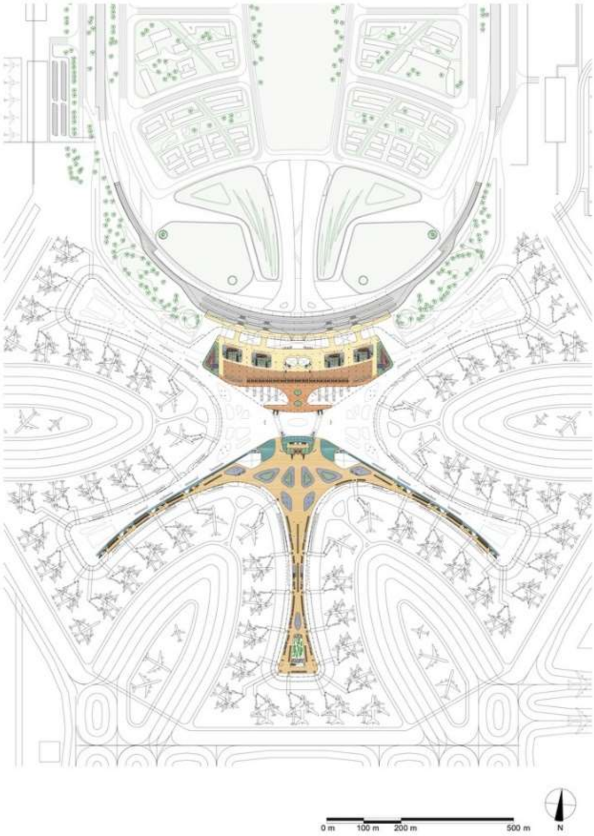


Figure M.28.5 Beijing Daxing, Level 3
Source: Architecture Daily

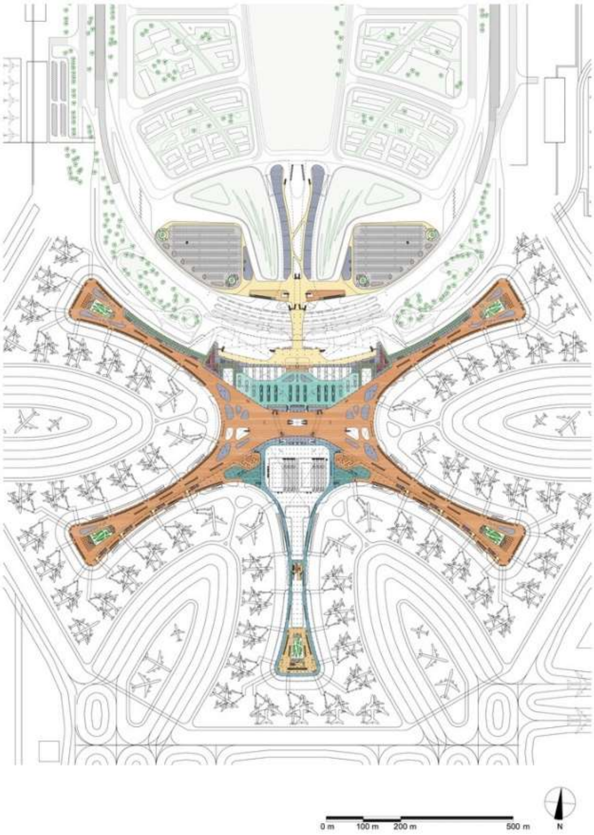


Figure M.28.6 Beijing Daxing, Level 2
Source: Architecture Daily

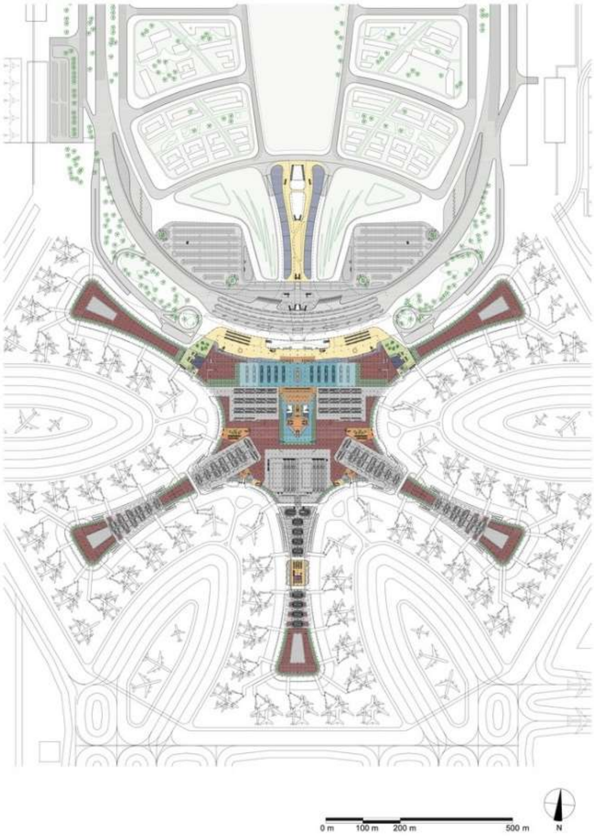
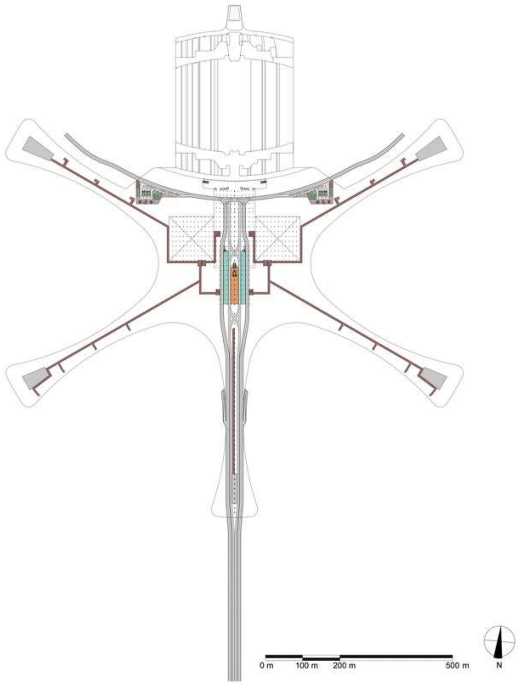


Figure M.28.7 Beijing Daxing, Level 1
Source: Architecture Daily



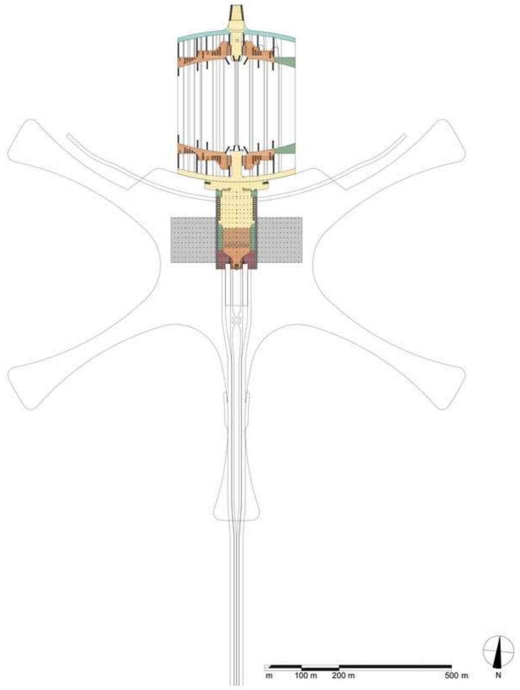


Figure M.28.8 Beijing Daxing, Basement 1
Source: Architecture Daily

Figure M.28.9 Beijing Daxing, Basement 2
Source: Architecture Daily

Figure M.28.10 Beijing Daxing, computer rendering - Source: Zaha Hadid Architects

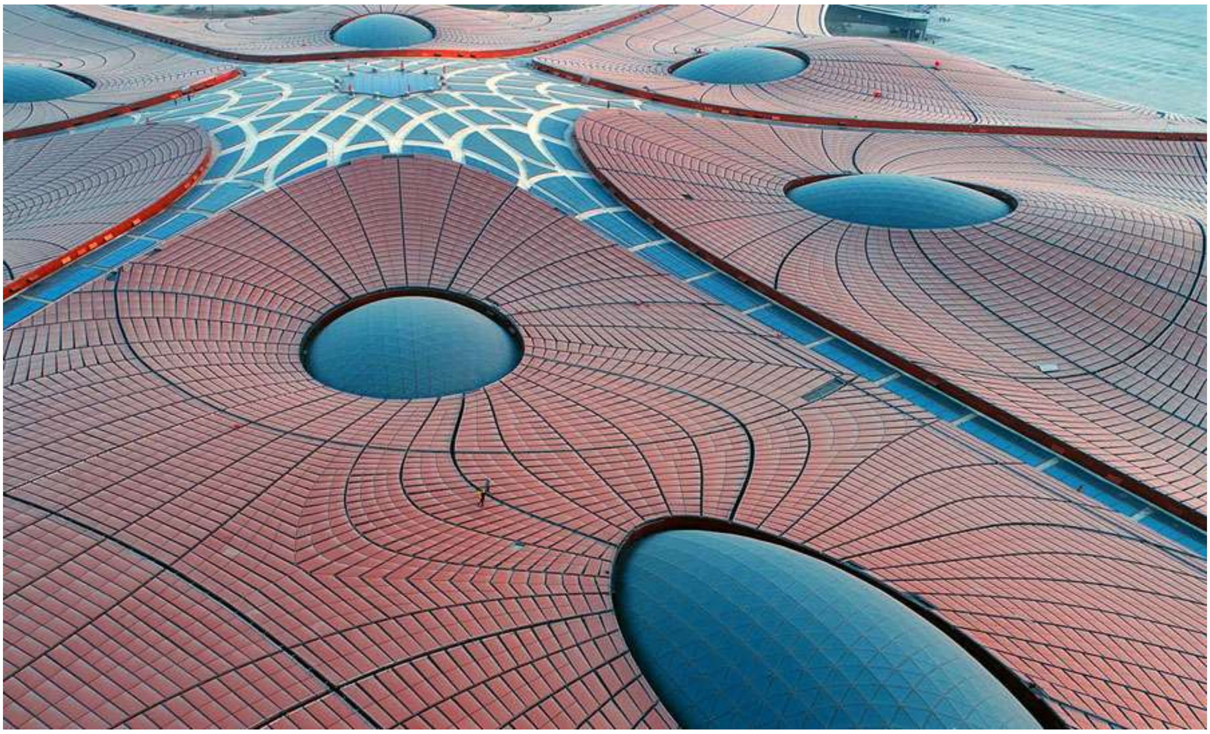


Figure M.28.11 Beijing Daxing Roof – Source: The Atlantic – Photo: Wang Mingzhu / VCG via Getty

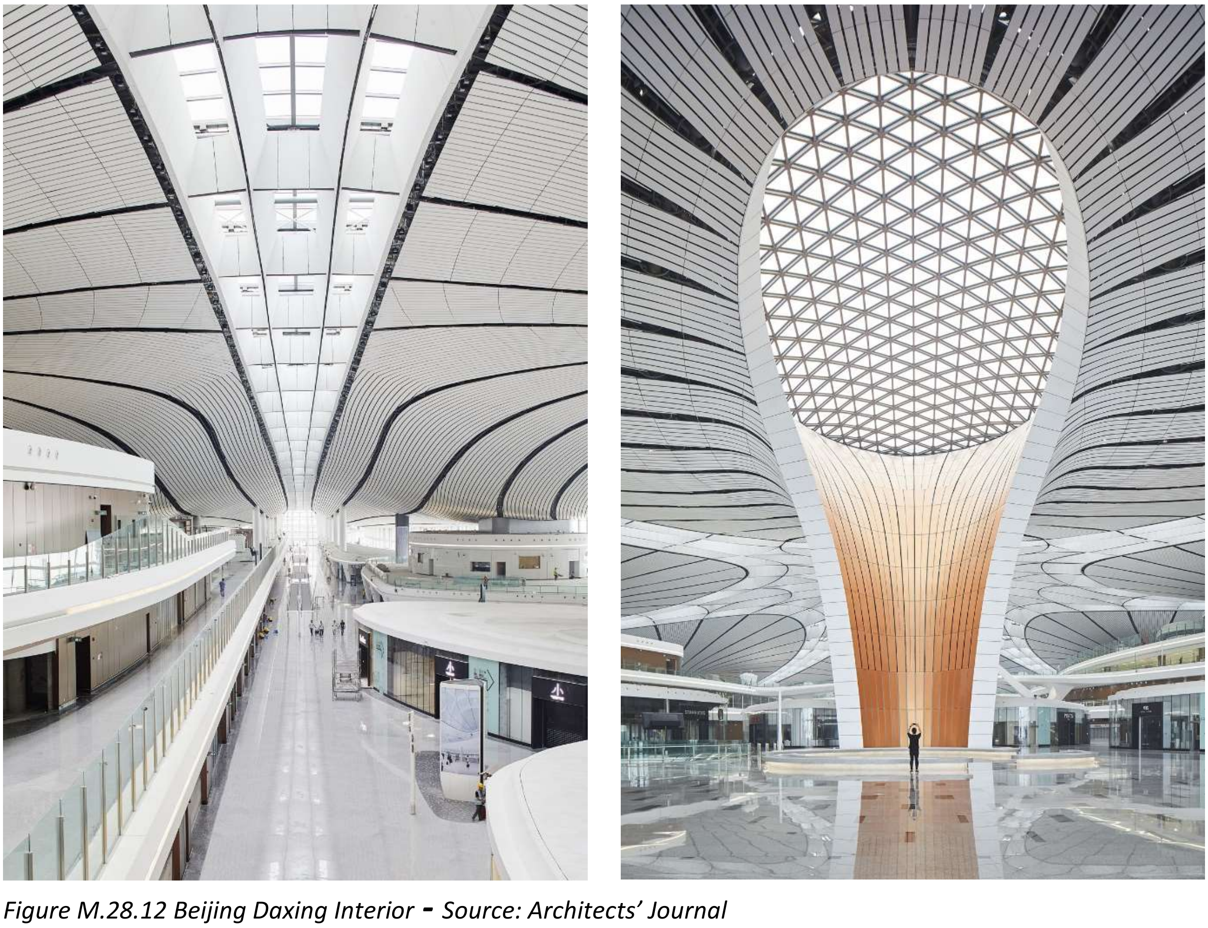


Figure M.28.12 Beijing Daxing Interior **-** *Source: Architects' Journal*

29 Mexico City (MEX)

The development of a new airport for Mexico City at Texcoco was planned in four stages. Phase I, scheduled to open by October 2020, would have consisted of one main terminal of 8,000,000 square feet (743,000m^2) and three independent runways, which would had a capacity for 68 million passengers annually. In its final Phase (2065) it would have consisted of six runways, an additional main terminal and two satellite terminals, with capacity for 125 million passengers, making it one of the largest airports in the world (figure M.29.1).

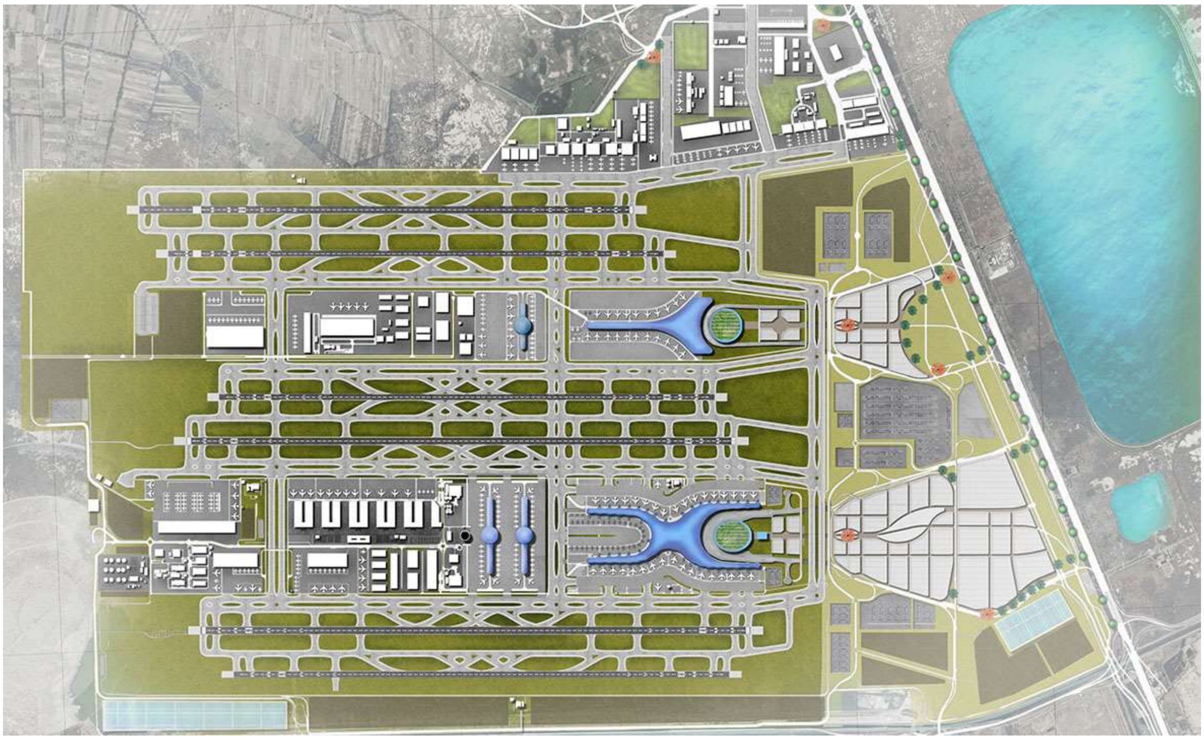


Figure M.29.1 Mexico City, Masterplan with 6 runways and 2 terminals – Source: Landrum and Brown

Figure M.29.2 Mexico City, Master Plan and CGI Aerial View - Source: Ronald Arquiteto

The terminal was designed by Norman Foster and Mexican Architect Fernando Romero . The terminal has a monumental scale inspired by Mexican architecture and symbolism. The roof of the terminal represented an eagle with its wings open to take flight. The X was also intended to be symbolic of the country's name "México". The X-shape is also promoted as an efficient alternative to the Beijing Daxing concept and provide the maximum number of gates within reasonable walking distances without a transit system. (Figures M.29.3, M.29.4, M.29.5, M.29.6, M.29.7, 11.29.8, & M.29.9). The X shape is also used in the airports of Abu Dhabi, Mumbai, Nairobi, Incheon, Pittsburgh, and SeaTac. Foster describes the concept as follows:-

'The maximum span internally is 170 metres. The lightweight glass and steel structure and soaring vaulted roof were designed for Mexico City's challenging soil conditions. Its unique pre-fabricated system could be constructed rapidly, without the need for scaffolding – the airport was to be a showcase for Mexican innovation, built by Mexican contractors and engineers. The entire terminal is enclosed within a continuous lightweight gridshell, embracing walls and roof in a single, flowing form, evocative of flight. The design ensures short walking distances and few level changes, it is easy to navigate.'

Figure M.29.3 Mexico City International, aerial view - Source: Foster + Partners

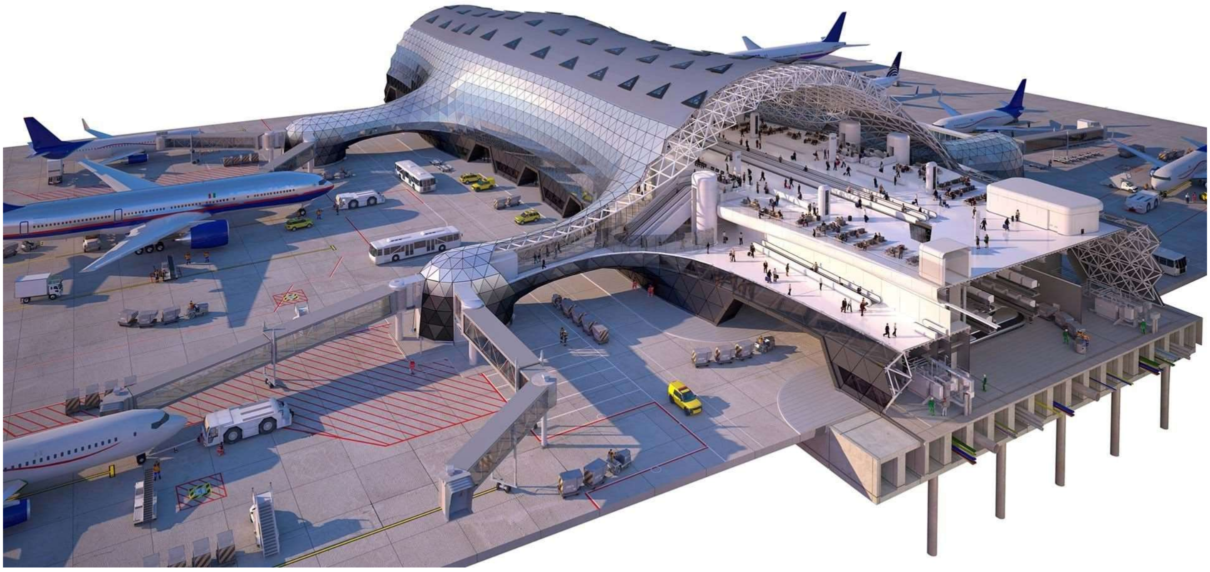


Figure M.29.4 Mexico City International, Cutaway CGI of Pier - Source: Modlar.com

'The entire building is serviced from beneath, freeing the roof of ducts and pipes and revealing the environmental skin. This hardworking structure harnesses the power of the sun, collects rainwater, provides shading, directs daylight and enables views – all while achieving a high performance envelope that meets high thermal and acoustic standards. The LEED Platinum design works with Mexico City's temperate, dry climate to fill the terminal spaces with fresh air using displacement ventilation principles. For a large part of the year, comfortable temperatures will be maintained by almost 100% outside air, with little or no additional heating or cooling required' (Foster, 2018).

Figure M.29.5 Mexico City International, Departures Forecourt – Source: Dbox for Foster & Partners

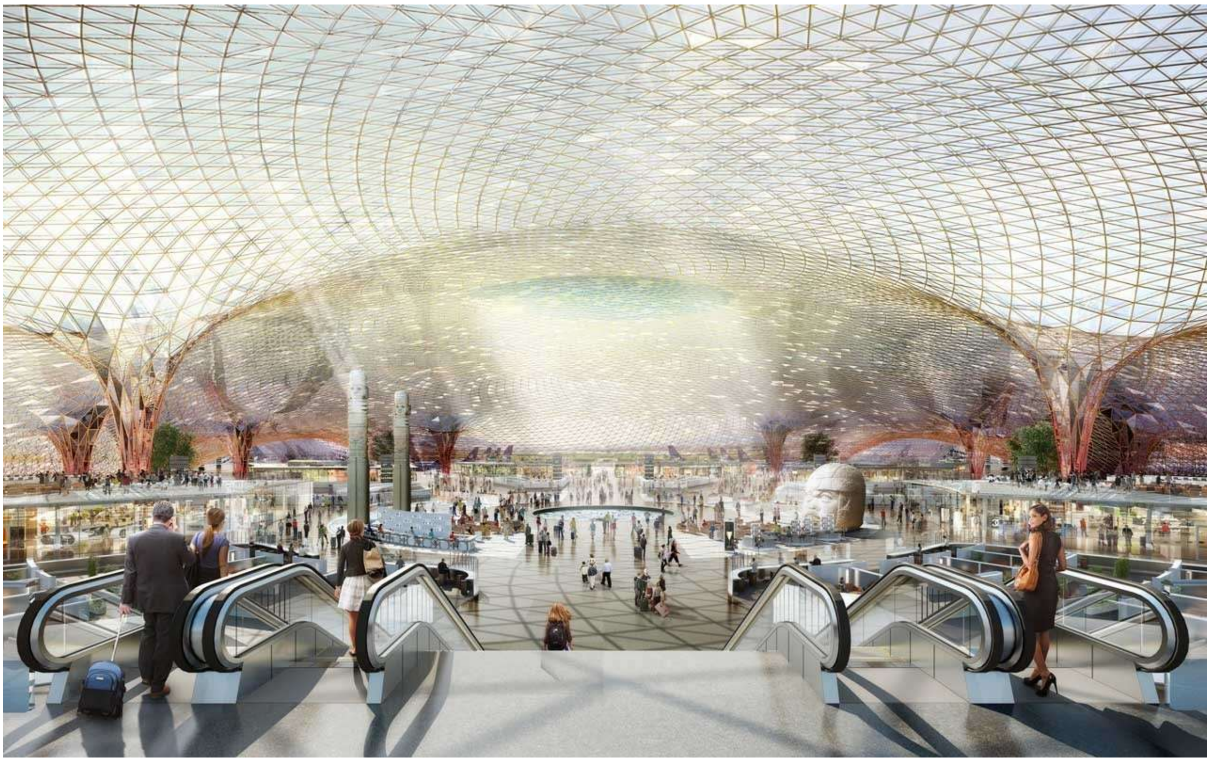


Figure M.29.6 Mexico City International, Departures Lounge – Source: Dbox for Foster & Partners


Figure M.29.7 Mexico City International Interior View – Source: Foster and Partners


Figure M.29.8 Mexico City International Interior View – Source: Foster and Partners

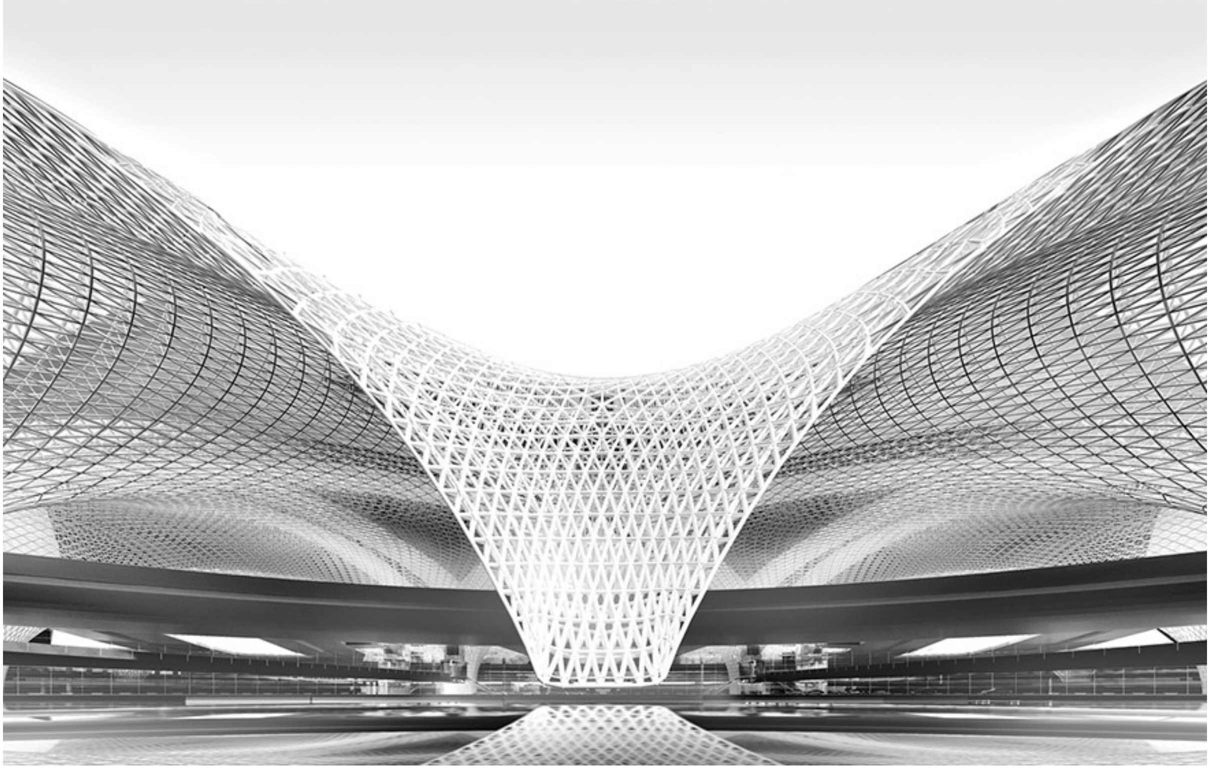


Figure M.29.9 Mexico City, Rendering - Source: Foster + Partners and FR-EE

30 Dubai World Central (DWC)

The airport will ultimately have five parallel runways, each 4500 metres long. The main terminal building will house a fully automated baggage handling system capable of handling around 240 million bags per annum. The cargo facility will allow air to sea connections to Jebel Ali Port and Free Zone (figure M.30.1) is less than four hours via a dedicated road. Over 80% of passengers passing though the airport are estimated to be transferring (figure M.30.2).

Figure M.30.1 Dubai World Central & Aerotropolis – Source: Youtube

Figure M.30.2 Dubai World Central, Model – Source: Leslie Jones Architecture

Unlike the preceding 3 new airports, Istanbul, Beijing and Mexico City, Dubai World Central plans to make use of a transit system to move all passengers around the airport and has all stands accessed from remote satellites (figures M.30.3, M.30.4, M.30.5 & M.30.6).

Figure M.30.3 Dubai World Central, Terminal building in foreground and Satellites in background
Source: International Airport Review

Figure M.30.4 Dubai World Central, Satellite – Source: Leslie Jones Architects

The project is currently under review as the economy in the region slows down, and load factors on Emirates airline have sunk to below 80%. It is now not expected to open until 2030. Dubai Airports said in 2016 it was expanding Dubai International to handle 118 million passengers a year by 2023, 18 million more than its initial cap in case the development of Al Maktoum International was delayed.

Figure M.30.5 Source: Dubai Al Maktoum International Airport

Figure M.30.6 Dubai World Central, Retail Mall – Source: Leslie Jones

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Berlin Tempelhof, described by Norman Foster as 'The Mother of all Airports'
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