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NEW AIRCRAFT CHARACTERISTICS RELATED TO AIRPORT PLANNING

Alexandre Gomes de Barros
&
Sumedha Chandana Wirasinghe

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Alexandre Gomes de Barros[1]
Sumedha Chandana Wirasinghe[2]

The compatibility of aircraft and airport facilities is of critical importance to the process of planning and design of airports. This becomes particularly true when manufacturers are carrying studies on the development of new aircraft, which might have a heavy impact on airport operations. Examples of these new developments are the New Large Aircraft (NLA) for up to 800 passengers, and the new generation of supersonic aircraft for 250 passengers. This paper reviews the main issues regarding compatibility of airport and aircraft and discusses some implications of the introduction of new aircraft.

1. INTRODUCTION

Aircraft characteristics have an important role on airport planning. Both the airport airside and landside planning are based on operating characteristics of the aircraft which will be operated at the airport. On the airside, the representative aircraft will determine the runway length and width, the minimum separation between runways and taxiways, the geometric project of taxiways, and the pavement strength. Additionally, environmental issues such as noise and air pollution are also based on the aircraft which will make use of the airport. On the terminal area, aircraft characteristics will influence the number and size of gates, and consequently the terminal configuration. Finally, the aircraft passenger capacity will influence the size of facilities within the terminal – such as passenger lounges and passenger processing systems –, and the size and type of the baggage handling system.

On the other hand, modern aircraft are also projected as a function of the airports where they are intended to operate. The costs of adapting an airport to changes in aircraft characteristics – for example, runway stretching to accommodate a larger aircraft – has become so high in the last decades that manufacturers are now concerned of fitting new developments to existing airports. For instance, the efforts of Boeing and Airbus to develop a new large aircraft (NLA) with 500 to 800 seats and a new-generation supersonic aircraft are being carried such that the runway requirements of these new products should not overcome the

[1] Research Assistant
[2] Professor of Transportation Engineering
The University of Calgary – Department of Civil Engineering
2500 University Drive NW – Calgary, Alberta, T2N 1N4 – CANADA

length of the existing runways [David, 1995; Boeing, 1994, 1996a] – what means a maximum of approximately 3500 m.

The development of new aircraft is critical to the airport planning and operation. This is particularly true when these aircraft have characteristics that may not be compatible with existing airports. This is the case of the NLA and the new-generation supersonic aircraft cited above.

The main purpose of the NLA is to accommodate the increase in demand for air transportation without overloading the air traffic. Many airports are now constrained by busy airspace and runway capacity, and the opportunity for development of aircraft able to move more people more rapidly [Building Research Board, 1989], helping relieving the effects of air traffic congestion, is in evidence. The first NLAs are expected to be flying by the year 2001 or later [Chevalier & Gamper, 1996].

In addition to the NLA, manufacturers are also developing the next generation of supersonic aircraft. The forecast demand of these aircraft is 1000 to 1500 units. This market will be generated by the doubling in long-haul, overwater travels from the year 2000 to 2015. This new-generation supersonic aircraft will be capable of carrying 250-300 passengers at a speed between Mach 2.0 and 2.5 and could fly from Los Angeles to Tokyo in less than 6 hours [Boeing, 1996a]. The first prototypes are not expected until the year 2010.

A general knowledge of the existing and projected aircraft characteristics is clearly an important requirement in airport planning [Horonjeff & McKelvey, 1994], especially when new aircraft are expected to impact airport operations. For this purpose, this paper will review, in the next sections, the main characteristics of the most used aircraft in the world and of current developments, which affect airport design. As it will be seen in the next sections, these characteristics can vary within a very wide range. Large hub airports will certainly be projected to accommodate the largest aircraft available, making the task of choosing the representative aircraft easier than for small and intermediate airports. The latter will require a careful analysis in the planning phase, since the choice of the wrong aircraft could lead either to undesirable aircraft size constraints or to an uneconomical design.

2. CHARACTERISTICS OF MAIN AIRCRAFT

The characteristics related to airport design of the most used aircraft around the world and of new ones being developed are shown in Table 1. Because some of the aircraft presented in that table are still being developed or have been released very recently, not all information are available for those ones. This is namely the case of the new members of the Boeing 737 family and of the so-called NLA being developed by Boeing (B747-X) and Airbus (VLA-600). On the other hand, very old aircraft – such as the B707 and the DC-8 – are not presented because there appears to be no sense in planning airports for aircraft which are falling in disuse. Figure 1 shows the definition of measures used in Table 1.

The differences observed between aircraft listed in Table 1 explain the difficulty stated in the last section of choosing the aircraft on which the planning of facilities will be based. For instance, runway length requirement ranges from 1,100 m (ATR-42) to over 4,400 m (DC-10-40), a difference of 300 %. The passenger capacity range is even wider: from 30 seats (EMB-120) to 800 seats (the intended capacity of B747-X). Finally, the maximum takeoff weight ranges from 11,500 kg (EMB-120) to over 770,000 kg (B747-X). It is very important to notice these differences, since they perform a high influence on airport design. Runway length is highly limited by land availability and land costs; the amount of runway required by aircraft is therefore determinant for the airport cost. Wheel track and wingspan determines the runway and taxiway widths, and the separation between those ways. Additionally, wingspan and aircraft length rules the design of the apron area. Pavement strength determination is based on the aircraft weight and on the distribution of the weight between the landing gears. Passenger terminal facilities are sized to accommodate peak hour demand, which is highly influenced by aircraft passenger capacity. In the next sections, these relationships between aircraft characteristics and airport planning matters will be discussed in more detail.

Table 1: Main aircraft characteristics

Aircraft	Wingspan (m)	Length (m)	Wheel base (m)	Wheel track (m)	Runway length (m)[a]	Passengers	Maximum takeoff weight (kg)
A300-600	44.8	53.3	18.6	9.6	2316	247-375	165000
A310-300	43.9	46.6	14.9	9.6	2308	200-280	149997
A320-200	33.8	37.5	12.5	7.6	1715	138-179	71998
A321-100	34.1	44.5	N/A	7.6	N/A	186	82200
A330-300	60.3	63.7	25.6	10.7	N/A	295-335	208000
A340-200	60.3	59.4	23.2	10.7	2316	262-375	253511
A340-300	60.3	63.7	25.6	10.7	N/A	295-335	253500
Airbus VLA-600[b]	76.0	80.0	N/A	N/A	N/A	500-600	N/A
Airbus AST2[b]	39.0	94.8	35.0	N/A	N/A	250	N/A
B727-200	32.9	46.6	19.2	5.7	2620	145-189	83823
B737-300	28.6	33.4	12.5	5.2	1920	128-149	56472
B737-400	28.6	36.5	14.3	5.2	2224	146-189	62822
B737-500	28.6	31.0	11.1	5.2	1554	108-149	52390
B737-600[b]	34.3	31.2	N/A	N/A	N/A	108-132	65090
B737-700[b]	34.3	33.6	N/A	N/A	N/A	128-149	69626
B737-800[b]	34.3	39.5	N/A	N/A	N/A	162-189	78244
B747-100	59.4	70.7	25.6	11.0	2895	452-480	322048
B747-300	59.4	70.7	25.6	11.0	2346	565-608	322048
B747-400	64.9	70.4	25.6	11.0	2681	400	362871
B747-X[b]	88.0	85.0	N/A	17.0	N/A	600-800	771101
B757-200	37.8	47.3	18.3	7.3	1767	186-239	99790
B767-200	47.5	48.5	19.7	9.3	1828	216-255	142880
B767-300	47.5	54.9	22.8	9.3	2438	261-290	156488
B777-200	60.6	63.7	25.9	11.0	2651	305-375	242670
B777-300[b]	60.6	73.8	25.9	11.0	2651	368	299369
Boeing HSCT[b]	39.6	94.5	N/A	N/A	3352	292	315000
MD-81	32.6	45.1	22.1	5.1	2209	155-172	63502
MD-87	32.6	39.7	19.2	5.1	2316	130-139	67812
MD-90-30	32.6	46.5	23.5	5.1	2072	158-172	70760
DC-10-30	50.3	55.5	22.1	10.7	2831	255-380	259453
DC-10-40	50.3	55.5	22.1	10.7	4418	255-399	251742
MD-11	51.8	61.3	24.6	10.7	2986	323-410	273287
L-1011-500	50.0	50.0	18.8	11.0	2803	246-330	231330
Concorde	25.3	62.6	18.2	7.7	3443	108-128	185064
BAC111-500	28.3	32.6	12.6	4.3	2102	86-104	53999
BAe146-300	26.2	31.0	12.5	4.7	1706	103	44225
F-28-4000	25.0	29.6	10.4	5.1	1584	85	33112
F-50	28.0	25.3	9.7	7.2	1356	50.0	20820
F-100	28.0	32.5	14.0	5.0	1720	108	44452
ATR-42-300	24.4	22.7	8.8	4.1	1090	42-50	16699
ATR-72	26.8	27.1	10.8	4.1	1408	64-74	21500
EMB-120 Brasilia	19.5	20.0	6.8	2.0	1402	30	11500

Source: Horonjeff & McKelvey [1994], Ashford & Wright [1992], David [1995], Burns & McDonnell [1995].
N/A: not available.
[a] At sea level, standard day, no wind, level runway
[b] Unreleased until this date. Data shown are preliminary.

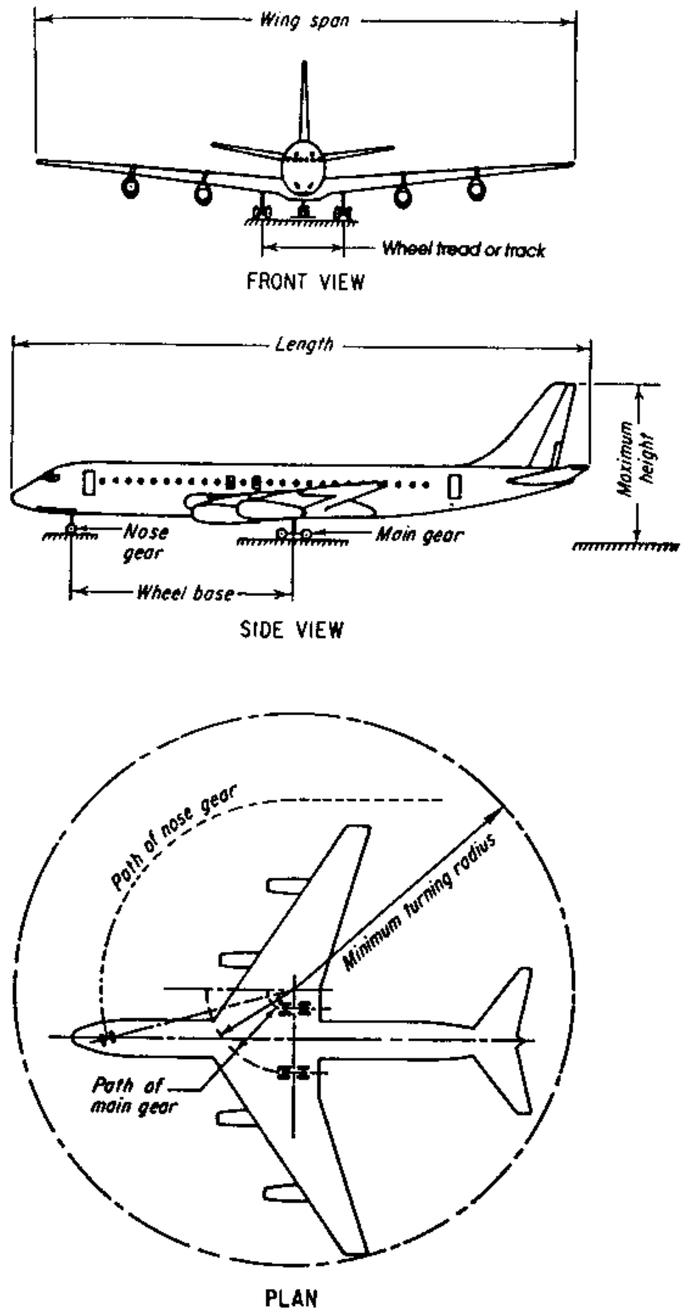

Figure 1: Aircraft dimensions
Source: Horonjeff & McKelvey [1994]

3. AIR TRAFFIC CONTROL

A minimum separation between aircraft approaching an airport is necessary because of wing tip vortex – or wake vortex – generation. Table 2 shows the FAA separation rules under IFR conditions. Wake vortex effects are generally proportional to aircraft weight [Horonjeff & McKelvey, 1994], and the lighter the following aircraft, the more it suffers from wake vortex effects, demanding greater separation from the leading aircraft. The consequence of this relationship is that runway capacity decreases as the aircraft sizes are more spread through a wider range.

So far, no study has been concluded on the wake vortex effects generated by the NLA. However, given that its height could be as much as twice the 747's, it is assumed that separation requirements will have to be increased in 1 or 2 nautical miles for the NLA [Chevallier & Gamper, 1996]. This raise in the separation will impact runway capacity. On the other hand, the number of aircraft operations is expected to be increased in a lower rate, compensating for the greater separation requirement.

Table 2: IFR Minimum Separation Rules on Approach (nm)

	Trailing aircraft type[a]		
Leading aircraft type[a]	Small	Large	Heavy
Small	3.0	3.0	3.0
Large	4.0	3.0	3.0
Heavy	6.0	5.0	4.0

Source: FAA [1978]
[a] Small: aircraft weighting no more than 12,500 lb. (5,625 kg)
Large: aircraft weighting more than 12,500 lb. (5,625 kg) and less than 300,000 lb. (135,000 kg)
Heavy: aircraft weighting in excess of 300,000 lb. (135,000 kg)

4. AIRFIELD DESIGN

4.1 Runway length requirement

The runway lengths shown in Table 1 are for reference only. They consider that the aircraft will be departing at its maximum takeoff weight, from an airport located at sea level, in a standard day, with no wind and a level runway. Actual runway length requirement will vary as the conditions cited above change. For instance, an aircraft performing a short-haul flight

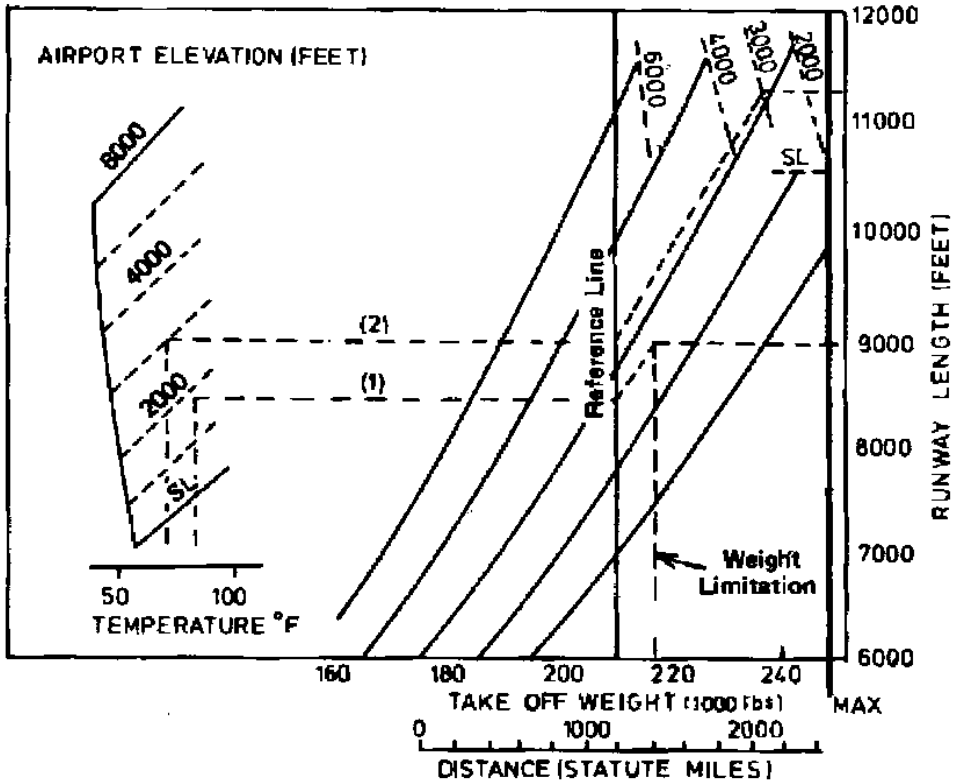

Figure 2: Aircraft performance on takeoff – large aircraft
Source: ICAO [1980]

might not be departing with its maximum takeoff weight. To assess the actual runway length requirement for a given set of conditions, it is necessary to refer to the individual operator's flight manual [Ashford & Wright, 1992]. For planning purposes, however, it is recommended to consider the maximum takeoff weight. Figure 2 shows an example of ICAO runway requirements for large aircraft.

Runway length limitation due to landing performance is very unlikely. Normally, runway requirements for takeoff are higher than those for landing. If, however, the landing requirement is higher for a given aircraft, then its landing performance will determine the runway requirement for it.

Due to land availability limitations, current runway requirements are not likely to change to accommodate new aircraft. In fact, new aircraft developments are looking at achieving performances which match the existing runway lengths (see section 1).

4.2 Runways - taxiways layout

The size of runways and taxiways and the separation between them is ruled by the size of the larger aircraft to which the airport is designed. The airport is classified in one of the categories shown in Table 3 (ICAO) or Table 4 (FAA), according to the size of the aircraft. The larger the aircraft which will operate at the airport, the higher the requirements for separations and dimensions of the runways and taxiways.

Again, the proposed NLA and supersonic aircraft represent a potential problem. Comparing the dimensions of both Boeing 747-X and Airbus VLA-600 seen in Table 1 to the categories found in Table 3 and Table 4, it can be seen that none of them fits any ICAO airport reference code, and only the Airbus plane fits FAA's group VI. Airports designed in strict compliance with these codes might have problems to operate the NLA. In fact, to partially overcome this problem, ICAO is considering the creation of a new code "F" [Fife, 1994; Chevallier & Gamper, 1996].

Figure 3 shows the proposed changes in JFK airport layout to accommodate the NLA.

Table 3: ICAO Aerodrome Reference Code

Aerodrome code number	Reference field length (m)	Aerodrome code letter	Wingspan (m)	Outer main gear-wheel span (m)
1	<800	A	<15	<4.5
2	800–<1200	B	15–<24	4.5–<6
3	1200–<1800	C	24–<36	6–<9
4	≥1800	D	36–<52	9–<14
		E	52–<65	9–<14

Source: ICAO [1990]

Table 4: FAA Airport Reference Code

Aircraft approach category	Aircraft approach speed (kn)	Airplane design group	Aircraft wingspan (m)
A	<91	I	<15
B	91–<121	II	15–<24
C	121–<141	III	24–<36
D	141–<166	IV	36–<52
E	≥166	V	52–<65
		VI	65–<80

Source: FAA [1989]. Units converted from ft to the most next integer value in m.

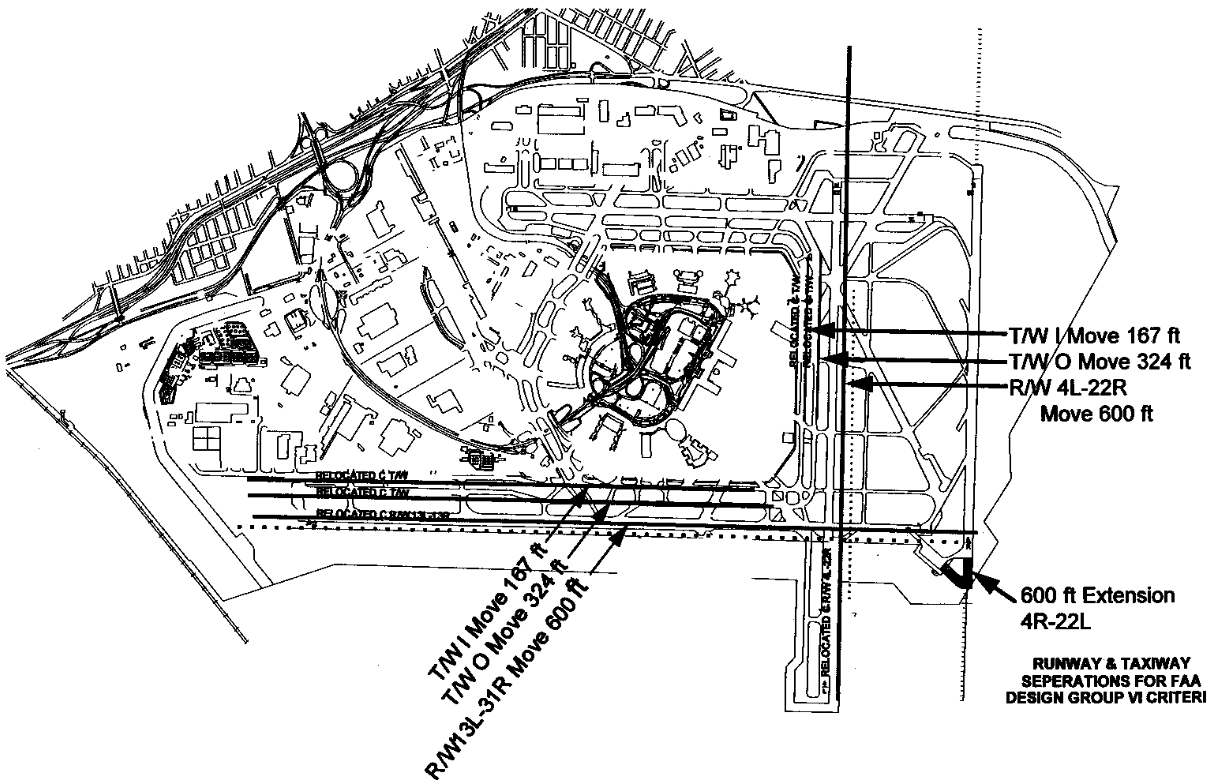

Figure 3: Proposed changes to JFK Airport to accommodate the NLA
Source: Fife [1994]

5. TERMINAL AREA

Nearly all aspects of passenger terminal planning – from the airport access to the number of gates – are affected by aircraft size and capacity. This section discusses some of those aspects.

5.1 Number of gates

The number of gates is the first variable to be considered when planning the passenger terminal. The number of gates required is directly proportional to the gate occupancy time, as it can be seen in the following equation [Bandara & Wirasinghe, 1989]:

$$G = A(T + S) \tag{1}$$

where *G* is the number of gates required, *A* is the aircraft arrival rate, *T* is the gate occupancy time and *S* is the gate separation requirement. The gate occupancy time is clearly dependent on the aircraft size – given either in passenger capacity or in weight – i.e., the larger the aircraft, the greater the occupancy time. This variable is so critical to airport gate capacity that development of new large aircraft – capable of carrying over 500 passengers in three-class configuration– is considering the use of two-level access of passengers to the aircraft, in order to allow a minimum boarding time [Gervais, 1994]. Many studies are also being carried with the purpose of maintaining the turnaround time at the current levels (90 minutes for international turnaround flights).

5.2 Apron layout

Both apron layout and ramp equipment are affected by aircraft size.

Aircraft length and wingspan, as well as the minimum turning radius – as defined in Figure 1 – will determine the distance between piers and clearances from taxiways. The distance between gates is a function of aircraft wingspan. In order to minimize the space requirement, airport terminals are usually built with gates of different sizes, such that very large aircraft have their operations restricted to a few gates. Determination of the number and size of gates must be done very carefully, in order to avoid undesired levels of congestion in the future. For example, the São Paulo/Guarulhos International Airport in Brazil has only six positions – located at the passenger terminals – which can accommodate aircraft as large as or greater than the DC-10. However, the actual aircraft mix is different from the forecast mix – there is a greater proportion of aircraft of this size than originally forecast –, and delays are being imposed to those aircraft due to lack of suitable positions [Barros & Müller, 1995].

Ramp utilities – such as fuel, electric power and others – are provided in two ways: by using a mobile vehicle or by fixed installations on the ground. In the latter case, positioning of this installations is determined by the aircraft type, as it can be seen in Figure 4. Careful is recommended when dimensioning apron facilities to the NLA, which may require 30% more equipment [Chevallier & Gumper, 1996].

5.3 Passenger processing and lounges

While aircraft external dimensions influence the airport airside design, aircraft passenger capacity affects the airport landside. In fact, one of the main functions of the passenger terminal is *change of movement type*, i.e. the accumulation of passengers who come to the airport in small groups to form batches, which will be carried together in an airplane and split into small

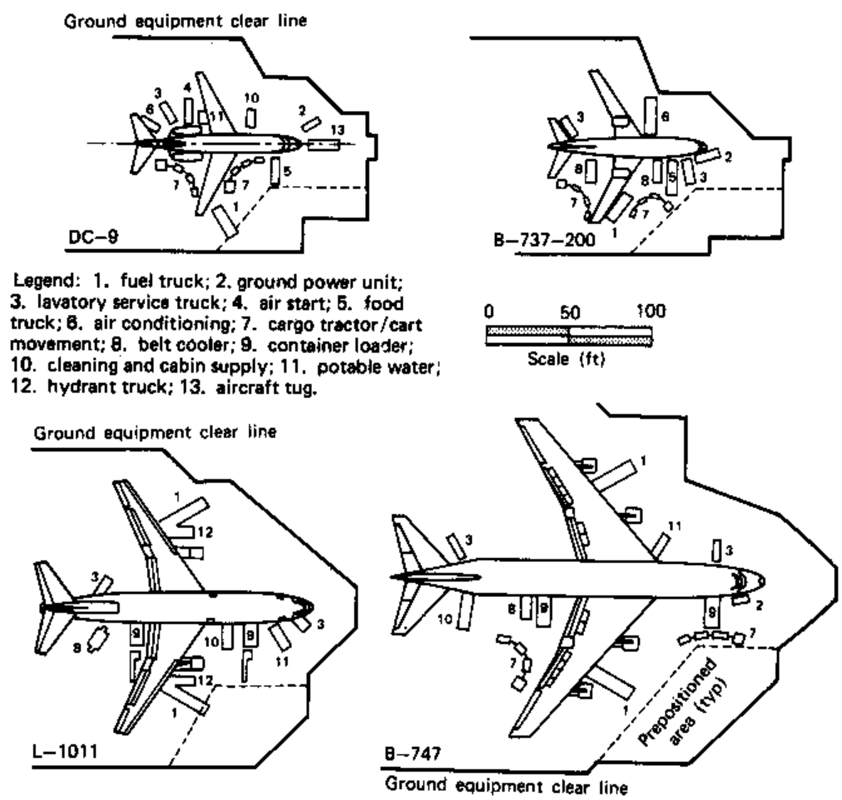

Figure 4: examples of ramp utilities equipment
Source: FAA [1989]

groups again at the destiny airport [Ashford & Wright, 1992]. That means, no matter the aircraft size, all passengers will have to be processed during a short time range. This implies that the greater the aircraft passenger capacity, the greater the passenger facilities. In fact, the NLA may necessitate a 50% increase in existing departure lounge areas [Chevallier & Gumper, 1996], and so may restaurants, rest rooms and other airside areas. Furthermore, most passengers would prefer to go on board as close as possible to the departure time, trying to enjoy their freedom of movements as much as they can before entering a crowded aircraft [Wirasinghe & Shehata, 1993]. An S-shaped curve like the one shown in Figure 5 is usually assigned to describe the passenger arrival process associated with a departure flight to any terminal facility. The dimension on the Y-axis varies with the aircraft passenger capacity. A great number of studies have been carried out to assess the impact of aircraft size on terminal facilities dimensioning – using both simulation and analytical models.

Of all the components of the passenger processing system affected by aircraft capacity, three seem to be the most critical: the check-in facilities, the departure and arrival lounges, and the baggage handling system. The number of check-in counters must increase with the aircraft capacity, if a given minimum level of service is to be achieved. The space provided for queues must also be evaluated so that crowded queues are avoided. That means, larger aircraft such as the NLA might require a higher number of check-in counters (a recent survey made with the authorities of the largest airports in the world suggested 10 to 12 as a suitable number [Chevallier & Gumper, 1996]).

The same is valid for arrival and departure lounges. An important matter in sizing departure lounges is the boarding rate, given in passengers per unit of time. Under given conditions, this rate can be considered the same for every aircraft, independent on the aircraft size. However, aircraft carrying over 500 passengers could take a long time to board all passengers. A longer time would allow smaller lounges; however, it would generate a discomfort for the passenger, forced to go on board earlier [Wirasinghe & Shehata, 1993]. For this reason, manufacturers are studying the viability of two-level boarding systems, which would allow a higher boarding rate. On the other hand, this would create the need for greater lounge areas to accommodate the increase in the number of passengers to be served. These larger areas could be accommodated, however, in two levels.

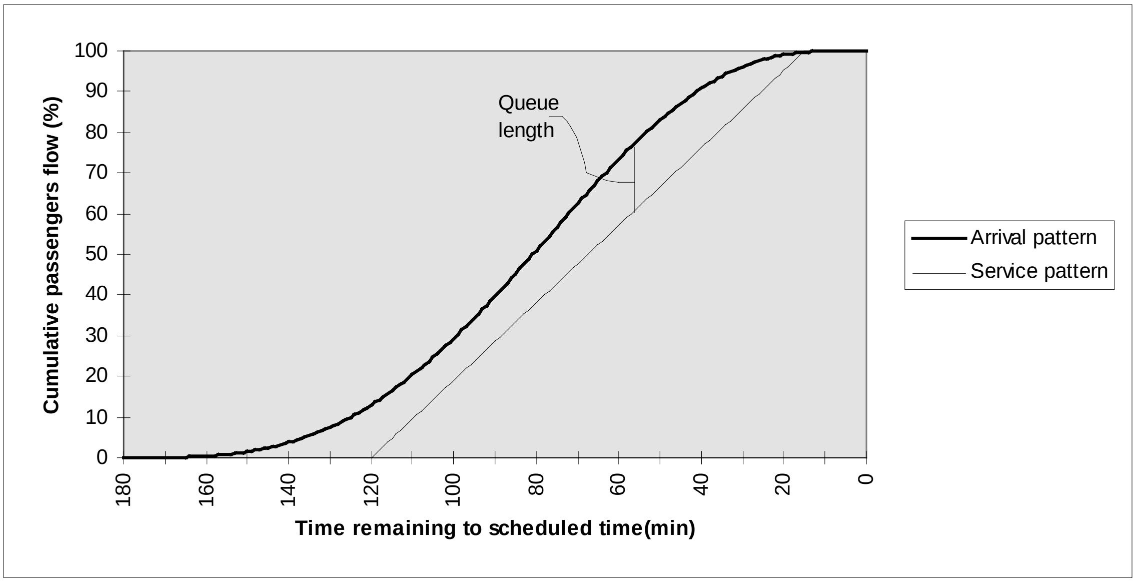

Figure 5: Typical arrival and service patterns at airport facilities

Finally, baggage handling systems also have to be capable of serving peak hour demand, if delays are to be avoided. This includes the hourly capacity of the conveyor systems, the length and number of the baggage claim carousels and the baggage claim lounge size [Tošic, 1992]. For example, the carousel length suggested by the IATA Airport Development Reference Manual for the NLA is 110 m. In airports where such a long carousel does not fit in the terminal building, two carousels should be allocated to each NLA [Chevallier & Gamper, 1996]. The obvious difficulties imposed to the passengers by such solution (one might not realize on which carousel his baggage will come) could be overcome allocating, for example, one carousel to each deck.

6. AIRPORT FIRE/EMERGENCY EQUIPMENT

Determination of the level of protection at an airport is done through the categorization of the airport. Table 5 shows the ICAO criterion of airport categorization for security purpose. The category into which the airport is assigned determines the level of protection necessary. The assignment of an airport to a category is done by the following criteria based on aircraft movements in the busiest consecutive three months of the year [Ashford, Stanton & Moore, 1984]:

1. When the number of movements of the longest aircraft in the same category totals 700 or more, that category should be adopted.

2. When the number of movements of the longest aircraft in the same category totals less than 700, the airport category adopted should not be lower than one below that of the longest aircraft normally using the airport.
3. When there is a wide range in the lengths of the aircraft that are included in the 700 movements, the category adopted may be reduced to be no lower than two categories below that of the longest aircraft.

As can be seen in Table 1 and Table 5, neither the NLA nor the new supersonic aircraft fit any category in the ICAO classification. It looks like the NLA, whose passenger capacity is as much as twice the B747's, might represent a major concern. The proposed design of the NLA includes a second deck and, consequently, a much higher passenger capacity. Thus emergency procedures, equipment and staff requirements might be completely different for the NLA, requiring much research still to be carried. In the same way, the supersonic developments are much longer than any existing aircraft, and might also require specific studies regarding emergence equipment and procedures.

Table 5: Airport categorization for security purpose

Airport Category	Airplane Overall Length (m)
1	0-9
2	9-12
3	12-18
4	18-24
5	24-28
6	28-39
7	39-49
8	49-61
9	61-76

Source: ICAO [1983]

7. CONCLUSIONS

It has been shown in this paper that, since airports are designed as a function of the aircraft it will serve, aircraft characteristics highly influence the size and operation of the airport facilities. Planners must be careful when choosing the aircraft on which airport design will be based. It has been shown that aircraft dimensions can vary considerably, and the choice of the wrong representative aircraft can lead either to uneconomical design or to insufficient airport capacity, resulting in a low level of service.

The development of the NLA and of the next generation of supersonic aircraft is also an important matter to be studied now. As seen above, the introduction of the NLA will impact practically all aspects of airport planning, from runway capacity to the number of car parking lots. This paper has discussed some of these impacts, but much research is still necessary to evaluate the overall impact of these new aircraft developments on the airside and especially on the landside facilities. New airports and even expansion of existing facilities may not fail to recognize the importance of these questions, under risk of very bad consequences to airport operations and level of service.

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