Analysis of Trends in Aircraft Sizing and Fleet Mix: Implications for Airport Design

Florian Poirier
University of California at Berkeley
National Center of Excellence for Aviation Operations Research (NEXTOR)
107A McLaughlin Hall, Berkeley, CA 94720
Phone: (510) 642-5896 Fax: (510) 642-5687
florip@berkeley.edu

Jasenka Rakas
University of California at Berkeley
National Center of Excellence for Aviation Operations Research (NEXTOR)
107B McLaughlin Hall, Berkeley, CA 94720
Phone: (510) 642-9064 Fax: (510) 642-5687
jrakas@berkeley.edu

Linda J. Perry
Jacobs Consultancy
555 Airport Boulevard, Suite 300
Burlingame, CA 94010
Phone: (650)375-5311 Fax: (650) 343-5220
Linda.Perry@jacobs-consultancy.com

ABSTRACT

This paper analyzes current trends in aircraft characteristics and fleet mix and the implications of these trends on airport design.

The airline industry is continuously exploring new ways of efficiently and economically operating their fleets in order to overcome the economic and financial pressures of a competitive operating environment. In response to these challenges, airlines are introducing aircraft into their fleets with lower fuel consumption and geometric characteristics to improve aircraft performance and efficiency. In the near future, the efficiency of gate operations and other airport facilities could be significantly impacted if the trends and changes in aircraft characteristics and airline fleet mix profiles are not well analyzed, projected, and accommodated.

In this study, a comprehensive database is developed to estimate trends in important aircraft and airline characteristics, including aircraft wingspan and length, cargo payload, passenger seating capacity and configuration, aircraft purchase orders, and airline fleet mix. The results of this analysis are used to (i) determine future airfield and gate design deficiencies and (ii) evaluate how those trends may affect the future design of airport terminal areas and airfield geometry. In long-term planning, this study should be useful to airport planners and designers for better sizing of airfield infrastructure in accommodating projected aircraft fleet mix profiles.

Keywords: Airport Design, Fleet Mix Trends, Aircraft Trends.

INTRODUCTION

The financial and economic conditions facing the airline industry in recent years (i.e., airline bankruptcies, mergers, and consolidations, increasing fuel costs, the expansion of low-cost carriers into large hub markets, and the increasing use of regional jets) have resulted in a continued re-evaluation of airline fleet mix and efficiencies. Airlines are modifying their fleet mixes to minimize costs, adding winglets to increase efficiencies, and downsizing fleets in the face of financial uncertainty. In addition, aircraft manufacturers are responding to these trends by designing aircraft with increasing wing aspect ratios and other characteristics to increase fuel efficiencies and aircraft capacity. As a result, data on the aircraft fleet and new aircraft orders are constantly changing at the same time that an understanding of these trends is important to evaluating the implications for airport facility planning and requirements.

BACKGROUND

Existing literature on aircraft characteristics and airport design is rich in standard engineering tables and figures (*1,2,3,4,*) that provide guidelines to airport designers and engineers about planning and sizing of airport airside facilities (*5,6*). In recent years, special attention was given to new airfield requirements for New Large Aircraft (NLA) (7,8), with new standards being already applied to airports around the world that expect NLA operations. New airport classifications have also been proposed, suggesting that the proportion of different aircraft categories should be further accounted for prior to determining airport classes (*9*). The emerging trends in aircraft design and the related implications for airport planning gain a sharper perspective in the context of the historical changes that have occurred since the first commercial flight. A few selected historical examples are noted in the following paragraphs.

In 1928, Boeing introduced the Model 80, with a fuselage made of welded-steel tubing, removable wooden wingtips so the airplane could fit into the hangars along its route, and a seating configuration for 12 passengers. The facility requirements for these aircraft were minimal, consisting of a hangar and a section of apron space.

In 1933, the Douglas Aircraft Company introduced the DC-1, with a streamlined fuselage, shorter wingspan (56 feet vs. 80 feet for the Model 80A) and all-metal construction. The airport terminal of the time allowed passengers to board their flights from the tarmac without the aid of modern day loading bridges and jetways.

In 1935, the DC-3 was introduced with a wingspan that was 39 feet wider than that of the DC-1 and a fuselage that was 5 feet longer than that for the DC-1. Between 1938 and 1959, Douglas Aircraft Company introduced the DC-4 and DC-6 aircraft, each with wingspans 23 feet wider than that of the DC-3, aircraft lengths longer than that of the DC-3 (93 feet for the DC-4 and 101 feet for the DC-6), and seating configurations of 102 passengers (compared with 28 passengers on the DC-3). At this time, passengers were still boarding the DC-6 aircraft using stairs from the tarmac.

The DC-7 was the last propeller driven aircraft produced by Douglas Aircraft Company and led to the development of the DC-8, the first jet powered commercial transport and the beginning of the large capacity aircraft which presented a new set of challenges for airport operators. The Douglas Aircraft Company produced seven different Series of the DC-8, including the DC-8-63 which could fly more than 4,500 miles nonstop and carry 259 passengers because of its extended fuselage, aerodynamic improvements to nacelles, pylons and flaps, and increased wingspan and fuel capacity. For airport operators, the large capacity of the DC-8 created the need for additional terminal space to accommodate a large number of passengers (more than twice the number carried on the DC-6) and loading bridges to enplane and deplane passengers.

From the Model 80A aircraft parked at a simple hangar to the DC-8 aircraft positioned next to one of the first passenger loading bridges, changes in aircraft characteristics have provided the impetus for new designs in airport planning. While many airport designs of the past were created in response to changes in aircraft characteristics, modern day airport operators are also faced with understanding the financial and operational conditions of airlines that serve their airports and devising strategies to maximize the use of their facilities and minimize costs to all stakeholders. It is the understanding of these challenges for airport operators in planning and designing their facilities that provided the impetus for conducting this research.

OBJECTIVE AND SCOPE

The primary objective of this research was to identify and analyze trends in the aircraft geometric characteristics of the future aircraft fleet mix and evaluate how those trends may affect the future design of airport terminal areas and airfield geometry.

METHODOLOGY

The methodology used in conducting this research included (1) compiling a database on current and future aircraft fleet mix and trends of more than 70 airlines, (2) refining the database to reflect future trends, and (3) analyzing these trends in relation to information on airport design.

Information was collected from aircraft manufacturers and airlines, using company annual reports, press releases, news releases and specialized books. A large sample was collected (data for 10,901 aircraft) for airlines with a range of operational characteristics (domestic, international, freight), including information on airline alliances, code shares, and the number of owned or capital/operating leased aircraft among those currently in service.

After the initial data was compiled, the results were evaluated and additional data sources and aircraft characteristics were identified. Additional data was collected on future airline fleet mixes to provide a more complete foundation for conducting an analysis of future trends.

RECENT TRENDS IN AIRCRAFT DESIGN

This research covers two recent trends in aircraft design: (1) the increasing use of blended winglet technology, and (2) the use of regional jets to augment or replace existing large jet service.

Blended Winglet Technology

In the face of increasing fuel prices, airlines have limited options to minimize fuel costs as a share of their operating costs. If the financial situation of an airline permits, an airline can buy the latest models of the most fuel efficient aircraft to reduce operating costs. If the cost of operating an existing aircraft exceeds the expected revenue, an airline can retire that aircraft but, in doing so, loses the seating capacity and future revenue of that aircraft. Another option that has surfaced in recent years is to adapt blended winglets on the wings of aircraft in order to improve fuel and operational performance. A number of airlines, including Southwest, Alaska, and Continental airlines, have taken advantage of this alternative, proposed by Aviation Partners Boeing (APB). Some aerodynamic experts are still pessimistic concerning the advantages provided by classic winglets (due to the marginal benefits related to the weight added by winglets). However, blended winglets have been proven to improve aircraft efficiency by 3% to 5% depending on the range of the flight (*10*).

Description and Benefits of Blended Winglets

The first winglet technology was introduced in 1976 at NASA, when vertical wingtip extensions were invented as a means to increase lift-to-drag performance (*10*). Although blended winglets have been in use, the blended winglets produced by APB are being installed in large numbers as a result of airline efforts to increase fuel efficiencies and performance. As shown in Figure 1, the installation of blended winglets at the tip of a B737-800 wing increased the wingspan by 4 feet 7 inches.

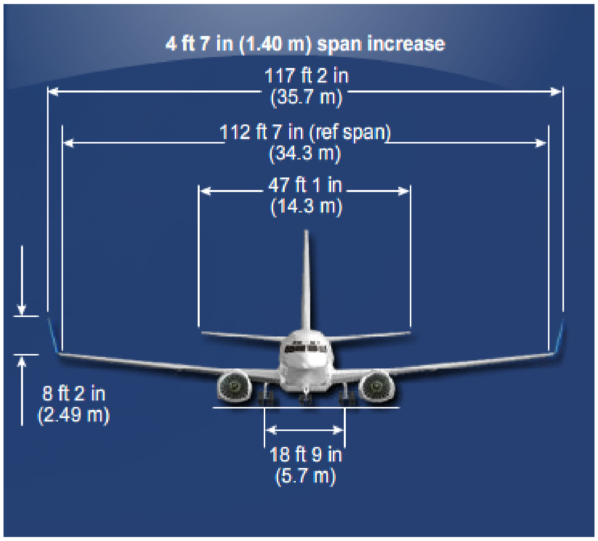


FIGURE 1 Blended Winglet aspect ratio and wingspan increase for a B737-800. (*11*)

As shown in Table 1, the change in aircraft wingspan from the addition of blended winglets ranges from about 5 feet to as much as 11 feet. The increased wingspan from the addition of blended winglets may impact airport operations and the configuration of gate and apron space, depending on the configuration of airport gates, the types of aircraft parked at adjacent gates, and the operating procedures of individual airlines.

TABLE 1 Change in Aircraft Wingspan from the Addition of Winglets (*11*)

Equipment type	Original wingspan	Increase in wingspan from the addition of winglets	Total wingspan
B737-300	94 ft 9 in	**7 ft 4 in**	102 ft 1 in
B737-500	94 ft 8 in	in development	--
B737-700	112 ft 7 in	**4 ft 7 in**	117 ft 2 in
B737-800	112 ft 7 in	**4 ft 7 in**	117 ft 2 in
B737-900	112 ft 7 in	**4 ft 10 in**	117 ft 5 in
B757-200	124 ft 10 in	**9 ft 9 in**	124 ft 10 in
B767-300ER	156 ft 1 in	**10 ft 11 in**	167 ft

The shape of a blended winglet differs from the conventional wing in many ways. There is a smooth and continuous curve to link the tip of the wing to the winglet, which allows for the perfect integration of the winglet to the wing. The installation can be done in less than one week for retrofitting (usually during a C-type check) and even quicker for an in-production installation.

In addition to increasing the market value and useful life of an aircraft, blended winglets increase fuel efficiencies and result in the reduction of fuel consumption during a flight, all other parameters constant. The share of fuel expense in total airline operating costs has increased significantly in recent years. For example, the fuel cost share of total airline operating costs for US Airways increased from 13.4% in 2004 to 21.5% in 2006, in response to increases in the average price per gallon of fuel (*12*).

Airlines, particularly low cost airlines, are constantly looking for ways to reduce operating costs. Blended Winglets appear to have several added benefits, including: (*11*).

1. Lower block fuel by reducing the drag due to vortex.
2. Increased payload-range capability by increasing the range and possible seating configuration of the aircraft, as well as adding a margin of safety for over water flights.
3. Lower emissions, because less stress is placed on the engines.
4. Reduced engine maintenance costs.
5. Improved take-off performance, useful at high-altitude airports or at warm weather airports.
6. Higher initial/optimal cruise altitudes, and, as a result, reduced airport community noise.
7. Significantly different appearance and higher aircraft residual value.

As of June 2007, at least 117 airlines and leasing companies had ordered blended winglets to equip existing aircraft in their fleet. Most airlines and leasing companies, after trying blended winglets on one aircraft type in their fleet, have decided to equip their entire fleet, in large part because the return on blended winglets is significant. An average of three years are required to return the financial investment of installing blended winglets, a short time in comparison with the 35-years average life expectancy of an aircraft.

Blended Winglets for the Boeing 737 New Generation Aircraft

In recent years, blended winglets have been installed in two different ways: (1) by retrofitting an existing aircraft or (2) by installing the kit during the construction of an aircraft. In this study, data are evaluated for the number of blended winglets installed on the Boeing 737 New Generation aircraft, in particular, the Series 700 and 800, largely because these aircraft are the first to adapt this technology and the number of units installed represents a large sample. A total of approximately 2,180 Boeing 737 New Generation aircraft have been produced to date, making it the most popular aircraft [*13*]. Using information provided by the manufacturer, Figure 3 presents the trends in the number of B737-700/800 aircraft equipped with blended winglets [*14*].

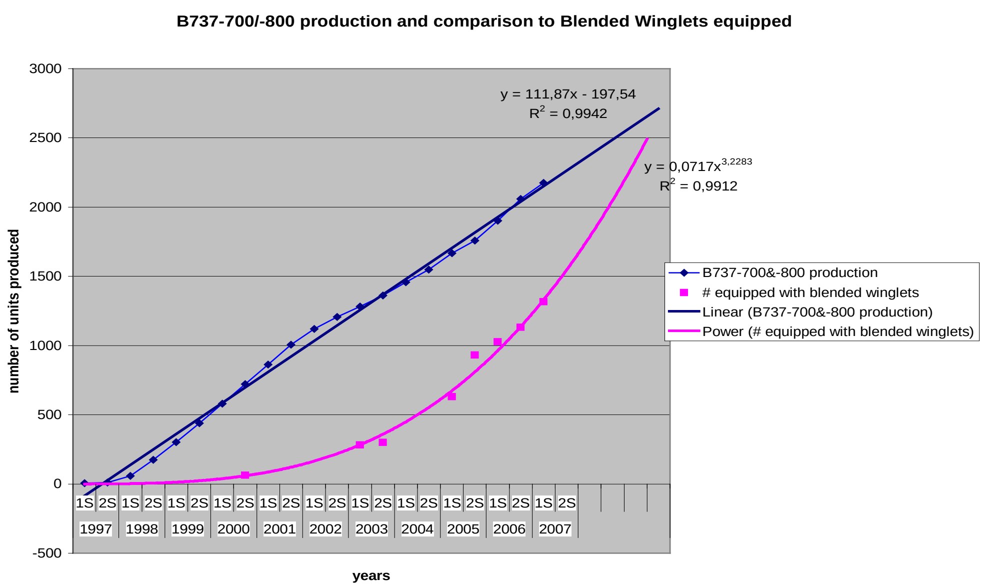


FIGURE 2 B737-700 and 800 Series trends: total production vs. blended wings. [*14*]

Figure 2 presents the trends in the number of B737-700/800 aircraft equipped with blended winglets based on information provided by the manufacturer. A regression analysis of the production of B737-700/800 aircraft explains 99% of the linear trend (R^2 coefficient equal to 0.9942). In comparison, the number of B737-700/800 aircraft equipped with Blended Winglets can be approximated by a logarithmic regression, with an R^2 coefficient of 0.9912. Hence, the analysis results reveal that the addition of blended winglets to the B737-700/-800 fleet will continue at an increasing rate in the near-term. As a result, it is likely that nearly 90% of B737-700/-800 aircraft will be equipped with blended winglets by early 2009, compared with 60% today.

After 2009, based on this analysis, it is expected that the addition of blended winglets will continue but at a decreasing rate, reaching an inflexion point in 2 years. This means that the logarithmic expression defining the addition of blended winglets will converge toward the production equation. As a result, all the new aircraft produced will be equipped with blended winglets in-production (the Boeing Business Jet version is the only case to date). If this situation is realized, the two curves will be strictly parallel because some airlines will not add winglets if the aircraft is too old or if aircraft are already stored or inactive.

Additional data on the orders and deliveries of the B737-700/-800 aircraft with blended winglets, specifically for Aviation Partners Boeing customers, are presented in Figure 3. The concave downwards shape of the curve is similar to the logarithmic expression explaining the addition of blended winglets described earlier and confirms the expected fast rate of blended winglet additions in the near-term. However, it should be noted that the number of aircraft with blended winglets includes aircraft options (which may change) and assumptions regarding the expected schedule of blended winglet installations and delivery dates which are also subject to change.

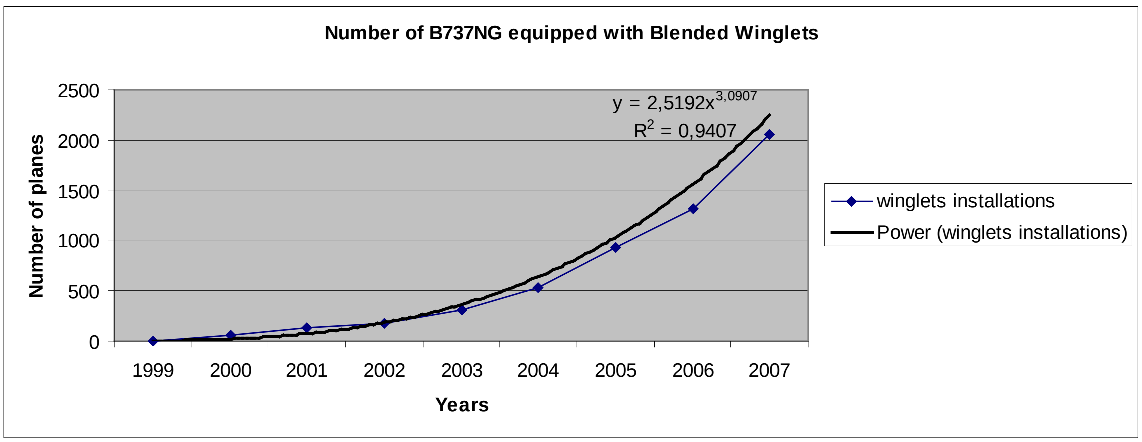


FIGURE 3 Additional data for Boeing 737 New Generation aircraft equipped with blended winglets.

Aircraft other than the B737-700/800 aircraft are also being fitted for blended winglets, including Airbus' A320 Series. Although Aviation Partners Boeing continues to develop this technology for all the Boeing aircraft, it is important to note that all aircraft do not necessary need blended winglets. For example, the Long Range series aircraft are already designed to improve range. In some cases, winglets can have adverse effects on gate facilities. For instance, a B747-400 equipped with winglets would exceed wingtip clearances for apron parking and require a reconfiguration of gate facilities.

The Increasing Use of Regional Aircraft

The increasing use of regional aircraft (regional jets and turboprop aircraft) also presents challenges in predicting trends in aircraft sizing and fleet mix and in understanding the implications for airport design. According to the forecasts of regional aircraft manufacturers, the demand for regional aircraft is increasing. Bombardier's Business Aircraft Market forecasts for 2007 are for the delivery of approximately 995 regional jet (and turboprops) annually over a 10-year period, for a total forecast of 9,950 deliveries in the 10 year-period and 11,200 new aircraft in the 20-year period from 2007 to 2026 (*15*). The strong growth in regional aircraft forecast by aircraft manufacturers is also supported by a number of market factors, including the financial pressures on airlines to abandon non-profitable routes and the increasing competition from low cost carriers. As a result, regional airlines have increasing opportunities to serve outsourced routes and provide feed to major airline hubs.

To evaluate the regional aircraft market in recent years, data for deliveries and orders were obtained from a number of regional aircraft manufacturers, including ATR, Embraer, Saab, Bombardier Canadair, Fokker and British Aerospace. Over the next seven-year period, Embraer and Bombardier are forecast to account for more than 70% of the regional aircraft market, with shares of 38.3 percent and 32.5 percent, respectively (16). For the purposes of this analysis, data for regional aircraft deliveries (excluding aircraft retirements) have been sorted by 3 main classes of seating capacity: 20 to 59-seats, 60 to 99-seats and 100 to 149-seats. As shown in Figure 4, it is important to note that:

1) The 20 to 59-seat class accounts for 68% of the total number of regional aircraft for the selected aircraft manufacturers, down from 74% three years ago. This decrease reflects the increasing demand for regional aircraft with greater seating capacities. Much of the growth in this class is accounted for by the 50-seat regional jet, with nearly 1,800 aircraft in operation worldwide today.
2) The 60 to 99-seat class developed rapidly in recent years with the production of the Embraer170/175 and CRJ700/900 aircraft. The current demand for this class of regional aircraft reflects the interest by low costs airlines to develop underserved point-to-point narrowbody routes and additional demand for 50-seat routes.
3) The 100 to 149-seat class for regional aircraft manufacturers has not yet been fully developed. Existing aircraft in this class include the Fokker 100, MD-80, DC-9 and older series of the B737.

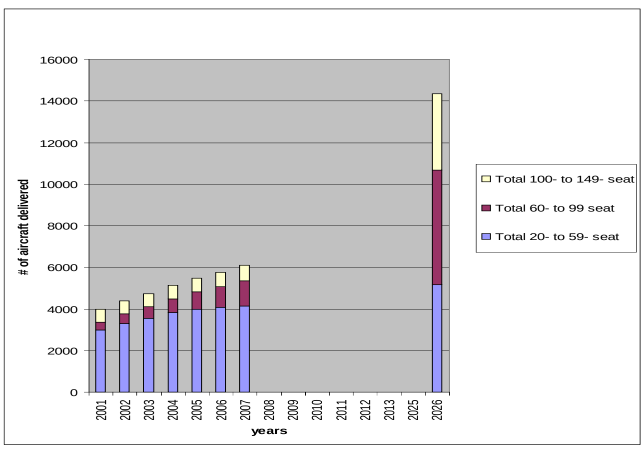


FIGURE 4 Expected regional aircraft deliveries.

As shown in Figure 5, the total number of regional aircraft deliveries increased by 50% between 2001 and 2007—from 4,000 to 6,000. The growth in regional jets has outpaced the growth in turboprop aircraft since 2001, with regional jets accounting for more than half of all deliveries in 2007.

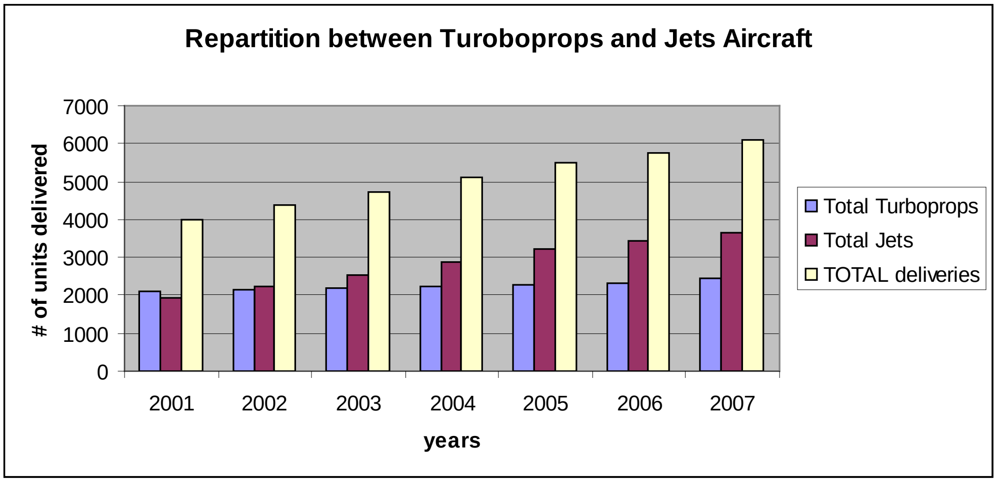


FIGURE 5 Regional jet and turboprop aircraft deliveries.

Regional jets are increasing in size, in terms of the average number of seats per aircraft, in response to an increasing demand for service to small markets and as a means to increase frequencies and improve the level of service. In addition to the challenges that regional jets may present for airport facility requirements (in terms of wing span and length), the smaller seating capacity and increasing frequencies of regional jets mean a greater number of operations to serve the same passenger base, which, in turn puts pressure on airfield capacity requirements. Ten years ago, most aviation forecasts, including the Federal Aviation Administration's (FAA's), assumed that the aircraft size will increase for the domestic fleet in terms of seats per departure. In recent years, because of the increasing number of regional jets, aviation forecasts (including the FAA's) have included assumptions for a decrease in aircraft size. Today, regional jets are increasing in size such that the average aircraft size for the domestic fleet is beginning to stabilize and is forecast to increase slightly in the next ten years.

EVALUATION OF RECENT TRENDS IN AIRCRAFT SIZING AND FLEET MIX

In this study, an evaluation of (1) the trends in average aircraft seating capacity and (2) the trends in aircraft wingspan and fuselage length was conducted using the 10,901 aircraft included in the database.

Trends in Average Aircraft Seating Capacity

As shown in Figure 6, there are two notable groupings of aircraft by seating capacity: (1) 30 to 70 seat aircraft and (2) 120 to 180 seat aircraft. The 30 to 70 seat aircraft include regional jets and turboprop aircraft used in domestic service to secondary airports and connecting airline hubs. The 120 to 180 seat aircraft account for more than one third of all the aircraft included in the database, with the representative aircraft being the B737 or the single aisle family of Airbus. It also important to note that there is a gap between the two groupings of aircraft shown in Figure 7 in the 100 seat aircraft category. The development of aircraft in the 100 seat category may prove to be the source of future growth in the aircraft fleet.

Aircraft manufacturers have already started to develop aircraft in the 100 seat category, such as the Embraer 190, to accommodate the demand for larger regional jet aircraft to serve secondary markets as well as the demand for smaller jet aircraft at major airline hubs to manage capacity, increase frequencies, and improve service levels. The geometric characteristics of the aircraft developed in the 100 seat category could have implications for airport design and facility requirements in terms of the space required for the apron parking area, boarding bridges and holdroom areas.

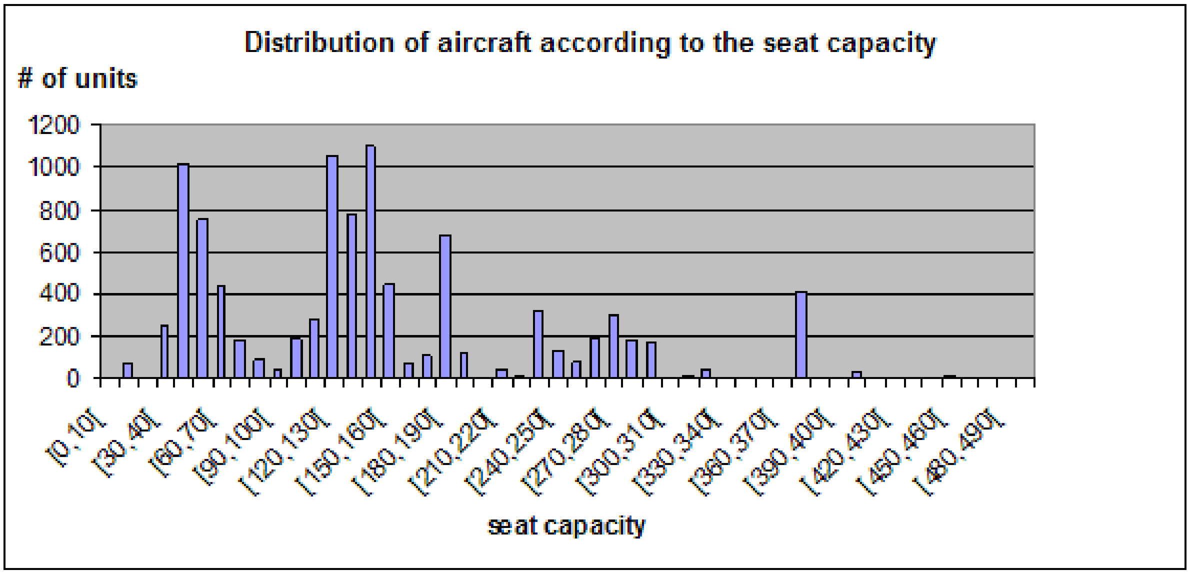


FIGURE 6 Distribution of aircraft in terms of seating capacity.

Trends in Aircraft Wingspan and Fuselage Length

Figure 8 presents a comparison of aircraft wingspans with aircraft seating capacity based on the aircraft included in the database. A regression analysis of the relationship between aircraft wingspan and seating capacity explains 86% of the linear trend (R^2 coefficient equal to 0.858). However, as shown in Figure 7, there are two aircraft whose characteristics place them apart from the linear trend—the A380 with a double deck and the B747Combi aircraft.

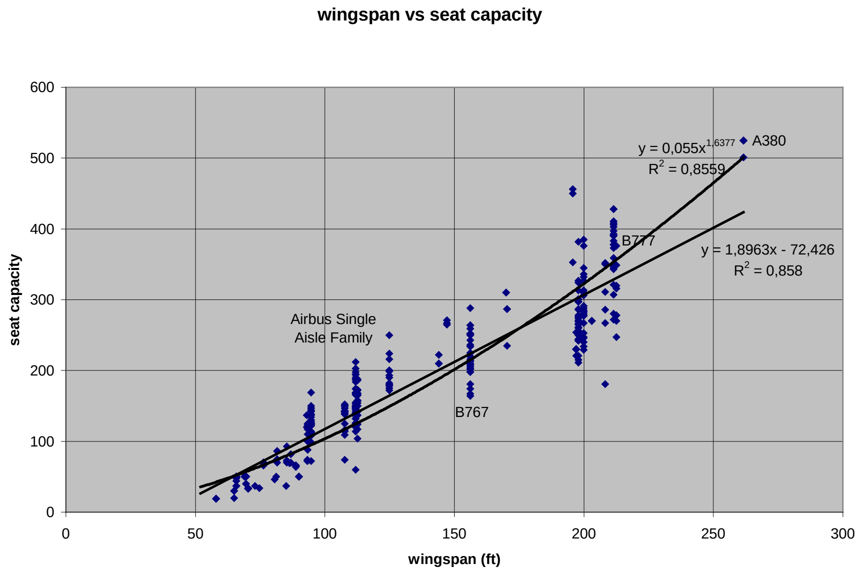


FIGURE 7 Comparison of wingspan with seating capacity.

The series of the same model aircraft are often built on the same wing structure and the same wingspan, while the length of the fuselage in an aircraft series can vary greatly. For example, an Aer Lingus A321-200 aircraft with a 212-seat capacity requires an A-type gate, while an Air France A330-200 aircraft with a 215-seat capacity requires a D-type gate. The longer lengths of aircraft affect the taxiway clearances required in the gate area. Figure 8 presents a comparison of aircraft fuselage lengths with aircraft seating capacity based on the aircraft included in the database. As shown in Figure 8, the aircraft fuselage lengths vary greatly even though the aircraft have similar seating capacities.

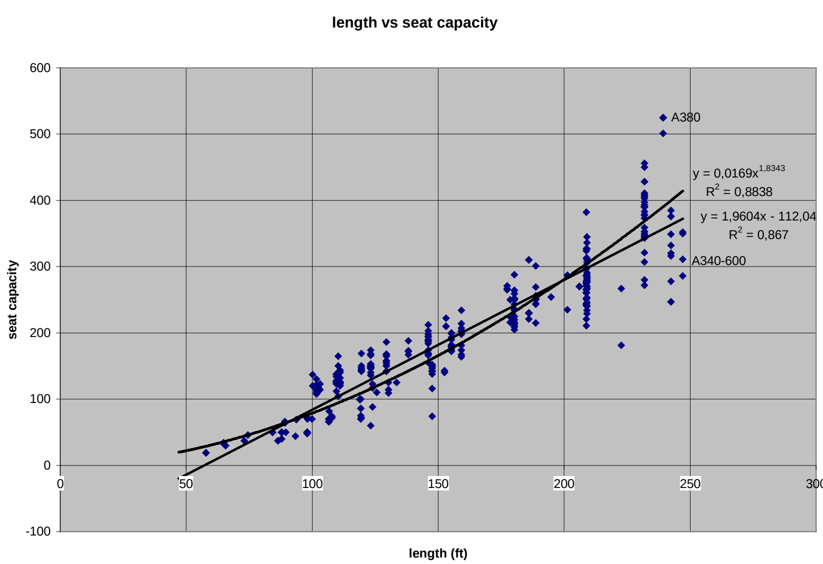


FIGURE 8 Comparison of fuselage length with seating capacity.

IMPLICATIONS FOR AIRPORT DESIGN

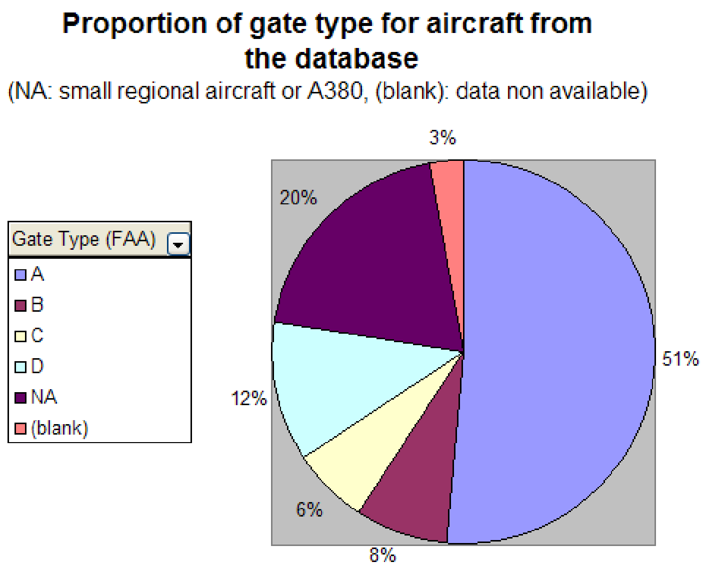
Fleet composition directly impacts the planning of airports. Airport operators have to plan and size their facilities based on the type of aircraft serving the airport. The aircraft fleet mix of an airport affects all planning, from the terminal and holdroom areas, to the runway and radio-navigation systems. Based on the discussion and evaluation of recent trends in aircraft sizing and fleet mix presented in this study, the following implications for airport design were identified and summarized, including (1) the use of aircraft gates, (2) the need for additional apron parking space, (2) the changes required to accommodate aircraft with blended winglets, (3) the reconfiguration of loading bridges, (4) the changes required for taxiway clearance, and (5) changes in passenger holdroom requirements.

Aircraft Gate Use

Terminal facility planning is greatly influenced by the type of aircraft serving an airport. In recent years, aircraft wingspans have increased as aircraft manufacturers redesign aircraft to improve fuel and operational efficiencies. Increases in aircraft wingspans are significant for terminal facility planning because (1) FAA requires a 25 ft clearance between wingtips and (2) the area required to park an aircraft at a gate is related to the wingtip clearance requirement and the aircraft wingspan. The FAA sets rules and clearances that have to be respected to avoid collision on the taxiway or on the apron between parked and moving aircraft. In its circular on the planning and design guidelines for airport terminal facilities (*3*), the FAA defines four gate types as described below.

- (i) Gate Type A for aircraft with a wingspan between 79 feet (24 m) and 118 feet (36 m) (Airplane Design Group III). The route structures of these aircraft vary from short range/low density to medium range/ high density.
- (ii) Gate Type B for aircraft with a wingspan between 118 feet (36 m) and 171 feet (52 m) and with a fuselage length less than 160 feet (49 m) (Airplane Design Group IV). These aircraft serve longer range routes than those using Gate Type A, but have similar passenger demands.
- (iii) Gate Type C for aircraft with a fuselage length greater than 160 feet (49 m) (Airplane Design Group IV). The typical route structure is similar to aircraft using Gate Type B, although with a higher passenger volume.
- (iv) Gate Type D for aircraft with a wingspan between 171 feet (52m) and 213 feet (65m) (Airplane Design Group V). These aircraft operate on a long-range route structure and carry a high volume of passengers.

Figure 9 presents a percentage distribution of aircraft included in the database for the four gates types defined by the FAA. Gate Type A accounted for the largest percentage (51%) of aircraft in the database, followed by Gate Type D with 12%. These percentages vary by airport, depending on the airlines serving an airport, the type of aircraft operated, the assignment of gates at an airport, and, if applicable, the allocation of slots. The implication for airport design is that once gate design is established for terminal construction based on the current and expected future fleet of aircraft, the ability to change apron and gate areas is limited.



Gate Type (FAA)	Total
A	5599
B	845
C	695
D	1317
NA	2151
(blank)	294
Grand Total	10901

FIGURE 9 Percentage distribution of aircraft from the database by gate type.

Apron Parking Space

In the last decade, the longest (A430-600) and the largest (A380-800) aircraft ever developed were built by the aircraft industry. According to the International Industry Working Group (*17*), aircraft wingspans and lengths have increased, but at decreasing rates in recent years. The increase in aircraft length is to increase the passenger seating capacity of aircraft, while the increases in aircraft wingspan are to improve fuel efficiency and performance. The implications of these new design trends is that they will require more apron parking space, which may have a significant impact on the future design of airport terminals and airfield geometry .

Accommodation of Aircraft with Blended Winglets

As Blended Winglets increase the wingspan of the aircraft, they have some effect on the aircraft parking aprons in the airside facilities and the corresponding taxi lanes in order to respect the clearances defined by the FAA. For example, in a recent analysis of the gate utilization at San Francisco International Airport (*18*), a number of gates were impacted by the retrofitting of the B757-200 with Blended Winglets. Hence, when the gate was first designed for a B757-200, a B757-300 or aircraft with lower wingspan, the 10 foot increase in wingspan from blended winglets was not included in the evaluation of the clearance of 20 foot separation required between wingtips. The implications of accommodating aircraft with blended winglets requires airport operators to reevaluate their existing gate areas and assignments and, if possible, to redesign and reallocate available gate and airside facilities.

Loading Bridge Use

Loading bridges suitable for full-size jets may require modification to accommodate smaller aircraft. For New Large Aircraft (NLA) such as the A380-800, a new loading bridge arrangement is necessary to serve the upper deck door, including additional limit switches and infrared sensors to trigger alarms and to prevent collisions with the A380 aircraft engine or wing and with the other loading bridge. The accommodation of the A380 aircraft, in particular, has significant implications for airport design in terms of the facility and financial requirements. Special A380 gates must be designed and financed and very few airports in the United States today have A380 ready gates.

Taxiway Clearance

The increasing number of aircraft with blended winglets in the airline fleet necessitates evaluations of taxiway clearances and movements around piers or satellites areas. Numerous case of ground collisions have been reported for general aviation aircraft between wingtips of a moving aircraft and tail of a noise-in parked aircraft but consequences can be more dramatic for commercial planes. The implications for airport design are that changes in taxiway clearances may not be possible based on the footprint or area of an airport and these changes may affect other airport facilities.

Passenger Holdroom Requirements

The introduction of NLA such as the A380 and the increasing use of regional aircraft require airport operators to reevaluate the flow of and space for passengers in the terminal and waiting areas. Typically, airport terminal waiting areas are designed based on a number of factors, including aircraft capacity, type of flights (domestic or international), passenger arrival time at the airport before the flight, boarding time, and time required before departure for check-in and security. If any of these factors change significantly, the implications for airport design may necessitate the addition of holdroom space or concourses.

CONCLUSIONS AND RECOMMENDATIONS

Based on the discussion and evaluations of recent trends presented in this paper, it can be concluded that changes in aircraft sizing and fleet trends will continue and that these changes are likely to have implications for airport design, depending on the operational profiles of individual airports. Airport operators, in addition to maximizing the financial and operational efficiencies of their airports, will need to continuously reevaluate the requirements for facilities in the context of a changing airline operating environment. These evaluations may include a review of the existing and future fleets of the airlines serving the airport (including plans for aircraft modifications such as blended winglets), modifications to facilities that may be required at the airport as a result of fleet changes, cost benefit and risk analyses of facility changes, and assessments of the potential growth of passenger traffic. At the same time, airport operators must balance these challenges with the needs of the community that the airport serves and the role of the airport as the community gateway.

It is recommended that future work focuses on at least two issues. First, a survey of airport operators to determine the types and ranges of airport design changes that are being made to accommodate recent trends in aircraft sizing and fleets. This information could assist other airport operators when faced with similar changes in facility requirements. Second, a further evaluation of the characteristics of aircraft fleets including the age of individual airline fleets and the likely replacement aircraft that will be used will help airport operators conduct long-range planning of airport facilities.

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