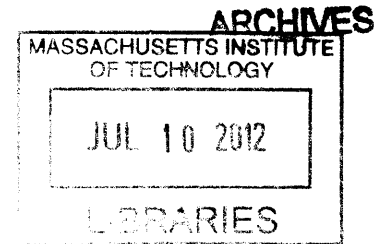


THE EVOLUTION OF U.S. COMMERCIAL DOMESTIC AIRCRAFT OPERATIONS FROM 1991 TO 2010

by

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B.S., Aerospace Engineering
University of Notre Dame (2008)



*Submitted to the Department of Aeronautics and Astronautics
in Partial Fulfillment of the Requirements for the Degree of*

MASTER OF SCIENCE

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ABSTRACT

The main objective of this thesis is to explore the evolution of U.S. commercial domestic aircraft operations from 1991 to 2010 and describe the implications for future U.S. commercial domestic fleets.

Using data collected from the U.S. Bureau of Transportation Statistics, we analyze 110 different aircraft types from 145 airlines operating U.S. commercial domestic service between 1991 and 2010. We classify the aircraft analyzed into four categories: turboprop, regional jet, narrow-body, and wide-body. Our study consists of three parts. First, we compare the four aircraft classes and explore trends in available seat miles, revenue passenger miles, load factor, aircraft departures, average stage length, aircraft utilization, seat capacity, daily departures per aircraft, aircraft ground time, and fuel burn. Second, we examine each of the aircraft classes in detail and provide insights on specific aircraft types. Finally, we compare product offerings from competing aircraft manufacturers in both the regional jet and narrow-body aircraft classes.

The results indicate that more than 150 wide-body aircraft have been shifted from the U.S. commercial domestic market to international service while narrow-body stage lengths have increased 50% over the 20 year period analyzed. In addition, the introduction of more than 1,390 regional jets in the late 1990s and 2000s allowed airlines to expand hub operations and increase frequency on routes between major cities. A 10% decline in the turboprop fleet coupled with the lack of turboprop replacement aircraft in the 30 to 50-seat category suggest a potential for future reductions in air service to some smaller cities. Lastly, increasing fuel prices threaten the growth of the U.S. commercial domestic fleet in the upcoming decade and could potentially cause a significant number of aircraft to be no longer economically viable.

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Dedicated to:

Christina Marie Ostrowski

You are my life and my world

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1. Introduction

1.1. Motivation

The U.S. airline industry has grown significantly since its deregulation in 1978. New airlines have emerged, seemingly indestructible airlines have declared bankruptcy and disappeared, and increased competition coupled with rising fuel prices have become commonplace within the industry.

Over the past three decades, airports around the country have seen the arrival and subsequent disappearance of wide-body jets. In other cases, narrow-body service has been reduced and replaced with regional jet aircraft. Even major routes connecting hub airports to large, metropolitan cities have seen a shift to smaller aircraft and increased frequencies.

These changes, among others within the U.S. airline industry, have had a direct impact on the evolution of the U.S. commercial domestic aircraft fleet. Recent research has placed a heavy emphasis on revenue management and fleet planning; however, very little has been documented on the underlying trends driving the changes within the U.S. commercial domestic aircraft fleet. In an industry where the business cycle spans 8 to 10 years, even the slightest change in the competitive landscape affects the industry and its outlook for the future.

1.2. Focus of Thesis

The focus of this thesis is to investigate how U.S. commercial domestic aircraft operations have shifted from wide-body aircraft to narrow-body aircraft, and subsequently to regional jets. First, the evolution of domestic aircraft operations will be presented through an analysis of industry data. The aircraft analyzed are classified into one of four categories: turboprop, regional jet, narrow-body, and wide-body. Using these four aircraft classes, we provide insights on trends with respect to fleet size, available seat miles (ASMs), revenue passenger miles (RPMs), load factor, aircraft departures, average stage length, aircraft seat capacity, ground time per departure, and fuel consumption. Second, we breakdown each of the classes and explore comparisons between specific aircraft types. Lastly, we discuss how competing aircraft manufacturers have shaped both the regional jet and narrow-body segments.

1.3. Data Sources

The data analyzed in this paper was collected from the U.S. Bureau of Transportation Statistics (BTS) from the Research and Innovative Technology Administration, the government agency responsible for coordinating the U.S. Department of Transportation's research programs. All data was gathered using the *T2: U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type* for each year from 1991 to 2010. The data, presented in table form, summarizes the T-100 traffic data reported by U.S. air carriers on Form 41 and includes ASMs, RPMs, aircraft revenue miles flown, revenue aircraft departures performed, revenue aircraft hours airborne, aircraft hours ramp to ramp, aircraft days assigned, and total aircraft fuel in gallons.

In addition to the BTS data, numerous sources were utilized to compile the historical perspectives given on the airline industry, aircraft manufacturers, and deregulation. A full listing of sources is found in the Works Cited.

1.4. Thesis Objectives

The objective of this thesis is to provide insight on the evolution of U.S. domestic aircraft operations from 1991 to 2010. In order to do so, we first classify the aircraft analyzed into one of four categories: turboprop, regional jet, narrow-body, and wide-body. For the purposes of this analysis, the definitions of the four aircraft classes are as follows:

Wide-body Jet: a commercial airliner having a fuselage wide enough to allow passenger seating to be divided by two aisles running from front to back.

Narrow-body Jet: a commercial airliner with a single aisle and seating capacity greater than 100 seats.

Regional Jet: a commercial airliner powered by jet engines with a seating capacity between 30 and 100 seats.

Turboprop Aircraft: a commercial airliner powered by two or more turbine-driven propellers.

The first part of the analysis will focus on the aircraft classifications and will examine the homogeneity of each group with respect to fleet size, ASMs, RPMs, load factor, departures,

average stage length, aircraft seat capacity, ground time per departure, and fuel consumption. The second part of the analysis will compare specific aircraft types in each of the four aircraft classes and provide insight on the trends observed. The last part of the analysis will consist of observations when comparing aircraft manufacturers in both the regional jet and narrow-body segments.

The following questions were used to guide us through the analysis and enable us to draw conclusions from the data.

- a. To what extent has domestic wide-body flying ceased and been replaced by narrow-body, regional jets, and turboprops?
- b. How has the total number of aircraft flying commercially within the domestic U.S. changed year over year?
- c. In which years is the emergence of the regional jet apparent and which type is most common?
- d. Is there a noticeable and meaningful re-emergence of the turboprop between 2005 and 2010?
- e. To what extent have trends in aircraft size (number of seats per departure) fluctuated over the past 20 years?
- f. To what extent has daily aircraft utilization increased over the past 20 years?
- g. To what extent has the average stage length changed over the past 20 years within each aircraft class?
- h. To what extent has airport congestion increased? Specifically, are we able to see indications of longer ground times domestically?
- i. To what extent does fuel consumption (gallons of fuel per hour) vary between aircraft types? What aircraft is the most fuel efficient?

1.5. Thesis Structure

This thesis will consist of six chapters:

In Chapter 1, we introduce the focus of the thesis and briefly describe the data sources used throughout our analysis. In addition, we present the objectives of the thesis along with the questions we hope to answer regarding the evolution of U.S. commercial domestic aircraft operations. Lastly, we outline the thesis by chapter.

Chapter 2 begins with a literature review of commercial aircraft operations within the U.S. Following the literature review, we present some background on the U.S. aviation industry, both prior to and after deregulation. We also provide some rationale to explain the composition of U.S. airline fleets prior to 1991. Then, we briefly discuss the six aircraft manufacturers that heavily influence our data set. Last, we define the data set used for the analysis and explain the methodology developed for this thesis.

Chapter 3 consists of a class-level analysis of turboprop, regional jet, narrow-body, and wide-body aircraft. For each class, we examine the composition of the fleet, ASMs, RPMs, load factor, aircraft departures, average stage length, aircraft seat capacity, ground time per departure, and fuel consumption.

Chapter 4 expands on the Chapter 3 analysis as we make comparisons between aircraft types within each of the aircraft classes. The comparisons consist of fleet size, aircraft seat capacity, average stage length, and daily utilization.

Chapter 5 focuses on additional comparisons with respect to the aircraft manufacturers. First, we examine the Bombardier CRJ-200 series and the Embraer ERJ-145 series. Second, we explore the 70-seat to 100-seat market through comparisons between the Bombardier CRJ-700 series and the Embraer E-Jet family. Last, we examine the Airbus A320 family and the Boeing 737 series and their impact on the U.S. commercial domestic narrow-body fleet.

Finally, Chapter 6 summarizes the findings within this thesis and presents the implications for future U.S. commercial domestic fleets.

2. Literature Review, Historical Background, Dataset, & Methodology

2.1. Literature Review

A large number of studies have been performed relating to commercial aviation over the past decades. In many cases, these studies relate to airline operations, advancement of global alliances, or environmental concerns in one of many regions throughout the world. However, few deal directly with aircraft operations, and more specifically, with operational trends within the domestic United States.

One of the most applicable studies performed was published in 1992 focusing on aircraft fleets of major airlines since deregulation. Ferrer concluded that airline fleets primarily consisted of low capacity/short range aircraft and that airlines were responding favorably to aircraft innovations such as two-crew member cockpits and twin-engine aircraft (as opposed to the tri-jet and quad-jet aircraft of the 1960s) (Ferrer 61). Ferrer determined that the industry focused largely in the 1980s on the domestic market as evident from the increased amount of short-range aircraft within the respective airline fleets.

Another study of interest was performed by Mozdzanowska in 2004 relating specifically to regional jet operating patterns in the continental United States. Mozdzanowska concluded that the early regional jet resembled both the flight patterns and utilization of turboprops for hub feeder operations (Mozdzanowska 29). However, by 2003, it was noted that the regional jets were flying longer routes at higher altitudes and faster speeds than the early regional jets, while also bypassing hubs. Mozdzanowska suggests that regional jets were filling a gap in the market by flying longer routes than turboprops, but shorter routes than the traditional narrow-body jets. In addition, Babikian concluded in 2001 that regional jets already accounted for 40% to 50% of departures at U.S. airports and were projected to continue to grow at 7% to 8% annually (Babikian 16).

In 2008, *USA Today* published an article noting the withdrawal of wide-body aircraft on domestic routes. As of November 2008, only 143 wide-body domestic flights were scheduled per day, nearly one-third fewer than the previous year, and less than 1% of all domestic flights. In addition, the article cited the industry trend toward higher-frequencies between cities has resulted

in significant regional jet growth, with regional jets operating 12% of domestic flights in 2000 to 37% in 2008 (Lollis, Hansen, “Jumbo Jets Become a Rare Treat”).

The studies performed by Ferrer, Mozdzanowska, and Babikian as well as the *USA Today* article offer some, albeit limited, insight into aircraft operations. Ferrer’s focus on aircraft operations stems from an individual airline perspective, while Mozdzanowska and Babikian focus strictly on regional jet aircraft. It is for these reasons that we will focus this paper on U.S. commercial domestic aircraft operations for turboprop, regional jet, narrow-body, and wide-body aircraft from 1991 to 2010.

2.2. Historical Background

Since the advent of the U.S. airline industry, commercial aircraft operations have been largely dependent on the types of aircraft made available by manufacturers world-wide. As this thesis explores the evolution of domestic aircraft operations from 1991 through 2010, the following paragraphs will capture the themes of the U.S. aircraft fleet both prior to and post-deregulation, as well as touch upon the major aircraft manufacturers contributing to the U.S. domestic landscape over the past 40 years.

2.2.1. U.S. Commercial Domestic Operations Prior to Deregulation

Prior to the Deregulation Act of 1978, airline routes and corresponding fares were governed by the Civil Aeronautics Board (CAB). The CAB structured fare levels by distance flown and allowed airlines to operate a cost-plus model, which permitted them to sell fares that accounted for the operating costs of the route in addition to a modest profit margin. From 1950 to 1970, U.S. airlines saw a 10% growth in passengers corresponding to 8.35 billion additional RPMs per year (Hansman 9). Due to the steady increase in passenger demand, airlines continued to purchase large 110-seat to 500-seat jets, which were still proving economic given the cost-plus model (MacDonald 161). By the end of the 1970s, over 1000+ wide-body aircraft had entered into service world-wide (Bowen 54).

2.2.2. U.S. Domestic Operations After Deregulation

CAB regulation slowly diminished in 1977 as it began honoring airline requests for discounted fares on select routes. In 1978, CAB Chairman Alfred Kahn recommended Congress

pass the Airline Deregulation Act, which reduced and ultimately eliminated the CAB's route and fare authority by 1984. The resulting free-market environment, coupled with significant overcapacity and increased fuel prices due to the Arab Oil Embargo, caused many of the larger airplanes operating domestically to fly with empty seats and become unprofitable (MacDonald 162). In an effort to counter empty seats and diminishing profits, airlines began to drop point-to-point routes and concentrate the remaining, more efficient fleet at a major airport, signifying the emergence of the hub and spoke system. Hub systems encouraged the regional airlines to offer service linking small cities and providing connections to hub airports using turboprop aircraft. By 1985, the number of code-sharing agreements between regional airlines and major carriers grew dramatically (Wensveen, Wells 157).

By the mid-1990s, the emergence of the regional jet became apparent as smaller aircraft manufacturers such as Bombardier Inc. and Embraer S.A. began producing the Canadair RJ-100 and Embraer 145, respectively. Since the introduction of the modern regional jet, commuter carriers have strengthened their ability to support their larger, hub-based partners by feeding more traffic into the mainline carrier's hub ("Regional Jets").

2.2.3. Aircraft Manufacturers

Over the past 50 years, six major aircraft manufacturers have provided the majority of the U.S. commercial domestic fleet: Airbus Industrie, Boeing Company, Bombardier Inc., Embraer S.A., Lockheed Corporation, and McDonnell Douglas Corporation. The following sections provide some insight into the various manufacturers and the aircraft produced.

a. Airbus Industrie

Airbus Industrie was formed in December 1970 through an agreement between the governments of France, Germany, and the United Kingdom. While growth came slowly in the early years, Airbus penetrated the U.S. market in 1977 through a six-month trial leasing arrangement with Eastern Air Lines, which subsequently purchased 23 A300 airplanes in 1978 with options for 9 additional aircraft (Bauer 241). In addition, rising oil prices in 1981 cast the two-engine A300 in favorable light in comparison to the three-engine Douglas DC-10 and Lockheed L-1011 (Bowen 50).

Over the past 40 years, Airbus has positioned itself as one of the premier aircraft manufacturers worldwide (alongside Boeing Company) with 1,419 orders and 534 deliveries in 2011 (Keller). Table 1 outlines the commercial aircraft manufactured by Airbus, a short description, seating capacity, and the year of first flight.

Table 1 Commercial Aircraft Manufactured by Airbus

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
A300	2 engines, twin aisle	228-361	1972
A310	2 engines, twin aisle	187-279	1982
A318	2 engines, single aisle	107-117	2002
A319	2 engines, single aisle	124-150	1996
A320	2 engines, single aisle	150-180	1987
A321	2 engines, single aisle	185-220	1993
A330	2 engines, twin aisle	253-440	1992
A340	4 engines, twin aisle	239-440	1991
A350*	2 engines, twin aisle	270-475	--
A380	4 engines, double deck, twin aisle	555-700	2005

**A350 is scheduled to make its maiden flight in 2014 ("Commercial Aircraft")*

b. Boeing Company

The Boeing Company was founded in 1916 by William E. Boeing in Seattle, Washington. Although producing various commercial piston-engine aircraft throughout its early years, Boeing emerged into the commercial jet world with the Boeing 707 in 1957, a four-engine aircraft developed from the 367-80 prototype (Bauer 144). During the 1960s and 1970s, Boeing continued to grow its commercial business with the introduction of the Boeing 727, 737, and Boeing 747, the latter of which was roughly twice as big as any other airliner in 1969 (Yenne 196).

Over the past 40 years, Boeing has seen increased competition from Airbus as the two companies strongly compete for narrow-body and wide-body orders. In 2011, Boeing recorded 805 orders and 477 deliveries (Weitzman). Table 2 outlines the commercial aircraft manufactured by Boeing, a short description, seating capacity, and the year of first flight.

Table 2 Commercial Aircraft Manufactured by Boeing

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
B707	4 engines, single aisle	137-189	1954
B717	2 engines, single aisle	106	1998
B727	3 engines, single aisle	131-189	1963
B737	2 engines, single aisle	102-215	1967
B747	4 engines, twin aisle	331-660	1969
B757	2 engines, single aisle	201-279	1982
B767	2 engines, twin aisle	181-375	1981
B777	2 engines, twin aisle	301-550	1994
B787	2 engines, twin aisle	242-317	2009

c. Bombardier Inc.

Bombardier Inc. was founded in 1942 in Quebec, Canada by Joseph-Armand Bombardier; however, it did not expand into the aerospace industry until the mid-1980s. In 1986, Bombardier acquired struggling Canadair Ltd., the manufacturer of the Challenger business jet, at a severely discounted price. Bombardier used the opportunity to stretch the Challenger fuselage into a 50-seat, short-range aircraft marketable to regional airlines. In addition, Bombardier acquired three additional companies between 1989 and 1992 to further grow its aerospace business: Short Brothers PLC, Learjet Corporation, and de Havilland (MacDonald 138). By 1996, Bombardier had emerged as a strong force in the regional world with a market share of 42%, up from only 10% in 1992.

Over the past 20 years, Bombardier has increased its presence in the regional jet market despite recent drops in sales with only 54 orders in 2011 (Deveau). Table 3 outlines the commercial aircraft manufactured by Bombardier, a short description, seating capacity, and the year of first flight.

Table 3 Commercial Aircraft Manufactured by Bombardier

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
CRJ-100/200	2 engines, single aisle	50	1991
CRJ-700	2 engines, single aisle	70	1999
CRJ-900	2 engines, single aisle	86	2001
CRJ-1000	2 engines, single aisle	100	2008
Dash 7	4 turboprop engines, single aisle	50	1975
Dash 8 Q100/200	2 turboprop engines, single aisle	37-39	1983
Dash 8 Q300	2 turboprop engines, single aisle	50-56	1987
Dash 8 Q400	2 turboprop engines, single aisle	70-78	1998

d. Embraer S.A.

Embraer S.A. was formed in 1969 as a government-owned corporation in Brazil. During the early years, Embraer was supported through the Brazilian government and manufactured the EMB-120, a small, twin-propeller aircraft. However, it was the launch of the ERJ-145 in 1989 that helped springboard the company into the regional spotlight. In 1996, Embraer announced the sale of 25 50-seat ERJs. While it was known that the ERJ climbed slower, had a shorter range, and less efficient engines, it also sported a lower price than Bombardier’s regional jet (MacDonald 185). In 1999, Embraer announced the production of its E-Jet series, a line of commercial aircraft seeking to fill the gap between 50-seat and 100-seat aircraft (Rich).

Over the past 20 years, Embraer has emerged as a significant player in the regional market through the advent of both its ERJ and E-Jet families. In 2011, Embraer recorded 124 orders and 105 deliveries ("Brazil-Arab News Agency"). Table 4 outlines the commercial aircraft manufactured by Embraer, a short description, seating capacity, and the year of first flight.

Table 4 Commercial Aircraft Manufactured by Embraer

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
EMB-120	2 turboprop engines, single aisle	30	1983
ERJ-135	2 engines, single aisle	37	1998
ERJ-140	2 engines, single aisle	44	2000
ERJ-145	2 engines, single aisle	50	1995
E-170	2 engines, single aisle	70-78	2002
E-175	2 engines, single aisle	78-86	2003
E-190	2 engines, single aisle	94-106	2004
E-195	2 engines, single aisle	106-118	2004

e. Lockheed Corporation

Lockheed Corporation was originally founded as Loughhead Aircraft Manufacturing Company in 1912. Throughout its early years, the company went through many changes, and in 1936, it was renamed Lockheed Corporation. Lockheed focused primarily on military applications; however, it produced both the Constellation and Super Constellation in 1946 and 1951, respectively. The company reentered the commercial market in the 1960s with the three-engine, twin-aisle L-1011. However, stiff competition from the Douglas DC-10 as well as power plant issues stemming from the Rolls Royce RB211, led to the demise of Lockheed’s commercial success.

In 1983, Lockheed delivered the last of its 252 aircraft built ("L-1011 Tristar History"). Table 5 outlines the specifications of the L-1011.

Table 5 Commercial Aircraft Manufactured by Lockheed

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
L-1011	3 engines, twin aisle	233-400	1970

f. McDonnell Douglas Corporation (including the Douglas Aircraft Corporation)

McDonnell Douglas was formed through the merger between the Douglas Aircraft Corporation and McDonnell Aircraft Corporation in 1967. Prior to the merger, the Douglas DC-8 became the basic model for domestic operations in 1958 and competed directly with the Boeing 707, which was launched 11 months earlier (Yenne 145). Douglas also introduced the smaller DC-9 that made its maiden flight in 1965 and was built to compliment the size of the DC-8. Following the merger in 1967, McDonnell Douglas introduced the DC-10 in 1970, which directly competed with the Lockheed L-1011. In 1997, McDonnell Douglas merged with Boeing.

Table 6 outlines the commercial aircraft manufactured by both the Douglas Aircraft Corporation and the McDonnell Douglas Corporation.

Table 6 Commercial Aircraft Manufactured by McDonnell Douglas

<i>Name</i>	<i>Description</i>	<i>Seats</i>	<i>First Flight</i>
DC-8	4 engines, single aisle	124-269	1958
DC-9	2 engines, single aisle	105-139	1965
DC-10	3 engines, twin aisle	250-380	1970
MD-11	3 engines, twin aisle	285-410	1990
MD-80	2 engines, single aisle	114-168	1980
MD-90	2 engines, single aisle	152-172	1993

2.3. Dataset

The dataset used for the analysis was compiled through the BTS T2: *U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type* for each year from 1991 to 2010. The data, arranged in tabular form, summarizes the T-100 traffic data reported by U.S. air carriers on Form 41 and includes ASMs, RPMs, aircraft revenue miles flown, revenue aircraft departures

performed, revenue aircraft hours airborne, aircraft hours ramp to ramp, aircraft hours airborne, aircraft days assigned, and total aircraft fuel in gallons.

2.3.1. Definitions

The following definitions are pertinent to the analysis and are defined using the BTS glossary.

Aircraft Days Assigned: “The number of days that aircraft owned or acquired through rental or lease (but not inter-change) are in the possession of the reporting air carrier and are available for service on the reporting carrier's routes plus the number of days such aircraft are in service on routes of others under interchange agreements. Includes days in overhaul, or temporarily out of service due to schedule cancellations. Excludes days that newly acquired aircraft are on hand but not available or formally withdrawn from air transport service.”

Aircraft Fuel: The amount of fuel in gallons delivered to an aircraft.

Aircraft Hours Airborne: “The airborne hours of aircraft computed from the moment an aircraft leaves the ground until it touches the ground at the end of a flight stage.”

Aircraft Hours Ramp to Ramp: “The time computed from the moment an aircraft first moves under its own power for purposes of flight, until it comes to rest at the next point of landing.”

Aircraft Revenue Miles Flown: The aircraft miles flown in each inter-airport segment for which remuneration is received by the carrier.

Available Seat Mile: “The aircraft miles flown in each inter-airport segment multiplied by the number of seats available for revenue passenger use on that segment.”

Domestic Operations: “All air carrier operations having destinations within the 50 United States, the District of Columbia, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands.”

Revenue Aircraft Departures Performed: Takeoffs made at an airport for which remuneration is received by the carrier.

Revenue Aircraft Hours Airborne: The airborne hours of aircraft computed from the moment an aircraft leaves the ground until it touches the ground at the end of a flight stage for which remuneration is received by the carrier.

Revenue Passenger Mile: “One revenue passenger transported one mile in revenue service. Revenue passenger miles are computed by summation of the products of the revenue aircraft miles on each inter-airport segment multiplied by the number of revenue passengers carried on that segment.”

2.4. Methodology

The *T2: U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type* data included ASMs, RPMs, aircraft revenue miles flown, revenue aircraft departures performed, revenue aircraft hours airborne, aircraft hours ramp to ramp, aircraft hours airborne, aircraft days assigned, and total aircraft fuel in gallons. This data in raw form was organized by aircraft type for each operating carrier in one of five distinct carrier regions: Atlantic, Domestic, International, Latin America, and Pacific. Due to the focus on U.S. domestic aircraft operations, the data was filtered to only include domestic operations.

To maintain a focus on revenue operations, all data entries void of available seat miles were removed from the dataset. In addition, all of the airlines associated with the dataset were analyzed to ensure that operations included revenue passenger service. A complete listing of the airlines contributing aircraft data to this analysis is located in Appendix A.

It is important to note that the BTS revised its reporting protocol in October 2002 by requiring all Part-135 operators to report via the Schedule T-100 as opposed to Form 298-C (Bright). As a result, the raw data from BTS contains only Part-121 operators from 1991 through September 2002, while containing both Part-121 and Part-135 operators from October 2002 onward. In order to maintain consistency within our analysis, all Part-135 operators were removed from the data set.

2.5. Chapter Summary

The first part of this chapter focused on the literature review where we concluded that a very limited amount of literature exists focusing on the evolution of U.S. commercial domestic aircraft operations. We encountered some literature emphasizing a shift in aircraft operations; however, with limited detail. This thesis seeks to provide a detailed perspective on U.S. commercial domestic aircraft operations across all aircraft types between 1991 and 2010.

Next, a brief historical background of the U.S. aviation industry was presented with a focus on aircraft types operating domestically, both prior to and after deregulation. In addition, we commented on six major aircraft manufacturers that significantly affected the U.S. commercial domestic fleet between 1991 and 2010.

Last, the formulation of the data set was presented along with relevant definitions. In order to ensure a valid comparison among aircraft types, all data entries void of ASMs or relating to airlines not providing revenue passenger service were removed.

3. U.S. Commercial Domestic Aircraft Operations

3.1. Introduction

This section discusses our analysis of U.S. commercial domestic aircraft operations from 1991 to 2010. First, we present an overview of total industry fleet size for turboprop, regional jet, narrow-body, and wide-body aircraft. A listing of aircraft studied in this analysis is found in Appendix B. Next, we explore trends in available seat miles, revenue passenger miles, load factor, aircraft departures, average stage length, aircraft utilization, aircraft seat capacity, daily departures per aircraft, aircraft ground time, and fuel burn for each aircraft class. For each trend, we highlight the most significant takeaways and explain potential root causes for the trend.

3.2. Analysis of U.S. Commercial Domestic Aircraft Operations

Between 1991 and 2010, the U.S. commercial domestic fleet size, calculated using the metric “aircraft days assigned” discussed in Section 2.3.1, increased 36.7% from 3,264 aircraft in 1991 to 4,462 aircraft by 2010. As seen in Figure 1, the majority of the increase in fleet size is due to the introduction of the Bombardier Regional Jet (CRJ) and the Embraer Regional Jet (ERJ) in 1996. In addition, the subsequent launch of the CRJ-700/-900 series and Embraer E-Jet family in the early 2000s further increased the growth rate of the regional jet population. A continued point of emphasis within this paper will be the dramatic growth of regional jets and their relative fleet size in comparison to turboprop, narrow-body, and wide-body aircraft. In 1991, regional jet aircraft comprised only 2.1% of the total domestic fleet; by 2010, that number had increased to 32.9%.

During this same period, the number of turboprop aircraft declined 4.4%, despite a significant increase in the mid-1990s due to the introduction of the Aerospatiale ATR-42, Embraer EMB-120 Brasilia, and Saab-Fairchild 340/B. By 2006, the Aerospatiale ATR-42 had been retired from commercial domestic service and both the Embraer EMB-120 Brasilia and the Saab-Fairchild 340/B fleet sizes had decreased by over 50% from their peaks in 1996 and 2000, respectively.

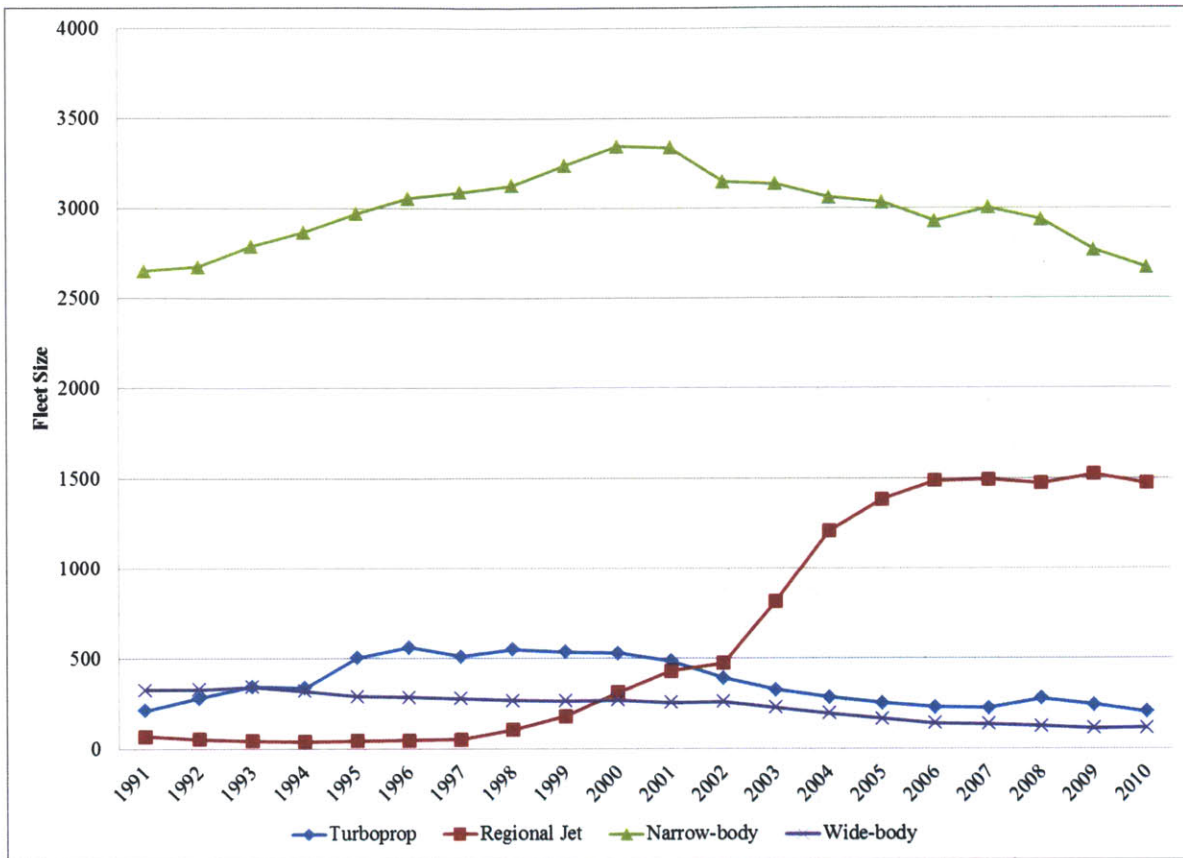


Figure 1 Fleet Size.

Narrow-body aircraft increased steadily at an average 2.6% annually leading up to 2001; however, the economic downturn coupled with the events of September 11, 2001 forced the airlines to withdraw capacity and reduce costs. In addition, both the McDonnell Douglas MD-80 and the Boeing 737-300 saw a significant withdrawal from service between 2001 and 2010, most likely due to increasing fuel prices making these aircraft less economical to operate. Furthermore, the decline in narrow-body aircraft is coupled with the introduction of the larger regional jets as airlines were able to adjust route capacity and schedule frequency using the new 70 to 100-seat airplanes.

Wide-body aircraft in domestic service declined 64.3% from 327 aircraft in 1991 to 117 aircraft in 2010. The decline in the 1990s is attributed to the significant withdrawal of 150+ Lockheed L-1011s and Douglas DC-10s from service, while the continued decline in the 2000s is due to the shift of wide-body aircraft from domestic to international services. By 2010, the

majority of remaining wide-body flying within the domestic U.S. consisted of transcontinental flights, and to a lesser extent, revenue repositioning flights for international service.

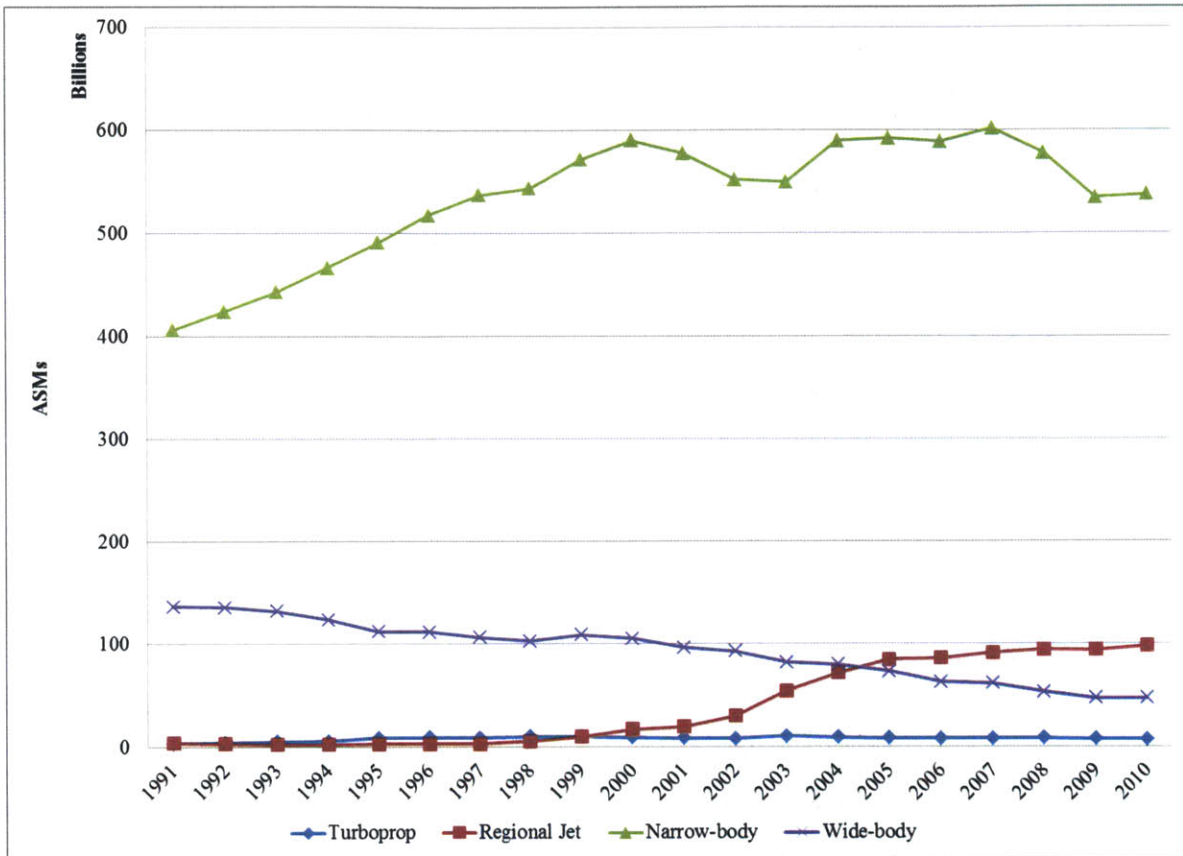


Figure 2 Available Seat Miles.

The trends in available seat miles (ASMs) shown in Figure 2 largely resemble those shown in Figure 1 detailing fleet size with one notable exception. The number of narrow-body ASMs increased in 2004 followed by a subsequent decrease in 2008, despite the narrow-body fleet declining at an average 2.2% annually from 2001 to 2010. The increase in ASMs in 2004 is attributed to an 8.6% increase in narrow-body utilization from 2003 to 2004, the first time narrow-body utilization averaged more than 10 hours daily. To a lesser extent, as the 130-seat McDonnell Douglas MD-80 and Boeing 737-300 aircraft were being retired, newer, larger 150-seat Boeing 737-800 aircraft were being introduced to the domestic fleet. In contrast, the reduction in ASMs in 2008 was the result of a 4.8% decrease in utilization coupled with the withdrawal of 75+ Boeing 757-200 aircraft, each equipped with approximately 180 seats. The

withdrawal of the Boeing 757-200 aircraft can be attributed to airlines shifting the aircraft type from domestic service to transatlantic and Latin American service.

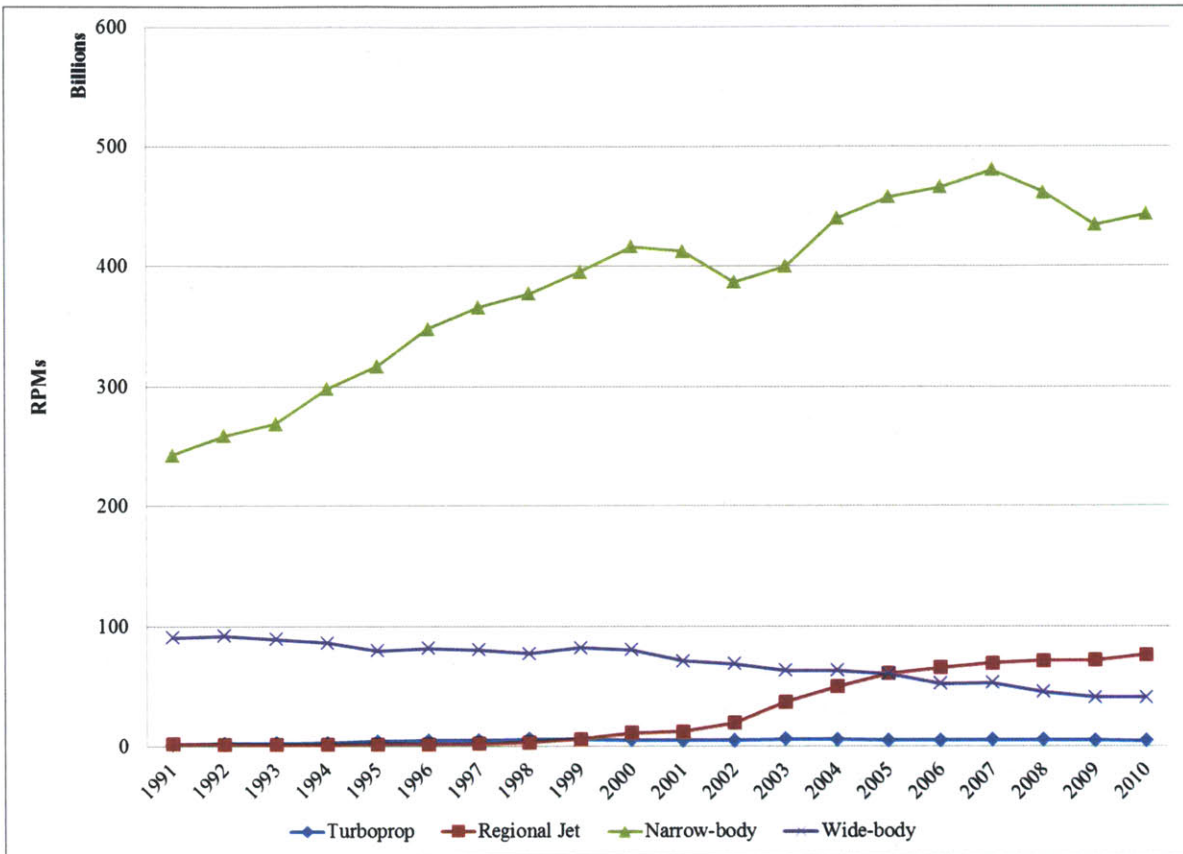


Figure 3 Revenue Passenger Miles.

Despite the fluctuations in ASMs from 1991 to 2010, narrow-body revenue passenger miles (RPMs) increased steadily with the exception of the economic downturn in late 2000 and the economic recession in 2008, as shown in Figure 3. Not surprisingly, domestic air travel demand is highly dependent on the U.S. economy. As the economy slows, corporate America works to reduce costs which usually results in tighter travel budgets. Similarly, leisure travelers limit their spending in the midst of uncertain economic times. As a result, the downturn shown in Figure 3 in 2001 and 2008 is expected. While not easily visible in Figure 3, turboprop, narrow-body, and wide-body aircraft all experienced a decline in total RPMs in 2001, while regional jets experienced a modest increase. This increase is most likely due to the fact that regional jets were still being introduced at a high rate and replacing narrow-body aircraft on thinner routes and supplementing narrow-body aircraft between larger cities for increased frequency.

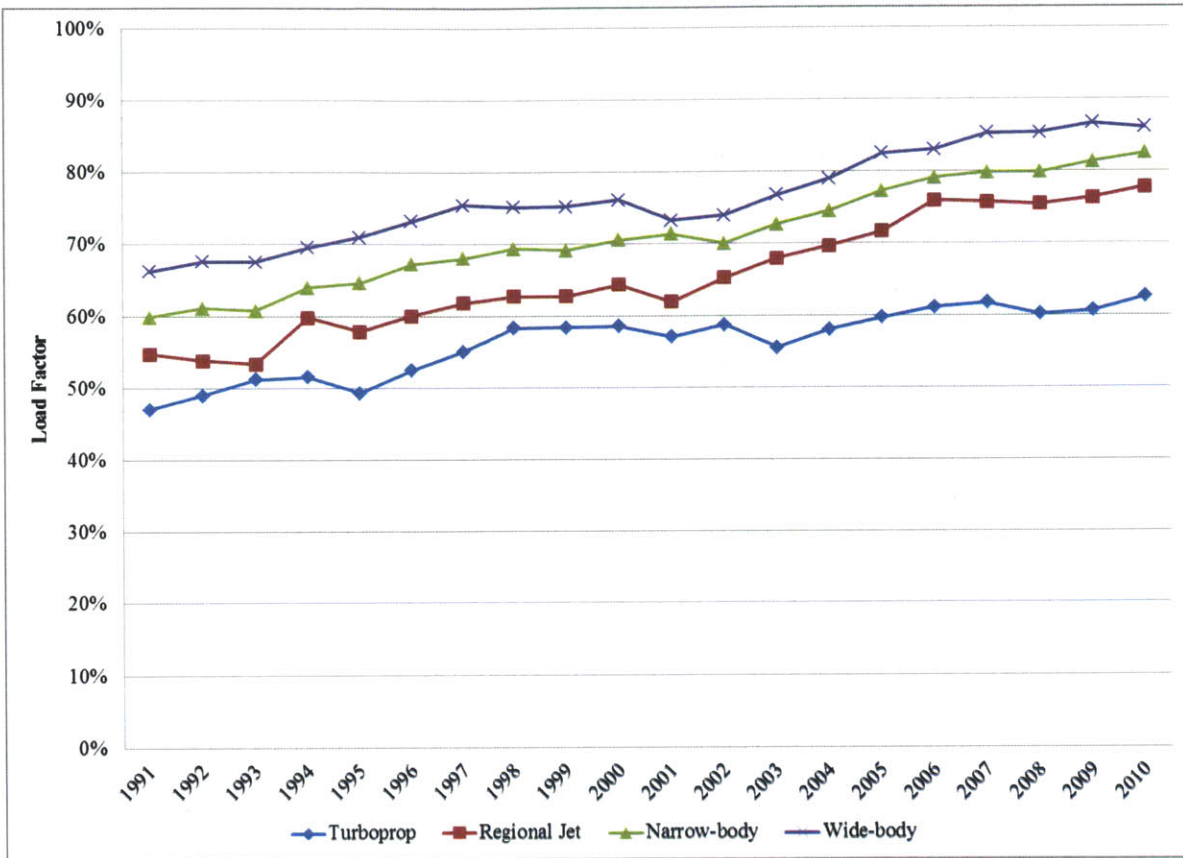


Figure 4 Load Factor.

As a result of the trends seen in ASMs and RPMs, the domestic system load factor as well as the load factors of each described aircraft class grew significantly from 1991 to 2010 as shown in Figure 4. Load factor, defined as the ratio of RPMs to ASMs, represents the proportion of airline output that is consumed (Belobaba 48). As mentioned previously, the significant increase in load factor is due to a combination of increased domestic air travel demand and the removal of overcapacity within the domestic network. In 2010, the system load factor reached a high of 81.9% for the time period analyzed. Due to fluctuations in passenger demand, including time of day, time of week, and seasonal fluctuations, we do not expect the system load factor to increase much beyond its current state. It is interesting to note that within the domestic market, higher load factors were associated with the larger aircraft types. The higher load factors associated with wide-body aircraft are due to the fact that wide-body aircraft operate less-frequent, long-haul services between high density markets, as opposed to the smaller regional jets and narrow-body aircraft that operate higher frequency services between smaller markets.

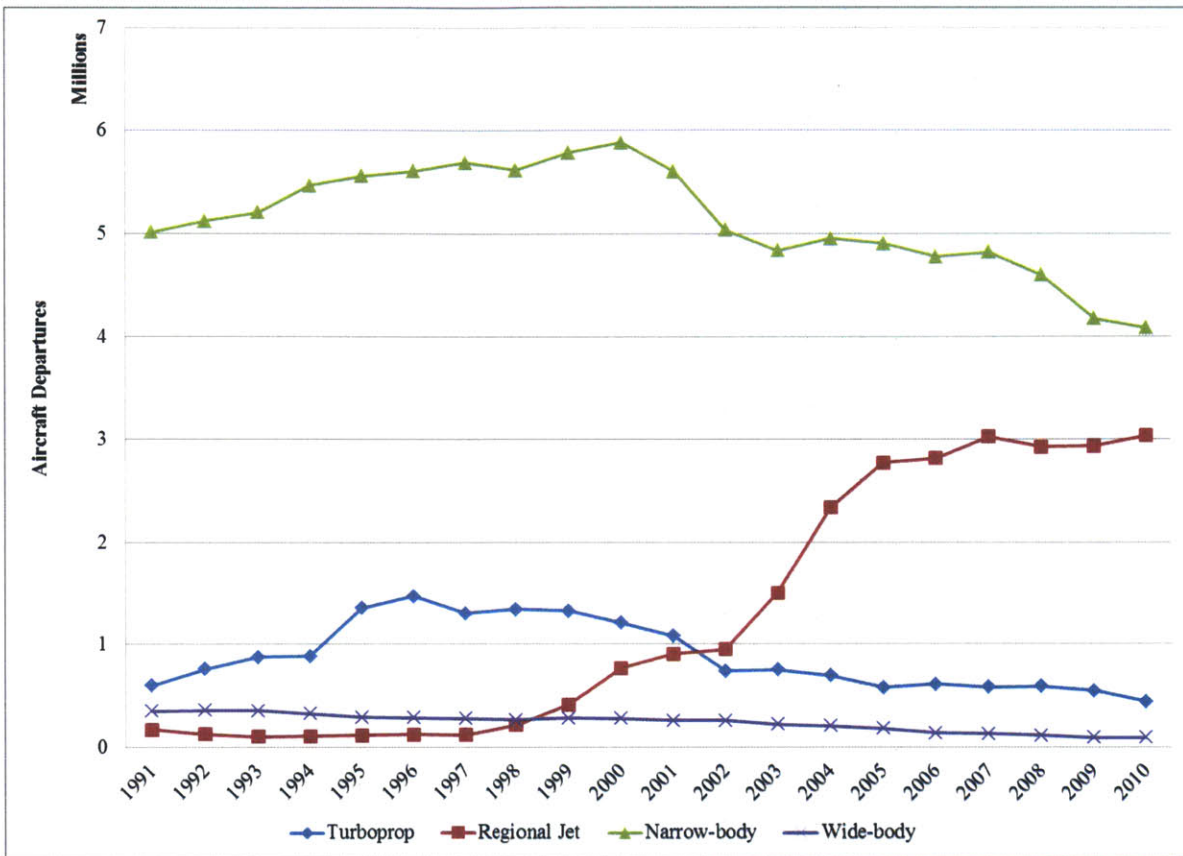


Figure 5 Aircraft Departures.

Over the 20 year period, aircraft departures from 1991 to 2010 declined in each aircraft class with the exception of regional jets as shown in Figure 5. Regional jet departures grew continuously through 2007 and stabilized at 3 million departures. The significant increase in departures was a result of the continued introduction of the CRJ and ERJ by Bombardier and Embraer, as previously shown in Figure 1. By 2005, over 1000 CRJ-100/-200 and ERJ-145 aircraft had been introduced into domestic service. The stabilization seen from 2007 through 2010 is a result of CRJ-100/-200 and ERJ-145 retirements coupled with the continued introduction of the CRJ-700/-900 series, and to a less extent, the E-jet family. During this period, approximately 100 CRJ-100/-200 and ERJ-145 aircraft were retired and 115 CRJ-700/-900 aircraft were introduced. With respect to the other aircraft classes, regional jets accounted for 39.6% of the departures in 2010 while only comprising of 32.9% of the domestic fleet.

Turboprop departures, despite only a 4.4% decline in fleet size, declined 26.1% over the same period. This is largely attributed to a 29.8% increase in the average stage length and a 7.3%

decline in daily utilization. These metrics indicate that turboprop aircraft were flying longer segments but less total time each day, which supports the large decline in departures despite the small reduction in fleet size.

The increase in narrow-body departures from 1991 to 1999 largely resembles the increase in fleet size shown in Figure 1. However, from 2000 to 2010, the number of narrow-body aircraft declined 20.2% and the number of departures declined 30.6%. Similar to regional jets, this decline is a direct result of significantly increased stage lengths, from an average of 719 miles in 1991 to 886 miles in 2010. With the continued shift of wide-body aircraft from domestic to international routes, narrow-body aircraft, and to a smaller extent, regional jets were shifted onto longer flight segments.

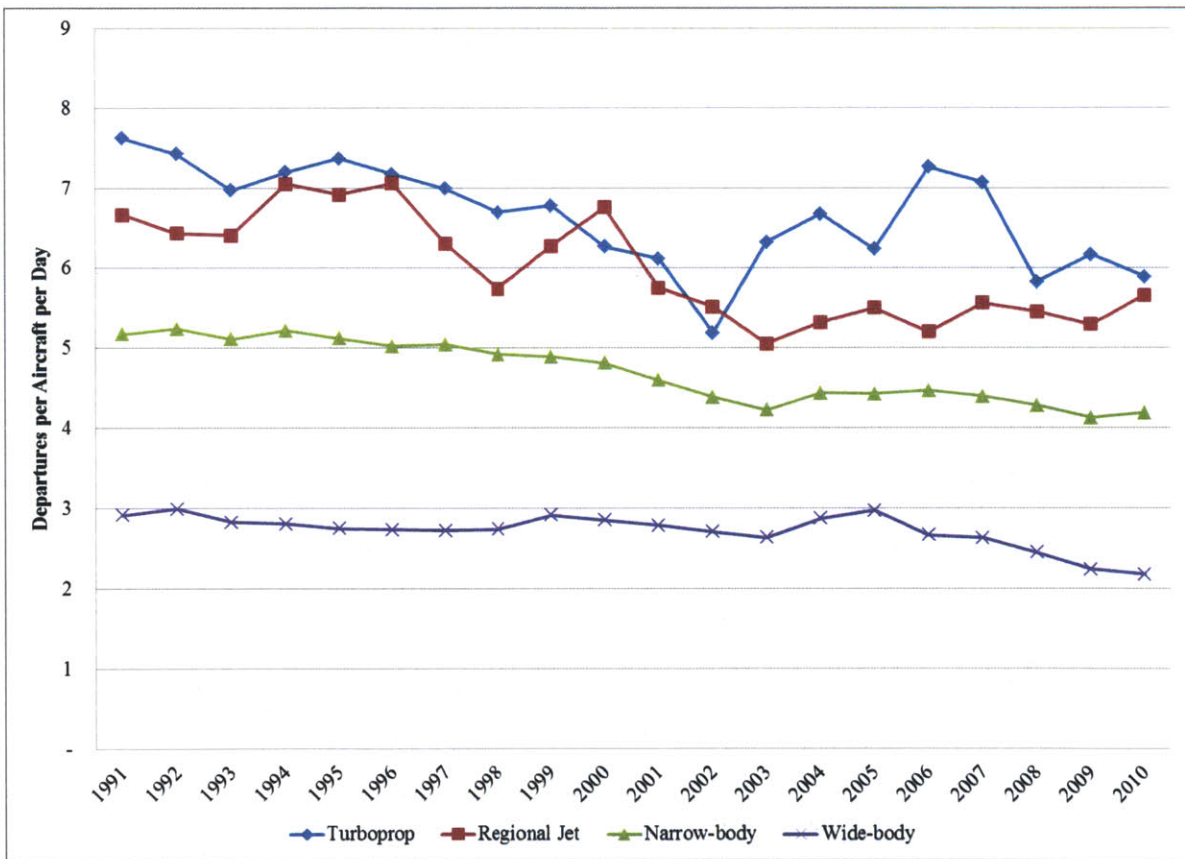


Figure 6 Departures per Aircraft per Day.

On a per aircraft basis, each aircraft class experienced a decline in daily departures from 1991 to 2010 as seen in Figure 6. For turboprop, regional jet, and narrow-body aircraft, this is mostly due to the longer stage lengths despite increases in utilization over the same period. For

domestic wide-body aircraft, the reduction in daily departures is likely associated with the shift of aircraft from domestic to international services. As fewer wide-body planes operate short-haul domestic routes, the corresponding departures per aircraft become diluted by wide-body aircraft operating revenue repositioning flights and transcontinental flights.

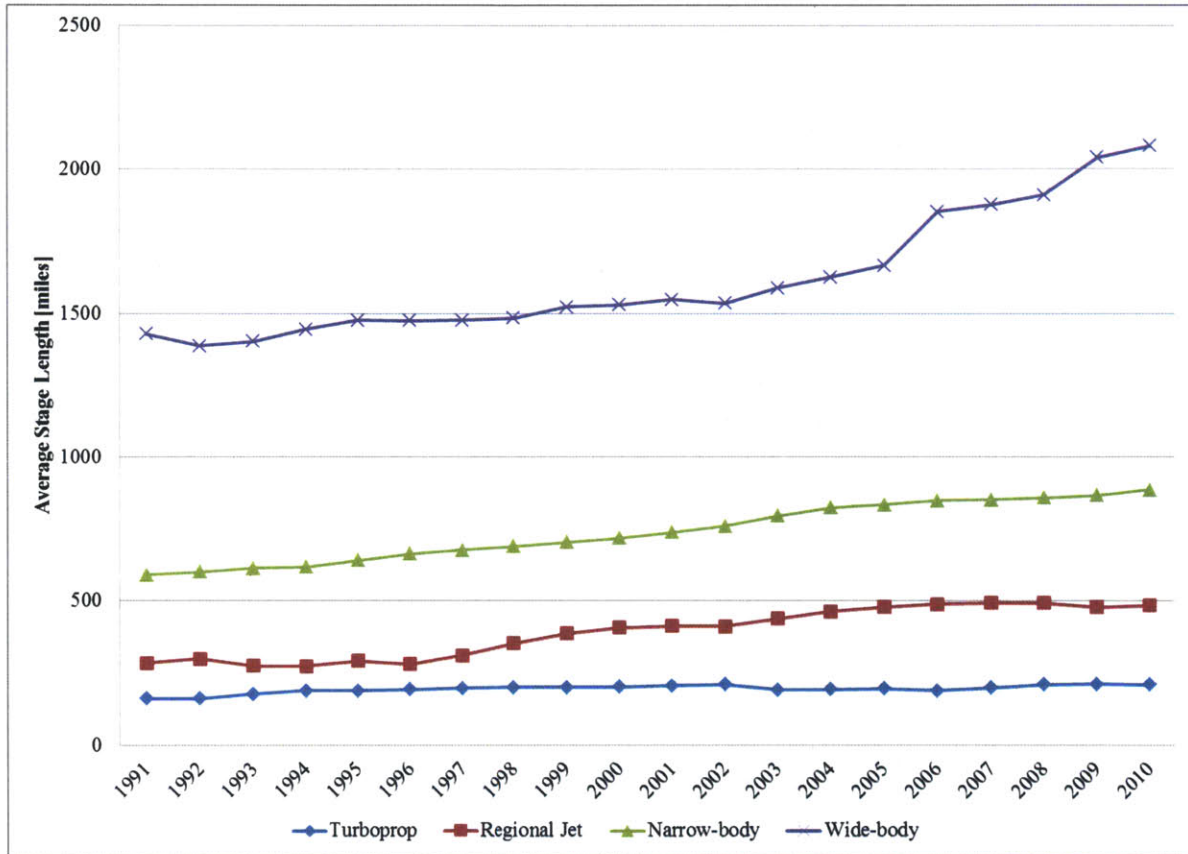


Figure 7 Average Stage Length.

However, more significant in Figure 6 is the variation in departures per day for both turboprop and regional jet aircraft. For turboprop aircraft, the steady decline in daily departures per aircraft compares well with the increasing average stage length shown in Figure 7. All else equal, as the average stage length per departure increases, we would expect the number of daily departures to decrease. In addition, in the case of turboprops, the fleet experienced an increase in size in the late 1990s and a decrease in size in the 2000s. Both of these trends further support the decline in daily departures in the late 1990s and the increase in daily departures in the early 2000s as more available aircraft would indicate fewer departures required per aircraft. In addition, we believe changes in the operating structure of regional airlines directly affected the

number of daily departures. For example, in the 1990s, the regional airlines mainly operated into small airfields close to hubs which allowed for multiple turns in a single day. However, with the advancement of technology and the introduction of larger turboprops, regional carriers now fly farther than before, which has amounted to fewer daily departures and increased stage lengths. For example, Colgan Air, a subsidiary of United Airlines, operates three daily flights from Albany, N.Y. to Washington, D.C. using a Bombardier Q400 covering a distance of 325 miles, 124 miles farther than the average stage length for turboprops in 2010 (United Airlines). In addition, airlines are also utilizing turboprop aircraft in markets that require higher frequencies for business travelers. For example, Colgan Air also operates its Bombardier Q400 between the United Airlines hubs of Newark, N.J. and Washington, D.C. spanning a distance of 201 miles.

The variation in daily departures experienced by regional jets is explained through increased stage lengths and a shift in the definition of regional jets. Similar to the turboprops, regional jets saw a dramatic increase in the average stage length between 1991 and 2010 as shown in Figure 7. However, more importantly, the regional jet was redefined in the late 1990s by the CRJ and ERJ. Prior to 1998, the number of regional jets within the domestic fleet totaled approximately 50 aircraft. However, the introduction of the CRJ and ERJ redefined the role of the regional jet, allowing airlines to fly the jets between more hub and spoke cities, increasing stage lengths, and correspondingly, reducing the total daily departures per aircraft. Regional jet stage lengths increased 70.1% to 484 miles over the same period, largely attributed to airlines overflying hubs and providing more point-to-point services. In addition, the inexpensive fuel costs of the 1990s and the outsourcing of flying from legacy carriers played a significant part in the increase of the regional jet stage length. Due to the lower fuel costs of the 1990s, flying the 50-seat regional jets was more profitable than with today's \$100+ barrel fuel. In addition, legacy carriers, which typically operated only aircraft greater than 100 seats, found it much more profitable to outsource the flying to regional carriers than to try to operate the flights themselves with larger aircraft.

Over the 20 year period, daily utilization rates for each aircraft class increased with the exception of turboprop aircraft as shown in Figure 8. It is important to note that domestic wide-body aircraft had the highest utilization rates, followed by narrow-body, regional jet, and turboprop aircraft, respectively. This is due to the fact that domestic wide-body aircraft, which typically operate transcontinental flights or occasional repositioning flights, encountered the

longest stage lengths. Similarly, narrow-body aircraft encountered slightly shorter stage lengths as a result of taking over many routes formerly operated by wide-body aircraft. For regional jets, this growth was largely driven by significant increases in the average stage length due to the ability to employ the regional jets on longer routes that overfly hubs. Interestingly, from 1993 to 1998, turboprop utilization is in fact greater than regional jet utilization, which we attribute to the fact that the CRJ and ERJ had not yet been introduced into the U.S. fleet. Regional jets operating prior to the CRJ and ERJ introduction flew significantly shorter stage lengths albeit more daily departures than the post-1998 regional jet. In addition, we suspect that the decline in turboprop utilization in the late 2000s is attributed to the decline in the turboprop fleet size coupled with a reduced number of daily departures.

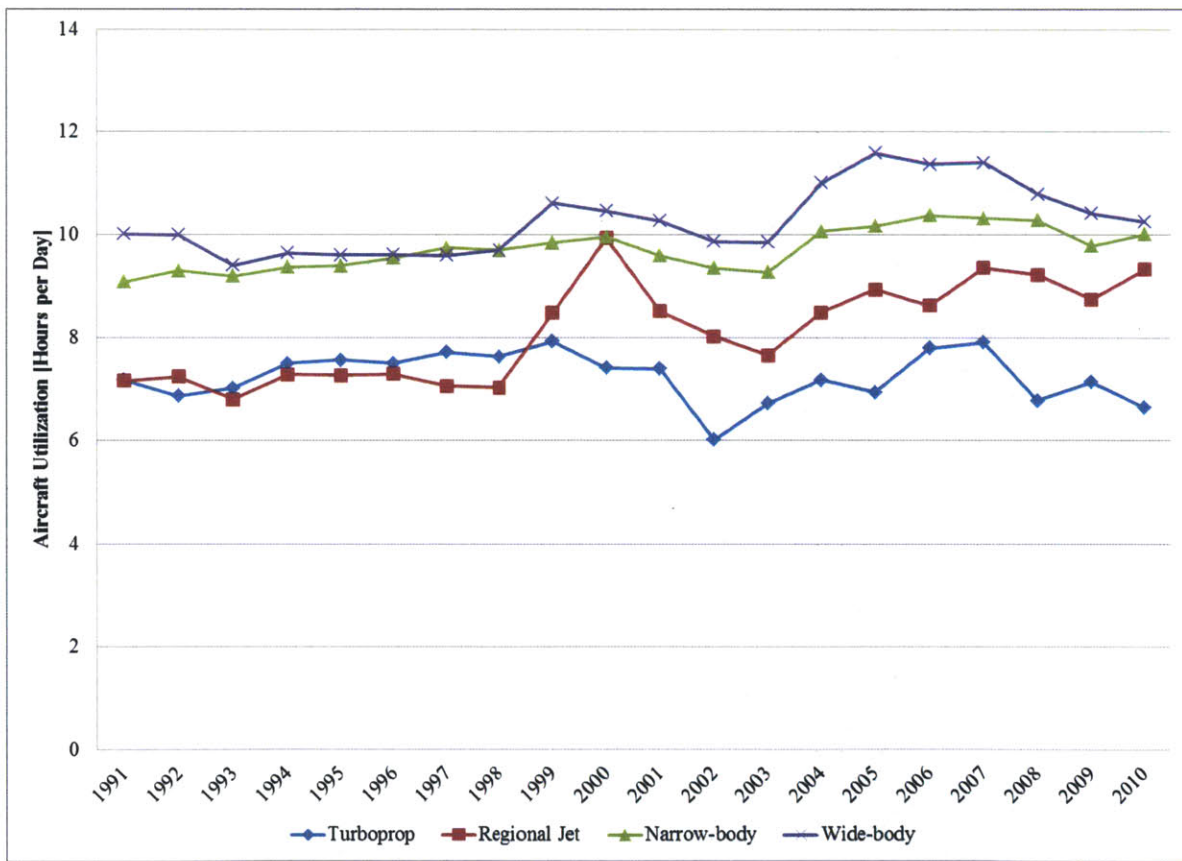


Figure 8 Aircraft Utilization.

The average aircraft seat capacity, a measure of seats per aircraft mile, increased in each of the aircraft classes with the exception of wide-body aircraft. As seen in Figure 9, wide-body seat capacity declined 10.8% over the 20 years period due to the shift of large, wide-body aircraft to

international routes. Aircraft such as the Boeing 747, capable of seating upwards of 400 passengers, which during the 1990s spent a majority of time in domestic operations, are now exclusively on international flights. As a result, the majority of the U.S. wide-body fleet now consists of Boeing 767 transcontinental flights configured for approximately 200 seats.

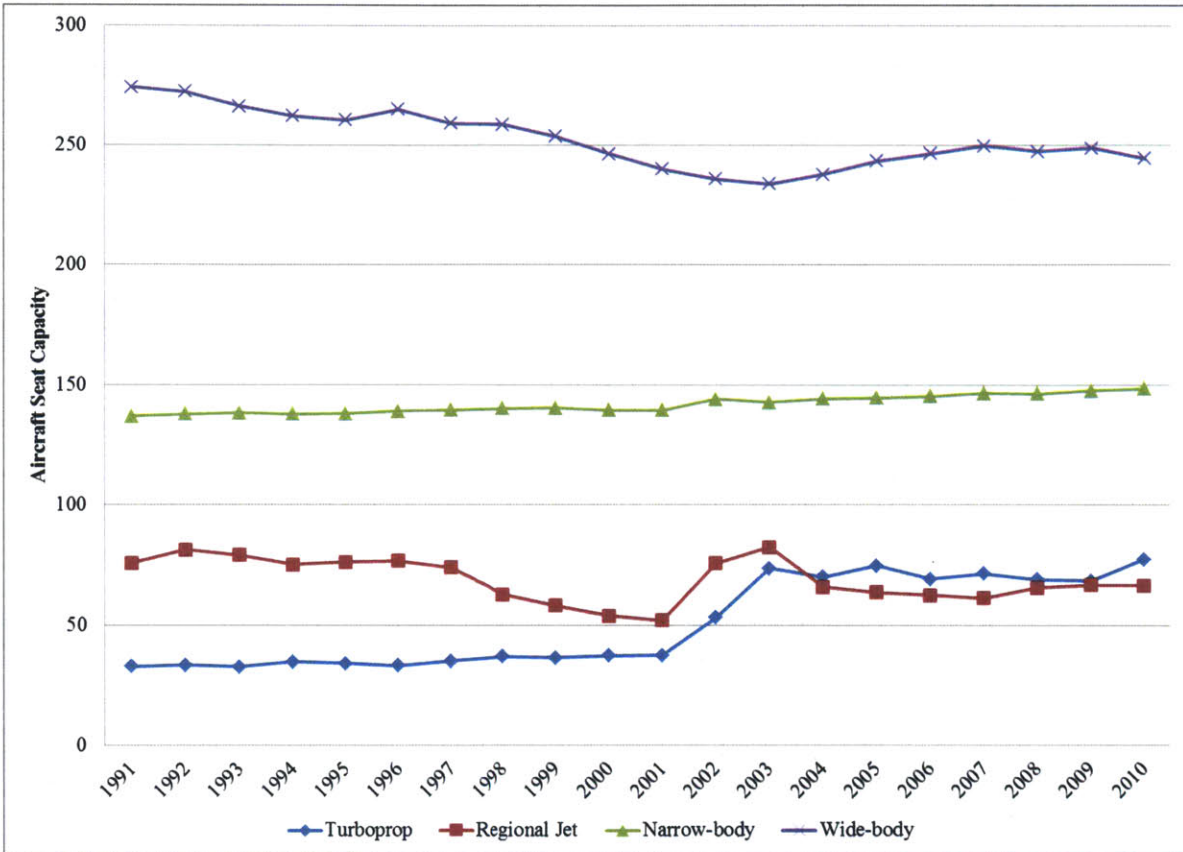


Figure 9 Aircraft Seat Capacity.

A second important trend seen in Figure 9 is the sharp increase in turboprop aircraft seat capacity, which is attributed to the introduction of larger turboprops such as the Aerospatiale Atr-72 and the Bombardier Q400 coupled with the retirement of smaller turboprop aircraft such as the Saab-Fairchild 340/B. The Aerospatiale Atr-72 and the Bombardier Q400 are capable of transporting 65 and 75 passengers, respectively; as opposed to the Saab-Fairchild 340/B that only seats 34 passengers.

In comparison, the regional jet seat capacity declined 12.1% over the same time period; however, the decline is largely due to the fact that the aircraft operating from 1991 to 1996 within the regional jet class, defined as jet-powered aircraft with less than 100 seats, were much

larger than the initial regional jets produced by Bombardier and Embraer. These aircraft included the Fokker F28-4000/6000 and British Aerospace Bae-146, both capable of seating capacities above 60 and 80 seats, respectively. However, as these aircraft were retired from U.S. fleets in the late 1990s, the bulk of the regional jet fleet comprised of 50-seat CRJ-100/-200s and ERJ-145s, and as a result, the seating capacity declined significantly. Only within the last ten years, with the advent of the CRJ-700/-900 and the ERJ-170/-190, has the metric increased to an average of 66.5 seats per regional jet.

Although not as apparent in Figure 9, narrow-body seat capacity increased 8.4% to 148.5 seats in 2010, which is largely attributed to the introduction of newer, larger 737 models such as the 737-800/-900, and to a lesser extent, the stretched 757-300 in 2001. In addition, multiple airlines within the U.S. have begun the process of installing new, slim line seats in the economy cabin, allowing the airline to install an additional row of seats (Ashley).

Another factor that affected the U.S. commercial domestic fleet is aircraft ground time per departure, defined as the non-flying portion of total block hours per departure. Over the 20 year period, the average aircraft ground time per departure increased 20.2% from 18.85 minutes in 1991 to 22.67 minutes in 2010. The trends shown in Figure 10 indicate that ground times typically increased with aircraft size with the exception of regional jets and narrow-body aircraft from 2004 through 2010. One potential explanation for the trends is the relationship between ground time and the airports served by the aircraft. For example, turboprop aircraft ground times were the lowest on average of all aircraft classes as these aircraft typically operate feeder flights to and from hubs. On flights departing from a hub, these aircraft operate into airports that are small and not subject to take-off or ramp delays, thereby reducing the overall ground time. On the other hand, wide-body aircraft typically operate into and out of major hubs when flying domestically, which likely explains why wide-body aircraft had the longest ground times over the 20 year period, as they were subject to potential take-off and ramp delays at both airports. Ground times for regional jets and narrow-body aircraft fell in between those for turboprop and wide-body aircraft, which is likely attributed to the fact that both aircraft classes operate from hubs to a wide variety of airports, some notorious for delays. From 2004 through 2010, regional jet ground times surpassed narrow-body ground times, which is likely related to the large use of regional jets at delay-prone airports such as New York's LaGuardia Airport.

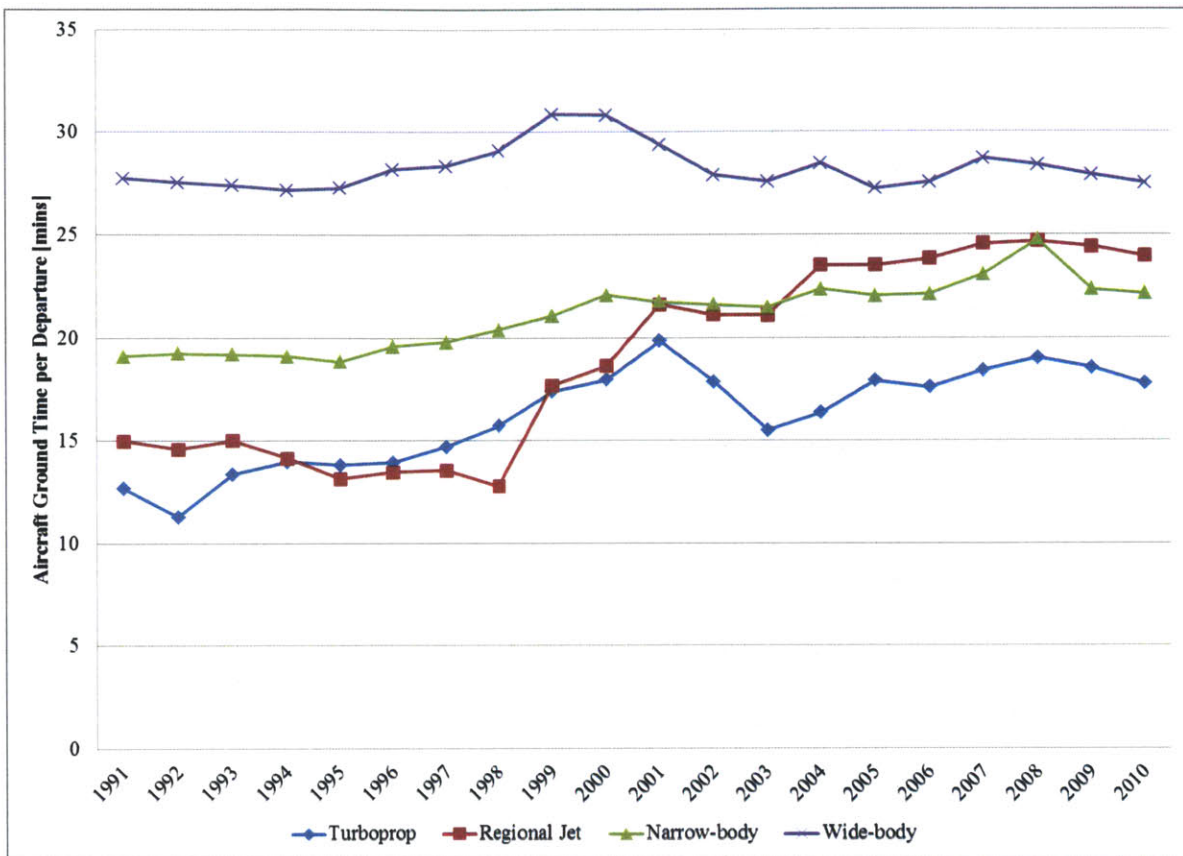


Figure 10 Aircraft Ground Time per Departure.

The last metric that we will examine in this section is gallons of fuel per block hour per aircraft seat, a surrogate for fuel burn. The trends shown in Figure 11 illustrate two important points. First, there is a clear distinction in fuel burn between turboprop and jet-powered aircraft as seen by the regional jet, narrow-body, and wide-body grouping at the top of Figure 11. Second, advances in engine technology coupled with retirements of older aircraft are apparent in each of the aircraft classes. For example, turboprop aircraft use approximately half as much fuel per block hour per seat than jet aircraft. With that said, it is important to keep in mind that the majority of turboprops in use between 1991 and 2000 are no longer in service or only remain in limited service. As such, the majority of the newer turboprops such as the Bombardier Q400 utilize newer engine technology and carry more passengers, both of which reduce the per seat fuel burn. Regional jet fuel burn has drastically decreased since the advent of the Bombardier CRJ and Embraer ERJ, partially due to new engine technology and partially due to larger aircraft, again reducing the per seat fuel burn. In addition, the sharp decrease in both the

turboprop and regional jet per seat fuel burn in 2001 is likely attributed to the larger, high-density variants becoming mainstream coupled with the retirements of older, less efficient aircraft types within the class.

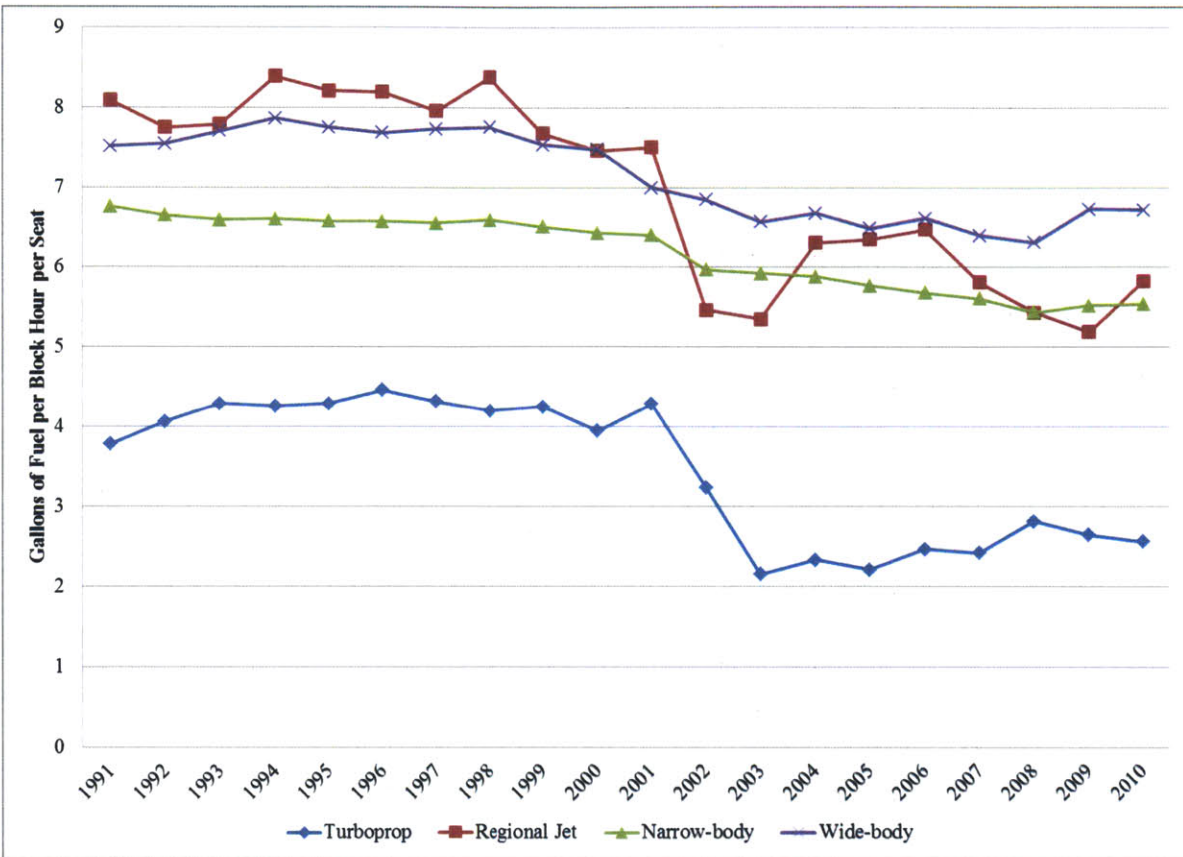


Figure 11 Gallons of Fuel per Block Hour per Seat.

Narrow-body and wide-body aircraft both experienced a gradual decline in per seat fuel burn, which is largely attributed to the retirement of older aircraft from commercial service. For example, within the 20 year period, the narrow-body Boeing 727 series, Boeing 737-200, McDonnell Douglas DC-8 series, and the McDonnell Douglas DC-9 series were retired or significantly withdrawn from commercial domestic service. Similarly, wide-body aircraft including the Airbus A300 series, McDonnell Douglas DC-10 series, and Boeing 747-100/-200/-300 were also retired or significantly withdrawn from service. The retirements of both aircraft sets altered the composition of narrow-body and wide-body aircraft within the U.S. commercial domestic market, and due to the newer technology within jet engines, the gallons of fuel per block hour per seat decreased over time.

3.3. Chapter Summary

This chapter focused on our analysis of U.S. commercial domestic aircraft operations from 1991 to 2010. The most significant finding was the introduction of the regional jet in 1996 and its impact on U.S. commercial domestic aircraft operations. Table 7 compares each aircraft class in 1991 and 2010 as a percentage of the industry in terms of fleet size, ASMs, RPMs, and aircraft departures. As seen in Table 7, the regional jet had less than 3% of the industry fleet size, ASMs, RPMs, and aircraft departures in 1991. However, by 2010, the regional jet performed over 39% of the industry departures despite only having 33% of the industry fleet. In addition, the increase in ASMs and RPMs for the regional jet came at the expense of wide-body aircraft, as both turboprop and narrow-body aircraft maintained the same proportions of ASMs and RPMs in 2010 as they had in 1991.

Table 7 Comparison of Aircraft Class as Percentage of Industry

	Turboprop		Regional Jet		Narrow-body		Widebody	
	1991	2010	1991	2010	1991	2010	1991	2010
Fleet Size	6.59%	4.61%	2.12%	32.91%	81.26%	59.87%	10.02%	2.61%
ASMs	0.58%	1.05%	0.66%	14.14%	73.88%	77.97%	24.88%	6.84%
RPMs	0.45%	0.80%	0.59%	13.43%	72.10%	78.58%	26.87%	7.19%
Revenue Departures	9.76%	5.78%	2.75%	39.61%	81.80%	53.39%	5.69%	1.21%

A second point that resonated throughout the chapter was the withdrawal of wide-body aircraft from U.S. commercial domestic service. In the early 1990s, the large reduction in domestic wide-body flying was the result of Lockheed L-1011 and Douglas DC-10 retirements; however, in the 2000s, further decline in wide-body aircraft was due to the significant shift of aircraft to international services. As a result of this shift, narrow-body aircraft began to fly longer routes and the average stage length for narrow-body aircraft increased 50% from 1991. Similarly, regional jets became widespread within the industry and began to overfly hubs, providing more point-to-point services and increasing stage lengths by up to 70%.

Finally, a third trend that appeared in the chapter was the shift within turboprop, regional jet, and narrow-body aircraft to increase seat capacity. This was made possible by aircraft manufacturers producing larger turboprop, regional jets, and narrow-body aircraft such as the Aerospatiale Atr-72, Bombardier Q400, the Bombardier CRJ-700/-900, the Embraer ERJ-170/-

190, and the Boeing 737-800/-900. In addition, the larger turboprop and regional jet aircraft aided legacy airlines by allowing them to redefine their networks. Turboprop and regional jet aircraft could now overfly hubs on thinner routes or compliment narrow-body service for increased frequency between key cities within the airline's network.

4. U.S. Commercial Domestic Aircraft Operations by Aircraft Class

4.1. Introduction

In the previous chapter, we focused our analysis on U.S. commercial domestic aircraft operations comparing the four defined aircraft classes: turboprop, regional jet, narrow-body, and wide-body aircraft. In this chapter, we again focus on U.S. commercial domestic aircraft operations from 1991 to 2010; however, we examine each aircraft class independently and highlight individual aircraft trends. In addition, we review key operational parameters and relate the findings to our analysis in Chapter 3. For each of the aircraft classes, we performed studies on operational parameters including fleet size, aircraft departures, seat capacity, utilization, and average stage length. Studies that led to significant insights are reported within this chapter.

4.2. Turboprop

The U.S. commercial domestic turboprop fleet declined 4.4% from 215 aircraft in 1991 to 205 aircraft in 2010; however, the fleet grew as large as 571 aircraft during that time period. Although the fleet consisted of 40 different aircraft types over the 20 year period, five aircraft types accounted for 66.6% of the fleet as seen in Figure 12. Most notable is the Saab-Fairchild 340/B and its growth from 1997 through 2000. During this time, over 180 Saab 340/B aircraft operated within the U.S. commercial domestic turboprop fleet for American Eagle Airlines, ATA Connection, and Mesaba Airlines providing regional service to and from hub cities. Following the economic downturn in late 2000 and the events of September 11, 2001, both American Eagle and Mesaba began to reduce their Saab 340/B fleets while ATA Connection ceased operation further reducing the fleet. As of 2010, the two remaining airlines using the Saab 340/B included Mesaba Airlines and Colgan Air.

The Embraer EMB-120 Brasilia was the second most-common turboprop within the U.S. commercial domestic fleet between 1991 and 2010, flown extensively in the mid-1990s by SkyWest Airlines, Atlantic Southeast Airlines, and ExpressJet Airlines. We attribute the continued decline of the Brasilia during the late 2000s to the advent of newer turboprops such as the Bombardier Q400, as the Brasilia first entered service back in 1985. As of 2010, SkyWest Airlines is the last commercial operator of the EMB-120 with the exception of some small charter operators.

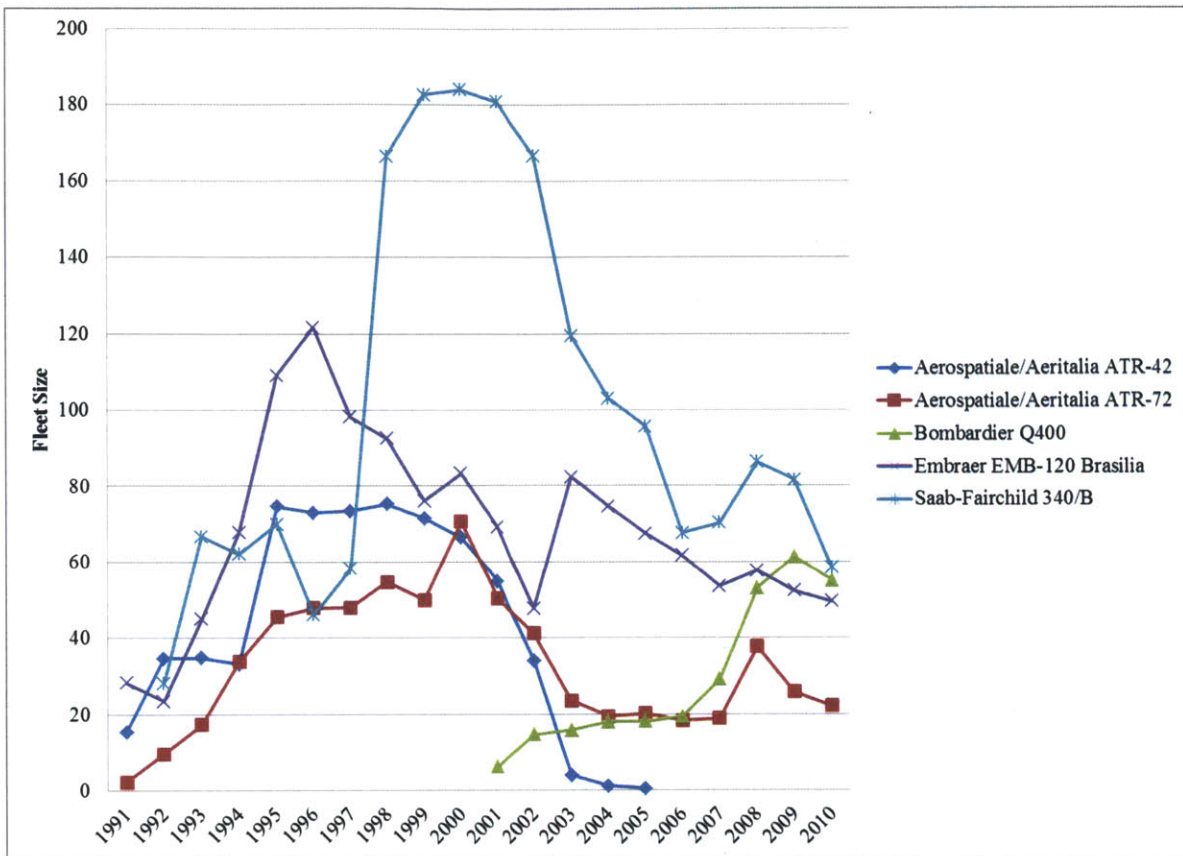


Figure 12 Turboprop Fleet Size.

Despite the overall declining trend of the turboprop fleet between 2000 and 2010, the Bombardier Q400 was introduced in 2001 and grew to 55 aircraft by 2010. We believe the increasing trend in fleet size for this particular turboprop is linked directly to advances in engine technology, allowing the Q400 to cruise 30% faster than previous turboprops and offer higher fuel efficiency, which makes it an attractive alternate to jets on shorter routes ("Bombardier Q400").

The turboprop fleet average stage length increased by approximately 50 miles from 1991 to 2010; however, three specific aircraft types experienced significant changes during this time period as shown in Figure 13. It is important to note that stage length is both a function of the aircraft range and the airline network in which it operates. With that in mind, the first notable trend is the increase and subsequent decrease in the average stage length by the Bombardier Q400. The Q400 was operated by four different carriers between 2001 and 2010; however, prior to 2006, Horizon Air was the sole operator of the type. During this time, Horizon Air increased

the average stage length of its Q400 fleet to just over 350 miles. However, in the late 2000s, three additional carriers began operating the Q400: Colgan Air, Island Air Hawaii, and Lynx Aviation. Island Air Hawaii and Colgan Air introduced the Q400 at much shorter stage lengths of 106 miles and 284 miles, respectively. In addition, the average stage length of the Q400 fleet at Horizon Air began to decline in 2007, which resulted in the average stage length for the entire domestic Q400 fleet to drop below 300 miles, thus explaining the trend seen in Figure 13.

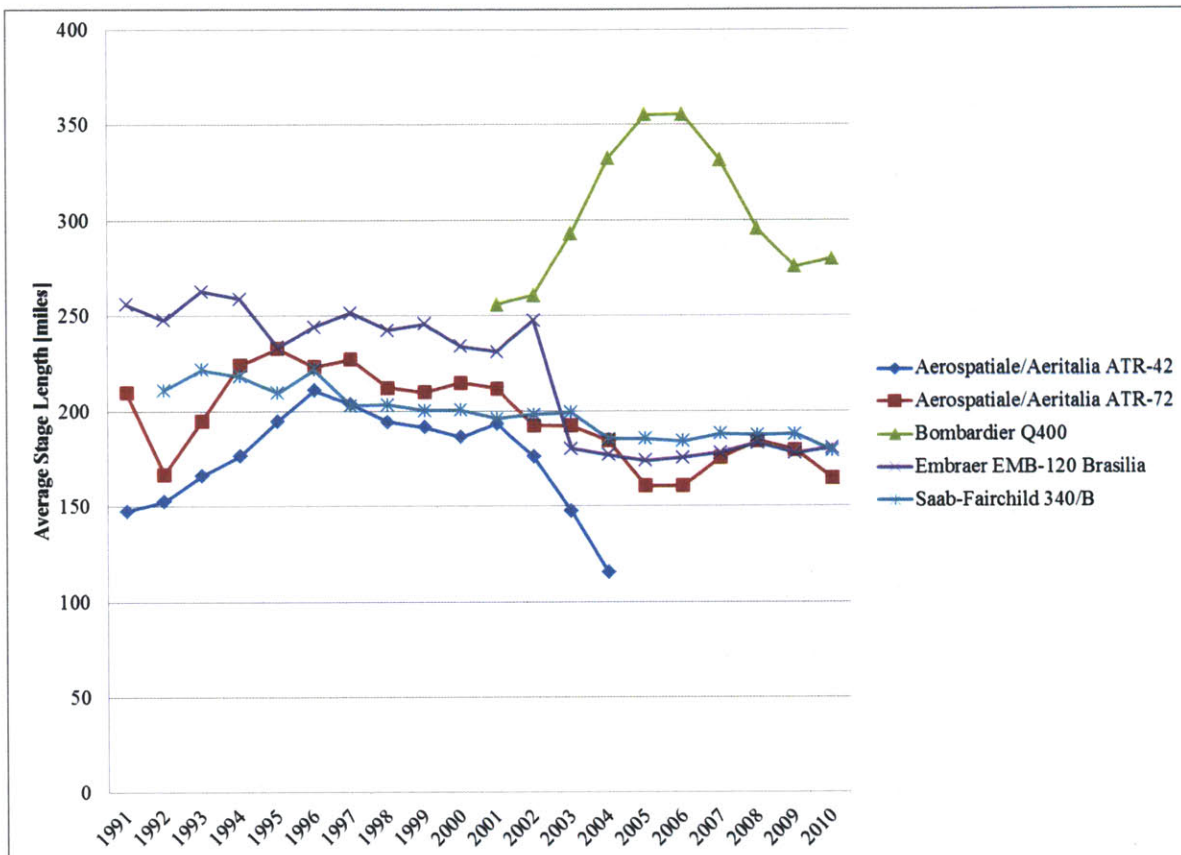


Figure 13 Average Stage Length.

The second interesting trend is the decline in the Embraer EMB-120 Brasilia average stage length from 2002 to 2003. Prior to 2003, the Brasilia was operated primarily by three airlines: Atlantic Southeast Airlines (ASA), Comair, and ExpressJet Airlines. However, between 2002 and 2003, ASA, Comair, and ExpressJet withdrew the Brasilia from their fleets in favor of the Bombardier and Embraer regional jets. As a result, many of the Brasilia aircraft were purchased by SkyWest Airlines to operate on the west coast, which caused the ensuing reduction in average stage length seen in 2003.

The third trend seen in Figure 13 is the decline in the average stage length of the ATR-42 between 2001 and 2004. By 2001, the ATR-42 was nearing its retirement from the U.S. commercial domestic market and only operated by Trans States Airlines. As a result, Trans States Airlines continued to use the ATR-42 in a limited capacity on significantly shorter routes, resulting in the decline in the average stage length.

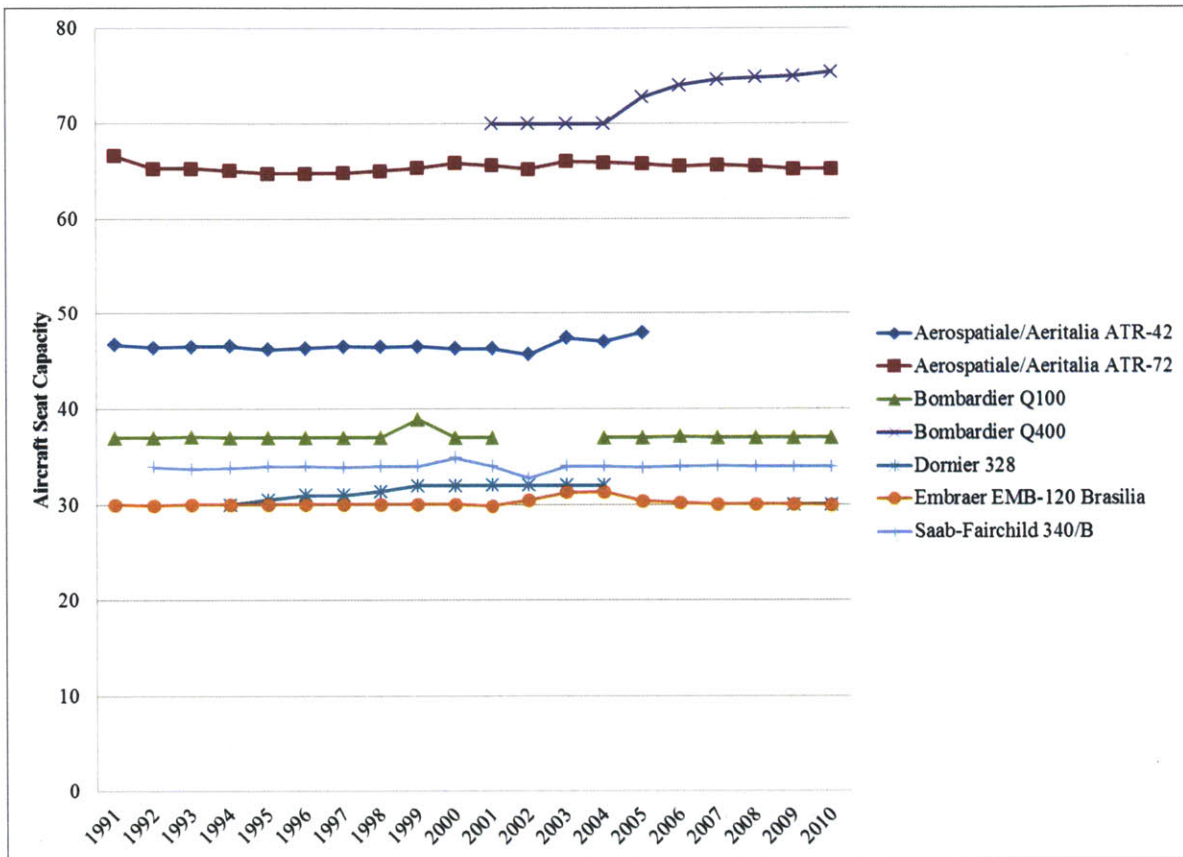


Figure 14 Aircraft Seat Capacity.

In Chapter 3, we highlighted the increased seat capacity within the turboprop class due to the introduction of the Aerospatiale Atr-72 and the Bombardier Q400. Our subsequent analysis of the turboprop class indicates that two distinct turboprop size groups existed in the U.S. commercial domestic for turboprop aircraft with a capacity greater than 25 seats. The first, as seen in Figure 14, are turboprops between 30 and 50 seats. The majority of these turboprop aircraft operate feeder flights from spoke cities to airline hubs. The second distinct size is turboprop aircraft between 65 and 75 seats, which captures both the Aerospatiale Atr-72 and the Bombardier Q400. These aircraft operate from spoke cities to airline hubs; however, their routes

also include flights between larger city pairs as well as supplemental frequency to narrow-body aircraft on major hubs routes.

4.3. Regional Jet

Between 1991 and 2010, the types of aircraft operating under the definition of regional jet, jet-powered aircraft with less than 100 seats, changed significantly. The regional jets of the early 1990s were retired, succumbing to the dawn of new-age regional jets produced by Bombardier and Embraer. Throughout the following discussion on fleet size and aircraft seat capacity, we felt it appropriate to discuss the regional jet in two groups. The first group consists of regional jets operating in 1991, while the second group consists of regional jets operating in 2010.

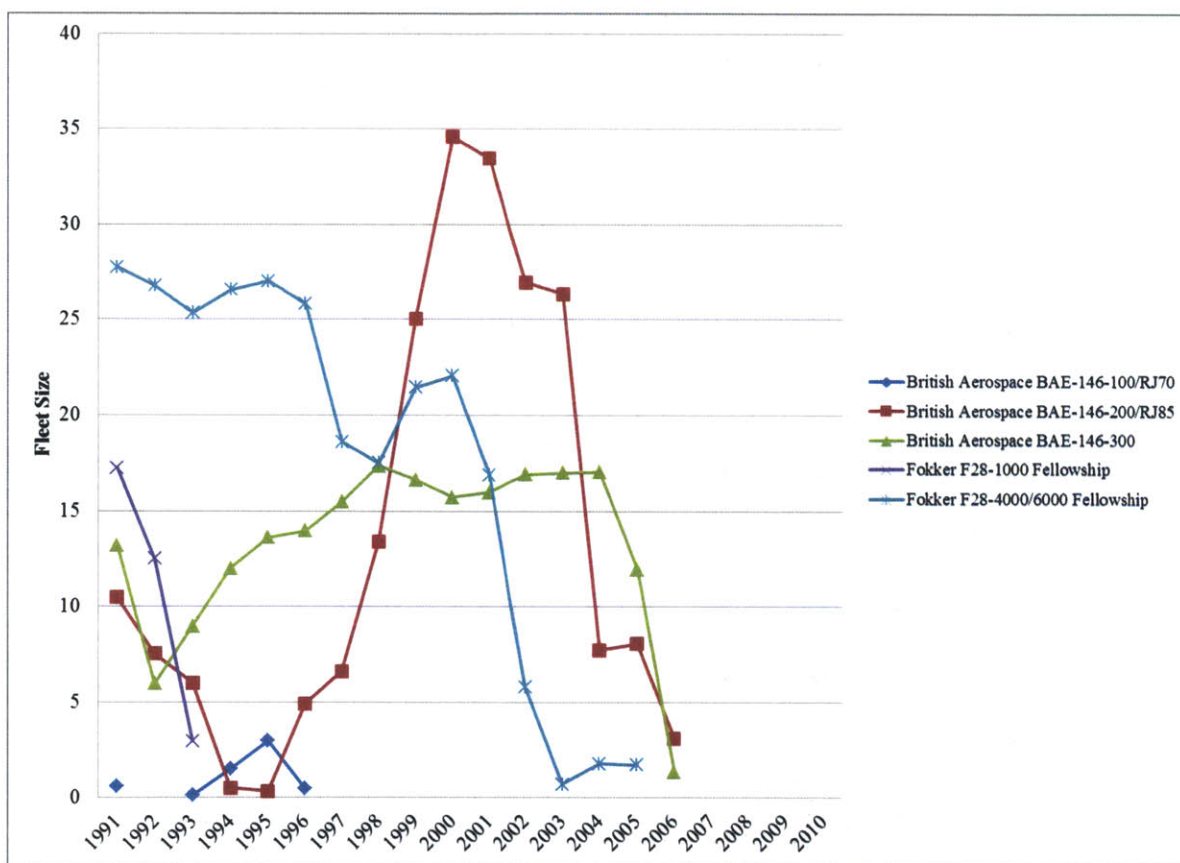


Figure 15 Regional Jet Fleet Size for Aircraft in Service in 1991.

Figure 15 describes the fleet size for regional jets in service in 1991. In total, the five aircraft types operating in the early 1990s accounted for only 69 aircraft, less than 2% of the entire U.S. commercial domestic fleet. The three most significant aircraft operating within this

category were the Fokker F28-4000/6000 Fellowship, British Aerospace BAE-146-200/RJ85, and the British Aerospace BAE-146-300. The Fokker F-28-4000/6000s were operated by both Horizon Air and US Airways in the early 1990s; however, US Airways retired their fleet in 1996, as seen by the decline shown in Figure 15. In addition, Horizon Air retired its fleet of Fokker F-28-4000/6000s in 2003, with the remaining aircraft operated by a charter airline. Similarly, the BAE-146-200/RJ85s were operated by Atlantic Southeast Airlines until 1998, when the fleet was transitioned to Mesaba Airlines flying as Northwest Airlink until 2006. Lastly, the BAE-146-300s were operated exclusively by Air Wisconsin as United Express from 1991 to 2006. In total, the majority of the 69 regional aircraft were operated only by a handful of airlines in the early 1990s.

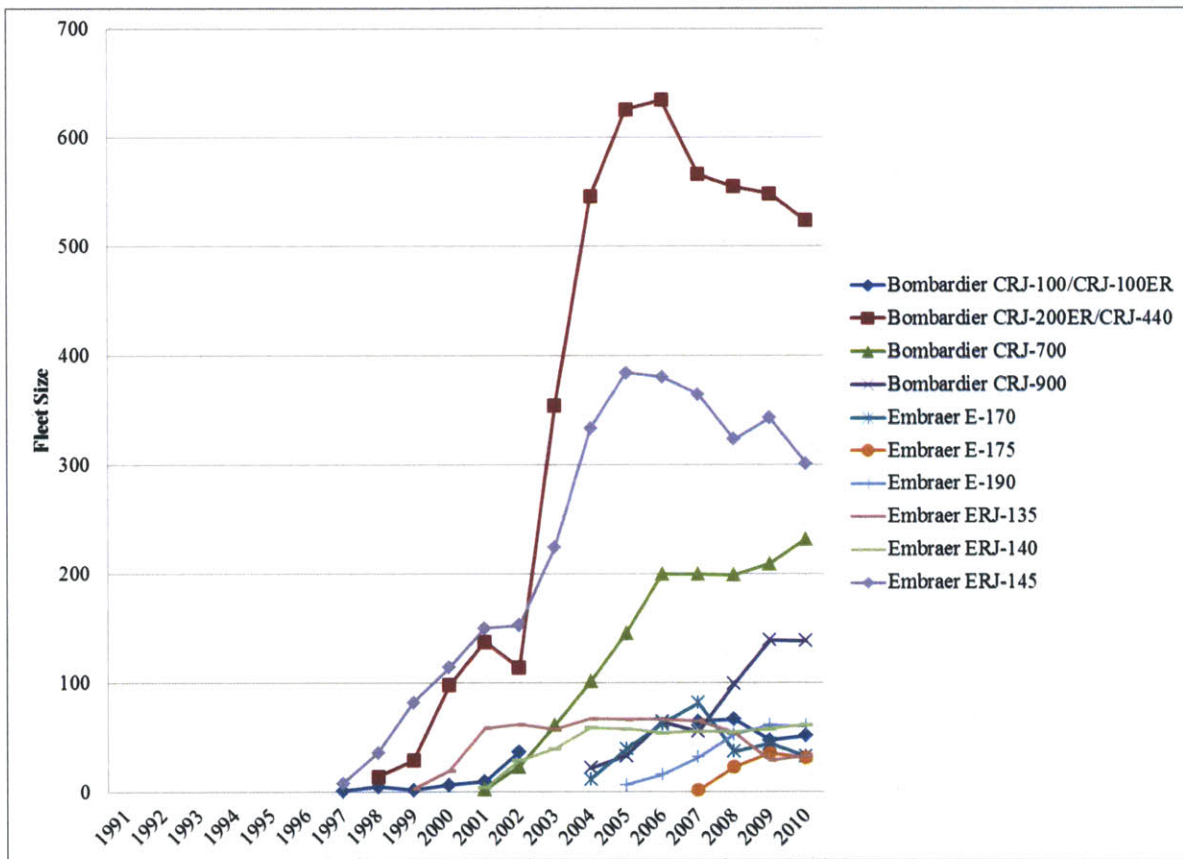


Figure 16 Regional Jet Fleet Size for Aircraft in Service in 2010.

In comparison, the U.S. commercial domestic regional fleet grew to 1,468 aircraft by 2010 due to the introduction of Bombardier and Embraer regional jets. Three important trends emerge in Figure 16. The first is that the growth of the regional jet from 1997 through 2010 is one of the

largest changes within the U.S. commercial domestic fleet since 1991. In a span of 20 years, the regional jet increased its share of the entire U.S. commercial domestic fleet from 2.1% to 32.9%. In addition, by 2010, regional jets provided 14.1% of the total commercial domestic ASMs and 39.6% of all commercial domestic departures, in comparison to just 0.66% and 2.75%, respectively, in 1991.

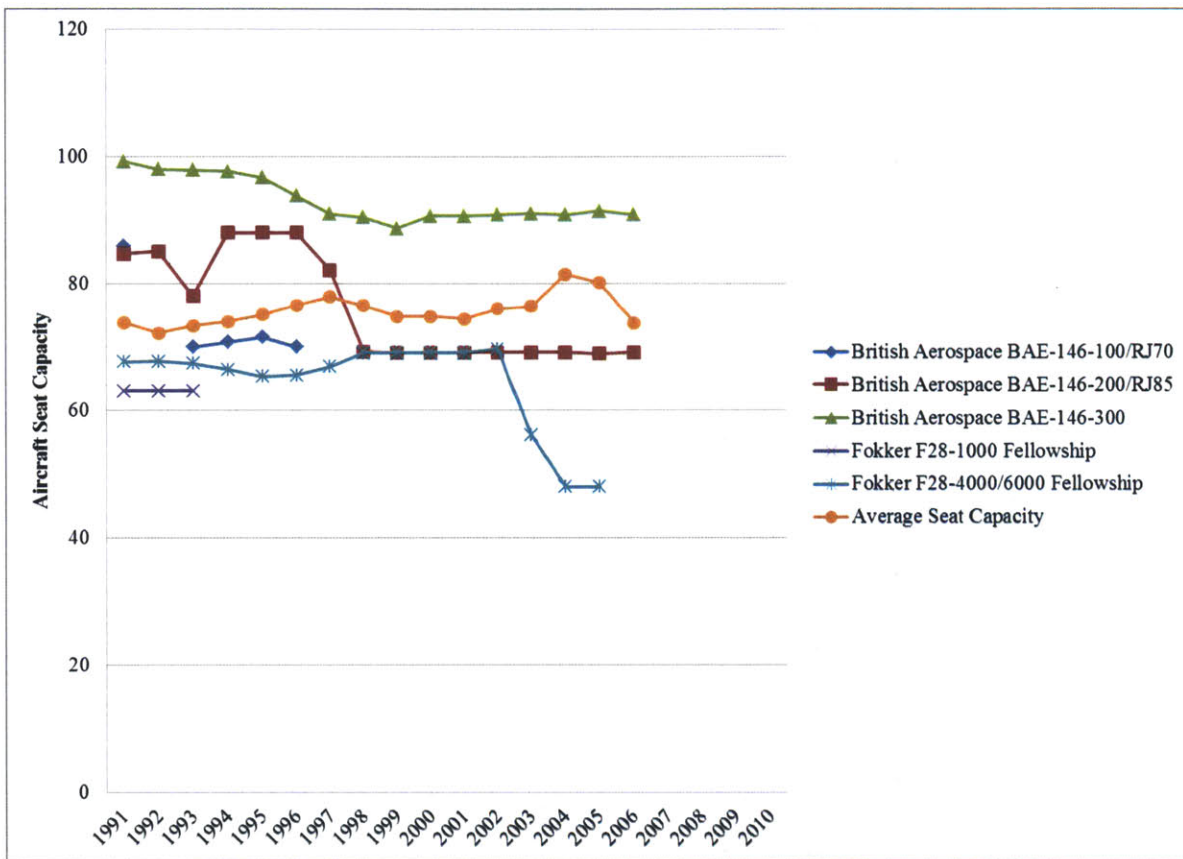


Figure 17 Regional Jet Aircraft Seat Capacity for Aircraft in Service in 1991.

The second trend seen in Figure 16 is that the Embraer ERJ-145 and Bombardier CRJ-200 fleets, both 50-seat regional jets, began to decline in 2005 and 2006, respectively, after 8 years of near-continuous growth. In that time frame, approximately 75 50-seat regional jets left the U.S. commercial domestic market. We attribute the reduction in fleet size to rising fuel prices, which made the 50-seat jets less economical to operate. As a result, certain routes that once were economical became no longer viable for the airlines. In addition, many of the 50-seat jets were sold to airlines in other countries during this time period. For example, in 2005, over 30 CRJ-200

aircraft were sold to non-U.S. operators when U.S. based Independence Air ceased operation ("Canadair Regional Jet in Independence Air History").

The third notable trend is the continuous increase in CRJ-700/-900 and Embraer E-175/-190 aircraft from 2001 onward. These variants have increased in popularity among U.S. regional airlines as they fill a long-time void in the 70 to 100-seat aircraft category. Many of these aircraft now serve larger cities once only served by mainline aircraft. In addition, many of the airlines have installed premium cabins and wireless internet on these smaller aircraft to improve their appeal to the traveling public. We believe that these newly introduced jets will continue to grow in size as mainline domestic carriers continue to lean their domestic networks in hopes of increased profits.

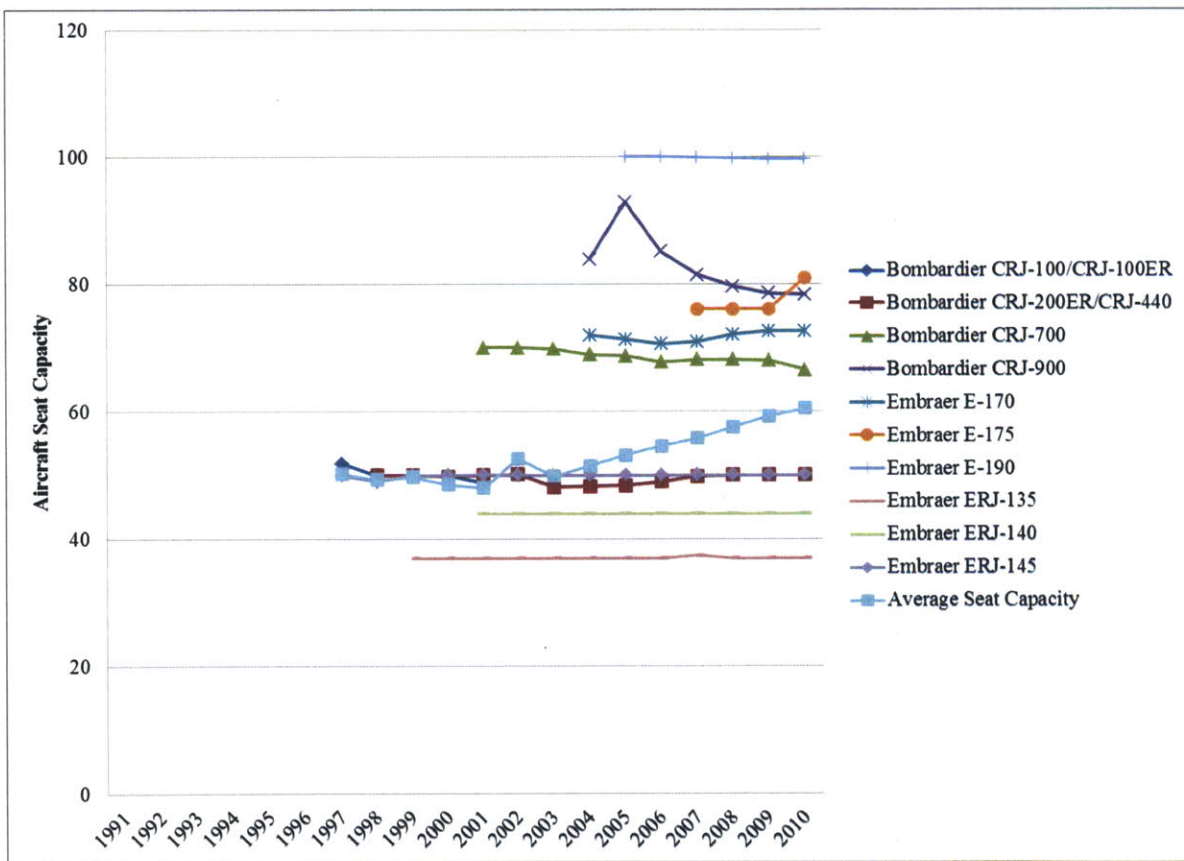


Figure 18 Regional Jet Aircraft Seat Capacity for Aircraft in Service in 2010.

A second metric that clearly illustrates the change in the regional jet from the early 1990s to the late 2000s is aircraft seat capacity. Figure 17 highlights the regional jet seat capacity for aircraft that were in service in 1991. Overall, the regional jets of the early 1990s had an average

capacity of 75-80 seats. The two major shifts seen in Figure 17 are the decline in seat capacity of the Fokker F28-4000/6000 and the BAE-146-200/RJ85. The decline in the Fokker's seat capacity is due to the aircraft being operated only by a charter airline in its last few years of commercial domestic service, during which we suspect the interiors were reconfigured to accommodate fewer passengers. Similarly, the BAE-146-200/RJ85s were reconfigured into a two-class 69-seat configuration to allow Mesaba Airlines to operate the aircraft within the Northwest Airlines scope clause ("Mesaba to Double RJ85 Fleet").

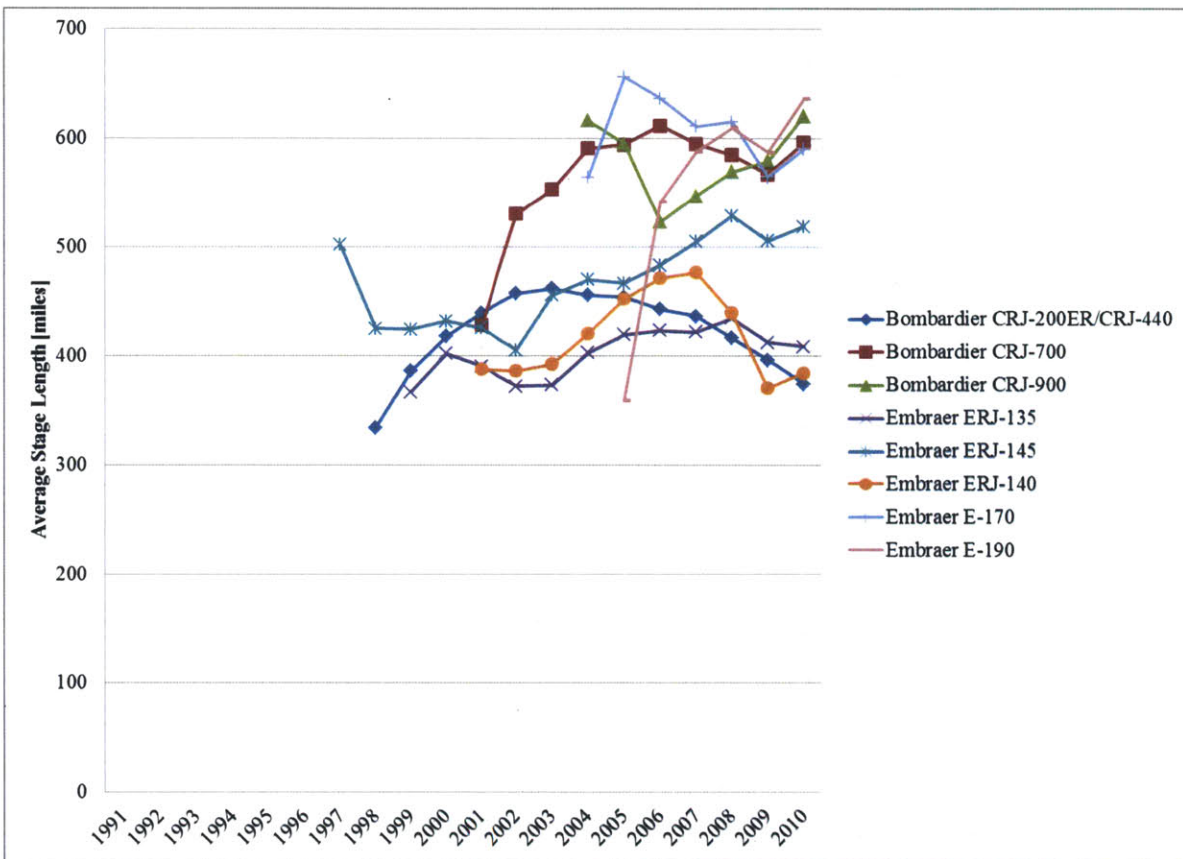


Figure 19 Regional Jet Average Stage Length.

In contrast, the regional jets in service in the late 2000s offered a large variation in seat capacity as shown in Figure 18. Most noteworthy is the increasing trend in seat capacity from 2003 through 2010, due to newly introduced CRJ-700/-900 and Embraer E-Jet series. In addition, we feel that this trend will carry on as fuel prices continue to increase as the larger regional jets offer lower unit costs compared to the 50-seat jets. The sharp spike observed in 2005 for the CRJ-900 is due to early customers adopting different cabin configurations. Some

early customers adopted an all-economy configuration of more than 90 seats; however, since 2005, the majority of the customers have opted for a two-class cabin consisting of 70-80 seats.

The average stage length for the modern day regional jets are shown in Figure 19. Two major trends are immediately apparent. The first is that the newer, larger regional jets including the CRJ-700/-900 and the Embraer E-190 exhibit increasing stage lengths from 2006 through 2010. As the larger regional jets became available in the early 2000s, these aircraft filled a void between the 50-seat jet and the 130-seat small narrow-body. In addition, some of the new jets offered a two-class configuration, making them very attractive to business passengers. As a result, the larger regional jets were used on longer routes to and from hubs that had traditionally been flown with small narrow-body aircraft.

The second interesting trend is the decline in stage length seen in the CRJ-200 from 2002 through 2010. Again, we attribute the decline in stage length to the introduction of the newer, larger regional jets. As the CRJ-700/-900 and Embraer E-170/-190 were introduced, we believe the CRJ-200 fleet shifted focus to cities within a smaller radius of the major hubs. In turn, the larger regional jets were then used to serve cities outside this radius that were not economically viable to serve with small narrow-body aircraft. It is important to note that the ERJ-145 continued to see increased stage lengths despite the fact that it is comparable to the CRJ-200. During this time, more than 70% of the ERJ-145 fleet was operated by ExpressJet Airlines for Continental Airlines, in a network where no larger regional jets existed due to the union scope clause. As a result, the ERJ-145 served cities that would have traditionally been served by both the smaller and larger regional jets, which led to the continuous increase in stage length through the 2000s.

4.4. Narrow-body

The U.S. commercial domestic narrow-body fleet grew by only 19 aircraft from 1991 to a total 2,671 aircraft in 2010. However, despite the limited change in absolute size, the narrow-body aircraft class saw a significant change in fleet composition between 1991 and 2010. During this time period, 10 different aircraft types had fleets that exceeded 200 aircraft as seen in Figure 20. The first notable trend shown in Figure 20 is the retirement of the Boeing 727-200/231A, Boeing 737-100/200, and the McDonnell Douglas DC-9-30. With each of these aircraft types,

the fleet has been completely retired from U.S. commercial service with the exception of a few aircraft that still remain with charter operators.

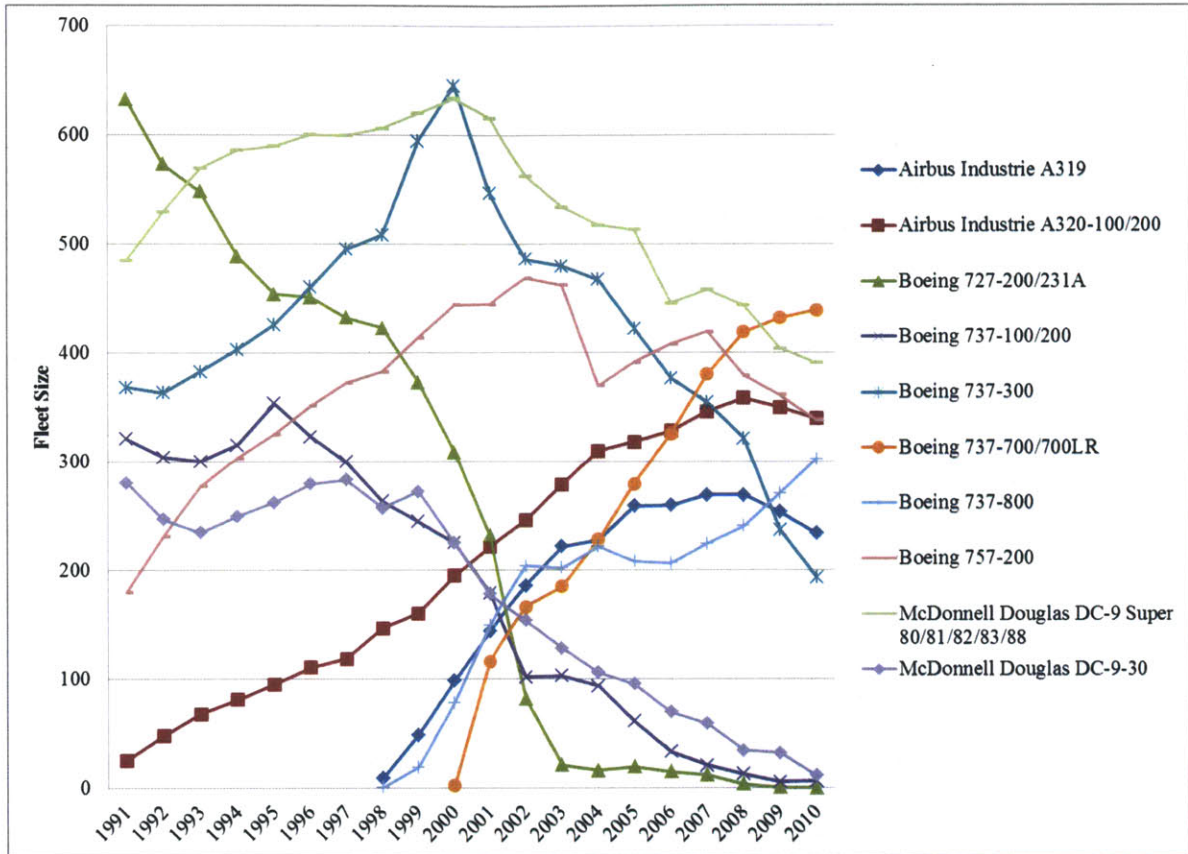


Figure 20 Narrow-body Fleet Size.

In addition, in the years following 2001, the U.S. commercial domestic fleet began to see the withdrawal of the McDonnell Douglas Super 80 Series, Boeing 737-300, and Boeing 757-200. The decline of the McDonnell Douglas Super 80 Series from over 600 aircraft in 2000 to fewer than 400 aircraft in 2010 is largely due to increasing fuel prices, making the aircraft type less economic to operate. In addition, the retirement of the Boeing 737-300 from the fleets of both Continental Airlines and United Airlines was due to the higher operating costs associated with the 737-300 in comparison with the next generation Boeing 737 and Airbus A320 aircraft, respectively. In contrast with the removal of both the McDonnell Douglas Super 80 Series and Boeing 737-300 aircraft, the withdrawal of the Boeing 757-200 from the U.S. commercial domestic fleet was linked to expanded use of the aircraft on transatlantic flights from east coast

hubs. American Airlines, Continental Airlines, Delta Air Lines, and US Airways all used Boeing 757-200 aircraft to operate from their respective east coast hubs to points in Western Europe.

With the retirement and withdrawal of the aforementioned aircraft, four new aircraft types were introduced between 1991 and 2010 to fill the growing void. Both the Airbus A319 and A320 were introduced in the 1990s to multiple airlines across the United States, accounting for a combined fleet of 573 aircraft in 2010. It is interesting to note that both the A319 and A320 suffered two consecutive years of declining fleet sizes at the end of the decade. In comparison, the Boeing 737-700/700LR and Boeing 737-800 were introduced at around the same time as the A319, yet the combined fleet size is larger by nearly 200 aircraft at a total of 741 airframes. We attribute the decline of the Airbus A319 fleet to both Frontier Airlines and Spirit Airlines, which reduced their respective fleets during this time period. Similarly, both Northwest Airlines and US Airways marginally reduced their A320 fleets as well. In contrast, Alaskan Airlines, American Airlines, and Southwest Airlines all received new Boeing 737 aircraft between 2008 and 2010.

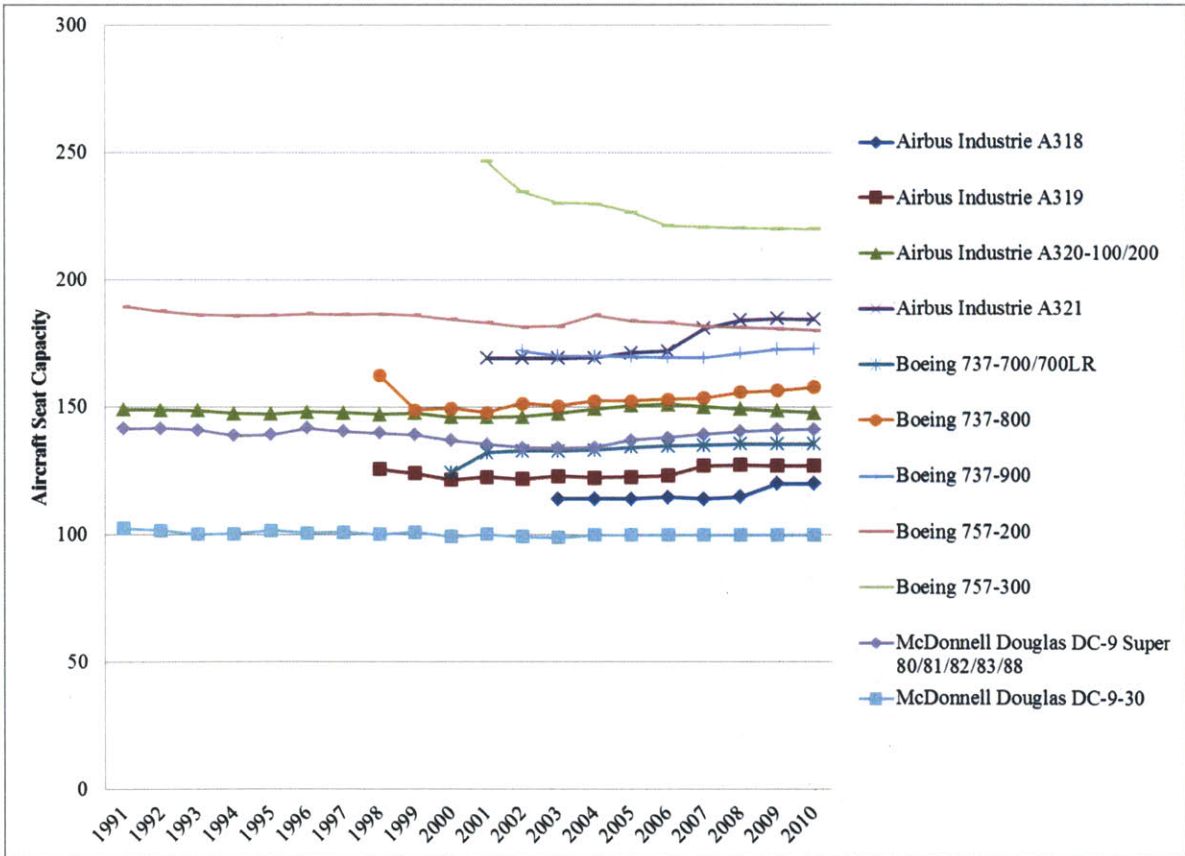


Figure 21 Narrow-body Aircraft Seat Capacity.

In terms of aircraft seat capacity, the U.S. commercial domestic narrow-body fleet had numerous aircraft in the 100 to 150-seat range as seen in Figure 21. Despite the coverage of the 100 to 150-seat region, the two areas of interest in Figure 21 are in the 150 to 200-seat region and the 200 to 250-seat region. Within the 150 to 200-seat region, only the Boeing 757-200 has existed since the early 1990s. However, with the continual trend of transitioning Boeing 757-200 aircraft to transatlantic routes, both Airbus and Boeing entered into this market segment with the Airbus A321 in 2001 and the Boeing 737-900 in 2002. From a seat capacity standpoint, these are the only two aircraft that offer a narrow-body alternative to the aging Boeing 757-200 fleet.

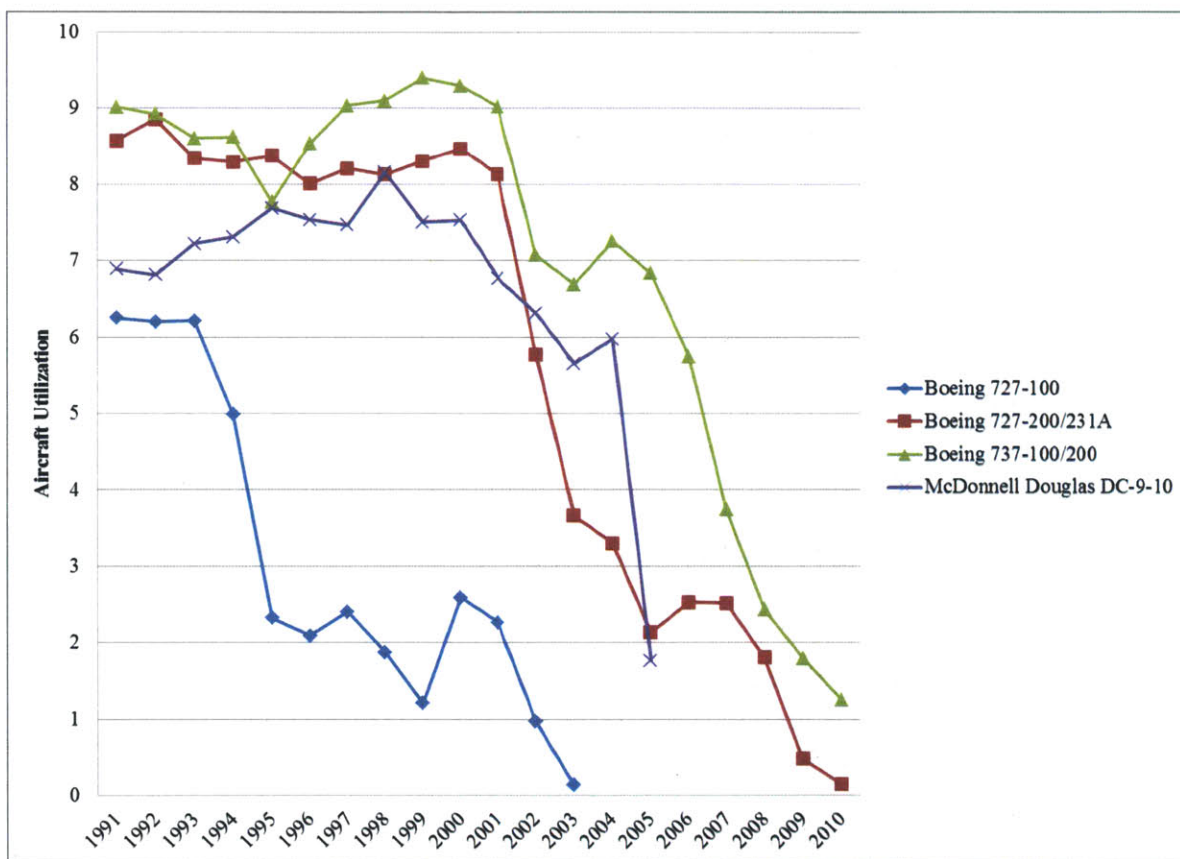


Figure 22 Narrow-body Aircraft Utilization.

The second area of interest in Figure 21 is in the 200 to 250-seat category, where the Boeing 757-300 is the largest narrow-body in the U.S. commercial domestic fleet. The decline in seat capacity from 2000 to 2007 is attributed to interior reconfigurations performed by the airlines. The first 757-300 aircraft was delivered to ATA Airlines, which operated the type in an all economy configuration until 2004 (Perkins). In addition, when Continental Airlines and

Northwest Airlines took delivery of their 757-300 aircraft, both airlines operated the aircraft in a two-class configuration, which subsequently lowered the overall seat capacity.

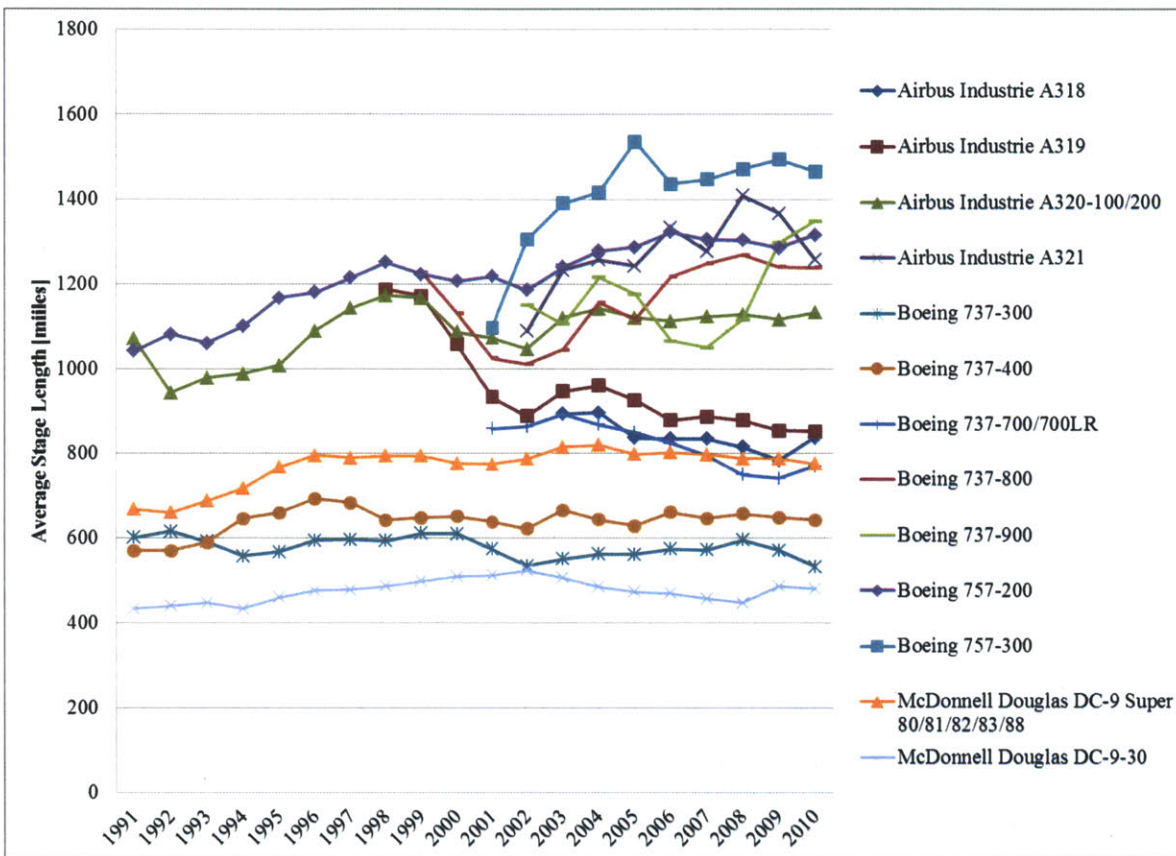


Figure 23 Narrow-body Average Stage Length.

Between 1991 and 2010, four narrow-body aircraft fleets were withdrawn from U.S. commercial domestic service as seen in Figure 22. In each case, we observed that as aircraft are retired, their respective daily utilization rates decline. We attribute this to charter operators using the aircraft on a limited basis after the airlines removed the aircraft from commercial domestic service. For example, the Boeing 727-200/231A experienced a significant decline in daily utilization from 2001 to 2004. During that same time period, the Boeing 727-200/231A fleet declined from 232 aircraft to 16 aircraft. Essentially, as the airlines retired the aircraft from service, charter operators purchased airframes to use on a limited basis, which reduced the overall daily utilization for the aircraft type.

Another interesting observation is seen in the narrow-body average stage length between 1991 and 2010 as shown in Figure 23. While the narrow-body average stage length increased

50.0% from 591 miles in 1991 to 886 miles in 2010, Figure 23 illustrates that two distinct aircraft groupings exist. The first grouping, roughly defined as aircraft with average stage lengths of less than 1,000 miles, appears to remain flat with limited overall growth from 1991 to 2010. However, the second grouping's average stage length, consisting of the Boeing 757-200, Boeing 757-300, Airbus A320-100/200, Airbus A321, Boeing 737-800, and Boeing 737-900, appears to grow significantly from 1991 through 2010. We attribute this growth in stage length as a result of wide-body aircraft transitioning to international routes. As a result, the aforementioned aircraft began operating longer stage lengths to replace the missing wide-body aircraft. Intuition would indicate that the short-range narrow-body aircraft would subsequently increase their stage lengths as well, filling the void left by the long-range narrow-body aircraft. However, the data in Figure 23 indicates that on an aggregate basis, the short-range narrow-body aircraft did not increase their average stage length in any significant fashion.

4.5. Wide-body

The U.S. commercial domestic wide-body aircraft fleet declined significantly from 1991 to 2010. Figure 24 details the fleet size for nine different wide-body aircraft types over the 20 year period. The most significant discovery in Figure 24 is that only four wide-body aircraft types operated U.S. commercial domestic routes in 2010, with the exception of irregular wide-body substitutions. In addition, as wide-body aircraft were retired from service, no new wide-body aircraft were introduced to replace the retired fleet. As a result, routes formally flown by wide-body aircraft were subsequently operated by narrow-body aircraft.

The four wide-body aircraft types that operated U.S. commercial domestic service in 2010 included the Boeing 767-200/ER/EM, Boeing 767-300/300ER, Boeing 767-400/ER, and the Boeing 777-200/200LR/233LR. Of the four types, the Boeing 767-300/300ER was the most common and was operated by American Airlines, Delta Air Lines, Hawaiian Airlines, and United Airlines, each with a fleet of approximately 15 aircraft. Despite airlines operating these types on domestic routes, the significant decline in fleet size within the Boeing 767 fleet from 2003 through 2010 is attributed to the withdrawal of wide-body aircraft from domestic routes in favor of international routes. In the case of American Airlines, the airline opted to keep a dedicated fleet of Boeing 767-200/ER/EM aircraft for its transcontinental service between New York City and Los Angeles and San Francisco ("Boeing 767").

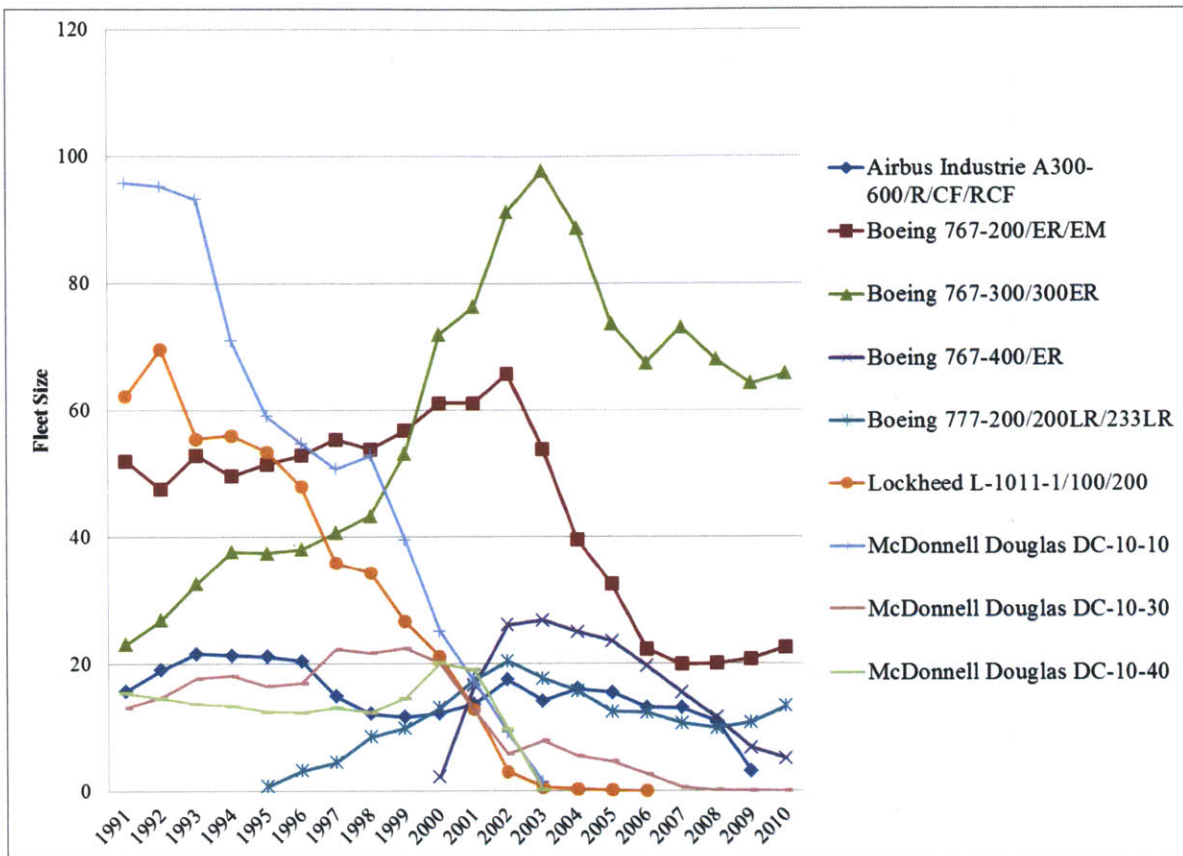


Figure 24 Wide-body Fleet Size.

Despite the overall reduction in wide-body fleet size between 1991 and 2010, wide-body seat capacity remained flat with a few notable exceptions. As seen in Figure 25, the Lockheed L-1011-1/100/200, McDonnell Douglas DC-10-30, and McDonnell Douglas MD-11 all experienced a significant increase in seat capacity in the mid-2000s. At this point in time, the majority of these three aircraft types had already been retired, with the only remaining airframes operated by charter airlines. In addition, the charter airlines reconfigured the interior of the airplanes into single class, high-density layouts, which led to the increase in seat capacity.

In addition, the seat capacity of the Boeing 767-200/ER/EM decreased from 199 seats to 173 seats over the 20 year period. This near-continuous decline is likely due to airlines adding additional premium cabin seats, thereby reducing the total number of seats on-board. In 1991, some airlines operated the Boeing 767-200/ER/EM aircraft in a two-class configuration, which accommodated nearly 200 passengers. In contrast, American Airlines reconfigured its Boeing

767-200/ER/EM fleet to accommodate a three-class configuration, thereby reducing the total seat capacity to 168 seats (“Boeing 767”).

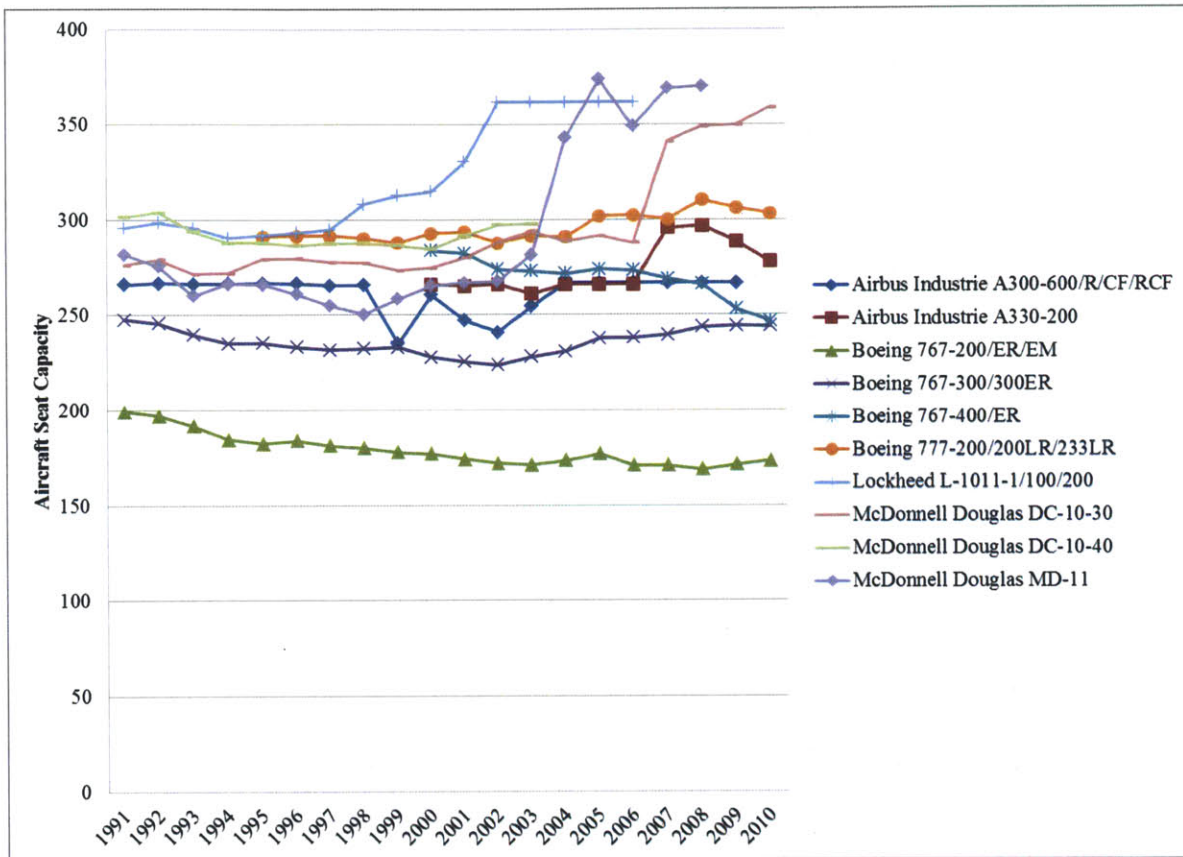


Figure 25 Wide-body Aircraft Seat Capacity.

The average stage length for wide-body aircraft increased significantly from 1,430 miles in 1991 to 2,080 miles in 2010. As seen in Figure 26, nearly every aircraft shown increased in the average stage length over the 20 year period, with two separate aircraft groups coming to light. The first is the Boeing 767-400/ER, operated by both Delta Air Lines and Continental Airlines, which increased its average stage length from 723 miles in 2000 to 3,398 miles by 2010. We attribute this significant growth to Continental Airlines using this aircraft extensively in the late 2000s on its Newark, NJ and Houston, TX to Honolulu, HI routes, which are 4,962 miles and 3,917 miles, respectively.

The second grouping in Figure 26 consists of the remaining Boeing 767s, Boeing 777s, McDonnell Douglas DC-10s, and the Lockheed L-1011s. Despite the overall trend of less

commercial domestic flying in the late 2000s, the average stage lengths of the remaining flights increased as the wide-body aircraft were being used more on transcontinental flights rather than short-haul domestic flights. The variation in year-to-year average stage length, as seen by the Lockheed L-1011, we suspect is linked to the fact that the aircraft was mostly withdrawn from service by 2002, and the average stage length shown in Figure 26 from 2002 through 2006 is a result of charter operations.

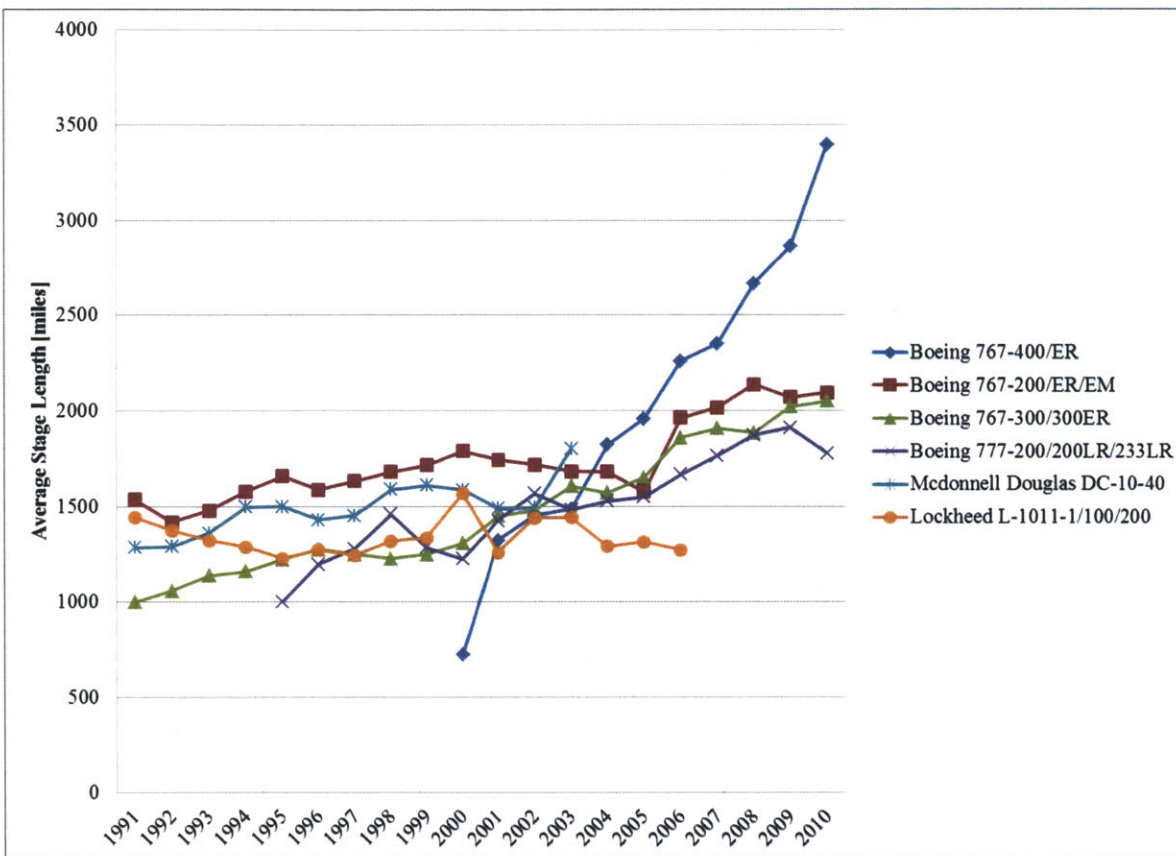


Figure 26 Wide-body Average Stage Length.

4.6. Chapter Summary

This chapter highlighted the major trends within each of the described aircraft classes from 1991 to 2010. One of the major themes within this chapter is the decline of the turboprop fleet from 2000 through 2010. Over this period of time, all turboprops with a fleet greater than 60 aircraft experienced a significant decline in size with the exception of the Bombardier Q400. We believe this declining trend will continue as the majority of the turboprop fleet entered service

before 1991 and will be retired in the upcoming years. In addition, turboprops, which once accounted for 14.2% of the U.S. commercial domestic fleet, only accounted for 4.6% in 2010. Lastly, the Q400 is marketed as a 70+ passenger airplane, begging the question as to which aircraft will replace the turboprops in the 30 to 50-seat markets.

A second theme within this chapter is the dichotomy within the described regional jet class. Prior to the introduction of the Bombardier and Embraer regional jets, the regional jet fleet numbered fewer than 70 aircraft. By 2010, this number had risen to more than 1,450. During this 20 year period, regional jet departures accounted for 2.75% of the all departures in 1991 to just fewer than 40% of departures in 2010. In addition, the regional jet became a vital asset to serving the hub and spoke systems of U.S. commercial domestic airlines as the average stage length increased 70% from 285 miles in 1991 to 484 miles in 2010.

A third theme that resonated in this chapter is the change in composition of the U.S. commercial domestic narrow-body fleet. With only an absolute increase of 19 aircraft between 1991 and 2010, the narrow-body fleet experienced the complete retirement of the Boeing 727-200/231A, Boeing 737-100/200, and the McDonnell Douglas DC-9-30. In addition, the early 1990s brought with it significant increases in the McDonnell Douglas DC-9 Super 80 Series, Boeing 737-300, and Boeing 757-200, all three of which have since slowly been withdrawn from U.S. commercial domestic service. Furthermore, between 1991 and 2010, four new aircraft types were introduced to the fleet including the Airbus A319, Airbus A320-100/-200, Boeing 737-700/700LR, and the Boeing 737-800. In total, in the 20 year time period, more than 2,670 narrow-body aircraft were withdrawn from U.S. commercial domestic service while another 2,690 narrow-body aircraft entered service.

Lastly, a fourth major theme in this chapter was the significant decline in the U.S. commercial domestic wide-body fleet between 1991 and 2010. During this time, the wide-body fleet declined from 327 aircraft in 1991 to less than 120 aircraft by 2010. In addition, the only aircraft types with a domestic fleet larger than 10 aircraft in 2010 were the Boeing 767-200/ER/EM and the Boeing 777-200/200LR/233LR. As a result, the transitioning of the wide-body fleet to international routes prompted U.S. airlines to substitute narrow-body aircraft on routes once dominated by the wide-body fleet.

5. Manufacturer Comparisons

5.1. Introduction

The previous chapter focused on each of the defined aircraft classes and presented insights on fleet size, utilization, seat capacity, and stage length. In this chapter, we examine three specific comparisons between aircraft manufacturers within both the regional jet and narrow-body aircraft classes. In both of these defined classes, two aircraft manufacturers are responsible for producing the majority of aircraft. The first two comparisons focus on the regional jet class, where Bombardier and Embraer were the only two manufacturers with regional jets in U.S. commercial domestic operation in 2010. Within this class, we analyze both the 50-seat and 70 to 100-seat regional jets separately as each group focuses on a different market segment. The third comparison focuses on the narrow-body aircraft class, where Airbus and Boeing produced over 65% of narrow-body aircraft in U.S. commercial domestic operation in 2010. For each of the comparisons, we discuss trends as they relate to fleet size, seat capacity, aircraft utilization, daily departures, average stage length, and fuel per block hour per seat. Studies that led to significant insights not yet presented in previous sections are reported within this chapter.

5.2. Bombardier & Embraer: The 50-Seat Regional Jet

In the late 1990s, both Bombardier and Embraer introduced regional jets that had a significant effect on the U.S. commercial domestic fleet. As mentioned in Chapter 3 and Chapter 4, the introduction of these regional jets totaled more than 1,450 aircraft and by 2010, accounted for almost 40% of the U.S. commercial domestic departures. Table 8 outlines the aircraft introduced by Bombardier and Embraer between 1991 and 2010 that have 50 or fewer seats.

Table 8 Bombardier & Embraer 50-Seat Regional Jet Specifications

<i>Name</i>	<i>Seats</i>	<i>Range w/ Max Payload [miles]</i>	<i>Cruise Speed [knots]</i>	<i>Max Altitude [ft]</i>
CRJ-100	50	1,118	427	41,000
CRJ-200	50	1,553	427	41,000
ERJ-135	37	1,926	448	37,075
ERJ-140	44	1,864	448	37,075
ERJ-145	50	1,243	448	37,075

The Bombardier and Embraer 50-seat regional jets were introduced into the U.S. commercial domestic fleet in 1997. As shown in Figure 27, Bombardier accounted for the majority of this fleet with a market share of nearly 60% in 2010. From 1997 through 2005, the rapid growth of both the CRJ-200 series and ERJ-145 series was due to the strong demand from airlines to serve more distant, smaller markets to feed their hubs, which became possible with the advent of the regional jet. In addition, the existence of pilot scope clauses at many of the U.S. commercial domestic airlines further encouraged the growth of the 50-seat regional as many of the contracts limited regional flying to 50-seat aircraft. For example, Continental Airlines was only able to operate 50-seat regional jets as larger regional jets violated the union contracts. More interesting, however, is the plateau in the regional jet fleet after 2005. We attribute the slowdown in the 50-seat regional jet growth to an oversaturation of the aircraft type within the U.S. commercial domestic market coupled with rising fuel prices, making the aircraft type no longer as economically viable.

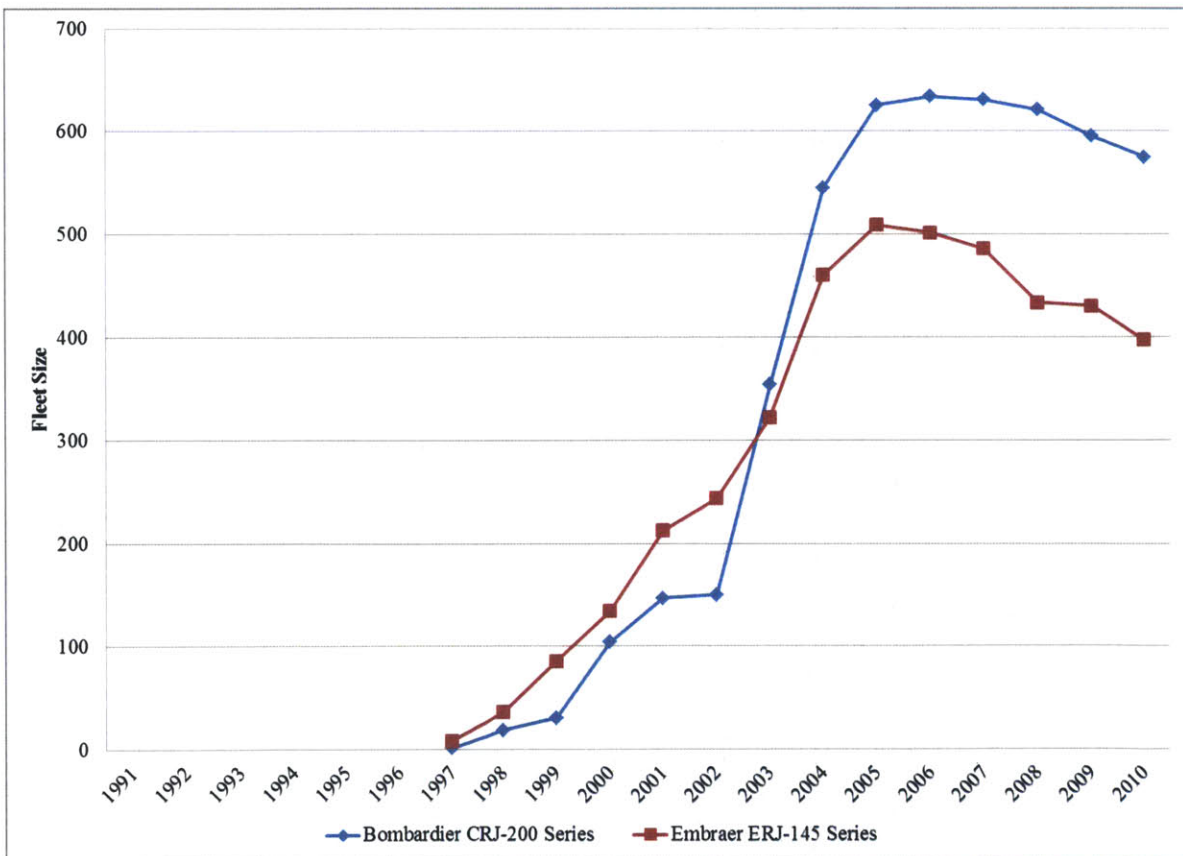


Figure 27 Bombardier & Embraer 50-Seat Regional Jet Fleet Size.

The seat capacity for both the Bombardier CRJ-200 series and Embraer ERJ-145 series aircraft are shown in Table 9. In each year from 1997 through 2010, the Bombardier regional jets had the larger average seat capacity as compared to the Embraer ERJ-145 series. However, it is important to understand that Embraer offered three different variants of its Embraer ERJ-145 series aircraft as shown in Table 8. As a result, the lower seat capacity shown in 2002 is a function of the ERJ-135 and ERJ-140 aircraft operating in the U.S. commercial domestic market. In contrast, Bombardier offered two variants of its Bombardier CRJ-200 series aircraft, a standard 50-seat version and a reduced capacity version with 44-seats. However, whereas Embraer shortened the fuselage for the ERJ-135 and ERJ-140, Bombardier used the same fuselage for both variants.

Table 9 Bombardier & Embraer 50-Seat Regional Jet Seat Capacity

	1998	2000	2002	2004	2006	2008	2010
Bombardier CRJ-200 Series	50.0	49.8	48.7	48.2	48.9	50.0	50.0
Embraer ERJ-145 Series	49.0	47.4	46.1	47.6	47.9	47.8	48.6

5.3. Bombardier & Embraer: The 70 to 100-Seat Regional Jet

In addition to the Bombardier CRJ-200 series and Embraer ERJ-145 series, both Bombardier and Embraer also entered the 70 to 100-seat regional jet market in the early 2000s. Table 10 highlights the aircraft within this market and some of the performance characteristics.

Table 10 Bombardier & Embraer 70 to 100-Seat Regional Jet Specifications

<i>Name</i>	<i>Seats</i>	<i>Range w/ Max Payload [miles]</i>	<i>Cruise Speed [knots]</i>	<i>Max Altitude [ft]</i>
CRJ-700	67	1,647	448	41,000
CRJ-900	78	1,553	448	41,000
ERJ-170	73	1,926	481	39,050
ERJ-175	81	1,740	481	39,050
ERJ-190	100	1,988	481	39,050

Similar to the 50-seat regional market, the growth of the Bombardier CRJ-700 series and Embraer E-Jet series has been strong since its introduction in 2001 and 2004, respectively, as shown in Figure 28. By 2010, Bombardier had claimed almost 75% of the 70 to 100-seat regional jet fleet within the U.S. commercial domestic market. In addition, in the 10 years since

its introduction, the 70 to 100-seat regional jet grouping comprised over 10% of the entire U.S. commercial domestic fleet. We anticipate that the demand for the larger regional jets will continue as airlines seek to provide increased frequency on key routes with a lower cost basis than traditional narrow-body aircraft.

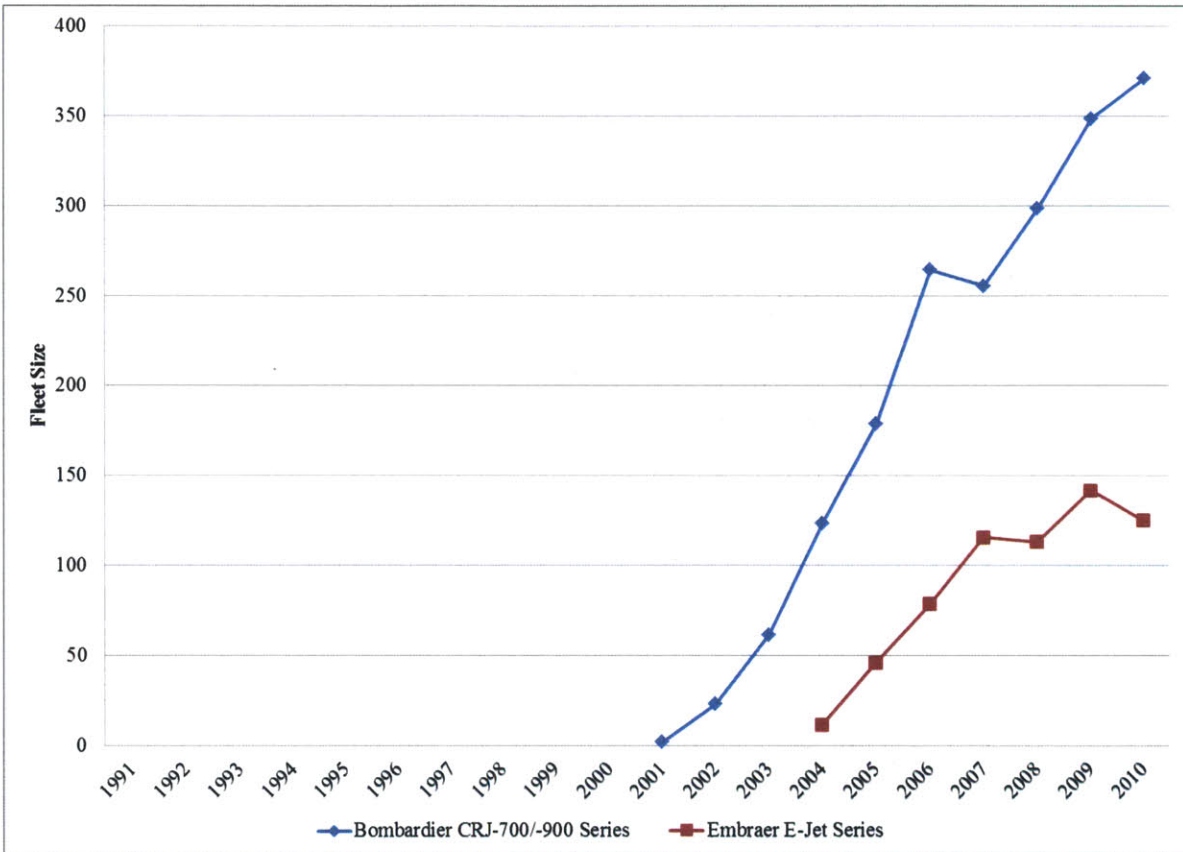


Figure 28 Bombardier & Embraer 70 to 100-Seat Regional Jet Fleet Size.

The seat capacity of both the Bombardier CRJ-700 series and Embraer E-Jet series is shown in Table 11. The most interesting discovery is that the Embraer E-Jet series had a substantially higher average seat capacity over the Bombardier CRJ-700 series. Upon further analysis, the largest Bombardier variant, the CRJ-900, was typically flown in the U.S. commercial domestic market in a 76-seat, two-class configuration. In contrast, the largest Embraer variant, the E-190, was flown with a 100-seat, two-class configuration. As a result, Embraer had a significant sales advantage over Bombardier in the regional jet market greater than 76-seats. At the time of this writing, Bombardier began delivering a new variant of the CRJ-

700 series known as the CRJ-1000; however, no U.S. commercial domestic operators have placed any orders for this aircraft type to date.

Table 11 Bombardier & Embraer 70 to 100-Seat Regional Jet Seat Capacity.

	2002	2004	2006	2008	2010
Bombardier CRJ-700 Series	70.0	71.5	70.5	71.7	70.8
Embraer E-Jet Series	-	72.0	75.6	88.0	83.2

5.4. Airbus & Boeing: Battle for the Narrow-body Market

The U.S. commercial domestic narrow-body fleet is the largest of all the defined aircraft classes. At its peak between 1991 and 2010, the narrow-body fleet consisted of more than 3,300 aircraft and accounted for over 80% of the entire U.S. domestic commercial fleet. With that said, a large portion of the narrow-body fleet stems from Airbus and Boeing introducing the Airbus A320 family and Boeing 737 series. These two aircraft groups comprised of more than 1,700 aircraft and by 2010, accounted for more than 35% of all U.S. commercial domestic departures. Table 12 highlights the aircraft specifications for both the Airbus A320 family and Boeing 737 series.

Table 12 Airbus & Boeing Narrow-body Specifications

<i>Name</i>	<i>Seats</i>	<i>Range w/ Max Payload [miles]</i>	<i>Cruise Speed [knots]</i>	<i>Max Altitude [ft]</i>
A318	120	3,728	481	39,050
A319	127	4,225	481	39,050
A320	148	3,449	481	39,050
A321	184	3,418	481	39,050
B737-200	116	1,839	421	37,075
B737-300	136	1,802	429	37,075
B737-400	138	2,175	429	37,075
B737-500	118	2,113	429	37,075
B737-700	136	3,753	459	41,000
B737-800	158	3,355	459	41,000
B737-900	173	3,157	459	41,000

Between 1991 and 2010, the composition of the U.S. domestic narrow-body fleet changed significantly with the arrival of Airbus and its A320 family as shown in Figure 29. In 1991, the Boeing 737 series accounted for 28.9% of the narrow-body fleet, with the remainder of the fleet

consisting primarily of Boeing 727, McDonnell Douglas DC-9, and McDonnell Douglas MD-80 aircraft. In contrast, the Airbus A320 family consisted of only 1.0% of the narrow-body fleet in 1991. However, by 2010, both the Airbus A320 family and Boeing 737 series had grown their percentage of the U.S. commercial domestic narrow-body fleet to 23.5% and 41.9%, respectively. The success of the Airbus A320 family is largely due to the growth seen from 1998 through 2005 as a result of large aircraft orders from JetBlue Airways, US Airways, and United Airlines.

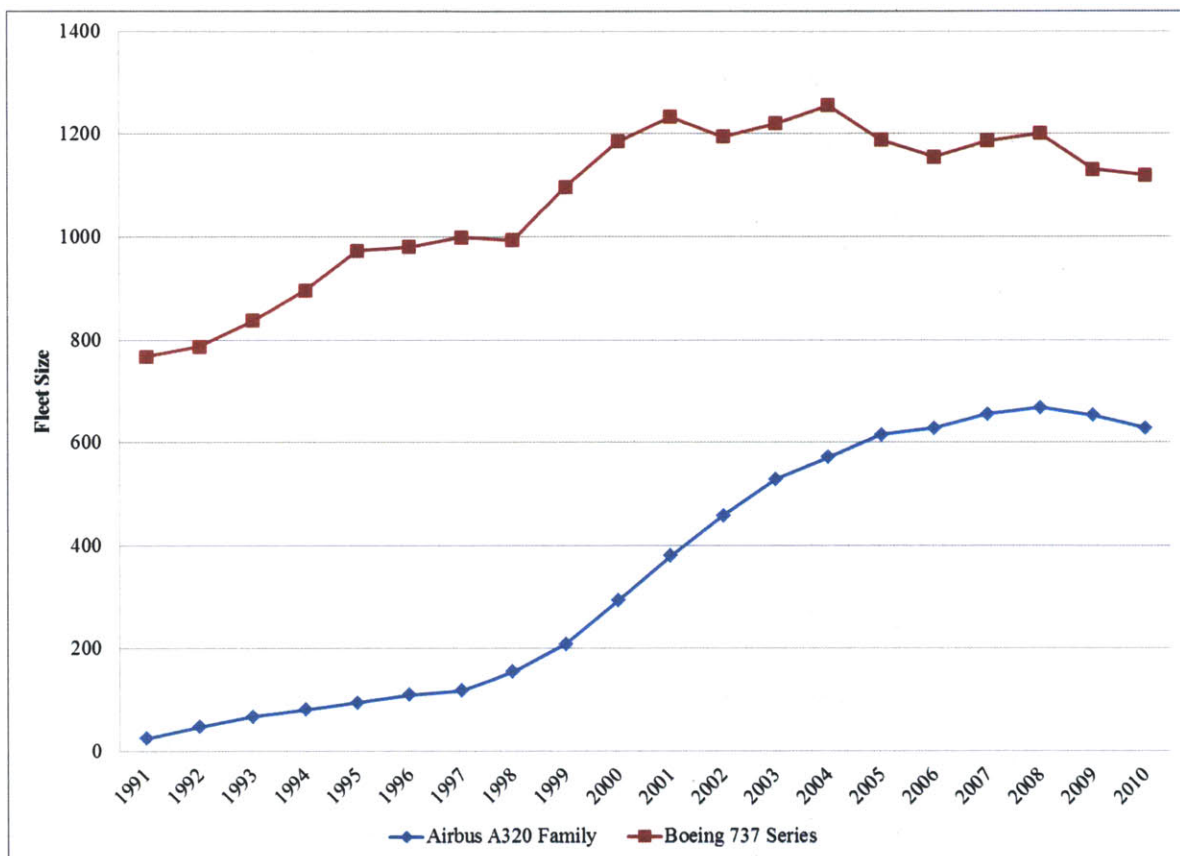


Figure 29 A320 Family & 737 Series Fleet Size.

In the following pages, we highlight trends between the Boeing 737 series and the Airbus A320 family with respect to seat capacity, utilization, daily departures per aircraft, average stage length, and fuel burn. However, in order to better understand the significance the trends, it is necessary to first discuss the types of operators flying each aircraft family. Within the U.S. commercial domestic market, two types of operators exist: legacy carriers and low-cost carriers (LCC). Legacy carriers typically operate hub and spoke networks while LCCs operate more

point-to-point service (Belobaba 10). For example, United Airlines and Delta Airlines would be considered legacy operators, while Southwest Airlines and JetBlue Airways are considered low-cost carriers. Figure 30 illustrates the Boeing 737 series fleet for both the legacy carriers and LCCs from 1991 through 2010.

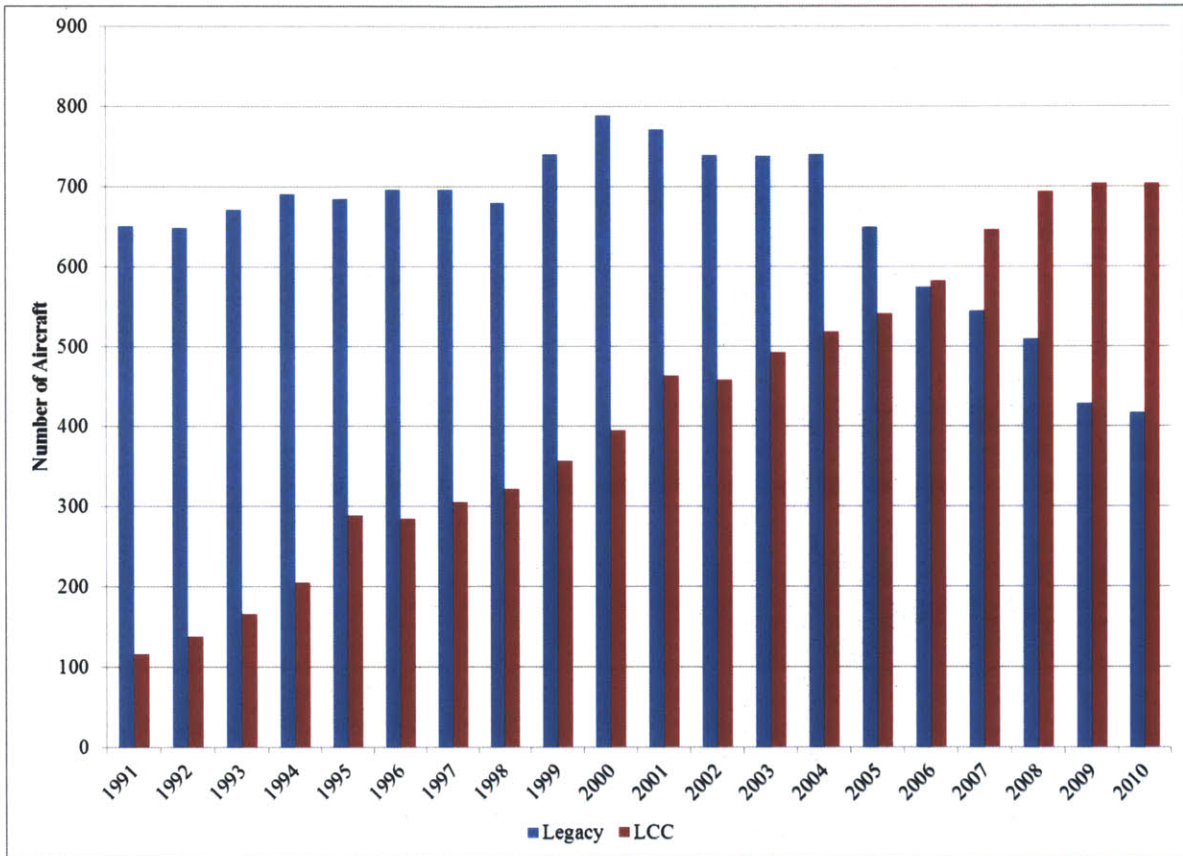


Figure 30 Legacy & LCC Boeing 737 Series Fleet.

As seen in Figure 30, the Boeing 737 series was primarily operated by the legacy carriers in the early 1990s; however, by 2010, LCCs accounted for more than 60% of all the Boeing 737 aircraft in the U.S. commercial domestic fleet. The significant growth in the Boeing 737 series by LCCs is largely attributed to Southwest Airlines, which grew its Boeing 737 fleet from 114 aircraft in 1991 to over 540 aircraft in 2010. In contrast, the Airbus A320 family has been primarily operated by legacy carriers in the U.S. commercial domestic market as seen in Figure 31. None of the domestic LCCs operated the A320 family until 2000, when JetBlue Airways began U.S. commercial domestic service. The growth seen between 2000 and 2010 is due to

other LCCs beginning to operate the Airbus A320 family in addition to JetBlue Airways, including Frontier Airlines, Spirit Airlines, and Virgin America.

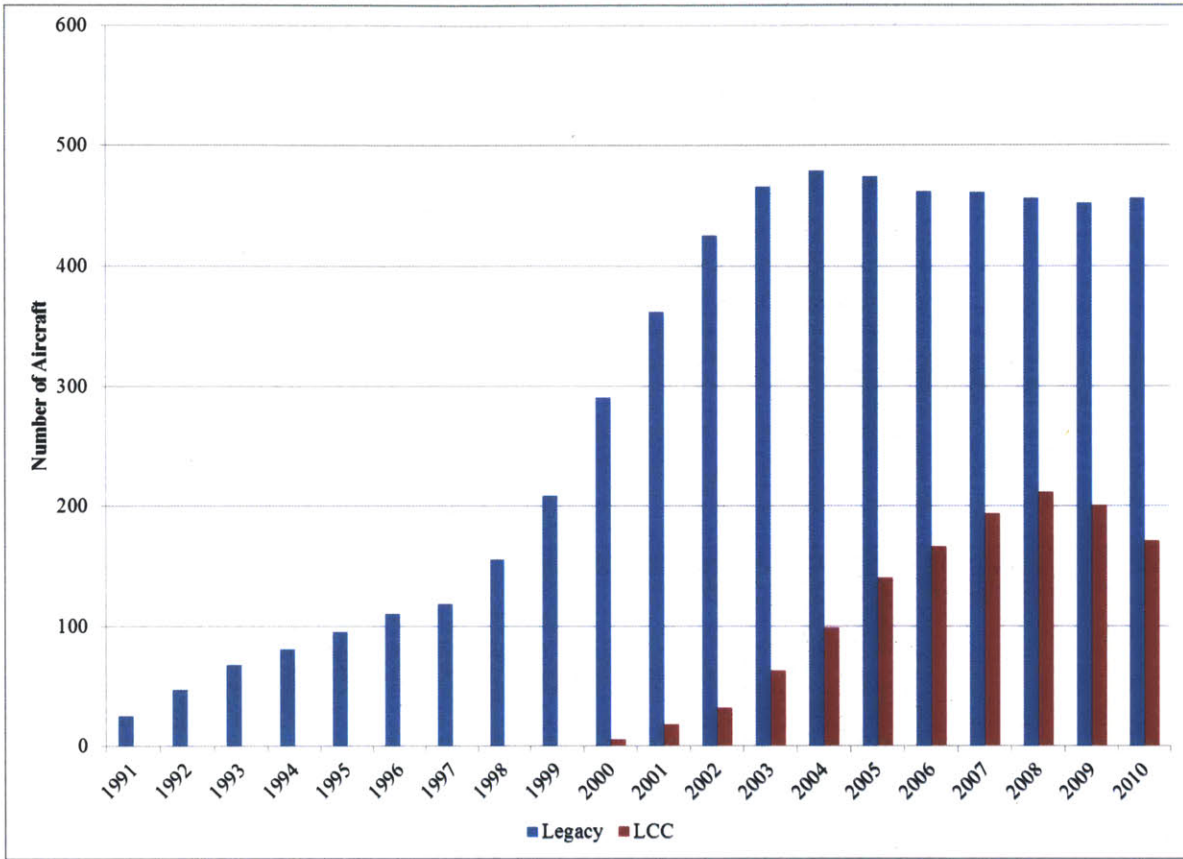


Figure 31 Legacy & LCC Airbus A320 Family Fleet.

The average seat capacity for the Airbus A320 family and Boeing 737 series is shown in Figure 32 and illustrates three important trends. First, the Airbus average seat capacity remained above 145 seats through 1997. This is due to the fact that all of the Airbus airplanes in operation between 1991 and 1997 were Airbus A320 aircraft. In addition, beginning in 1998, the smaller Airbus A319 was introduced by both US Airways and United Airlines, which began to reduce the average seat capacity of the Airbus fleet in U.S. commercial domestic operation.

The second trend seen in Figure 32 is the change in the Boeing 737 series fleet composition. In the early 1990s, the U.S. commercial domestic Boeing 737 fleet consisted primarily of the Boeing 737-100/-200 and the Boeing 737-300, which had seating capacities of approximately 110 and 130 passengers, respectively. As the Boeing 737-100/-200 aircraft were

withdrawn from service in the late 1990s, the Boeing 737-800 was introduced concurrently with a capacity of 158 seats, thereby increasing the average seat capacity of the Boeing 737 series.

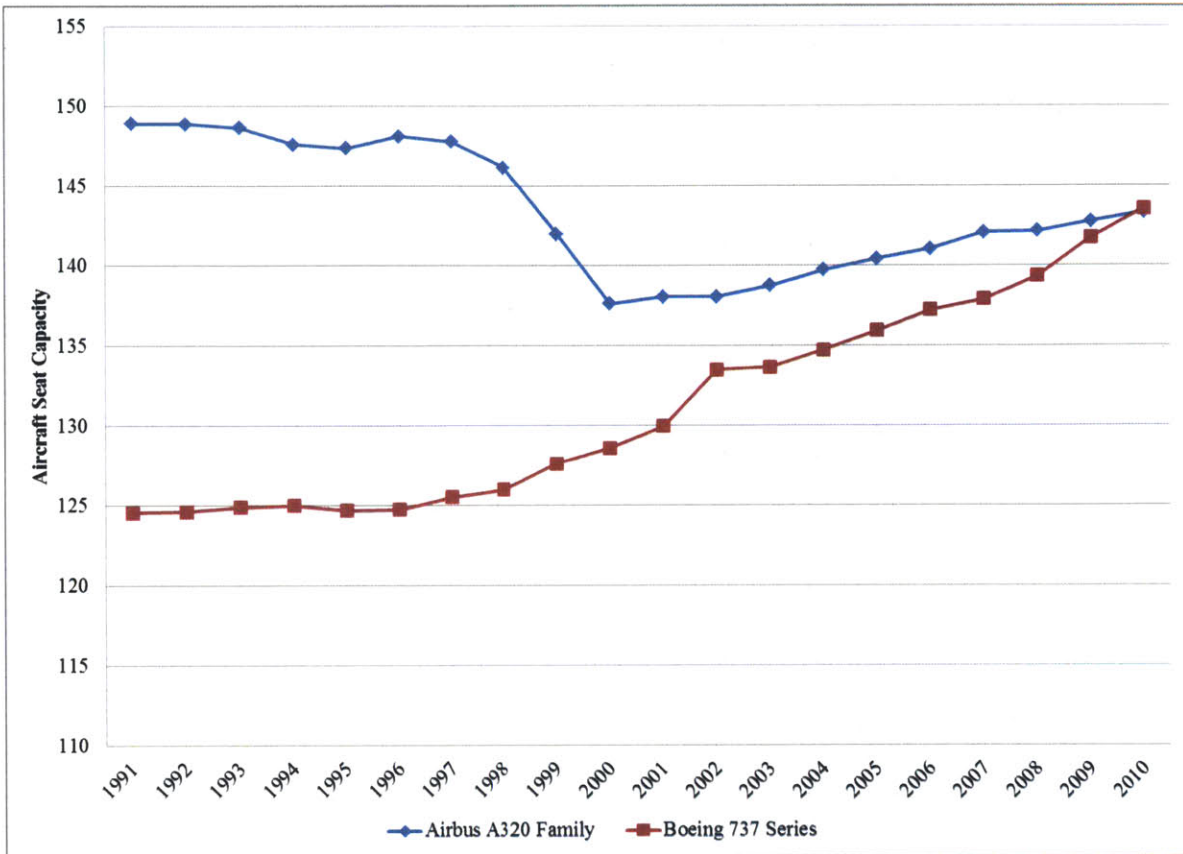


Figure 32 A320 Family & 737 Series Seat Capacity.

The third takeaway from Figure 32 is the convergence of seating capacity between both the Airbus A320 family and the Boeing 737 series. While the seat capacity metric is an average irrespective of fleet size, it does indicate that Airbus and Boeing are targeting the same market and working with the airlines to deliver the right aircraft mix. In addition, the increase in aircraft seat capacity from 2003 to 2010 supports the trend of narrow-body aircraft filling the void created by the wide-bodies and larger narrow-bodies that shifted from domestic to international operation. Also, as LCCs typically operate in a single class, high-density configuration, with the increasing share of LCC operated Boeing 737 aircraft, we would expect that the average seat capacity to increase proportionally over the same period.

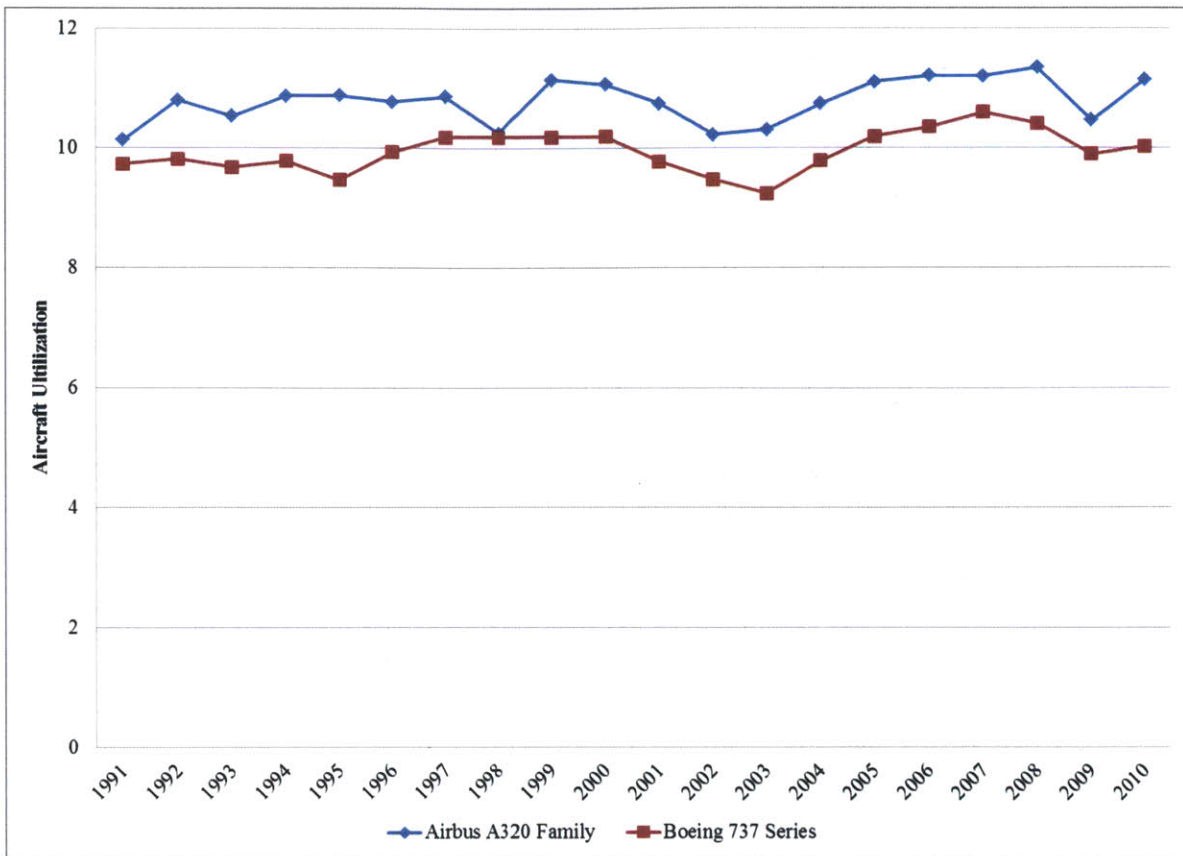


Figure 33 Airbus & Boeing Narrow-body Aircraft Utilization.

Another interesting insight we discovered during our analysis is how differently both groups of aircraft were utilized between 1991 and 2010. Using the trends seen in the daily utilization (Figure 33), daily departures (Figure 34), and average stage length (Figure 35), we were able to determine that during the 1990s, the Boeing 737 series was used more frequently on short-haul domestic flights below 750 miles in contrast with the Airbus A320 family, which typically had an average stage length of 1,000 miles. As was previously mentioned in Chapter 3 and Chapter 4, operational parameters such as utilization, daily departures, and average stage length are both a function of the aircraft design limitations as well as the airline network. With that said, our analysis of utilization, daily departures, and average stage length indicates that the two aircraft groups were used in different ways by different carriers as explained in the following paragraphs.

As seen in Figure 33 and Figure 34, from 1991 to 2010 the Airbus A320 family had a higher daily utilization rate than the Boeing 737 series despite the fact that the Boeing 737 series

was predominately operated by LCCs in the late 2000s. In addition, the number of daily departures for the Boeing 737 series far exceeded that of the Airbus A320 family in the early 1990s. This implies that the Boeing 737 series aircraft were flying shorter average distances than the Airbus A320 family, as confirmed by Figure 35. We attribute this directly to the composition of the Boeing 737 fleet in the early 1990s. At that time, the Boeing 737 series aircraft flying in the U.S. commercial domestic market had a maximum flight range of approximately 2,000 miles. In contrast, the newly developed Airbus A320 family had ranges that exceed 3,400 miles. As a result, airlines operating the Airbus A320 family used the aircraft for both short-haul and longer-haul domestic flights.

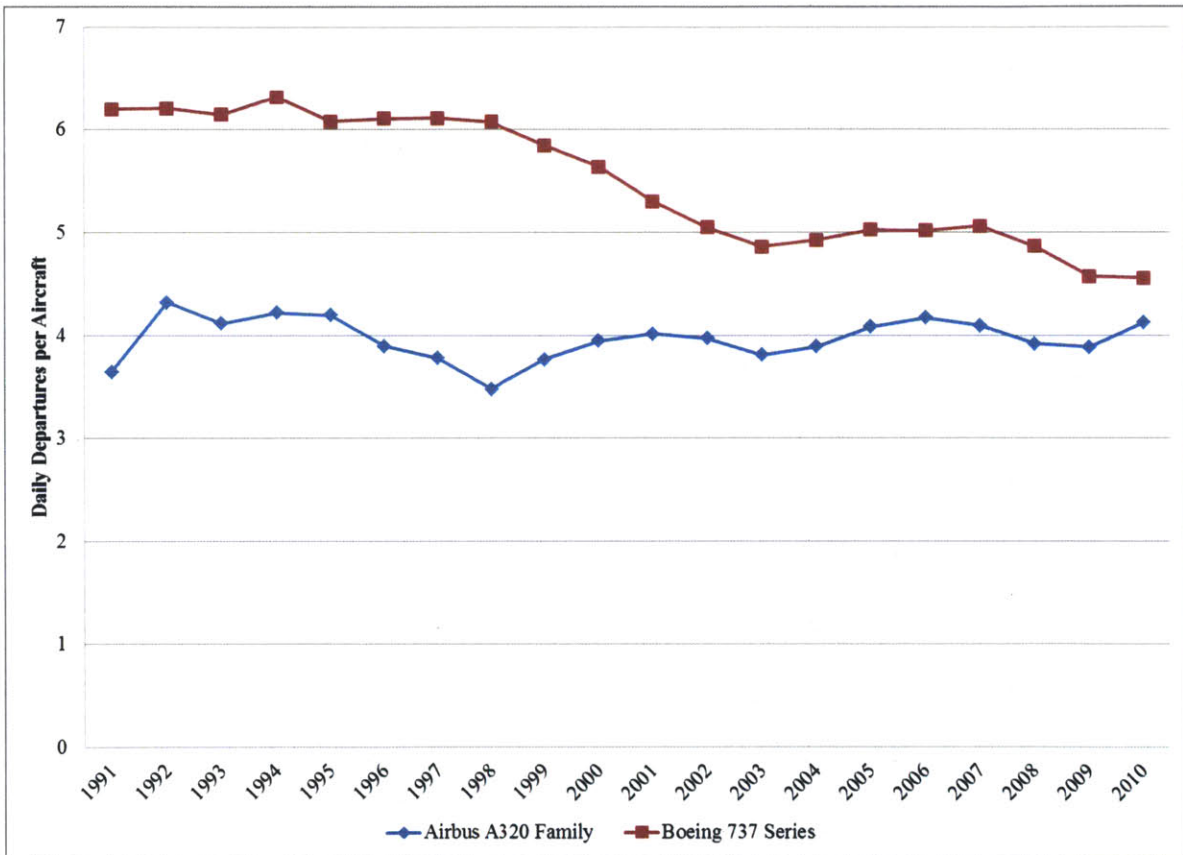


Figure 34 A320 Family & 737 Series Daily Departures per Aircraft.

In addition, Boeing did not offer a 737 variant with a range greater than 3,000 miles until 1998 when the Boeing 737-800 entered U.S. commercial domestic service. Consequently, Airbus had almost a 10 year period without direct competition from Boeing and its 737 series in terms of range. However, as Boeing introduced its next generation 737 series aircraft (737-600/-700/-

800), the 737 average stage length began to converge with that of the Airbus A320 family. We attribute this convergence to Boeing's newly designed fuselage, wing, and power plant upgrade. These factors enabled the Boeing 737 series to directly compete against the Airbus A320 family, allowing Boeing to maintain its share of the U.S. commercial domestic narrow-body fleet.

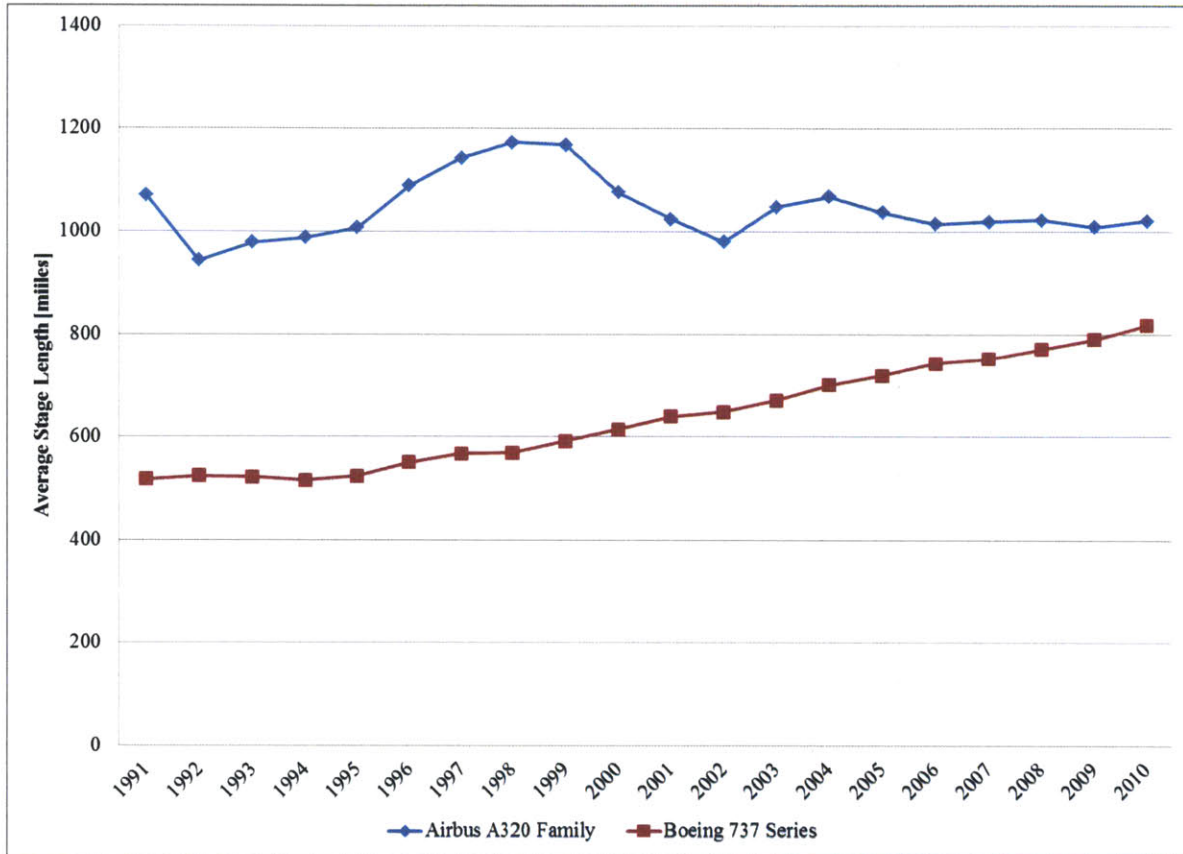


Figure 35 A320 Family & 737 Series Average Stage Length.

Lastly, Figure 36 details the fuel burn for both the Boeing 737 series and the Airbus A320 family, measured in gallons of fuel per block hour per seat. We attribute the disparity in fuel burn between the Boeing 737 series and the Airbus A320 family to differences in the aircraft power plants. The Airbus A320 family aircraft were equipped with either Pratt & Whitney PW6000, International Aero Engines IAE V2500, or CFM International CFM56-5 engines depending on the airlines' preference. However, all of these engines were designed for the newly introduced Airbus A320 family. In contrast, the original Boeing 737-100/-200 aircraft, which entered service in 1968, were equipped with Pratt & Whitney JT8D power plants and were much less efficient than the newer CFM56 engines found on latter Boeing 737 variants. As the Boeing

737-100/-200 aircraft were retired, the composition of the remaining fleet favored the more efficient CFM56-3B engines found on the 737-300/-400/-500 models. In addition, as the next generation 737 variants were introduced in the late 1990s, they included the upgraded CFM56-7B, which provided additional fuel efficiency. Consequently, as the fleet composition of the Boeing 737 series changed over time, the fuel burn converged with that of the Airbus A320 family.

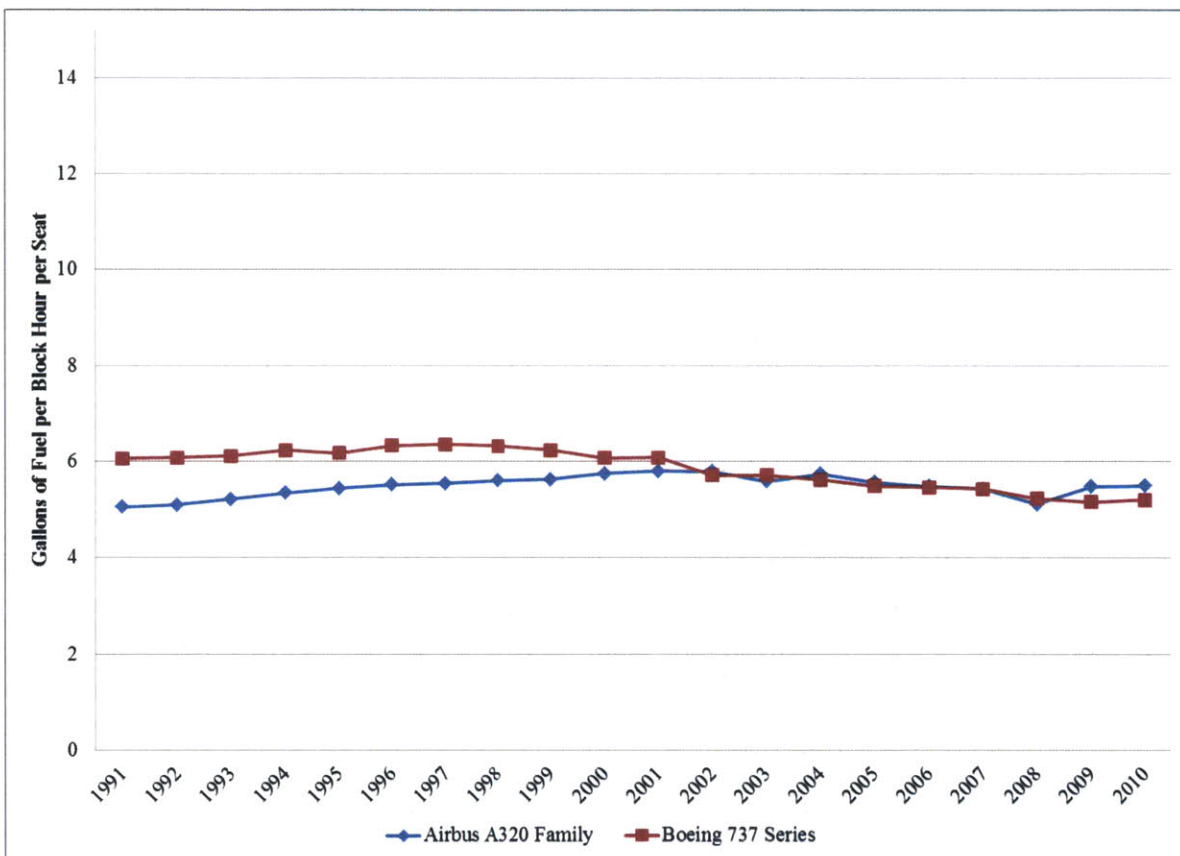


Figure 36 A320 Family & 737 Series Gallons of Fuel per Block Hour per Seat.

5.5. Chapter Summary

This chapter discussed comparisons between aircraft manufacturers in both the regional jet and narrow-body aircraft classes. Within the regional jet class, Bombardier and Embraer compete heavily in both the 50-seat and 70 to 100-seat regional jet markets. Within the 50-seat market, the most significant discovery following the rapid introduction of both the CRJ-200 series and the ERJ-145 series was the plateau and partial decline of both regional jet types after

2005. We attributed the decline to an oversaturation of the 50-seat regional jet within the U.S. commercial domestic fleet coupled with rising fuel prices, which rendered the aircraft types less economical to operate.

The second comparison we discussed in this chapter focused on the 70 to 100-seat regional jet. We expect the strong demand seen in the late 2000s for the larger regional jets to continue in the coming years as this aircraft type continues to fill a void in the U.S. commercial domestic market between the 50-seat regional jet and the 120-seat narrow-body aircraft. In addition, airlines are utilizing the larger regional jets to provide service between smaller, more distant markets that could not economically sustain narrow-body service, or in some cases, adding additional frequency between larger U.S. cities to provide more attractive schedules to business passengers. Interestingly, we also observed that Embraer had a distinct advantage over Bombardier in the late 2000s as its Embraer E-190 was capable of seating more than 20 additional passengers compared to any Bombardier variant in operation during the time period analyzed.

The last comparison made in this chapter focused on the narrow-body segment with the Airbus A320 family and the Boeing 737 series. During the time period analyzed, Airbus was able to penetrate the U.S. narrow-body market, growing its share of the narrow-body fleet from 1.0% in 1991 to 28.9% by 2010. In addition, with the introduction of the Airbus A320 family, Airbus had an advantage over its rival Boeing in terms of aircraft range in the early 1990s. However, the introduction of the next generation Boeing 737 series (737-600/-700/-800) with increased range allowed Boeing to maintain its share of the narrow-body segment through 2010.

6. Conclusions: Implications for Future U.S. Commercial Domestic Fleets

The objective of this thesis is to provide insight on the evolution of U.S. commercial domestic aircraft operations from 1991 to 2010. For this purpose, we classified the aircraft into four categories: turboprop, regional jet, narrow-body, and wide-body. Using data collected from the U.S. Bureau of Transportation Statistics, we analyzed 110 different aircraft types from 145 airlines operating U.S. commercial domestic service between 1991 and 2010. In the following sections, we will summarize the findings of our study and discuss the implications for future U.S. commercial domestic fleets.

6.1. Summary of Findings

In Chapter 1, we presented a series of questions which helped guide us in our analysis of the U.S. commercial domestic fleet. The following pages will address each of those questions and summarize our findings.

- a. To what extent has domestic wide-body flying ceased and been replaced by narrow-body, regional jets, and turboprops?*

In 1991, the U.S. commercial domestic wide-body fleet consisted of 327 aircraft and accounted for more than 10% of all U.S. commercial domestic aircraft. By 2010, the wide-body fleet comprised only 2.6% of the domestic fleet with 117 aircraft. In addition, the only wide-body aircraft types in operation in 2010 with a domestic fleet larger than 10 aircraft were the Boeing 767-200/ER/EM and the Boeing 777-200/200LR/233LR. This was in large part due to U.S. airlines shifting wide-body aircraft to international service. As a result of this shift, narrow-body aircraft began to take over routes formerly flown by wide-body aircraft.

The U.S. commercial domestic wide-body fleet also experienced corresponding declines in ASMs and revenue departures during the 20 year period analyzed. In 1991, the wide-body fleet accounted for almost 25% of the total ASMs flown in the U.S. commercial domestic market. However, this percentage dropped to less than 7% by 2010. Similarly, the wide-body fleet only accounted for 1.2% of all domestic departures by 2010, more than four percentage points lower than its 1991 value. In contrast, the turboprop, regional jet, and narrow-body

segments all experienced increases in ASMs on an absolute and percentage basis between 1991 and 2010.

b. How has the total number of aircraft flying commercially within the domestic U.S. changed year over year?

The total number of aircraft flying within the U.S. commercial domestic market increased from 3,264 aircraft in 1991 to 4,456 aircraft in 2010, with a peak of 4,857 aircraft in 2007. The increase over the 20 year period is largely attributed to the significant growth in the regional jet aircraft class. Between 1991 and 2010, the regional jet class introduced more than 1,390 aircraft as a result of new product offerings from Bombardier and Embraer. While the wide-body aircraft class saw a near-continuous decline due to the shift of wide-body aircraft to international routes, the narrow-body aircraft class remained flat as a result of the retirement of older and less efficient aircraft in exchange for next generation Boeing 737 series and Airbus A320 family aircraft.

c. In which years is the emergence of the regional jet apparent and which type is most common?

The modern-day regional jet entered the U.S. commercial domestic market in 1997 as Bombardier and Embraer began delivering the CRJ-200 series and ERJ-145 series. Over the course of the next 13 years, more than 1,390 regional jet aircraft were introduced into the U.S. commercial domestic fleet. We divided the regional jet class into two groups: 50-seat and 70 to 100-seat regional jets. In the 50-seat market, the Bombardier CRJ-200 and ERJ-145 were the most common regional jets in 2010 with 523 and 301 aircraft, respectively. In the 70 to 100-seat group, the most common regional jets in 2010 were the CRJ-700, CRJ-900, and E-190 with 232, 139, and 61 aircraft, respectively. However, in this second group, it is important to note that Bombardier introduced its larger regional jets into the U.S. commercial domestic market three years ahead of Embraer, which partially accounts for disparity between the number of 70 to 100-seat Bombardier and Embraer regional jets.

d. Is there a noticeable and meaningful re-emergence of the turboprop between 2005 and 2010?

Our analysis of the U.S. commercial domestic turboprop fleet concluded that there was not a significant re-emergence of the turboprop between 2005 and 2010. In fact, our analysis concluded just the opposite as all turboprops with a fleet greater than 60 aircraft between 1991 and 2010 experienced a significant decline in size with the exception of the Bombardier Q400. While we did observe growth in the Bombardier Q400 fleet, the overall U.S. turboprop fleet declined from a 14.2% share of the total U.S. commercial domestic fleet in its peak in 1996 to less than 5% in 2010.

e. To what extent have trends in aircraft size (number of seats per departure) fluctuated over the past 20 years?

Between 1991 and 2010, we observed a significant shift to increased seat capacity in the turboprop, regional jet, and narrow-body aircraft classes. For example, the turboprop seat capacity increased on average from 33 seats in 1991 to 77 seats in 2010 while narrow-body seat capacity increased from 137 seats to 149 seats in the same time period. This is largely due to aircraft manufacturers producing larger turboprop, regional jets, and narrow-body aircraft such as the Aerospatiale Atr-72, Bombardier Q400, Bombardier CRJ-700/-900, Embraer ERJ-170/-190, and the Boeing 737-800.

f. To what extent has daily aircraft utilization increased over the past 20 years?

Over the 20 year period, daily utilization rates for each aircraft class increased with the exception of turboprop aircraft. Of the four aircraft classes, wide-body aircraft had the highest daily utilization rates in 2010 at 10.3 hours, followed by narrow-body aircraft and regional jets with 10.0 hours and 9.2 hours, respectively. This is due to the fact that domestic wide-body aircraft, which typically operate transcontinental flights or occasional repositioning flights, are operated with the longest stage lengths. Similarly, narrow-body aircraft ended up flying slightly shorter stage lengths as a result of taking over many routes formerly operated by wide-body aircraft. For regional jets, this growth was largely driven by significant increases in the average stage length due to the ability to employ the regional jets on longer routes that overfly hubs.

- g. To what extent has the average stage length changed over the past 20 years within each aircraft class?*

The average stage length increased in each of the four aircraft classes from 1991 to 2010. Both the turboprop and regional jet aircraft classes experienced increases in stage length of 29.8% and 70.1%, respectively, during the 20 year period, which we attribute to a change in the operating structure of regional airlines. For example, in the 1990s, the regional airlines mainly operated into small airfields close to hubs which allowed for multiple turns in a single day. However, with the advancement of technology and the introduction of both larger turboprops and regional jets, regional carriers now fly farther resulting in an average stage length of 480 miles in 2010.

In addition, the narrow-body average stage length increased 295 miles over the 20 year period as narrow-body aircraft began replacing wide-body aircraft that were shifted from U.S. commercial domestic service to international routes. As a result, the remaining wide-body aircraft in U.S. commercial domestic service were then scheduled for mainly transcontinental routes, which further increased the wide-body average stage length from 1,430 miles in 1991 to 2,080 miles in 2010.

- h. To what extent has airport congestion increased? Specifically, are we able to see indications of longer ground times domestically?*

Over the 20 year period, the average aircraft ground time per departure increased 20.2% from 18.9 minutes in 1991 to 22.7 minutes in 2010. For the most part, ground times increased with aircraft size with the exception of regional jets and narrow-body aircraft between 2004 through 2010. We believe this is due to the relationship between ground time and the airports served by the different aircraft classes. For example, turboprop aircraft ground times were the lowest on average of all aircraft classes as these aircraft typically operate feeder flights to and from hubs. On flights departing from a hub, these aircraft operate into airports that are small and not subject to take-off or ramp delays, thereby reducing the overall ground time.

In contrast, wide-body aircraft typically operate into and out of major hubs when flying domestically, which likely explains why wide-body aircraft had the longest ground times over the 20 year period, as they were subject to potential take-off and ramp delays at both airports.

Ground times for regional jets and narrow-body aircraft fell in between those for turboprop and wide-body aircraft, which is likely attributed to the fact that both aircraft classes operate from hubs to a wide variety of airports, some notorious for delays.

- i. To what extent does fuel consumption (gallons of fuel per hour) vary between aircraft types? What aircraft is the most fuel efficient?*

Our analysis of fuel consumption illustrated two important points. First, there is a clear distinction in fuel consumption between turboprop and jet-powered aircraft as our data indicates that turboprop aircraft use approximately half as much fuel per block hour per seat as jet aircraft. Second, advances in engine technology coupled with the retirements of older aircraft are apparent in each of the aircraft classes. For example, the majority of the modern turboprops such as the Bombardier Q400 utilize newer engine technology and carry more passengers, both of which reduce the per seat fuel burn. In addition, regional jet fuel burn has drastically declined since the advent of the Bombardier and Embraer regional jets, partially due to new engine technology and partially due to larger aircraft, again reducing the per seat fuel burn. Due to variability in the data at the aircraft level, we were not able to make comparisons between aircraft types to determine which aircraft was the most fuel efficient.

In addition to the findings above, there were several other important discoveries that resulted from our research. First, the introduction of the regional jet in 1997 had a significant impact on the operational characteristics of the U.S. commercial domestic fleet. In 1991, the regional jet had less than 3% of the industry fleet size, ASMs, RPMs, and aircraft departures. However, by 2010, the regional jet performed over 39% of the industry departures despite only having 33% of the industry fleet. In addition, increases in ASMs and RPMs for the regional jet came at the expense of wide-body aircraft, as both turboprop and narrow-body aircraft maintained the same proportions of ASMs and RPMs in 2010 as they had in 1991.

A second important finding was the change in the U.S. commercial domestic narrow-body fleet composition. With only an absolute increase of 19 aircraft between 1991 and 2010, the narrow-body fleet experienced the complete retirement of the Boeing 727-200/231A, Boeing 737-100/200, and the McDonnell Douglas DC-9-30. In addition, the early 1990s brought with it significant increases in the McDonnell Douglas DC-9 Super 80 Series and Boeing 737-300, both

of which have since slowly been withdrawn from U.S. commercial domestic service. Furthermore, between 1991 and 2010, five new aircraft types were introduced to the fleet including the Airbus A319, Airbus A320, Boeing 737-700/700LR, Boeing 737-800, and the Boeing 737-900. In total, in the 20 year time period, more than 2,670 narrow-body aircraft were withdrawn from U.S. commercial domestic service while another 2,690 narrow-body aircraft entered service.

The last significant discovery focuses on the Airbus A320 family and the Boeing 737 series in the narrow-body aircraft class. During the time period analyzed, Airbus was able to penetrate the U.S. narrow-body market, growing its share of the narrow-body fleet from 1.0% in 1991 to 28.9% by 2010. In addition, with the introduction of the Airbus A320 family, Airbus had an advantage over its rival Boeing in terms of aircraft range in the early 1990s. However, the introduction of the next generation Boeing 737 series (737-600/-700/-800) with increased range allowed Boeing to maintain its share of the narrow-body segment through 2010.

6.2. Implications for Future U.S. Commercial Domestic Fleets

Based on our analysis of the U.S. commercial domestic fleet from 1991 to 2010, we anticipate several trends to continue through the next decade. Within the turboprop aircraft class, we believe that the Bombardier Q400 fleet and similar newer turboprop aircraft will continue to grow within the U.S. commercial domestic market as the Q400 has a significant fuel advantage over jet aircraft and is able to cruise 30% faster than conventional turboprops. In addition, with its 70-seat capacity, the Q400 complements existing narrow-body service between major cities.

In contrast, we observed that there is no small turboprop available in U.S. commercial domestic service to replace the aging 30 to 50-seat turboprops operating currently. In addition, with the rising cost of jet fuel, the 50-seat regional jets may no longer be economically viable, and therefore, unable to replace the 30 to 50-seat turboprops as they are retired, resulting in the potential reduction of air service to some smaller destinations.

There is currently an oversaturation of the 50-seat regional jet within the U.S. commercial domestic market. Since 2005, this segment has seen a steady decline which we expect to continue as long as fuel prices remain at current or higher levels. In addition, the U.S. airline industry has undergone significant consolidation over the past 10 years with numerous mergers including Delta Air Lines with Northwest Airlines and United Airlines with Continental Airlines.

As a consequence, regional operations for these carriers are likewise consolidating, resulting in reduced regional fleets.

On the other hand, the 70 to 100-seat aircraft fleet appears that it will continue growing over the course of the next decade. We expect the strong demand seen in the late 2000s for the larger regional jets to continue in the coming years as this aircraft type continues to fill a void in the U.S. commercial domestic market between the 50-seat regional jet and the 130-seat narrow-body aircraft. In addition, airlines are using the larger regional jets to provide service to smaller, more distant markets that could not economically sustain narrow-body service, or in some cases, adding additional frequency between larger U.S. cities to provide more attractive schedules to business passengers.

The futures of the narrow-body and wide-body aircraft classes are closely coupled. With an ever increasing focus on profitability, airlines will continue to deploy their specific aircraft fleets in the way that returns the greatest profitability for the airline. With this in mind, we anticipate that wide-body flying within the U.S. commercial domestic market will continue to decline. While we understand the need for airlines to reposition wide-body aircraft for international flights and utilize idle wide-body aircraft for quick-turns to and from hubs, we expect that the remaining wide-body aircraft strictly in U.S. commercial domestic service will either be retired and replaced by narrow-body aircraft or shifted to more profitable international routes.

Despite further withdrawal of wide-body aircraft from U.S. commercial domestic service, we anticipate that the narrow-body aircraft class will continue to decline slightly over the next decade and stabilize between 2,000 and 2,500 aircraft. The current U.S. commercial domestic fleet still has many aging McDonnell Douglas MD-80 series and Boeing 737-300 aircraft which will most likely be retired over the course of the next decade from domestic service. In addition, we expect that consolidation within the U.S. airline industry will continue, and as a result, will expedite the retirement of older aircraft as fleets are merged and create the potential for hub closures due to overlapping route networks.

A recent study released by the Federal Aviation Administration (FAA) forecasts U.S. domestic revenue passenger miles to grow at an average annual rate of 3.1% through 2031 (*“FAA Aerospace Forecast Fiscal Years 2011-2031”* 35). This forecast for continued growth in the U.S. commercial domestic market coupled with the anticipated reduction in 50-seat regional jets, the retirement of older narrow-body aircraft, and the shift of remaining wide-body aircraft to

international routes poses an interesting question for U.S. airlines. How will the additional demand be accommodated?

In the short-term, we anticipate U.S. airlines to continue reconfiguring existing fleets to increase seat capacity. For example, if just six additional seats were added to each narrow-body in domestic service in 2010, the total U.S. commercial domestic ASM capacity would increase by 3.2% for a given year. With that said, as the U.S. commercial domestic fleet continues to evolve over the next 20 years, we expect that airlines will order additional 70 to 100-seat regional jets and larger narrow-body aircraft. By 2030, we believe that the majority of the U.S. commercial domestic market will consist of these two aircraft types, with 50-seat regional jets in the minority. In addition, we anticipate that wide-body aircraft will not reemerge in the U.S. commercial domestic market in the foreseeable future.

A. Appendix: Airlines Included in the Analysis

The following 145 airlines were included in the analysis.

Accessair Holdings	Caribbean Sun Airlines, Inc. d/b/a World
Aerodynamics Inc.	Atlantic Airlines
Air 21	Carnival Air Lines Inc.
Air Midwest Inc.	Casino Express
Air South Inc. (1)	Champion Air
Air Wisconsin Airlines Corp	Chautauqua Airlines Inc.
Airmark Airlines Inc.	Chicago Express Airlines
AirTran Airways Corporation	Colgan Air
Alaska Airlines Inc.	Comair Inc.
Allegheny Airlines	Commutair Aka Champlain Enterprises, Inc.
Allegiant Air	Compass Airlines
Aloha Air Cargo	Continental Air Lines Inc.
America West Airlines Inc.	Delta Air Lines Inc.
American Airlines Inc.	Dynamic Airways, LLC
American Eagle Airlines Inc.	Eagle Airlines
Ameristar Air Cargo	Eastwind Airlines Inc.
Aspen Airways Inc.	Executive Airlines
ATA Airlines d/b/a ATA	Express One International Inc.
Atlantic Southeast Airlines	ExpressJet Airlines Inc.
Av Atlantic	Falcon Air Express
Big Sky Airlines Inc.	Flagship Airlines Inc.
Boston-Maine Airways	Freedom Air
Braniff International Airlines Inc.	Freedom Airlines d/b/a HP Expr
Buffalo Airways Inc.	Frontier Airlines Inc.
Business Express	GoJet Airlines, LLC d/b/a United Express
Cape Air	Grand Airways Inc.
Capitol Air Express Inc.	Great American Airways
	Great Lakes Airlines

Great Plains Airlines Inc.	Pacific Island Aviation
Gulfstream Int	Pan American Airways Corp.
Hawaiian Airlines Inc.	Pan American World Airways
Horizon Air	Pan American World Airways (1)
Independence Air	Panagra Airways
Island Air Hawaii	Peninsula Airways Inc.
Jet Fleet Intl. Airlines	Piedmont Airlines
JetBlue Airways	Pinnacle Airlines Inc.
Jettrain Airlines	Planet Airways
Key Airlines Inc.	Prestige Airways
Kiwi International	Primaris Airlines Inc.
Laker Airways Inc.	Private Jet Expeditions
Legend Airlines	Pro Air Inc.
Lorair Ltd.	PSA Airlines Inc.
Lynx Aviation d/b/a Frontier Airlines	Reeve Aleutian Airways Inc.
Markair Inc.	Regions Air, Inc.
MAXjet	Reno Air Inc.
Mesa Airlines Inc.	Renown Aviation
Mesaba Airlines	Republic Airlines
Miami Air International	Rich International Airways
Midway Airlines Inc.	Ryan International Airlines
Midway Airlines Inc. (1)	Seaborne Aviation
Midwest Airline, Inc.	Shuttle America Corp.
Morris Air Corporation	Sierra Pacific Airlines
Nations Air Express Inc.	Sky King Inc.
North American Airlines	Sky Trek International Airlines
Northwest Airlines Inc.	Skybus Airlines, Inc.
Omni Air Express	Skyway Airlines
Ozark Air Lines Inc.	SkyWest Airlines Inc.
Pace Airlines	Southeast Airlines
Pacific International Airlines Inc.	Southwest Airlines Co.

Spirit Air Lines
Sun Country Airlines d/b/a MN Airlines
Sun Pacific International
Sunworld International Airlines
Swift Air, LLC
Tatonduk Outfitters Limited d/b/a Everts Air
Alaska and Everts Air Cargo
Tower Air Inc.
Trans States Airlines
Trans World Airways LLC
TransMeridian Airlines
Tristar Airlines Inc.
UFS Inc.
UltrAir
United Air Lines Inc.

US Airways Inc.
USA 3000 Airlines
USA Jet Airlines Inc.
USAir Shuttle
Valujet Airlines Inc.
Vanguard Airlines Inc.
Victory Air Transport Inc.
Virgin America
Viscount Air Service Inc.
Vision Airlines
Westair Airlines Inc.
Western Pacific Airlines
Winair Inc.
World Airways Inc.
Worldwide Airlines Services

B. Appendix: Aircraft Included in the Analysis

The following 110 aircraft were included in the analysis.

Aerospatiale Caravelle Se-210	Boeing 737-900
Aerospatiale/Aeritalia Atr-42	Boeing 747-100
Aerospatiale/Aeritalia Atr-72	Boeing 747-200/300
Airbus A330-300	Boeing 747-400
Airbus Industrie A300-600/R/Cf/Rcf	Boeing 747sp
Airbus Industrie A300b/C/F-100/200	Boeing 757-200
Airbus Industrie A310-200c/F	Boeing 757-300
Airbus Industrie A310-300	Boeing 767-200/Er/Em
Airbus Industrie A-318	Boeing 767-300/300er
Airbus Industrie A319	Boeing 767-400/Er
Airbus Industrie A320-100/200	Boeing 777-200/200lr/233lr
Airbus Industrie A321	British Aerospace Bac-111-400
Airbus Industrie A330-200	British Aerospace Bae-146-100/Rj70
Avroliner Rj85	British Aerospace Bae-146-200
Beech 1900 A/B/C/D	British Aerospace Bae-146-300
Boeing 707-300c	British Aerospace Bae-Atp
Boeing 717-200	British Aerospace Jetstream 31
Boeing 727-100	British Aerospace Jetstream 41
Boeing 727-100c/Qc	Canadair Crj 900
Boeing 727-200/231a	Canadair Rj-100/Rj-100er
Boeing 737-100/200	Canadair Rj-200er /Rj-440
Boeing 737-200c	Canadair Rj-700
Boeing 737-300	Casa/Nurtanio C212 Aviocar
Boeing 737-300lr	Cessna 208 Caravan
Boeing 737-400	Cessna C206/207/209/210 Stationair
Boeing 737-500	Cessna Citation ii/ Bravo
Boeing 737-700/700lr	Cessna Citation X Model Ce750 X
Boeing 737-800	Convair Cv-340/440

Convair Cv-580	McDonnell Douglas Dc-10-10
Convair Cv-660	McDonnell Douglas Dc-10-20
Dehavilland Dhc7 Dash-7	McDonnell Douglas Dc-10-30
Dehavilland Dhc8-100 Dash-8	McDonnell Douglas Dc-10-40
Dehavilland Dhc8-200q Dash-8	McDonnell Douglas Dc-6a
Dehavilland Dhc8-300 Dash 8	McDonnell Douglas Dc-8-61
Dehavilland Dhc8-400 Dash-8	McDonnell Douglas Dc-8-62
Dornier 228	McDonnell Douglas Dc-8-63
Dornier 328	McDonnell Douglas Dc-8-71
Dornier 328 Jet	McDonnell Douglas Dc9 Super
Embraer 170	80/Md81/82/83/88
Embraer 190	McDonnell Douglas Dc9 Super 87
Embraer Emb-110 Bandeirante	McDonnell Douglas Dc-9-10
Embraer Emb-120 Brasilia	McDonnell Douglas Dc-9-15f
Embraer Erj-175	McDonnell Douglas Dc-9-30
Embraer-135	McDonnell Douglas Dc-9-40
Embraer-140	McDonnell Douglas Dc-9-50
Embraer-145	McDonnell Douglas Md-11
Fokker 100	McDonnell Douglas Md-90
Fokker 70	Nihon Ys-11
Fokker F28-1000 Fellowship	Piper Pa-31 (Navajo)/T-1020
Fokker F28-4000/6000 Fellowship	Piper Pa-32 (Cherokee 6)
Fokker Friendship F-27/Fairchild F-	Raytheon Beechcraft Hawker 400xp
27/A/B/F/J	Saab-Fairchild 340/A
Hfb-320 Hansa	Saab-Fairchild 340/B
Lockheed Jetstar	Shorts 360
Lockheed L-1011-1/100/200	Swearingen Metro Iii
Lockheed L-1011-500 Tristar	
Lockheed L-188a/C Electra	

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