JOURNAL OF AIRCRAFT
Vol. 42, No. 4, July–August 2005

Growth and Operating Patterns of Regional Jets in the United States

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Data concerning the growth and utilization of regional jets between 1998 and 2003 are presented and analyzed. During this period, daily regional jet operations increased by 356%. These additional flights were primarily used to enter new midrange markets that were previously too far to serve efficiently with a turboprop and too small to warrant a traditional jet. Analysis of aircraft situational display to industry operational data also shows an increase in the stage length of regional jet flights; for example, at Dallas–Fort Worth, the regional jet catchment basin increased from 299 n mile to 868 n mile. To better understand the reasons for the rapid growth of regional jets, an analysis of the economics of regional flight was performed. This analysis shows that airlines benefit from regional jets primarily because of the fee-per-departure payment structure and their current utilization patterns.

I. Introduction

THE number of regional jets in the national airspace system (NAS) has grown significantly over the past 10 years. Regional jets are small, 30–100 seat aircraft capable of flying up to 1000 n mile and have been growing in number at a nearly exponential rate since 1994 (Ref. 1). This increase represents a major change in the composition of the national fleet and may affect the efficiency of the air traffic control system, as well as the dynamics of the airline industry. This paper examines the evolution of regional jet utilization to better understand their growth and operating patterns, as well as possible future trends.

The goal just outlined was reached in two steps. The first was to analyze flight track data and develop methods to visualize and quantify any changes in the flight patterns of regional jets. Once this was accomplished, the second step was to analyze aircraft economics, aircraft utilization, airline scope clause agreements, and other factors to develop an understanding and explanation of the observed patterns.

II. Methodology

A. Data Sources

To perform an analysis of emerging regional jet trends and compare them to those of other aircraft, this study made use of actual flight data from the aircraft situational display to industry (ASDI) feed. The ASDI feed provides aircraft position and speed information during flight, in addition to the flight origin, destination, and departure/arrival times. The ASDI feed is compiled from the Federal Aviation Administration's (FAA's) Enhanced Traffic Management System (ETMS) and is made available to vendors, who can then pass the data on to other interested parties.

This study used ASDI data for one Thursday in January, between 1998 and 2003, resulting in a total of 6 days. Each data sample is from the same month and weekday to eliminate the effects of seasonal and weekly variations in airline operations. The specific dates were chosen to represent typical January days. In particular, holidays and days with severe weather conditions were avoided. Clear weather days were identified using the National Climatic Data Center weather archives.[2]

To understand the patterns observed using the ASDI data, Form 41 data were used to study and compare the cost structure of regional jets and other aircraft. Form 41 data include balance sheet and income statement information from all U.S. airlines that are required to file with the U.S. Department of Transportation's Research and Special Projects Administration. This includes all airlines with annual operating revenues of $20 million or more and includes all major and some regional airlines. The specific information used for this study includes the aircraft operating expenses grouped by aircraft type.[3]

B. Data Processing

To use the ASDI data effectively, they needed to be consolidated and formatted in a way that made it possible to analyze. The first step in creating a usable version of the data was to consolidate all information about one flight in a single record. During this process, flights with missing or incorrect data were removed. Flights with incorrect data were removed and include flights where the arrival time was before the departure time and flights where the time of travel did not reasonably correspond to the distance of travel. As a result of the aforementioned data processing, on average, 37% of flights were removed. It is not clear what fraction of the removed flights were actual flights that took place and what fraction was a result of noise in the data. A significant amount of noise can be introduced into the ETMS data because they are based on a real-time message stream and assembled from multiple sources.

The next step in creating a usable data file was to filter out transition and incomplete position updates from each record. Transition updates contain information about what the plane is required to do in the future rather than what it is doing now. For example, it may contain the cruising altitude to which the aircraft will climb. Because these updates do not contain information about the actual behavior of the aircraft, they were removed. Updates where the point did not fit in between those surrounding it, as well as updates where speed was zero but altitude was not, and vice versa, were counted as incomplete data and also removed. This filtering has no effect on the total number of flights that were kept.

Finally, for the purposes of this study the data were broken down into four categories based on aircraft type: the narrow-body traditional jets, the wide-body traditional jets, the turboprops, and the regional jets. Other aircraft such as general aviation or business jets were not included. As a result, from the data that survived the outlined process, on average about 63% of daily flights were used for analysis.

Received 24 June 2004; revision received 19 August 2004; accepted for publication 20 August 2004.

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C. Visualization of Traffic Data

To visualize the flight patterns of regional jets and other aircraft, density maps were generated from the ASDI data. The plots were generated in a grid format, and the number of flights whose paths intersected each square in the grid over a 24-h period was counted. The squares were coded based on the resulting number of aircraft. The top limit of the scale was set to best illustrate the change in flight patterns. The size of each square in the grid was 4 by 4 min. This resolution was chosen to be able to generate useful maps over the continental United States in a timely manner. Higher resolution maps could be generated with additional computation. These are typically more useful for studying smaller regions, for example, surrounding a particular airport, or over a shorter time period.

III. Operating Patterns of Regional Jet, Traditional Jet, and Turboprops

A. Regional Jet Growth

Since their introduction, regional jets have experienced a tremendous growth in number in the United States. This growth can be seen in Fig. 1, which shows the cumulative registration data between the first quarter of 1995 and the first quarter of 2004, for the regional jets commonly flown in the United States. Figure 1 shows the total number of registrations for each aircraft type in each quarter. Note that the growth between 1995 and 2004 is significant and exhibits a nearly exponential pattern.

Note from Fig. 1 that Embraer and Bombardier manufacture almost all of the regional aircraft currently flown in the United States. In particular, the EMB145 and the CRJ200 have shown the most rapid growth of all of the regional jets and are currently the two most numerous regional jets in the U.S. national fleet. In 2003, there were slightly fewer than 400 EMB145 aircraft and slightly more than 400 CRJ200 aircraft, which together account for 65% of the total registered regional jets and for over 50% of all regional jet flights in the United States.

Although the EMB145 and the CRJ200 have been the dominant aircraft since about 1998, two new aircraft have since been added to the national fleet and are slowly starting to grow in number. The CRJ700 and CRJ900 appeared in 2002 and 2003, respectively. Both of these aircraft are larger than the currently popular regional jets, which have about 50 seats, and possibly represent the future of regional aircraft. However, before the growth of these larger aircraft can become more rapid, scope clause restrictions, which limit the size and number of regional jets that an airline can operate, need to be relaxed. A more in-depth explanation of scope clauses is presented later in the paper.

B. Regional Jet Operating Patterns

As mentioned in the preceding section, there has been a significant increase in the number of regional jets in the United States. However, in addition to looking at the increase in the number of aircraft, it is also useful to analyze the growth in the number of flights, as well as where in the United States those flights cluster. Figure 2 shows the growth in the density of regional jet flights over the United States. Note that, in 1998, most of the regional jet flights clustered closely around large airports, such as LAX, ATL, CVG, CLE, and Dallas–Fort Worth (DFW). This clustering suggests that the jets were being used for hub feeder operations. In 1999 and 2000, these densities increased, but the patterns remained very similar. Between 2000 and 2001, a significant growth in traffic can be seen in the northeast part of the country, and in places like IAH and ORD. Finally, in 2002 and 2003, the densities increased significantly all over the United States, resulting in a dense covering of regional jet flights over the eastern half of the country. Furthermore, the highest densities can be observed at many of the major airports in the country. In addition, a change in the flight distances can also be observed. There are still flights clustered around hubs, but the distances that these aircraft are flying around the hubs have increased. Close observation of SLC between 1998 and 2003 shows a good example of this change.

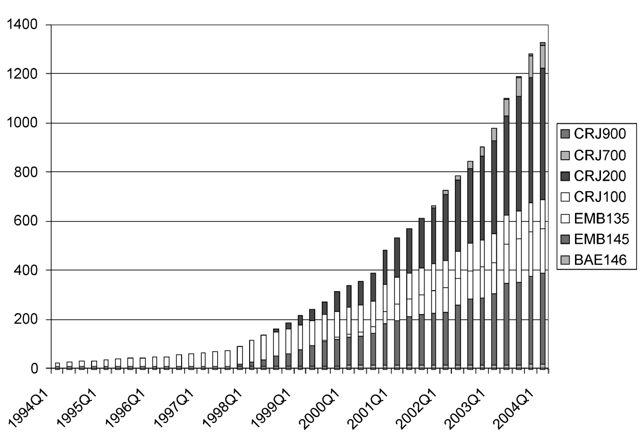

Fig. 1 U.S. cumulative regional jet registrations based on FAA registration data.

C. Regional Jet Operating Patterns Compared to Other Aircraft Types

The preceding section showed the growth and high-level development of regional jet patterns between 1998 and 2003. However, it also important to understand where the regional jet patterns fit as compared to other aircraft types. Figure 3 shows how the 2003 regional jet patterns compare to those of narrow-body traditional jets, wide-body traditional jets, and turboprops. As was already mentioned, regional jets have dense operations in the eastern part of the country and flew increasingly longer stage lengths between 1998 and 2003. In comparison, Fig. 3 shows that, in 2003, turboprops flew fewer flights than regional jets, but, like regional jets, showed the highest densities in the northeast. Also note that the turboprop operations clustered around major airports and exhibited relatively short stage lengths. A clear example of this clustering can be seen at DFW. Narrow-body jets have the largest number of flights, showing a high density over all of the United States, but, like regional jets and turboprops, show the largest concentration of flights in the northeast and near major airports. Also note that narrow-body jets fly longer routes than either regional jets or turboprops. These routes include many transcontinental flights and some international flights. Similar to narrow-body jets, wide-body traditional jets fly long stage lengths, with some transcontinental flights and a significant number of international fights. Unlike the preceding three categories of aircraft, wide-body jets do not exhibit the highest densities in the northeast, but show a corridor of dense flights between California on the west coast and the New York region on the east coast.

D. Stage Length Evolution

To better understand the observed changes in regional jet operating patterns, an analysis of the evolution of stage length was conducted. A specific case of this evolution can be seen by looking at a route map of DFW in 1998 and 2003, shown in Fig. 4. Figure 4 shows the catchment basin created around DFW by regional jets, turboprops, and narrow-body jets. The catchment basin was defined as the radius within which 95% of all flights from DFW fit. Note from Fig. 4 that, in 1998, regional jets and turboprops both covered about the same distances away from DFW, with the turboprops having a slightly longer range. Figure 4 also shows that, by 2003, regional jets provided service to cities within a radius of 868 n mile around DFW. This new regional jet pattern increased the catchment basin around DFW by over 500 n mile, whereas the turboprop range increased by only about 30 n mile. Regional jets evolved from flying the same ranges as the turboprops to flying ranges in between the turboprops and the narrow-body jets, effectively increasing the amount of traffic into DFW.

To compare the overall change in the stage length flown by regional jets to other aircraft types, a histogram of the stage length distribution for each aircraft category was created for January 1998 and January 2003. These histograms show data for flights over the entire United States, and not just from one city as in the preceding example. The histograms are normalized by the total number of aircraft in each category so that the relative shapes of the distributions are not distorted.

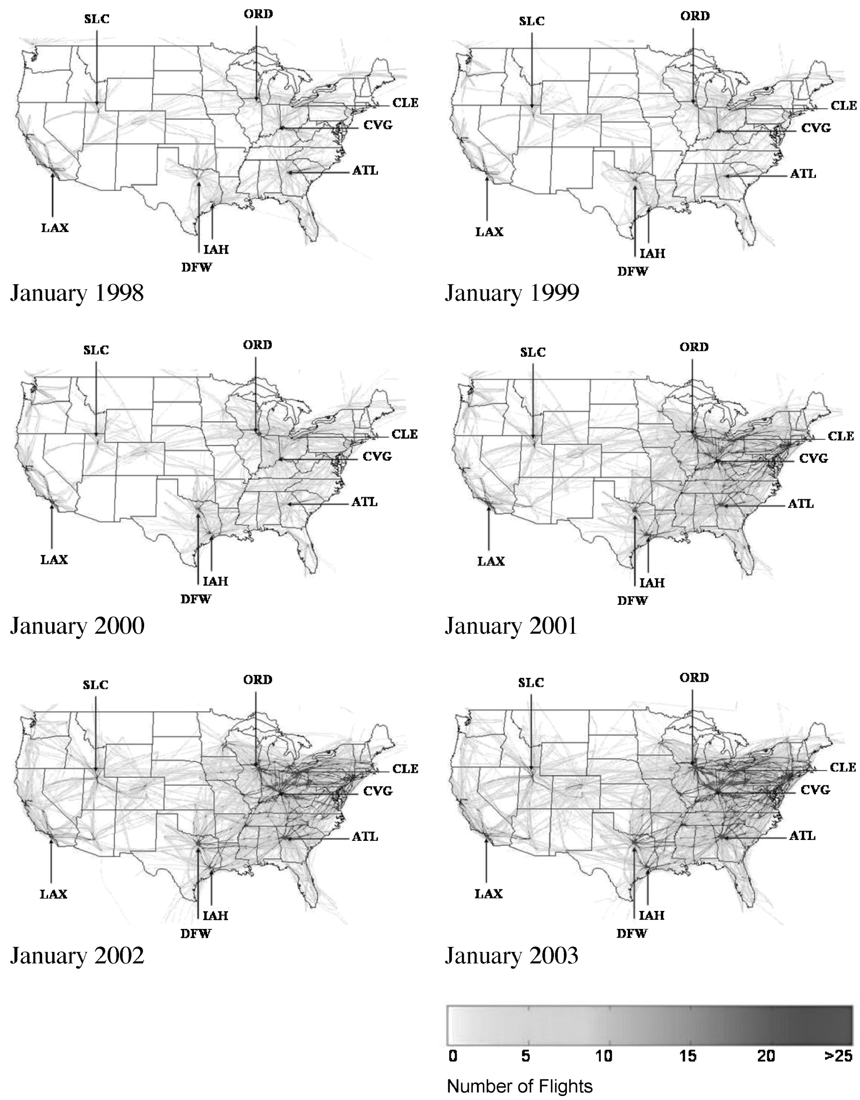

Fig. 2 Growth in regional jet density between 1998 and 2003.

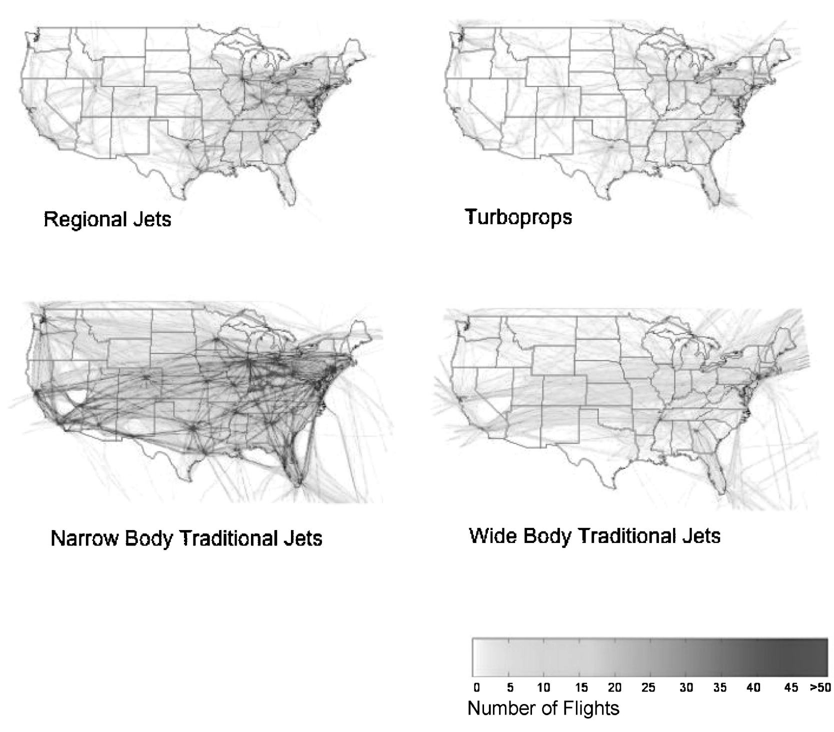

Fig. 3 January 2003 density maps.

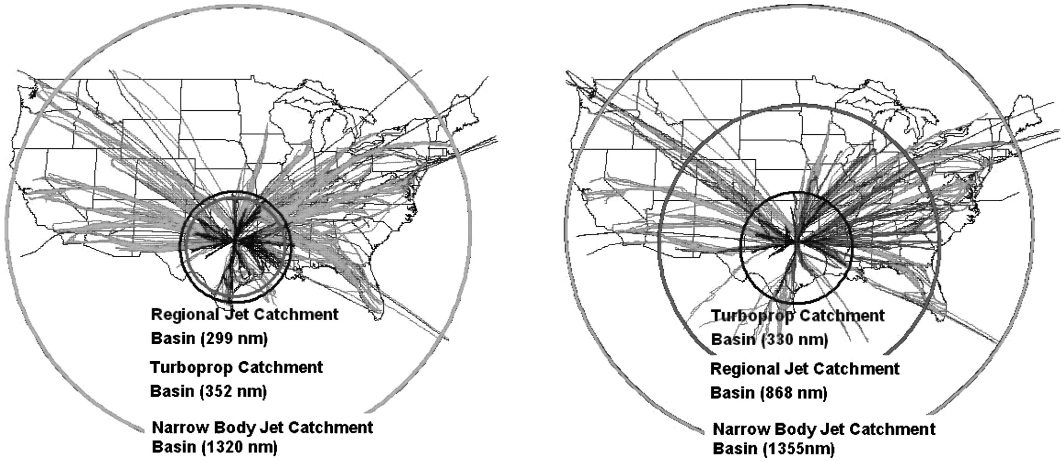

Fig. 4 January 1998 and 2003 departures from DFW.

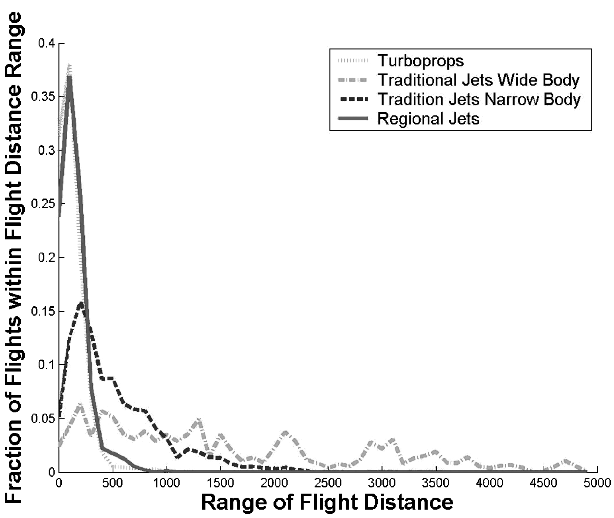

Fig. 5 January 1998 distance histogram.

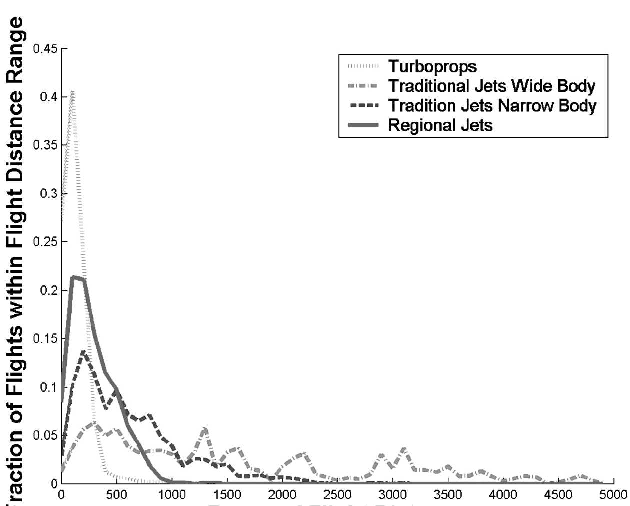

Fig. 6 January 2003 distance histogram.

Figure 5 shows that, in 1998, the regional jet and turboprop distributions were very similar, as can be seen from the way the two curves almost overlap. The respective peaks of the regional jet and turboprops both occur at about 250 n mile, and both distributions exhibit very few flights longer than 400 n mile. Figure 6 shows that, whereas the turboprop distribution changed little, by 2003, the percentage of regional jet flights with stage lengths less than 500 n mile had decreased, and the percentage with stage lengths greater than 500 n mile had grown. The 2003 stage length distribution still has a peak below 500 n mile, but now there are also a significant number of regional jets flying stage lengths between those of turboprops and narrow-body jets.

IV. Regional Jet Economics

A. Economic Analysis

The goal of this analysis was to understand the cost structure of both regional and traditional jets and to gain insight into the reasons for the observed regional jet patterns. Most regional jets are owned and operated by regional airlines. However, major airlines incorporate regional jets flights into their operations by having wholly owned subsidiaries or by code sharing with small regional carriers. An example of a wholly owned subsidiary is American Eagle, where American is the parent company. However, a regional carrier like Republic flies regional aircraft for America West, Delta, and USAir. This structure allows the major airlines to pay regional carriers on a fee-per-departure basis. This means that the cost of each regional flight is covered regardless of the distance of the flight or the number of passengers onboard.

To compare the cost of operating a regional jet vs a traditional jet, Form 41 data between the second quarter of 2002 and 2003 were used. Form 41 data are the mandatory filing of financial data for all large U.S. airlines. These data includes cost and operating information for all airlines with annual revenues over $20 million. As a result, the number of airlines that fly regional jets and are included in the study was limited because not many of these airlines have revenues high enough to require filing. In addition, the data were aggregated across airlines according to aircraft type. The aircraft types and air carriers included in the study, as well as the list of regional carriers not included in the study, are shown in Table 1. Finally, it is important to note that the diffarent operating environments of the airlines included in the study will have an effect on the data reported by these airlines. The agregation of data by aircraft type obscures this variation.

To evaluate the effect on cost as a result of changes in operation patterns, it is useful to first present the baseline data to which other scenarios can be compared. Table 2 shows the baseline data for all aircraft included in the analysis. The variables shown are those used to calculate the costs per ASM and per trip shown later in this section. The costs in this analysis do not include ownership costs because the data were not available.

B. Regional Jet Costs

The flight operating costs per ASM for all of the aircraft included in the study are shown in Fig. 7. The per ASM metric is a good way to look at costs because it directly relates the cost to the product that the airline is selling: a seat to a passenger on a specific route. It can be seen from Fig. 7 that the regional aircraft costs per ASM are much higher than those of the narrow-body jets. This is because regional

Table 1 Aircraft and carriers included in economic analysis[a]

Aircraft	Carriers included in analysis
B737	Aloha, Alaska, American, America West, Continental, Delta, Frontier, Northwest, Southwest, United
B757	American, Comair, Continental, Delta, Northwest, United, USAirways
A319	America West, Frontier, Northwest, United, USAirways
A320	America West, Jet Blue, Northwest, United, USAirways
CRJ2	Air Wisconsin, Atlantic Southeast, Comair
CRJ7	American Eagle, Atlantic Southeast, Comair, Horizon
E135	American Eagle
E140	American Eagle
E145	American Eagle, Trans States

[a]Excluded regional carriers include Ameristar, Chautauqua, Express Jet, Horizon, Mesa, Pinnacle, Republic, Sky West, and USA Jet.

Table 2 Baseline regional jet operations and economic data

Aircraft	Number of trips	Average trip length	ASMs, '000s	Pilot cost per block hours
		Traditional jets		
B737	2260194	663	198255980	430
B757	598628	1236	133443130	547
A320	325124	931	37057260	460
A319	379018	1094	60751749	411
		Regional jets		
CRJ2	285650	459	6230958	287
CRJ7	68209	542	2592234	215
E135	86333	351	1122784	181
E145	157506	354	2784478	187
E140	92788	386	1576162	169

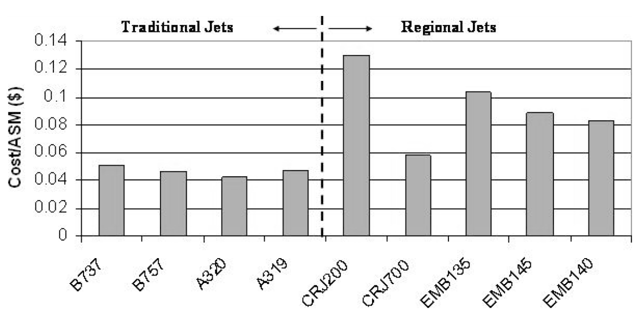

Fig. 7 2002–2003 flight operating costs per ASM.

jets have fewer seats and are generally operated on shorter routes. Given this cost difference, the rapid growth in regional jets may appear somewhat surprising. However, currently, many regional jet flights are flown on behalf of a major airline. Major airlines contract with regional airlines to incorporate regional jet flights into their network structure paying for the flights on a fee-per-departure basis.

Figure 8 shows the flight operating costs per flight. It can be seen from Fig. 8 that the costs of regional jets per flight are significantly lower than those of narrow-body jets. Given the fee-per-departure structure of many contracts between major and regional airlines, it can be seen that the regional aircraft flights are less expensive for the major airlines than their own narrow-body flights. This payment structure also benefits regional airlines because the airline is paid regardless of the number of people on a flight.

1. Regional Jet Costs as a Function of Stage Length

Whereas the preceding analysis provided information about each aircraft type, it did not provide any insight into how the costs of these aircraft would change if they were all used under the same operating conditions. In particular, the data do not show how operating costs per ASM and per departure change when flight distances are changed. The goal of the following analysis was to normalize the effect of stage length and compare the cost of regional and traditional jets if they were to fly the same routes. Changes in stage length were analyzed because, as shown earlier, the stage length of regional jets has increased significantly between 1998 and 2003. If this trend continues, it is valuable to know what the effect on the cost of regional jets will be.

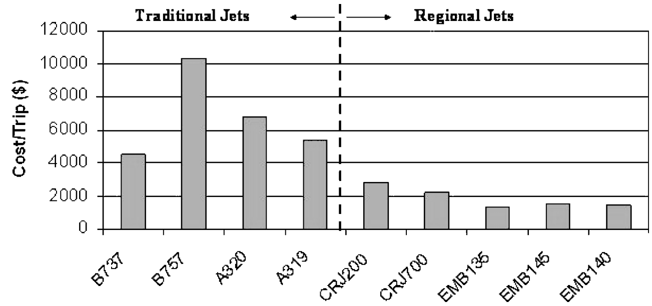

Fig. 8 2002–2003 flight operating costs per trip.

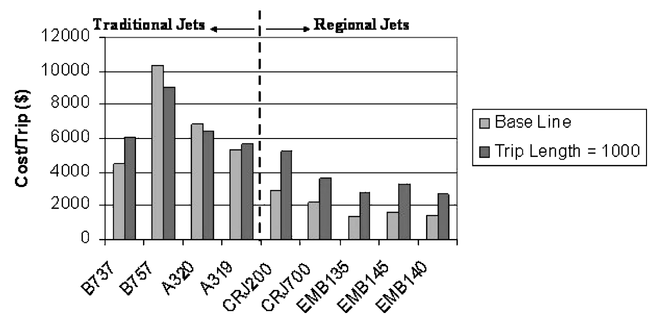

Fig. 9 Comparison of operating cost per trip with and without change to stage length.

To show the effects of changes in stage length on the overall operating cost per ASM and per trip, it was assumed that flight operating costs scale linearly with the number of block hours flown. It was also assumed that maintenance costs, which are added to the flight operating costs to make up the total operating costs, scale with the number of takeoffs. In this analysis, the number of takeoffs was kept constant, and, as a result, the maintenance costs did not change. These assumptions represent a significant simplification of the processes involved, and although it may have been more accurate to model costs using regression, not enough data points were available due to the small number of regional airlines that file Form 41 data. Once costs were modeled given changes in the stage length, the next step was to equalize the stage length to compare how expensive narrow-body and regional jets would be if they were used on the same trips. The chosen stage length was 1000 miles. This number represents the rounded average of the base case narrow-body jet stage lengths.

The analysis showed that regional jet costs per ASM and per trip both increase over the baseline case, but that the per trip costs increased by a higher percentage as can be seen in Fig. 9. This result indicates that if regional jets are flown on the same distance routes as traditional jet aircraft, the fee-per-departure payment structure will no longer make the regional jet a significantly cheaper alternative to a narrow-body jet. For example, when the CRJ200 is compared to the B737, it can be seen that, when the trip length is increased to 1000 miles, the difference in the costs per trip of the two aircraft lowers significantly.

2. Operating Cost as a Function of Pilot Cost

The effect of changes in pilot costs was studied because the lower crew costs of regional jets are often cited as the reason why regional jets have been growing rapidly in the United States.[4] As a result, it is

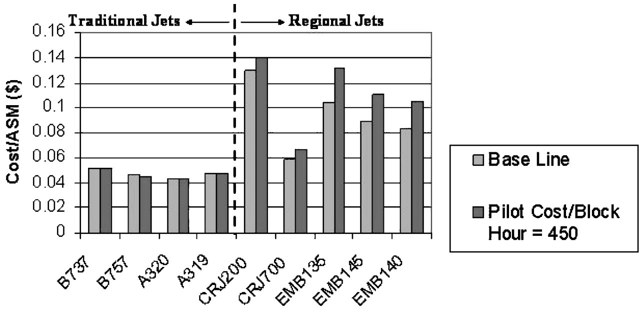

Fig. 10 Comparison of operating cost per ASM with and without change to pilot costs.

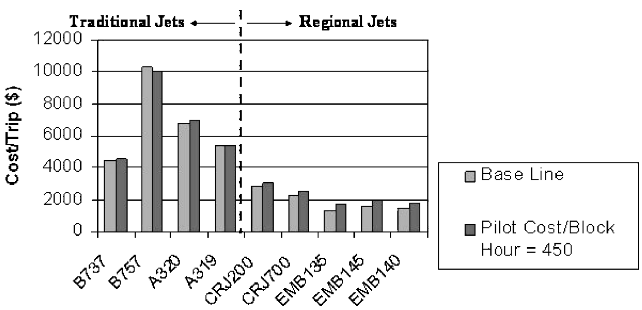

Fig. 11 Comparison of operating cost per trip with and without change to pilot costs.

valuable to know how regional jet costs compare to narrow-body jet costs when crew costs between the two aircraft types are equalized. To show the effects of changes in crew costs on the overall operating cost per ASM and per trip, it was assumed that pilots are paid per block hour of flight. The chosen pilot cost per block hour was $450, which is the average of the values for the narrow-body jets, rounded to the nearest $50.

Figures 10 and 11 show that regional jet costs increase in both cases, but the differences are not significant enough to make regional jets any more or less economical than traditional jets. Their cost per ASM is still significantly higher, and the cost per trip is still significantly lower, than the cost of traditional jets. This indicates that the lower crew costs of regional jet operations are not the reason that regional jets are considered to be less expensive. Rather, as shown in the preceding section, the fee-per-departure is what makes the regional jet an affordable alternative to narrow-body jets.

V. Understanding Regional Jet Growth and Patterns

When regional jets were first introduced, they provided service similar to turboprops, and in many cases replaced turboprop aircraft and flights. Part of the reason for this replacement was the public perception, most likely caused by the fact that turboprops fly at lower and more turbulent altitudes, that turboprops are less safe than jets. However, soon after their introduction, regional jets began to fly longer distances and serve new markets. From their introduction until the present, regional jets have been mainly used to create new routes, but also to supplement and replace traditional jet and turboprop flights.[5] In addition, during the economic downturn following the attacks of 11 September 2001, many airlines used regional jets strategically to hold valuable spots at slot restricted airports.

The use of regional jets has been successful in creating new routes because their smaller size means that they can serve routes that do not have enough demand to warrant a traditional jet. Whereas it was shown in the preceding section that regional jets are more expensive per seat because of yield management, having the right number of seats can be more profitable than having more seats to spread the cost among. Yield management allows an airline to maximize yield by selling as many high-priced tickets as possible. If an aircraft is correctly sized to the market, it can be filled with high-paying passengers and result in higher revenues. Passengers will compete for the available seats, and those willing to pay more will buy the

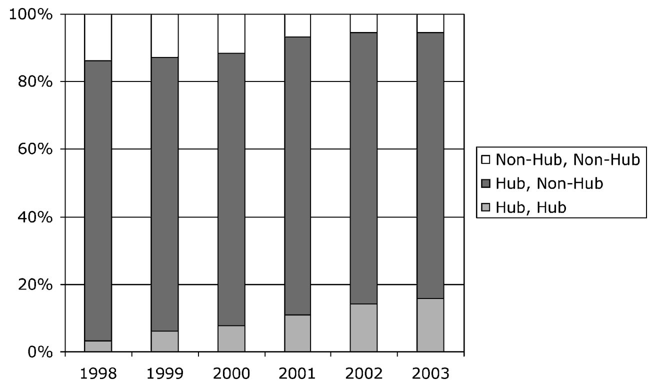

Fig. 12 Percentage of regional jet flights providing service between hub and nonhub airports.

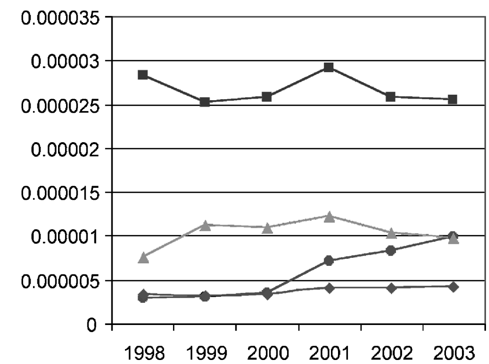

Fig. 13 Growth of aircraft operations normalized by number of RPMs: ●, regional jets; ■, narrow body jets; ◆, wide body jets; and ▲, turboprops.

tickets. However, if an aircraft is too large, there are always available seats. As a result, the airline has to discount the ticket prices to fill enough seats to cover their costs.

The addition of regional jets allowed major airlines to serve small but profitable cities that had been too far to serve efficiently with a turboprop and did not have enough demand to warrant traditional jet service. In addition, the airlines could expand and support their hub operations by using regional jets to feed passengers into the hub.[6] This utilization can be observed in Fig. 12. Figure 12 shows that, rather than providing point to point service, over 90% of regional jet flights start or terminate at a hub or major airport.

The growth in the number of regional jets, although rapid, would most likely have been faster if not for the restrictions placed on major airlines by scope clause agreements. Scope clauses are part of labor contracts between airlines and airline pilots. They limit the number and size of regional jets that an airline can own, as well as cities or routes where the airlines can operate regional aircraft. Pilots working at major airlines are thwarting the growth of regional jets because they see them as a direct threat to their jobs. Finally, because most major airlines pay pilots based on the size of the aircraft they fly, the popularity of new smaller aircraft threatens not only their jobs, but their salaries as well. As a result, pilots at major airlines have fought back with scope clauses.

VI. Future of Regional Jets

The future growth of regional jets depends on many factors and, as a result, is uncertain. However, current trends indicate that regional jets are the fastest growing category of aircraft in the United States. This trend can be seen in Fig. 13, which shows the number of aircraft operations normalized by the number of yearly RPMs in the United States. It is also known that in the next few years, both US Airways and Jet Blue will be receiving a large number of regional jets, which means that the current growth trend is likely to continue. Many airlines are currently in financial difficulty, and it is unclear what the future successful airline business model will look like, if it will include regional jets, and what the labor and code share arrangements will be like. It is possible that at some point the fee-per-departure structure will change, making the use of regional jets less affordable. It is also possible that the partnerships between regional and major airlines will be disbanded. Atlantic Coast Airlines has been a regional partner of United, but has announced that it will transition to operating independently.[7] Whether or not the airline will be successful may provide insight into the viability of regional jet economics.

The post 11 September 2001 economic downturn has also led many airlines to renegotiate their existing pilot contracts. As a result, the effect of scope clauses is likely to change. The changes in the scope clauses are complicated, and it is unclear if they will result in an increase in regional jet operations. However, there is evidence that airlines are negotiating contracts that will allow them to operate more regional aircraft with a higher number of seats. Between the fall of 2001 and 2003, United Airlines and USAirways both negotiated contacts that allow them to fly aircraft with an additional 20 and 7 seats, respectively.

At some point in the future, the economic situation will improve, and, as a result, demand and capacity will grow as well. It is unclear whether, under increased demand, regional jets will be able to provide the necessary amount of capacity, or if they will need to be replaced with narrow-body jets or larger regional jets. If regional jets will have to be replaced, it is unclear what they will be used for. One possibility is that they will replace the remaining turboprops in the national fleet.

Currently, both Embraer and Bombardier are building larger regional jets. These new airplanes seat between 70 and 110 passengers, which means that the line between regional jets and narrow-body traditional jets will blur further. Embraer believes that there is a capacity gap in the market and that the new 70 to 110 seat aircraft will help to fill that gap.[8] This new size of regional jets will further change the composition and performance range of the national fleet, making the future unclear.

VII. Conclusions

One of the recent significant changes to the national airspace system has been the emergence of regional jets. To understand the reason for this rapid growth, this study analyzed the emerging flight patterns of regional jets compared to traditional jets and turboprops. To conduct this analysis, ASDI data, which consist of actual flight track information, were used to compare flight patterns between January 1998 and January 2003. In addition, a study of regional jet economics, using Form 41 data, was conducted to better understand the observed patterns.

It was found that, in 1998, U.S. regional jet patterns and utilization closely resembled those of the turboprops. Both types of aircraft were used for hub feeder operations and flew relatively short distances of under 500 n mile. These patterns began to change as the number of regional jets increased. By January 2003, the regional jets were no longer used solely for hub feeder operations, but were flying significantly longer routes. As a result, regional jets have come to fill a gap in the market by flying on longer routes than the turboprops, but shorter routes than the narrow-body jets.

The economic analysis showed that regional jets have lower operating costs per trip and higher operating costs per ASM than traditional jets. As a result, regional jets are currently a lower cost alternative for traditional airlines because they cover the cost of regional jet flights on a per departure basis. However, if this structure were to change, regional jets would become a less appealing alternative. To better understand the consequences of a change in the operation patterns, changes in the cost of regional and traditional jets were analyzed when trip length and pilot costs per block hour were normalized. It was found that regional jet costs per trip are very similar to traditional jet costs per trip when the trip length between the two aircraft categories is normalized, but that the normalization of pilot cost per block does not have a significant effect on the relative costs of the two aircraft types.

The rapid emergence and growth in number of regional jets makes it clear that these aircraft will play an important role in the future of the NAS. As a result, continued research into operational patterns and underlying causes of growth will allow for better and more efficient planning for the future.

Acknowledgments

The authors would like to thank Robert Yackovetsky from the NASA Langley Research Center for funding this work under grant number NAG-1-2038. In addition, Dale Rhoda from the Volpe Center and Doug Williamson from the Air Traffic Airspace Laboratory helped with the acquisition of ASDI flight track data. Without their assistance, this work would not have been possible.

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