Rise and Fall of the Regional Jet

by

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ABSTRACT

Over the course of more than two decades, the aviation industry has seen the introduction of the regional jet and witnessed the many operational benefits that it has presented airlines. Its future, however, hangs in the balance as record fuel prices and other economic and operational factors seem to threaten its existence in the capacity that it holds today. This research paper attempts to explore some of the factors that have both helped the regional jet find its place within the industry and also factors that have been linked to the threat against its future use. One of the two factors discussed in this paper will be the effect of fuel cost on the operational costs between a time that regional jets were considered viable and present day. The other will be the effect on market capacity that has been presented by the regional jet since its introduction more than two decades ago. In addition to these factors, other reasons for the potential discontinuation of the regional jet will be discussed including the effects of pilot unions on airline operations.

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Chapter I – Introduction

According to the United States Government's Regional Air Service Incentive Program, the regional jet is defined as an aircraft powered by jet propulsion having between thirty and seventy-five seats. This definition is constantly changing as the ideal role of the regional jet has not yet been identified. It was once thought that these aircraft would only seat less than fifty, sometimes as low as the thirties, and only fly the routes that were unprofitable or inefficient for either turboprops or mainline supplements. The definition then changed to fewer than seventy-five seats and is now changing again.

Today, a growing number of regional jets do not adhere to the definition of between fifty and seventy-five seats, nor do they fit their originally intended niche within many major carriers' route networks. For decades airlines have felt that they needed an aircraft class of this size and speed to introduce service to the point to point routes in small and medium cities that were simply not feasible with turboprops or larger mainline jets. In actuality these new jets have started to either replace or supplement flying that has already been established by other available aircraft. In place of introducing new service to smaller cities, this relatively new class of jet has been tasked with servicing the thinner routes of their networks and feeding into their hub and spoke systems.

For a while, the airlines were content with these new jets and the use that they had found for them. Although they did not meet their envisioned purpose of opening up brand new markets, the airlines thought they had found a long-term solution for running many existing routes more cost efficiently. That was true for many years, but some factors have revealed that they may not be around for much longer.

Background

To better understand the importance of the regional jet overall, one must examine the mission and importance of the regional airline within the airline industry as a whole. Although there is no official definition for a regional airline, for the purposes of this paper the term regional airline will be defined as any airline that is used to supplement major airline flying to smaller markets that do not produce enough traffic to sustain major airline service. Through this definition, the term regional airline closely resembles and is virtually synonymous with the regional airline's historical predecessor, the commuter airline.

Prior the Deregulation Act of 1978, all markets and routes as well as the airlines that would serve them were decided and selected by the Civil Aeronautics Board (Forbes & Lederman, N.D.). Under this board's direction, air transportation was viewed as an industry of public utility rather than an industry based on profit. This meant that regardless of the size or potential traffic generated by a selected market, at least one carrier would establish and continue to provide service to it. This also meant that on unprofitable city-pairs, the CAB would subsidize the airlines on the selected routes to ensure a certain level of profitability in order to ensure that the air service was not discontinued.

Under this method of operating the industry, there was little room for the concept of a commuter airline. With the exception of a few early commuter airlines, virtually all city-pair markets, large and small in scope and profitability, were operated on one of the legacy carriers. The legacy carriers can be defined as the original air carriers that existed during the time prior to airline deregulation. These included Pan American Airways, Delta Airlines, Braniff Airways, American Airlines, United Airlines, Trans World Airlines, Northwest Airlines, and Eastern Airlines.

After the passing of the Airline Deregulation Act of 1978, the Civil Aeronautics Board dissolved and with it so did the subsidies that had kept major airline service present at America's smaller communities. Without government subsidies present to ensure profitability in these smaller community markets, it was a short time until they lost major airline service in an effort by major air carriers to compete on more profitable routes and city-pair markets.

The regional airline industry was founded upon the idea that major airlines were unwilling to operate routes to small markets themselves because servicing them with their unionized workforces and high pay schedules would render them unprofitable. However major airlines would be willing subcontract out smaller feeder markets to regional airlines because of the smaller aircraft they flew as well as the then non-unionized workforce that could provide much lower labor costs than would be possible at a major airline.

Regional carriers began to operate many of these un-serviced routes through contracts that they acquired through major air carriers. Soon, these new airlines had established a new sub-industry. Though the original intent of the regional airline industry was to service the smaller communities that had been left out after airline deregulation, it soon became apparent that the equipment and resources available to them were inadequate to service some of these smaller and more remote markets.

This is what made the advent of the regional jet so important to not only the regional airline sub-industry, but also the airline industry as a whole. The regional jet, unlike earlier equipment available to regional airlines, is unique in the respect that it has a small enough capacity to fly with few empty seats into smaller markets. Regional jets also possess the speed and range capabilities to allow these regional airlines to begin service to many of the smaller communities that have had very little or no service since the passage of the Deregulation Act. This was the original intent of the regional jet although many of the promises of this new class of aircraft have yet to become true.

How regional jets came into existence.

The idea of the regional jet has existed since the coming of the Jet Age. One of the problems with their widespread use has been that, until recently, turbine engine technology in smaller scale has not become advanced enough to offer the efficiency that is now making their use feasible on these smaller aircraft. Once that turning point in technological advancement had been met, the question then changed. The question was no longer how can we build a small, but efficient, passenger jet, but rather how small can these aircraft be built and still hold that same level of efficiency?

Another question that is still being answered is what exactly will be purpose of these jets within the airline industry? While they were still being dreamed of, the answer seemed to be that these aircraft could somehow be used to introduce new service to markets. Later, the answer seemed to be that this new class of aircraft could be used to make already existent routes more profitable for airlines. Now that certain economic factors have changed within the industry, the purpose of these aircraft has become a bit hazy.

There were many manufacturers of early regional jets but perhaps the first successful line was Bombardier's Challenger business aircraft conversion into the

Canadair Regional Jet family. The very first of this widely successful line of regional jets was the CRJ-100 model which was a stretched version of the already successful CL-600 business jet. It featured fifty seats which helped it become adopted under major airline's scope clauses that limited the size of regional jets commonly to fifty seats. These scope clauses would continue to evolve and change with respect to the size and quantity of allowable regional aircraft throughout time.

One of the factors that led to the success of this family of regional jets has been that they are all basically stretched and upgraded versions of the same basic concept. This has made them become very popular with regional airlines because of the commonality of parts between the models as well as the lower degree of fleet-wide training required for both maintenance and flight crews when using multiple models of this family.

Currently the CRJ family features five models; the -200 model with fifty seats, -700 with up to seventy seats, the -705 with up to seventy-five seats, the -900 with up to ninety, and the -1000 with up to one-hundred seats. Today, there are over 1668 aircraft in this family flying revenue service around the world with even more on order for the future (CRJ Series, 2012). Although these aircraft feature very capable capacities, there is a difference between the capabilities in seating capacity versus allowable seating capacity. Most of the time it is contingent upon the mainline carrier's pilot union contract allowances. These allowances, referred to as scope clauses, vary from airline to airline and will be discussed in another section of this paper.

The first regional jet powered aircraft were introduced in the late 1960's by the Soviet company, Yakovlev, called the Yak 40 (Goebel, 2011). The three-engine aircraft featured a seating capacity of thirty-two, a maximum cruising speed of just under than three hundred knots, and a range of just less than one-thousand miles. It wasn't long until the west caught on to this phenomenon and began designing its own set or regional jet aircraft.

Before regional jets.

Before the airlines had access to the effective spoke tools that are regional jets, they relied upon similarly sized but far less capable turboprop. These turboprop aircraft could definitely complete short-haul task as far as range and payload, but lacked the ability to perform at a high enough pace to meet the airlines' needs. Also, these aircraft were unable to satisfy the needs of operating efficiently on medium-thin routes.

Because of the insufficient range or inconveniently low cruising speeds found in turboprops of the time, these routes were being tasked to mainline aircraft with significantly low load-factors. Some airlines chose to cut service on some select routes altogether because of this. Others offered limited frequency in an effort to run these routes with higher load factors.

Another major reason that airlines wanted a replacement for the turboprop was the backlash in customer satisfaction found by operating them. This was mostly caused by the often cramped and overly loud flying conditions that early turboprop aircraft presented. Delta Airlines actually did an informal survey that concluded that a majority of passengers were willing to drive between two and five hours to avoid turboprop service (Morrow, 2000).

Before the first successful regional jet, the mainline carriers had few choices when deciding to extend service to smaller markets. They could of course run the bigger narrow body jets to these destinations but frequency was a problem. They could use piston or turboprop aircraft on the short legs out of the hub but customer satisfaction would come into question. The third option, to not service a market at all, was a reality for many smaller markets for a long time.

It is estimated that regional airlines account for the sole means of air carrier service at around two-thirds of six-hundred and fifty-five airports serviced by major carriers (Forbes & Lederman, N.D.). Before the regional jet many of these routes were not possible simply because the mainline carriers had little interest in sending larger jets to these remote markets which were usually thin medium routes. Turbo-props sometimes possessed the range for these types of routes but did not have a high enough cruising speed to make running the route efficient enough to fit into their mainline partner's schedule.

Advantages of Regional Jets in Networking

Originally the regional jet airliner was intended to be used by the airlines as a tool to link point to point routes for the major airlines (Forbes & Lederman, N.D.). This was anticipated to help them become more competitive with other airlines that offer direct service to many popular markets without the need to inconvenience passengers by traveling to and changing planes in a hub. While this has become true for some select routes, it was found to be much more beneficial logistically for these smaller aircraft to come into a centralized hub to carry the airlines' passengers to their final destinations.

Also, without going through a hub, the airline could make an attempt to reduce congestion at several major hubs around the country. In doing so, the airline could help alleviate some of the burdensome traffic at their largest hubs and help factors such as on-time performance and gate-space issues. This didn't turn out to be the case as regional jets were found to be most useful when replacing inefficient mainline flying or increasing customer satisfaction on the short routes previously receiving turboprop service. Possibly an overlooked aspect of a regional jet is that it requires the same amount of gate space and takeoff and landing slots as do mainline aircraft.

Routes served by the regional jet.

A study developed by a research collaboration between a University of California and University of Toronto professor, Silke Forbes and Mara Lederman, revealed that during the five year period between 1996 and 2000 there were a total of 537 city-pairs introduced to the regional jet (Forbes Lederman N.D). They then divided these into four categories which can be viewed on Table 1-1.

Table 1-1 Introduction of the Regional Jet

	Number of RJ Airports	Percentage of RJ Airports
Capacity Reduction	124	23%
Frequency Supplement	124	23%
Turboprop Replacement	118	22%
New Service	172	32%
Total	537	100%

One of these categories was capacity reduction in which the airlines were putting regional jets in place of larger mainline jets. Most of these routes were ones that could not be adequately serviced by the turbo-prop regional aircraft of the time because of range, cruising speed, or a combination of the two. Routes with lower load factors on mainline aircraft were changed to new then 50-seat regional jets which could help the airline stay profitable on these route segments.

For almost the same reason, airlines also used the new 50-seat regional jets to supplement off-peak times on routes that usually featured fairly high load factors on mainline aircraft which was Forbes's and Lederman's second category, frequency supplement. When a route segment had glimpses of steady traffic but not a solid schedule of high volume, the airlines had to make a decision. They can choose to either decrease the frequency between a city pair or use mainline aircraft with lower load factors to keep the same availability and frequency in an effort to capture larger portions of market share.

The regional jet helped bridge this gap by allowing the major carrier to continue to use bigger aircraft with high load factors on the peak time but also to cater to passenger's needs when it came to frequency. The regional jet also allowed the airlines to still run the same frequency but to also keep an adequate load factor to ensure profitability.

Forbes's and Lederman's third category was the condition in which regional jets would begin to replace turboprops in all regional markets, both medium and short-haul. This did help the airlines maintain a better schedule because of the superior speed, payload, and operational capability of the regional jet. Another reason why this became popular was due to the fact that jets tend to operate a lot more quietly from inside the cabin and they have other capabilities that make their comfort exceed the capabilities of the turboprop.

The fourth category was in which the regional jet introduced new services altogether (Forbes & Lederman, N.D.). This was the case in markets that had thin volumes of passengers paired with their longer distance from an airline's hub cities. These were situations in which it was not profitable for an airline to provide mainline aircraft service or send a turboprop such a long distance so they were just not served. Lederman and Forbes found that this final category accounted for around a third of all introductions of the regional jet between 1996 and the turn of the millennium which was more than any of the other three categories individually.

Why Regional Jets are Attractive

Regional Airlines also saw an increase in the number of routes that were awarded to them by the mainline carriers because of the increase in effective range brought by the introduction of the regional jet into their service. Starting out at 50 seats, these larger and more powerful regional jets could fly much further, at a higher cruising speed, and offered much less payload restriction than their turboprop counterparts which gave the regional airlines much better control over the operation and efficiency of their schedule to keep to keep pace with their mainline partners network.

Performance comparison.

The regional jet is not generally more economical than the turboprop. However, in addition to the capabilities of the jet over the turboprop a reason that many airlines chose to go with regional jets is to cater to the passenger comfort. Passengers have long seemingly dreaded riding on any turboprop aircraft regardless of the route segment. Some reasons for this are due in part to the loud cabin noise that is generated from prop-wash. Also, because these turbojet aircraft can cruise at much higher altitudes, the possibility of flying above weather exists which translates into a much more smooth and stress-free ride for the passenger.

Aircraft comparison.

Table 1-2 compares different options that mainline air carriers have to choose from in terms of deciding whether to contract out shorter and thinner routes to regional airlines. Also included are some of the most common mainline narrow body aircraft that the airlines have to choose from when deciding the economics of subcontracting versus running the routes themselves.

The aircraft are compared in terms of seating capacity, fuel capacity, total payload allowance, range, and cruising speed. As one can see, the regional jets that are depicted below have seating capacities that are comparable to the most common turboprops but have cruising speeds at flight levels that meet and sometimes exceed the capabilities of comparable mainline aircraft that they are usually used to replace. This places them in an opportune spot to take routes away from either competing aircraft category, but only when the conditions are just right.

Table 1-2 Mainline vs. Turboprop vs. Regional Jet Comparison

Manufacturer	Model	Introduction	MAX Seating Capacity	Range (NM)	Crusing Speed (Knots)	Maximum Flight Level	MTOW (lbs)
ATR	42-500	1985	50	840	300	FL250	41,005
	72-500	1989	74	715	276	FL250	49,604
Embraer	135	1998	37	1750	447 (M.78)	FL370	44,092
	145	1996	50	2000	470 (M.80)	FL370	53,131
Bombardier	Dash8 Q400	1998	78	1350	360	FL270	64,507
	200	1992	50	1229	424 (M.74)	FL410	53,000
	700	2001	78	1732	447 (M.78)	FL410	75,000
	900	2007	90	1777	447 (M.78)	FL410	82,500
Boeing	MD-88	1980	172	2050	420 (M.76)	FL350	149,500
	737-700	1996	149	3440	454 (M.785)	FL410	154,500
Airbus	318	2003	132	3200	447 (M.78)	FL390	150,000
	319	1995	156	3700	447 (M.78)	FL390	166,000
	320	1988	180	3300	447 (M.78)	FL390	172,000

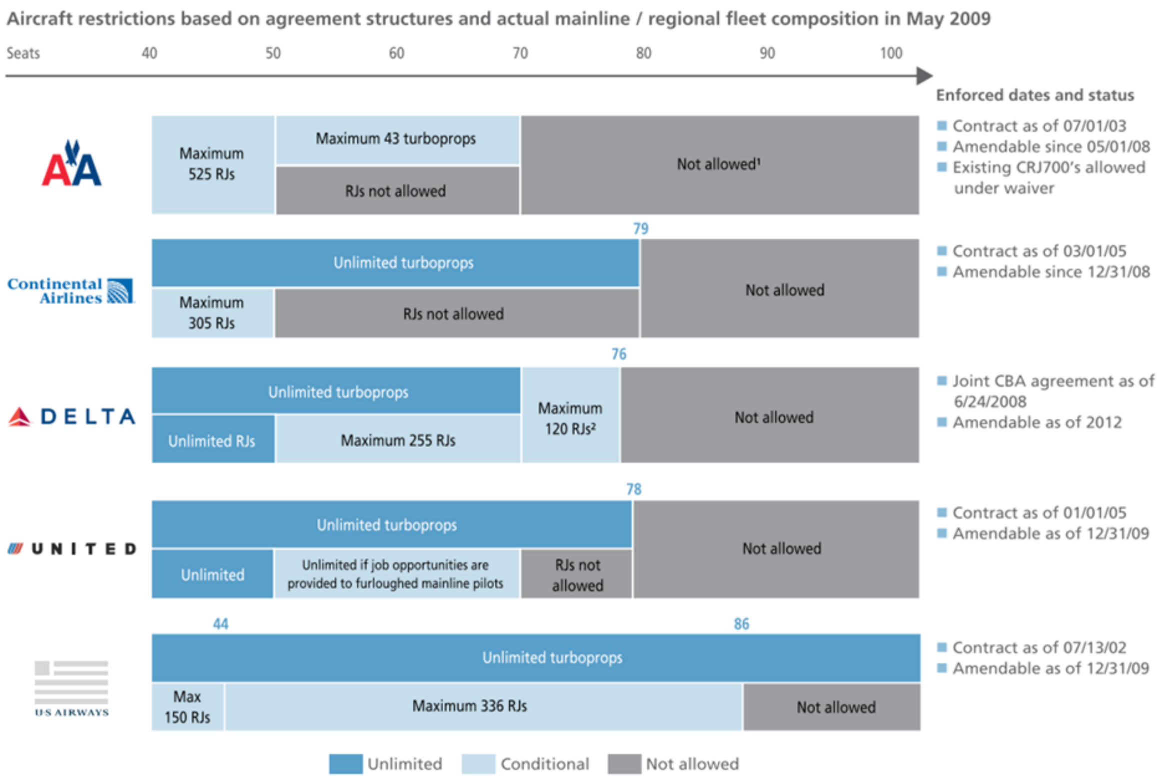
(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

In a the findings chapter, there will be information gathered by obtaining the fuel burns for each of these aircraft and doing an analysis of a variety of segment lengths that these aircraft could be used on. The thesis compares the economics of operating these aircraft over trip segments of two hundred all the way up to twelve hundred nautical miles. It also tested to see over which trip lengths the advantages lay within each type of aircraft.

Other factors for the regional jet's rise.

Of course it must be noted that the economics of each aircraft are not the only factor that an airline considers when assigning routes within its network. Another less talked about reason that regional flying is subcontracted out is the money that airlines save by not paying mainline pay schedules for low-density and less-profitable routes. This has become a hot topic among pilot unions at mainline carriers of late. More and more regional flying is being subcontracted out to regional carriers in place of mainline flying because it is being proven that it is cheaper for a mainline carrier to pay a flat reduced-rate fee to a regional airline than to pay for the maintenance, dispatch, scheduling, flight crew, and other expenses that have to be accounted for when paying at full mainline pay schedules.

Mainline pilot unions have caught on to this tactic by the network planners and have started to demand capacity agreements. These capacity agreements, referred to as scope clauses, show airline-specific allowable rates of regional flying that can be contracted out. The chart below shows some of the current agreements that exist within the mainline carriers as of 2009. Notice that Delta and United Airlines both have had agreements that put no limit on the number of fifty seat regional jets that they are allowed to use for regional flying.



Wyman 2009

Figure 1-1 Scope Clauses

This is all about to change as recently both airlines have begun to enter into negotiations with their pilot unions and this issue has come up. With this issue creeping around the corner, a question that comes up is whether or not some regional airlines will exist after the new scope clauses are finalized. The redefining of these scope clauses coupled with other factors has recently led to the demise of Comair and the future of Pinnacle Airlines is beginning to hang in the balance.

United has also ran into some issues with their pilot unions over the existence of the unlimited capacity in which the airline can use the fifty seat regional jet. The details have not been finalized but there are negotiations currently being discussed that will lead to the reduction in the number of fifty seat regional jets that the airline can subcontract.

Regional airlines have already begun to respond to this with orders for additional larger regional aircraft to help stay a viable option to their mainline partners as scope clauses are restructured. Some of the recent aircraft orders placed by Delta Airlines as well as SkyWest will be discussed as well as the options that they will present to their respective operations as a whole and the relation they have to the renegotiations of these contracts.

One way that the majors, particularly Delta Airlines, are selling this to their regional affiliates is that the fifty seat aircraft lack the ability to offer a first class to their customers. Although this is somewhat true, it will be examined further how much of a factor this is versus a copout for the airlines being forced to reduce the capacity of their fifty-seat regional jet fleets.

Statement of the problem

Although there are widely accepted reasons for the regional jet's developed and widespread use, there are various factors being blamed for the potential withdrawal of these aircraft from use in the degree that they are currently seen. Some of these reasons include the fuel inefficiency of smaller regional jets, the rise in fuel costs over the last decade, the change in cost structure within regional airlines and the subsequent change in unit costs used in capacity purchase agreements (CPA's).

Another reason that has become a large issue recently with two of the largest carriers in the U.S., Delta and United Airlines, has been the restructuring of pilot contracts and the subsequent impact on the airlines scope clauses. Scope clauses are essentially the number and size of aircraft that can be outsourced on behalf of the mainline carrier as either a supplement or replacement on certain routes for mainline flying. For some time now scope clauses have included limitations on the number of aircraft over fifty seats but sometimes unlimited outsourcing using aircraft with fifty or fewer seats. Recently there has been restructuring that has directly influenced the number of fifty seat aircraft that are available to be outsourced that is leaving the future of such aircraft in jeopardy.

This paper focuses on the rise in the cost of fuel over the past decade as one of the primary reasons for the potential scaling back of the use of regional jets. The paper compares costs associated with using these aircraft in today's environment with that of the relatively more stable environment that pre-dates the events on September 11th, 2001.

Research Questions

- In terms of cost per available seat-mile, has the rise in cost of commercial jet fuel caused significant differences between operating several types of aircraft on different route segments in 2013 versus in 2000?
- Over the course of a flight day, which aircraft included in the comparison will present the greatest operational advantage to the carrier in terms of the number of flight segments and market-seating capacity?

Chapter II – Methodology

Instruments

Research question one.

An answer to the first question was attempted through building generic aircraft data pertaining to operational costs. The first method of determining the operational costs for each specific aircraft was to obtain fuel burn per hour numbers to apply to each prescribed route segment. This was found to not be impossible due to a lack of adequate response from the respective aircraft manufacturers. Instead, an aircraft operational cost tool was utilized called *The Aircraft Cost Evaluator,* which was developed by the aviation information firm, Conklin and de Decker (ACE, 2012).

The *Aircraft Cost Evaluator* is a tool used to derive variable and fixed operational costs for aircraft varying from piston driven aircraft to commercial jets. For the purposes of this paper, only the variable costs were utilized in the comparison. Fixed costs were considered to not be a factor in this comparison for the lack of significant difference in cost between each individual type. Fixed costs in this instance are operational costs that every carrier endures regardless of the type of operation performed such as administrative positions, upper level management, and the costs associated with facility and equipment lease or purchase other than aircraft.

There are several parameters that the tool employs in determining the variable costs associated with each aircraft. One consideration is the maintenance of the aircraft. Because in-house airline maintenance personnel vary in cost, routine maintenance will be considered to be completed at third-party maintenance facilities with standard hourly rates. Also, there will not be a factor of unexpected costs used in the determination of operating costs.

The price per gallon for jet fuel was derived from the International Air Transport Association's *Fuel Price Monitor* (Fuel Monitor, 2013). The current price used in the analysis was the spot value of $3.22 per gallon taken on the 1st of March. The price for the year 2000 was the average given by the IATA page of $0.87 per gallon. It will be noted that one of the limitations of this method lies with the fact that it is a common practice for certain airlines to hedge fuel contracts and obtain fuel costs below these averages. Because this is a generalized study, the average fuel prices were used.

In the calculation of burned fuel during a route segment, the tool includes a two-hundred nautical mile alternate with an additional fifteen percent contingency fuel to account for unexpected delays, weather, or flow-control restrictions. The tool also uses a formula based on maximum gross weight of the aircraft to derive landing fees for each aircraft type. The tool also accounts for several crew costs that are likely to be incurred while the crew is operating a flight such as meal and hotel expenses.

The determination of trip time, demonstrated in table 2-1, in minutes was derived as a function of the total distance of the route segment and the average cruising speed of the individual aircraft type. Because it is known that the aircraft will travel at a different rate during the climb and descent phases of flight, a calculation was made to reflect these differences. Because most aircraft generally have the same taxi speed, a standard time of fifteen minutes on either side of the segment was used. In an attempt to be more accurate, regional aircraft were given a five minute credit overall based on the assumed ability to accept intersection takeoffs more often than mainline aircraft paired with the fact that turboprops and regional jets are generally operated into and out of smaller airports with significantly less traffic.

When calculating the climb phase of the flight, an average climb rate of 1,500 feet per minute and 250 KIAS was used across all aircraft types. It was assumed that turboprops will be climbing to an average altitude of 25,000ft MSL, or FL250. It was also assumed that in trips less than four hundred nautical miles, all jets will also cruise at an average altitude of FL250. For route segments of four hundred nautical miles or greater an average altitude of FL350 was be assumed. The time to top of climb was calculated by dividing the climb rate into the proposed flight level. When determining the distance covered in climb the time was be divided into the average indicated airspeed of 250 KIAS.

The descent calculation is very similar but used an average descent rate of 2,000 feet per minute and 280 KIAS. For the purposes of this calculation, it was assumed that this will be a continuous rate decent to approach and the aircraft did not encounter any holds or delays in descent until touchdown.

Table 2-1 Trip Times

Type of Operation	Taxi Time (Min)	Climb FL250**	Climb FL350**	FL250 CDP*	FL350 CDP*
Turbo Prop	25	17min 70nm	-	13min 60nm	-
Regional Jet	25	17min 70nm		13min 60nm	
Mainline Jet (Under 400nm)	30	17min 70nm	-	13min 60nm	-
Regional Jet	25		23.3min 97nm		17.5min 82nm
Mainline Jet (Over 400nm)	30	-	23.3min 97nm	-	17.5min 82nm
*Based on 1,500fpm avg climb a					
**Based on 2,000fpm avg desce	**Note: These distances deducted from total trip segment to get cruise segment**				

Once the times and distances for the taxi-out, climb, descent, and taxi-in times were compiled, the total distances for these phases was deducted from the total route segment distances to determine the distance flown in cruise.

This procedure was repeated two times. The first time was with the average price of commercial jet fuel recorded for the year 2013, and the second time was with the average price of commercial of commercial jet fuel recorded for the year 2000. After compiled, the data was then tested using two-tailed t-tests. The goal of these tests was to determine whether the costs per available seat-mile of these aircraft are statistically different from the year 2000 to the year 2013. Because this is a comparison of two time periods on the basis of cost, a factor of inflation was added in to help even out the time periods.

Research question two.

In an attempt to answer the second question, another comparison of the aircraft was made on the basis of the number of segments able to be completed in a flight day. For the purposes of this comparison, the number of completed segments was assumed by the number of departures of the aircraft within a flight day. A flight day, for this comparison, was defined as the seventeen hours between the times of 0600 and 2300 Eastern Standard Time.

Using the times calculated for each route segment previously, a calculation of the maximum number of departures was calculated by each aircraft type. Because an aircraft departure does not normally happen directly after an arrival, average turnaround times were used. Of course, it is also noted, that this was considered to be an ideal scenario in which there are no maintenance, crew, or other operational delays and the flights were conducted back to back for the entire flight day.

Based on the advisement of a former ramp service worker for a major airline, regional aircraft generally can be turned in about twenty to thirty minutes, or an average of twenty-five. Mainline aircraft such as the ones compared in this paper can generally be turned in between twenty-five and forty-five minutes depending on the level of service to be provided. This yielded an average value of thirty-five minutes for the mainline aircraft to be turned. For the purposes of simplicity, all routes were considered to be domestic service so customs processing times can be ignored on all aircraft.

The maximum number of trips for each segment was calculated for each aircraft and then the total number of seats, or capacity, offered by each aircraft was calculated. This was done by multiplying the number of filled seats, calculated previously, by the number of trips accomplished by that aircraft. Once this data is compiled, it was analyzed to determine which option gives an airline the best capacity on each route segment. The available capacity provided by each aircraft was then subject to the test method in the data-analysis section of this paper. The goal of this test was to determine if the capacity offered by a regional jet is statistically different from the available capacity offered by other options.

Scope and Limitations

In the attempt to answer the first aforementioned question, research looked primarily at data concerning certain performance and operational parameters regional jets possess that tend to make them viable alternatives to other options in equipment that exist to regional and major air carriers. Because of the constant competitive advancement in technologies that exist within the aircraft manufacturing world, only aircraft that are currently thought of as competitive for today's regional routes were compared.

This is to say that regional jets that are not currently still in widespread use for lack of operational profitability were not examined. This also means that other regional aircraft, such as turbo-props or route-comparable mainline aircraft, whose use has or is being phased out, were not included in the comparison. Also, aircraft that consistently fly route segments that are longer than the ability of the regional jet were be included.

Because much of this information is considered by aircraft manufacturers to be competitive, or proprietary, in nature it was impossible to garner and utilize the exact information needed to make these comparisons. Therefore, mathematical formulas by way of the *Aircraft Cost Evaluator* tool were employed to estimate to a relatively high degree of accuracy certain parameters needed to make these comparisons. It is important to know that this information is developed through mathematics rather than through actual performance data to develop the comparisons needed to draw conclusions about these comparisons.

The information gathered from the attempt at answering the first question was used to help answer the second question. In this question, a flight-day was defined as the hours between the 1100Z and 0300Z hours equal to sixteen hours. This is equivalent to the time between 0600 and 2200 EST which on a standard day represents the first and final blocks of flying by most major and regional airlines. There are flights that operate outside of these times but for the purposes of this thesis were not considered due to inconsistency.

The parameter of functionality that was focused on in this question was the number of flight segments that can be comfortably performed within this defined flight day. For the purposes of this examination, the individual manufacturers' claims to an individual aircraft's minimum turnaround times were ignored. This is because the airport environment is one of a list of factors that inhibit individual aircraft from meeting their manufacturer prescribed turnaround time. Instead, these turnaround times were based upon a standardized schedule of times proportional by aircraft seating capacity.

Chapter III – Data Analysis

Research Question One

Within each route segment the means and standard deviations were calculated with regard to the calculated costs per available seat-mile. Next, the data was analyzed by doing a two-tailed t-test to determine if the costs per available seat-mile calculated in 2013 are significantly greater, while accounting for inflation, than the same value in the year 2000.

The hypothesis was that there is no significant difference in operational cost, while accounting for inflation, between the two years specified. The alternate hypothesis was that the costs associated with the aircraft operations in the year 2013 are significantly different than in the year 2000. The critical value, alpha, was set at ten percent. These analyses were done for each route segment and then one was completed for the averages of the costs per available seat mile for the overall data set.

Two hundred nautical mile segment.

Table 3-1 shows the calculated trip times for each of the individual aircraft for the two hundred nautical mile segment. Notice that the trip times of each of the aircraft are relatively similar to each other because of the short distance of the trip and the relatively short time spent at cruise. The costs per-hour column is segment specific according to the *Aircraft Cost Evaluator,* although very marginal in difference.

Table 3-1 Mainline vs. Turboprop vs. Regional Jet 200 NM Trip Comparison (Current Jet-A)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	300	69	1,865	$ 2,144.70
	72-500	276	70	2,210	$ 2,586.42
Embraer	135	447	64	2,525	$ 2,710.25
	145	470	64	4,402	$ 4,690.83
Bombardier	Dash8 Q400	360	67	3,091	$ 3,434.16
	200	424	65	2,811	$ 3,041.28
	700	447	64	3,543	$ 3,802.91
	900	447	64	3,661	$ 3,929.08
Boeing	MD-88	420	70	6,537	$ 7,626.09
	737-700	454	69	5,005	$ 5,776.69
Airbus	318	447	69	4,713	$ 5,450.50
	319	447	69	4,978	$ 5,758.02
	320	447	69	5,429	$ 6,279.20

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

The next table, *Table 3-2*, shows the same information with the exception of certain aircraft that had not yet entered service in 2000. The fuel prices are changed to the average price of jet fuel per gallon in 2000, $0.87. Notice that the cost per hour is not directly proportional to the volatile change in fuel price over the time periods compared.

Table 3-2 Mainline vs. Turboprop vs. Regional Jet 200 NM Trip Comparison (Average Jet-A 2000)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	300	69	1,205	$ 1,385.56
	72-500	276	70	1,428	$ 1,670.92
Embraer	135	447	64	1,745	$ 1,872.50
	145	470	64	4,342	$ 4,626.91
Bombardier	Dash8 Q400	360	67	1,997	$ 2,218.60
	200	424	65	1,942	$ 2,101.21
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	420	70	4,516	$ 5,268.84
	737-700	454	69	3,458	$ 3,991.09
Airbus	318	-	-	-	-
	319	447	69	3,440	$ 3,978.20
	320	447	69	3,751	$ 4,338.28

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

In the next two tables, *Table 3-3* and *Table 3-4*,the costs per available seat-mile are calculated for the two hundred nautical mile segment. The total cost column in the year 2000 comparison is adjusted by 33% for the average inflation between 2000 and 2013 (Inflation, 2013).

Table 3-3 Mainline vs. Turboprop vs. Regional Jet 200 NM CASM Comparison 2013

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	$ 2,144.70	50	10,000	$ 0.21447
	72-500	$ 2,586.42	74	14,800	$ 0.17476
Embraer	135	$ 2,710.25	37	7,400	$ 0.36625
	145	$ 4,690.83	50	10,000	$ 0.46908
Bombardier	Dash8 Q400	$ 3,434.16	78	15,600	$ 0.22014
	200	$ 3,041.28	50	10,000	$ 0.30413
	700	$ 3,802.91	78	15,600	$ 0.24378
	900	$ 3,929.08	90	18,000	$ 0.21828
Boeing	MD-88	$ 7,626.09	172	34,400	$ 0.22169
	737-700	$ 5,776.69	149	29,800	$ 0.19385
Airbus	318	$ 5,450.50	132	26,400	$ 0.20646
	319	$ 5,758.02	156	31,200	$ 0.18455
	320	$ 6,279.20	180	36,000	$ 0.17442

In the same two hundred nautical mile segment, the standard deviation of the cost per available seat mile column for the 2013 time period is 8.6 cents while the same value for the year 2000 is 14.2 cents. This is to say that the values are closer together in the latter time period than the former for this segment showing a diminishing difference in operating cost between the time periods. The means were very close together in this segment showing a value of 24.6 and 24.7 cents per available seat mile for the 2013 and 2000 time periods respectively.

During the 2000 time period, the average regional jet cost $.24 per available seat mile more than a turbo-prop. In the 2013 time period, the average regional jet cost just $.12 more than a turboprop per available seat mile. Though it must be noted that the 2000 value was using costs that accounted for inflation, the average difference in cost per available seat mile between operating a regional jet and a turbo prop seems to be diminishing.

The same comparison can be made between the regional jet and the comparable mainline jets. During the 2000 time period, the average regional jet was $.23 more expensive per available seat mile than the average mainline jet. In 2013, the value changed to only $0.13 more expensive to operate a regional jet than a mainline, again accounting for inflation.

Table 3-4 Mainline vs. Turboprop vs. Regional Jet 200 NM CASM Comparison 2000

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	$ 1,846.95	50	10,000	$ 0.18469
	72-500	$ 2,227.84	74	14,800	$ 0.15053
Embraer	135	$ 2,496.61	37	7,400	$ 0.33738
	145	$ 6,169.06	50	10,000	$ 0.61691
Bombardier	Dash8 Q400	$ 2,958.05	78	15,600	$ 0.18962
	200	$ 2,801.54	50	10,000	$ 0.28015
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	$ 7,024.94	172	34,400	$ 0.20421
	737-700	$ 5,321.33	149	29,800	$ 0.17857
Airbus	318	-	-	-	-
	319	$ 5,304.13	156	31,200	$ 0.17000
	320	$ 5,784.22	180	36,000	$ 0.16067

Six hundred nautical mile segment.

Notice that in *Table 3-5*, the trip times for each of the aircraft start to show some separation in the six hundred mile segment. The times in the two-hundred nautical mile segment showed a standard deviation of 2.56 minutes for the range while the trip times during the six hundred nautical mile segment jumped to 11 minutes between each aircraft. This shows that as the trip segments are getting larger, the performance capabilities of the jet begin to present themselves.

Table 3-5 Mainline vs. Turboprop vs. Regional Jet 600 NM Trip Comparison (Current Jet-A)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	300	149	1,661	$ 4,124.19
	72-500	276	157	1,968	$ 5,155.48
Embraer	135	447	122	2,469	$ 5,033.85
	145	470	120	4,305	$ 8,576.70
Bombardier	Dash8 Q400	360	133	2,752	$ 6,116.24
	200	424	125	2,749	$ 5,744.78
	700	447	122	3,465	$ 7,063.29
	900	447	122	3,580	$ 7,297.61
Boeing	MD-88	420	131	6,392	$ 13,949.95
	737-700	454	126	4,894	$ 10,313.81
Airbus	318	447	127	4,608	$ 9,778.03
	319	447	127	4,868	$ 10,329.72
	320	447	127	5,309	$ 11,264.69

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

Table 3-6 Mainline vs. Turboprop vs. Regional Jet 600 NM Trip Comparison (Average Jet-A 2000)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	300	149	1,150	$ 2,855.10
	72-500	276	157	1,362	$ 3,569.04
Embraer	135	447	122	1,730	$ 3,525.74
	145	470	120	4,304	$ 8,576.29
Bombardier	Dash8 Q400	360	133	1,905	$ 4,234.16
	200	424	125	1,926	$ 4,023.69
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	420	131	4,477	$ 9,770.65
	737-700	454	126	3,428	$ 7,223.88
Airbus	318	-	-	-	-
	319	447	127	3,410	$ 7,235.02
	320	447	127	3,718	$ 7,889.88

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

In the six hundred nautical mile segment, the standard deviation of the cost per available seat mile column for the 2013 time period is 5.3 cents while the same value for the year 2000 changes to 8.7 cents. As was shown in the two hundred mile segment, the values are still getting closer together meaning that the difference in operational cost seems to be diminishing between the two time periods.

The means were very close together in this segment showing a value of 15.1 and 15.6 cents per available seat mile for the 2013 and 2000 time periods respectively.

Although the fuel cost has risen considerably over the past decade, it seems that the costs associated with operating these aircraft on a seat mile basis have changed very little.

During the 2000 time period, the average regional jet cost 13.9 cents per available seat mile more than a turbo-prop. In the 2013 time period, the average regional jet cost just 7 cents more than a turboprop per available seat mile. Comparing this difference with the values found in the two-hundred nautical mile segment, it is seen that the difference in cost per available seat mile is between operating a regional jet versus a turbo prop is still around double as much between the two time periods.

Table 3-7 Mainline vs. Turboprop vs. Regional Jet 600 NM CASM Comparison 2013

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	$ 4,124.19	50	30,000.00	$ 0.13747
	72-500	$ 5,155.48	74	44,400.00	$ 0.11611
Embraer	135	$ 5,033.85	37	22,200.00	$ 0.22675
	145	$ 8,576.70	50	30,000.00	$ 0.28589
Bombardier	Dash8 Q400	$ 6,116.24	78	46,800.00	$ 0.13069
	200	$ 5,744.78	50	30,000.00	$ 0.19149
	700	$ 7,063.29	78	46,800.00	$ 0.15092
	900	$ 7,297.61	90	54,000.00	$ 0.13514
Boeing	MD-88	$ 13,949.95	172	103,200.00	$ 0.13517
	737-700	$ 10,313.81	149	89,400.00	$ 0.11537
Airbus	318	$ 9,778.03	132	79,200.00	$ 0.12346
	319	$ 10,329.72	156	93,600.00	$ 0.11036
	320	$ 11,264.69	180	108,000.00	$ 0.10430

The same comparison can be made between the regional jet and the comparable mainline jets. During the 2000 time period, the average regional jet was 14.3 cents more expensive per available seat mile than the average mainline jet. In 2013, the value changed to only 8 cents more expensive to operate a regional jet than a mainline, again accounting for inflation. While in the two-hundred mile segment the difference between the two time periods was 10 cents, the six hundred nautical mile segment shows that the regional jet becomes marginally more competitive.

Table 3-8 Mainline vs. Turboprop vs. Regional Jet 600 NM CASM Comparison 2000

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	$ 3,805.84	50	30,000.00	$ 0.12686
	72-500	$ 4,757.53	74	44,400.00	$ 0.10715
Embraer	135	$ 4,699.82	37	22,200.00	$ 0.21170
	145	$ 11,432.20	50	30,000.00	$ 0.38107
Bombardier	Dash8 Q400	$ 5,644.13	78	46,800.00	$ 0.12060
	200	$ 5,363.58	50	30,000.00	$ 0.17879
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	$ 13,024.28	172	103,200.00	$ 0.12620
	737-700	$ 9,629.43	149	89,400.00	$ 0.10771
Airbus	318	-	-	-	-
	319	$ 9,644.28	156	93,600.00	$ 0.10304
	320	$ 10,517.21	180	108,000.00	$ 0.09738

One thousand nautical mile segment.

Table 3-9 and Table 3-10 start to show even more separation in standard deviation of the trip times for the one thousand mile segment. The times in the one thousand nautical mile segment show a standard deviation of just 7.73 minutes which is actually a drop in a comparison from both the two hundred and six hundred mile segments. Most of this difference can be attributed to the fact that two of the three turboprops were dropped from this segment of the comparison for lack of sufficient range.

The turboprop still involved, the Dash 8 Q400, is starting to show that it has lost its competitiveness during this segment averaging between twenty and twenty five minutes longer per trip than a regional jet. One of the regional jets, the CRJ-200, is also showing that it is not competitive time-wise on the longer segments falling behind the Boeing 737 and only marginally ahead of the three Airbus aircraft.

Table 3-9 Mainline vs. Turboprop vs. Regional Jet 1000 NM Trip Comparison (Current Jet-A)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	447	176	2,439	$ 7,154.22
	145	470	171	4,252	$ 12,089.24
Bombardier	Dash8 Q400	360	200	2,687	$ 8,957.41
	200	424	182	2,715	$ 8,235.52
	700	447	176	3,422	$ 10,038.50
	900	447	176	3,536	$ 10,371.53
Boeing	MD-88	420	188	6,313	$ 19,790.42
	737-700	454	179	4,834	$ 14,445.52
Airbus	318	447	181	4,551	$ 13,730.26
	319	447	181	4,808	$ 14,504.94
	320	447	181	5,243	$ 15,817.83

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

Table 3-10 Mainline vs. Turboprop vs. Regional Jet 1000 NM Trip Comparison (Average Jet-A 2000)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Costs Per Hour	Total Cost
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	447	176	1,721	$ 5,049.29
	145	470	171	4,284	$ 12,181.36
Bombardier	Dash8 Q400	360	200	1,888	$ 6,292.65
	200	424	182	1,916	$ 5,812.45
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	420	188	4,456	$ 13,967.65
	737-700	454	179	3,412	$ 10,195.33
Airbus	318	-	-	-	-
	319	447	181	3,394	$ 10,237.27
	320	447	181	3,701	$ 11,163.88

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

In the one thousand nautical mile segment, the standard deviation of the cost per available seat mile column for the 2013 time period is 4.8 cents while the same value for the year 2000 changes to 8.15 cents. As was shown in the two and six hundred mile segments, the values are still getting closer together meaning that the difference in operational cost seems to be diminishing between the two time periods for the one thousand mile segment.

The means were also close together in this segment showing a value of 13.2 and 14.2 cents per available seat mile for the 2013 and 2000 time periods respectively. Overall, it seems that operating an aircraft back in 2000 was marginally more expensive than today when accounting for inflation.

During the 2000 time period, the average regional jet cost 11.3 cents per available seat mile more than a turbo-prop. In the 2013 time period, the average regional jet cost just 5.4 cents more than a turboprop per available seat mile. Comparing this difference with the values found in the two and six-hundred nautical mile segments, the one-thousand mile segment still is showing a difference in cost per available seat mile between operating a regional jet versus a turbo prop of around double.

Table 3-11 Mainline vs. Turboprop vs. Regional Jet 1000 NM CASM Comparison 2013

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	$ 7,154.22	37	37,000.00	$ 0.19336
	145	$ 12,089.24	50	50,000.00	$ 0.24178
Bombardier	Dash8 Q400	$ 8,957.41	78	78,000.00	$ 0.11484
	200	$ 8,235.52	50	50,000.00	$ 0.16471
	700	$ 10,038.50	78	78,000.00	$ 0.12870
	900	$ 10,371.53	90	90,000.00	$ 0.11524
Boeing	MD-88	$ 19,790.42	172	172,000.00	$ 0.11506
	737-700	$ 14,445.52	149	149,000.00	$ 0.09695
Airbus	318	$ 13,730.26	132	132,000.00	$ 0.10402
	319	$ 14,504.94	156	156,000.00	$ 0.09298
	320	$ 15,817.83	180	180,000.00	$ 0.08788

The same comparison can be made between the regional jet and the comparable mainline jets. During the 2000 time period, the average regional jet was 12.8cents more expensive per available seat mile than the average mainline jet. In 2013, the value changed to only 6.9 cents more expensive to operate a regional jet than a mainline, again accounting for inflation. Compared to the two and six hundred mile segments, the one thousand nautical mile segment shows that the regional jet still maintains its competitiveness with mainline jets when comparing the two time periods.

Table 3-12 Mainline vs. Turboprop vs. Regional Jet 1000 NM CASM Comparison 2000

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	$ 6,730.70	37	37,000.00	$ 0.18191
	145	$ 16,237.75	50	50,000.00	$ 0.32476
Bombardier	Dash8 Q400	$ 8,388.10	78	78,000.00	$ 0.10754
	200	$ 7,748.00	50	50,000.00	$ 0.15496
	700	-	-	-	-
	900	--	-	-	-
Boeing	MD-88	$ 18,618.87	172	172,000.00	$ 0.10825
	737-700	$ 13,590.38	149	149,000.00	$ 0.09121
Airbus	318	-	-	-	-
	319	$ 13,646.28	156	156,000.00	$ 0.08748
	320	$ 14,881.45	180	180,000.00	$ 0.08267

Fourteen hundred nautical mile segment.

Table 3-13 and Table 3-14 show that the trip times separate even more. The times in the fourteen-hundred nautical mile segment show a standard deviation of 12.34 minutes. The Q400 completes this segment an average of 39 minutes longer than the regional jets showing that even the jet like speed that the Q400 advertises still doesn't make it competitive in on this segment. The regional jets average a 9 minute advantage over the mainline jets during the segment attributed mostly to the quicker turnaround times.

It must be noted that regional jet compilation did drop the CRJ-200, which features a lower cruise speed, from the comparison for lack of sufficient range. Without this aircraft, the regional jets enjoy the average 9 minute block time advantage over the mainline jets because of the lower cruising speed of the CRJ-200. One question that has yet to be answered is the capacity comparison on each of these segments influenced by the each of the aircrafts trip time.

Table 3-13 Mainline vs. Turboprop vs. Regional Jet 1400 NM Trip Comparison (Current Jet-A)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Fuel Cost Per Seat	Total Cost
ATR	42-500	-	-	-	
	72-500	-	-	-	
Embraer	135	447	230	2,408	$ 9,220.06
	145	470	222	4,198	$ 15,511.39
Bombardier	Dash8 Q400	360	267	2,687	$ 11,943.21
	200	-	-	-	-
	700	447	230	3,379	$ 12,937.21
	900	447	230	3,492	$ 13,366.41
Boeing	MD-88	420	245	6,234	$ 25,480.67
	737-700	454	232	4,774	$ 18,470.82
Airbus	318	447	235	4,495	$ 17,580.73
	319	447	235	4,748	$ 18,572.67
	320	447	235	5,178	$ 20,253.73

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

Table 3-14 Mainline vs. Turboprop vs. Regional Jet 1400 NM Trip Comparison (Average Jet-A 2000)

Manufacturer	Model	Crusing Speed (Knots)	Trip Time	Fuel Cost Per Seat	Total Cost
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	447	230	1,713	$ 6,558.10
	145	470	222	4,263	$ 15,751.54
Bombardier	Dash8 Q400	360	267	1,888	$ 8,390.20
	200	-	-	-	-
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	420	245	4,434	$ 18,124.04
	737-700	454	232	3,395	$ 13,138.03
Airbus	318	-	-	-	-
	319	447	235	3,377	$ 13,210.47
	320	447	235	3,683	$ 14,406.19

(Airbus, 2013; Boeing, 2013; CRJ, 2012; Q400, 2012; E135, 2012; E145, 2012; & ATR 500 Series, 2011; ACE, 2012)

In the fourteen-hundred nautical mile segment, the standard deviation of the cost per available seat mile column for the 2013 time period is 4.5 cents while the same value for the year 2000 changes to 8.1 cents. Contrary to the trend shown in previous segments, the values between the two time periods are getting further apart. This can be attributed to the fuel costs giving a greater advantage to some of the more efficient aircraft used in the comparison.

The means were very close together in this segment showing a value of 11.9 and 13 cents per available seat mile for the 2013 and 2000 time periods respectively. In this segment the average cost per available mile comparison of the two periods shows some separation which is an indication that the costs associated with this segment are in fact marginally less expensive when accounting for inflation that the values given by the year 2000.

During the 2000 time period, the average region jet cost 13.2 cents per available seat mile more than a turbo-prop. In the 2013 time period, the average regional jet cost just 4.6 cents more than a turboprop per available seat mile. Comparing this difference with the values found in the previous segments, it is seen that the difference regional jet has an even greater advantage over the turboprop in this segment.

Table 3-15 Mainline vs. Turboprop vs. Regional Jet 1400 NM CASM Comparison 2013

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	$ 9,220.06	37	51,800.00	$ 0.17799
	145	$ 15,511.39	50	70,000.00	$ 0.22159
Bombardier	Dash8 Q400	$ 11,943.21	78	109,200.00	$ 0.10937
	200	-	-	-	-
	700	$ 12,937.21	78	109,200.00	$ 0.11847
	900	$ 13,366.41	90	126,000.00	$ 0.10608
Boeing	MD-88	$ 25,480.67	172	240,800.00	$ 0.10582
	737-700	$ 18,470.82	149	208,600.00	$ 0.08855
Airbus	318	$ 17,580.73	132	184,800.00	$ 0.09513
	319	$ 18,572.67	156	218,400.00	$ 0.08504
	320	$ 20,253.73	180	252,000.00	$ 0.08037

When making a comparison between the regional jet and the comparable mainline jets during the year 2000, the average regional jet was 14.9 cents more expensive per available seat mile than the average mainline jet. In 2013, the value changed to only 6.5

cents more expensive to operate a regional jet than a mainline accounting for inflation. In the fourteen-hundred nautical mile segment, the regional jet seems to be more competitive in the 2013 time period when accounting for location showing that the cost per available seat mile is half as much as the same value in 2000.

Table 3-16 Mainline vs. Turboprop vs. Regional Jet 1400 NM CASM Comparison 2000

Manufacturer	Model	Total Cost	Seats Filled	Seat-Miles	CASM
ATR	42-500	-	-	-	-
	72-500	-	-	-	-
Embraer	135	$ 8,741.95	37	51,800.00	$ 0.16876
	145	$ 20,996.81	50	70,000.00	$ 0.29995
Bombardier	Dash8 Q400	$ 11,184.13	78	109,200.00	$ 0.10242
	200	-	-	-	-
	700	-	-	-	-
	900	-	-	-	-
Boeing	MD-88	$ 24,159.34	172	240,800.00	$ 0.10033
	737-700	$ 17,512.99	149	208,600.00	$ 0.08395
Airbus	318	-	-	-	-
	319	$ 17,609.56	156	218,400.00	$ 0.08063
	320	$ 19,203.45	180	252,000.00	$ 0.07620

CASM Comparison

The data was analyzed again by doing a two-tailed t-test to determine if the costs per available seat-mile calculated in 2013 are significantly greater, while accounting for inflation, than the same value in the year 2000. The hypothesis, shown in *Figure 3*-1, was that there is no significant difference in operational cost, while accounting for inflation, between the two years specified.

H0:	$\mu13- \mu00 = 0$
H1:	$\mu13 - \mu0 \neq 0$

Figure 3-1 Hypothesis and Alternate Hypothesis for CASM COMPARISON

The alternate hypothesis was that the costs associated with the aircraft operations would be significantly different between the two years used to compare the data. The critical value, alpha, was set at ten percent. These analyses were done for each route segment and then one was completed for the averages of the costs per available seat mile for the overall data set.

Table 3-17 shows the number of values, mean, standard deviation, and computed t-values for each of the individual segments and also the data set overall. The number of values varied between the two time periods and from segment to segment making this a t-test with unequal variance. This is due to certain aircraft not being released yet in the year 2000 and other aircraft lacking sufficient range in the longer trip segments. The significance of the t-test was set to ninety percent based on the assumption that this data does not actually come from an actual historical flight test dataset.

Table 3-17 Two Tailed CASM T-Test

Segment	Year	N	Mean	STD Dev	Significance	T-Value
200nm	2000	10	$ 0.247	$ 0.142	90%	-0.0365329
	2013	13	$ 0.246	$ 0.08607		
600nm	2000	10	$ 0.156	$ 0.087	90%	-0.1719640
	2013	13	$ 0.151	$ 0.05303		
1000nm	2000	8	$ 0.142	$ 0.082	90%	-0.3367941
	2013	11	$ 0.132	$ 0.04821		
1400nm	2000	7	$ 0.130	$ 0.081	90%	-0.3744414
	2013	10	$ 0.119	$ 0.04544		
Overall	2000	8.75	$ 0.169	$ 0.098	90%	-0.204629067
	2012	11.75	$ 0.162	$ 0.05819		

Table 3-18 shows the actual t-test data to suggest whether the null hypothesis was either rejected by the data or the data failed to reject the null hypothesis. In the two hundred nautical mile segment, the table suggests that the data was unable to reject the null hypothesis. This means that for the two hundred nautical mile segment, the costs per available seat mile did not show significant difference when accounting for the inflation between the two time periods of thirty-three percent meaning that the null hypothesis holds up during this segment

For the six hundred, one thousand, and fourteen hundred nautical mile segments the null hypothesis was disproven by the data sets. This means that the alternate hypothesis was proven to be true showing that between the two time periods there was a significant decrease in the cost per available seat mile when accounting for inflation.

The overall data set was also used to do a t-test and it was found that there was a significant decrease in the costs per available seat mile regardless of the segment length. This was surprising to the researcher because of the rationale that the enormous rise in fuel cost over the past decade would actually cause the data to show that the costs, even accounting for inflation, would be significantly greater when comparing the two time periods. Even the two-hundred nautical mile segment, although not statistically significant, showed a decrease over the period when accounting for inflation.

Table 3-18 Two Tailed CASM T Distribution

Segment	Year	DF	UPPER	LOWER	T-Value	Null Hyp?
200nm	2000	9	0.12719007	-0.12719007	-0.0365329	FAILTOREJECT
	2013	12				
600nm	2000	9	0.12719007	-0.12719007	-0.1719640	REJECT
	2013	12				
1000nm	2000	7	0.127552234	-0.127552234	-0.3367941	REJECT
	2013	10				
1400nm	2000	6	0.127806258	-0.127806258	-0.3744414	REJECT
	2013	9				
Overall	2000	31	0.126093348	-0.126093348	-0.2046291	REJECT
	2013	43				

Research Question Two

It is believed by this researcher that another one of the reasons that the regional jet is chosen over the turboprop on many route segment lies not in the operational costs of running the aircraft, but the possibility of increasing capacity through using this aircraft with a much higher cruising speed in order to increase the amount of segments operated in a single flight day.

The comparison was divided into two parts; regional aircraft with fifty seats or less and regional aircraft with greater than fifty seats. For the shorter segments, the t-tests compared the turboprop versus regional jet in general because there are relatively the same number of aircraft in each of the aforementioned groups in each of the categories of regional jet and turboprop. For the two longer segments this same comparison was made between the regional jets and comparable mainline jets.

In order to test whether this change in capacity is significant, a two-tailed t test was used on the data comparing concerning the turboprops, and regional jets compared. The null hypothesis*, Figure 3-2,* in this test was that there is no significant change in capacity and the alternative hypothesis was that there is a significant change in capacity between the regional jet and turboprop. Figure 3-3 shows the null and alternate hypothesis for the comparison of the regional and mainline jets. The critical values for either comparison were set at ten percent.

H0:	$\mu RJ - \mu TP = 0$
H1:	$\mu RJ - \mu TP \neq 0$

Figure 3-2 Hypothesis and Alternate Hypothesis for RJ and TP Comparison

H0:	$\mu RJ - \mu MJ = 0$
H1:	$\mu RJ - \mu MJ \neq 0$

Figure 3-3 Hypothesis and Alternate Hypothesis for RJ and MJ Comparison

Two hundred nautical mile segment.

Table 3-19 shows the computed flight time for each individual aircraft using the function described earlier paired with the average turnaround times determined by whether the aircraft is considered a regional. From there, the times are combined and used to determine the amount of flights that can be completed on the two hundred nautical mile segment in one flight day.

The flight day, detailed earlier, is defined as the hours between 0600 and 2300 Eastern Standard Time. This total time of seventeen hours was converted to one thousand and twenty minutes to be used more effectively in the comparison. The segments per-flight-day column shows the number of legs that are possible within this segment for the number of minutes available. Some limitations of this method include the inability to accurately depict the effect of crew rest periods, air traffic and weather delays, connecting crew mismatch times, and other factors that routinely affect airlines on-time performance.

Table 3-19 Turboprop vs. Regional Jet: 200nm FLIGHT DAY SEGMENT COMPLETION ANALYSIS

MANUFACURER	MODEL	TIME PER SEGMENT	TURN TIME	SEGMENTS PER FLIGHT DAY	CAPACITY
ATR	42-500	69	25	10	500
	72-500	70	25	10	740
Embraer	135	64	25	11	407
	145	64	25	11	550
Bombardier	Dash8 Q400	67	25	11	858
	200	65	25	11	550
	700	64	25	11	858
	900	64	25	11	990

In the two hundred nautical mile segment, the regional aircraft with fifty or fewer seats had an average capacity of 501.75 available seats on the segment. The standard deviation between these aircraft was 67.4 seats. The regional jets showed an average capacity of 2.33 seats more than the turboprops with fifty or fewer seats.

Comparing the regional aircraft with greater than fifty seats, the mean showed an average capacity of 862 available seats over the course of the flight day. The standard deviation for this group was 102 seats. The regional jets showed an average capacity of 125 seats more than the turboprops with greater than fifty seats.

Six hundred nautical mile segment.

The six hundred nautical mile segment, Table 3-20, shows an average of 281 available seats for the segment and a standard deviation of 56 seats for the aircraft with fifty seats or less. The regional jets showed an average capacity of 40.67 seats more than the turboprops with fifty or fewer seats.

For the aircraft with greater than fifty seats, the average number of available seats for the segment came out to be 462 seats with a standard deviation of 70 seats. The regional jets showed an average capacity of 85 seats more than the turboprops with greater than fifty seats.

Table 3-20 Turboprop vs. Regional Jet: 600nm FLIGHT DAY SEGMENT COMPLETION ANALYSIS

MANUFACTURER	MODEL	TIME PER SEGMENT	TURN TIME	SEGMENTS PER FLIGHT DAY	CAPACITY
ATR	42-500	149	25	5	250
	72-500	157	25	5	370
Embraer	135	122	25	6	222
	145	120	25	7	350
Bombardier	Dash8 Q400	133	25	6	468
	200	125	25	6	300
	700	122	25	6	468
	900	122	25	6	540

One thousand nautical mile segment.

Because regional jets are only primarily in competition with turboprops in the shorter segment markets, the next two segments will feature a comparison of the regional jet's market capacity versus that of the comparable mainline jets. The one thousand nautical mile segment, Table 3-21, shows an average of 295 available seats for the segment and a standard deviation of 119 seats for the regional aircraft. For the mainline aircraft, the average number of available seats for the segment came out to be 631 seats with a standard deviation of 76 seats. The regional jets showed an average capacity of 336 seats less than comparable mainline aircraft on this segment.

Table 3-21 Mainline vs. Regional Jet: 1000nm FLIGHT DAY SEGMENT COMPLETION ANALYSIS

MANUFACTURER	MODEL	TIME PER SEGMENT	TURN TIME	SEGMENTS PER FLIGHT DAY	CAPACITY
Embraer	135	176	25	5	185
	145	171	25	5	250
Bombardier	200	182	25	4	200
	700	176	25	5	390
	900	176	25	5	450
Boeing	MD-88	188	35	4	688
	737-700	179	35	4	596
Airbus	318	181	35	4	528
	319	181	35	4	624
	320	181	35	4	720

Fourteen hundred nautical mile segment.

Because CRJ 200 regional jet featured inadequate range to compete on this segment, it was dropped from the regional jet side of this comparison. The fourteen hundred nautical mile segment, Table 3-22, shows an average of 255 available seats for the segment and a standard deviation of 98 seats for the regional aircraft. For the mainline aircraft, the average number of available seats for the segment came out to be 473 seats with a standard deviation of 57 seats.

The regional jets showed an average capacity of 218 seats less than comparable mainline aircraft on this segment. This difference is even smaller primarily because of the shorter turnaround times of the regional jet that allow it to make one more trip on this segment in the flight day.

Table 3-22 Mainline vs. Regional Jet: 1400nm FLIGHT DAY SEGMENT COMPLETION ANALYSIS

Manufacturer	Model	TIME PER SEGMENT	TURN TIME	SEGMENTS PER FLIGHT DAY	CAPACITY
Embraer	135	230	25	4	148
	145	222	25	4	200
Bombardier	200	-	-	-	-
	700	230	25	4	312
	900	230	25	4	360
Boeing	MD-88	245	35	3	516
	737-700	232	35	3	447
Airbus	318	235	35	3	396
	319	235	35	3	468
	320	235	35	3	540

T-Test

Table 3-23 shows the tabulated values for each of the segment including the number of aircraft used in comparison for each segment, the means, standard deviations, and the calculated t-values. Just as in the previous t-test, the significance was set at ninety percent. The reason for this uncertainty lies in the inability to adequately account for the common operational delays that affect airlines every day.

Notice that the t-values in the two shorter segments are much smaller than the values given by the two longer segments. The reason for this is comes from the fact that in terms of airframe size and seating capacity regional jets are much more comparable to turboprops than mainline jets. This comparison is aimed at comparing the options that airlines have when selecting an aircraft category to fulfill a market segment. The large t-values presented by the longer segments suggest that maximum available capacity is likely not a major factor when deciding to use a regional versus mainline jet.

Table 3-23 Two Tailed Capacity T-Test

Segment	Year	N	Mean	STD Dev	Significance	T-Value
200nm	Regional Jet	5	671	242.75	90%	-0.1876150
	TurboProp	3	699	102.14		
600nm	Regional Jet	5	376	127.99	90%	-0.1495951
	TurboProp	3	363	109.18		
1000nm	Regional Jet	5	295	118.53	90%	5.3407887
	Mainline Jet	5	631	75.92		
1400nm	Regional Jet	4	255	97.89	90%	4.2174334
	Mainline Jet	5	473	56.94		

As shown in Table 3-24, each of the segments revealed a t-value that was outside of the upper and lower limits of the t distribution. This has resulted in a rejection of the null hypothesis and subsequent acceptance of the alternate hypothesis within each of the route segments.

Within the two shorter route segments, it was found that there was significant difference in the maximum available capacity presented between regional jets versus turboprops. Within this comparison this significant increase in capacity can be attributed to the substantially greater cruising speed of the regional jet versus the turboprop because each group has generally the same average seating capacity.

Within the two longer route segments, it was found that there was also significant difference in the maximum available capacity of the regional and mainline jets. There are more factors that affect this comparison than the previous. The regional jets generally have a much smaller seating capacity than the mainline jets, have generally the same cruising speeds, but generally can be turned quicker than mainline jets. Unfortunately, this shorter turnaround times was not able to overcome the large difference in seating capacity in the mainline jets.

Table 3-24 Two Tailed Capacity T Distribution

Segment	Year	DF	UPPER	LOWER	T-Value	Null Hyp?
200nm	Regional Jet	4	0.131075653	-0.131075653	-0.1876150	REJECT
	Turboprop	2				
600nm	Regional Jet	4	0.131075653	-0.131075653	-0.1495951	REJECT
	Turboprop	2				
1000nm	Regional Jet	4	0.129707272	-0.129707272	5.3407887	REJECT
	Mainline Jet	4				
1400nm	Regional Jet	3	0.130292797	-0.130292797	4.2174334	REJECT
	Mainline Jet	4				

Chapter IV – Discussion

Overall this research project sought to explore two of the factors that have surrounded the regional jet for almost the entirety of its existence. The first was to test the effect of the rise in fuel costs over the past decade on the costs associated with the operation of various types of aircraft. These aircraft included some of the more prevalent turboprops, regional jets, and market-comparable mainline aircraft that are often chosen on the lesser density short and medium haul markets.

The second question was to explore one of the reasons that the regional jet came into existence in the first place; its effect on market capacity. Throughout the preliminary literature review that was done on this project, the reason that regional jets became so popular was put into two basic categories: The replacement of turboprop service on shorter segments and the replacement or supplement to mainline service on thin medium haul routes.

Question One

In an attempt to answer the first question a study was done on the cost differential between various types of aircraft between two time periods. The time periods chosen were the year 2000 and present day. The year 2000 was chosen because it was a time period when fuel prices were still low and the large effects of the September 11th attacks had not yet been presented to the airline industry. The cost differential between the two time periods was based primarily on fuel costs because of the overwhelming claim that fuel costs are the primary reason for the regional jet's potential demise.

It was decided that the fuel costs used in the comparison needed to be converted to present day dollars for a comparison that was fairer to the issue. Almost any person that looks at the issue at face value can determine that costs have indeed dramatically risen over the past decade and in fact have made the operation of regional jets and aircraft in general substantially more expensive.

The researcher considered one of the problems with the future operation of regional jets to be the notion that the substantial rise in operational costs presented by the rise in fuel costs has caused the regional jet to become unaffordable to operate by many of the airlines that have operated it since its introduction. The researcher then thought that other factors have played a part in this issue over the past decade, the primary one being the rapid rise in inflation caused by the two economic crises that have taken place. Could this rise in inflation cancel out some of the cost differential experienced by the aviation industry over the past decade?

The hypothesis of the researcher was that when the costs from the year 2000 were adjusted to present day dollars by accounting for inflation there would be no substantial difference when comparing them to the costs presented in present day. The alternate hypothesis was, of course, that the effect of inflation would not be great enough to balance out the rise in fuel prices over the same period.

A compilation of operational cost data was performed for the two time periods by the utilization of a an *Aircraft Cost Evaluation* tool offered by the Conklin and de Decker group for several segment lengths thought to be to be typical for the aircraft being compared. Comparing operational costs across such a wide variety of aircraft such as the ones being discussed was thought to only be possible when comparing them on a per unit scale. This per unit scale was the individual aircraft's cost per available seat mile.

After this aircraft data was compiled it was analyzed through a two tailed t-test to determine if the present day costs differ substantially from the adjusted costs from the year 2000. This was done at each segment level and also done on the data set overall. With the exception of the shortest, 200nm, segment, every other segment resulted in a t value outside of the critical t value range showing that for those segments the null hypothesis was proven false. This means that the present day costs per available seat mile differ significantly from the adjusted costs from the year 2000.

The twist, however, was that in all of the individual segments, as well as the data set overall, the present day costs per available seat mile were actually found to be lower than the adjusted costs from the year 2000. This result was surprising to find because before the completion of this project it was believed by the researcher that the enormous rise in fuel cost over the past decade had caused the costs associated with operating these aircraft to actually rise in relation to the costs in the previous time period.

This question concludes with producing the notion that rising operational costs must not be the primary reason for the discussion about removing these aircraft from service. One consideration that must be mentioned is that the data for the present day costs per available seat mile included several aircraft not present in the data set for the year 2000. Several of these aircraft possess several technological advances that may have helped to push the average cost per available seat mile down.

This is not a bad thing though, as it shows that the technological advancements in the industry are in fact helping to drive operational costs down in the industry as a whole.

The reason for the potential demise of the regional jet must lie within another factor not discussed in depth within this research. One possibility that could be explored within further research is the effect of labor unions, specifically pilot unions, on the long-term outlook of regional jets and regional aircraft in general.

Question Two

The second question was to explore the effect that regional jets have had on the ability of airlines to increase market capacity on a variety of routes previously served by other aircraft or, in some cases, not at all. The comparison was divided into two parts; the shorter segments featuring competition between regional jets and turboprop aircraft and the longer segments featuring competition between regional jets and market-comparable mainline aircraft.

This question was examined through the compilation of data showing each aircrafts capabilities as they relate to maximum capacity with several market segments. The market capacity for each of the segments was calculated for each of the individual aircraft. The calculations used a function of the aircraft's maximum seating capacity and the number of trips that each aircraft was capable of performing on each segment within a single flight day.

After the data was compiled for each of the segments it was then analyzed through a two-tailed t-test to determine if there was a significant difference in market capacity offered by the regional jet in comparison to its competition within each market segment. It was the hypothesis of the researcher that the t-test would reveal that there was no significant difference in market capacity when comparing the regional jet in each of the market segments.

After the data was analyzed, it was determined that the null hypothesis was rejected in each of the route segments. When comparing the regional jet and the turboprop within the shorter segments, it was found that the regional jet did in fact present a significant difference in market capacity often offering at least one more trip per flight day on the individual segments. The primary reason for this was due to the regional jets significantly greater cruising speed. The only turboprop aircraft that was found to be comparable was Bombardier's Dash 8 Q400 series aircraft which features a substantially higher cruising speed than the other turboprop aircraft compared although not as high as that of a regional jet.

When analyzing the data from the longer segments it was found that the regional jet did offer significantly lower market capacity than the mainline jet. Although the regional jet offers a substantially lower seating capacity than most mainline jets, it was the researcher's opinion that shorter turnaround times would help make the regional jet more competitive on the medium haul markets. Although the shorter turnaround times offered by the regional jet did result in an average on one more trip on each of the segments it was unfortunately not substantial enough to overcome the large difference in maximum seating capacity offered by the regional jet.

This is not a total loss for the regional jet however. One of the primary reasons that the regional jet is chosen to operate on some medium haul routes is the inability of airlines to fill an adequate number of seats on the comparable mainline aircraft. Further research could include an analysis of the regional jet's market capacity versus that of the mainline jet in the average number of filled versus empty seats presented by an individual market within an airline's route network.

Limitations

The conclusions and recommendations made in this section of the paper were made only through the analysis of the factors examined by the researcher. One possible limitation to the study is that there could be factors that are currently outside of the realm of the researcher's knowledge, or possibly that of the public in general. Specifically, there could be other factors for the phasing out of the regional jet that are neither operational in nature nor influenced by the ongoing contract negotiations between the pilots unions and their respective carriers.

Another limitation of the study was be the inability of the researcher to completely isolate the independent variables used in this study from all known and unknown outside factors. Some of these outside factors could include market factors that have changed the volume of air traffic through many carriers' networks. Possibly the impact of the economic challenges on customer markets being made available to the airlines could have an effect on the decision to begin removing some smaller aircraft from service.

This suggestion comes from the idea that, for some markets, regional aircraft were initially introduced as a method of attracting lucrative business travelers into an airline's network from smaller and more remote locations. The decline of the regional jet could have something to do with the limiting of spending by companies on business travel instead favoring more economical means. There are a multitude of limitations to this study that cannot be reasonably avoided and therefore have influenced the research in an unknown direction.

Future Research Suggestions

Further research into why the future outlook for the regional jet looks bleak would include research into some of the other potential factors that were discussed in the problem statement part of this paper. It is the opinion of this researcher that although the outlook of regional flying in the future seems to be relatively stable, the restructuring of the capacity purchase agreements based on the changes in mainline air carrier scope clauses could potentially threaten the viability of many of the regional partners that operate smaller regional jets on behalf of them. A research study could be devised to investigate how the restructuring of these scope clauses would influence the regional airline industry.

Another possibility for further research would be the effect of the restructuring of scope clause's effect on the capacity purchase agreements that exist between mainline and regional partners. Research could be organized to include the effect of possibly using regional aircraft with differing seating capacities to affect the outlook of many regional carriers based on a cost per unit basis. Many regional airlines receive compensation based upon the number of flights completed. Some contracts go as far as to leave out conditions that are contingent upon the capacity of the regional aircraft operated. Some interesting research could be devised to look into the affect that such agreements could have on the long term outlook on the basis of cost per unit completed versus cost based on capacity.

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