The Impact of Regional Jets on Airline Networks

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Abstract

This paper examines the impact of a new technology, in the form of regional jets, on the US airline industry. Regional Jets are similar to large jets, though have a lower threshold for providing profitable service. This paper develops a theoretical framework that predicts the type of passengers that would travel on a direct flight that uses regional jets. The model predicts that passengers with high time costs (ie business travelers) would take such a flight. Data from 1997 to 2005 is also analyzed to see the trends of regional jet use on hub-spoke and point to point service in terms of new service, technology replacement, and frequency.

1 Introduction

The airline industry has seen dramatic change over the past 10 years, with the proliferation of low cost carriers offering direct service and many hub and spoke carriers reinforcing their network structures. Airplane makers have also been adapting to the change in network structures with the introduction of new technologies in the form of new plane types. Planes such as the fuel efficient Boeing 787 Dreamliner and the double decker Airbus A380 have the ability to give their operators the ability to change the nature of the business. Such products can be considered a disruptive technology, though are based on contrasting views of the industry. The Boeing 787 is designed to serve long-thin routes, routes that are long with relatively few passengers, typical of a direct flight between non-hub cities. This contrasts the Airbus A380, with a capability of carrying over 500 passengers between two points. Such volume is typically found on intra-hub flights, routes on which airlines can take advantage of economies of density by aggregating customers that want to go to different locations.

While the media has paid much attention to the 787 and A380 and their future effect on the aviation industry, a similar disruptive technology breakthrough was introduced with the debut of regional jets. Introduced in the early 1990s, regional jets are jet-engined planes designed to fly between 35 and 100 passengers. This capacity range is larger than turboprops, which are capable of carrying less than 35 passengers and smaller than traditional jets, which have a capacity of upwards of 100 passengers. Unlike smaller turboprop planes, these planes offer many of the conveniences of larger planes. Like jets[1], regional jets are able to cruse at a rate of 540 miles per hour, while turboprops cruse at 340 miles per hour. Regional jets, like their jet counter parts, allow for passengers to enplane and deplane via a jetway where as turboprops generally require passengers to climb and descend steep stairs in order to enplane and deplane. While the cabin sizes of regional jets are smaller than regular jets, they are larger than turboprops, which may lack other in-flight amenities such as a flight attendant or an on-board lavatory.

[1] Throughout this paper, jets imply planes that have a capacity of larger than 100.

Operationally, regional jets allow an airline great flexibility in offering direct service. Turboprops have lower weight restrictions thresholds than regional jets. If a flight requires more fuel due to distance or potential weather or air traffic delays, airlines will have to compensate by reducing passenger weight, and therefore leaving seats empty on a turboprop. Such weight restrictions are higher on a regional jet, so such a problem is not prevalent. Unlike larger jets, regional jets do not need as many passengers to break even due to operational fixed costs. The downside is the costs per seat mile are higher for a regional jet than a jet or turboprop.

The airline industry has been studied in various aspects in the economics literature. Among other areas, researchers have studied the efficiency of network structure in terms of point to point, or direct, networks versus hub-spoke, or indirect, network competition (Hendricks, Piccione, and Tan, 1995; Brueckner and Spiller, 1991) and frequency, an aspect of service quality (Brueckner, 2004; Brueckner and Flores-Fillol, 2006). Borenstein, 1991 and Morrison, 2004 shed some light on fares in the different network types. The impact of airport congestion, on capacity (Daniel, 1995) as well as on fares (Januszewski, 2004) has also been considered.

In the past, the literature has not explicitly considered the implications of a direct route and indirect route in the same market on passengers. In addition, little attention has been paid to airplane size or the impact of a new technology on airline networks. This paper aims to fill this gap in the literature in 2 ways. First a model is developed to determine the market outcomes when both a hub and spoke and a point to point route is present in the market between city pairs. Second, the impact of a new technology, in the form of regional jets, on new direct flights, existing technology, and frequency.

2 Model

Using the framework as proposed by Brueckner (2004), it is assumed that a monopolist airline offers two routes from city AB: direct or indirect, as shown in figure 1. An indirect route be flown by a jet and would require a traveler in A to go to city H before continuing on to B. In the direct routing, the

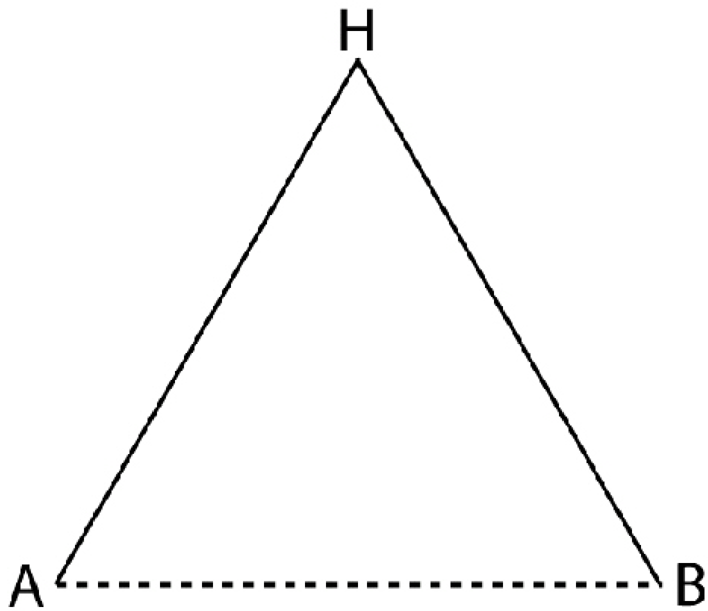


Figure 1: Network Configuration

traveler can go on a regional jet from A to B without any stops. Assuming that the passenger is indifferent between a jet and a regional jet, the utility for a traveling passenger is

$$u = c + b + \gamma/f$$

where c is consumption expenditure, b is the travel benefit, γ/f cost of schedule delay, and α cost of extra travel time on an indirect route. The consumption expenditure of all passengers is equal to $y - p$ where y is their income and p is the price of their ticket, with a resulting utility function of $y - p + b + \gamma/f - \alpha$. Assuming that the passenger will travel, the monopolist airline will extract all surplus from the traveler, until the traveler is indifferent between air travel and their next best alternative, which would provide utility $\bar{u}$. Therefore, the airline will set its price at $y + b - \bar{u} - \gamma/f - \alpha$. For simplicity, we set $w = y + b - \bar{u}$, with a resulting price equation of

$$p = w - \gamma/f - \alpha \tag{1}$$

When the benefit of air travel is sufficiently high, a passenger will choose between either a direct or indirect route, depending on their value of time. To make the model realistic, two types of passengers are considered, one with low time costs (leisure passengers), which make up a proportion of $1-\mu$ of the population, and another with high time costs (business travelers), which make up the remaining μ proportion of the population. All else being equal, since a business traveler derives greater benefit from traveler and has higher time costs than a leisure traveler, the benefit will be higher, as will their cost of schedule delay and cost of extra travel time $w_h > w_l, \gamma_h > \gamma_l$, and $\alpha_h > \alpha_l$, respectively, than for a leisure traveler. Given that the airline extracts all surplus from passengers, and therefore are indifferent between direct and indirect flights, the proportion of business travelers who travel direct is set to θ_h and indirect to $1-\theta_h$. Likewise, the proportion of leisure travelers who travel directly is set to θ_l and indirect to $1-\theta_l$. For simplicity, the number of passengers in the A to H and H to B market are each normalized to N. The quantity of passengers of each type is summarized in the following table

	AB-Direct	AB-indirect	xH[2]
Business	$\theta_h\mu$	$(1-\theta_h)\mu$	$N\mu$
Leisure	$\theta_l(1-\mu)$	$(1-\theta_l)(1-\mu)$	$N(1-\mu)$
Total	$q_d = \theta_h\mu + \theta_l(1-\mu)$	$q_c = 1-\theta_h\mu - \theta_l(1-\mu) + N$	

For further simplicity, the number of passengers that travel direct is set to q_d and the sum of indirect passengers and passengers traveling in the xH market to q_c. Indirect passengers are added into the xH market since they have to travel to and from H in order to reach their final destination. To derive the equilibrium, the cost structure must be defined. In providing indirect jet service and direct regional jet service, the airline has operational costs that are only dependent on the number of passengers[3], and so costs are characterized

[2] where x =A or B

[3] While the airline industry is characterized with fixed costs (Caves, Christensen, and Tretheway (1984)), such costs are ignored, for the purposes of this paper.

by:

$$c_d = q_d \tau_d$$

$$c_c = q_c \tau_c$$

for direct and indirect travel, respectively. Given that the costs of operating a regional jet are higher on a per seat basis than a jet, $\tau_d > \tau_c$.

The size of a regional jet is necessarily smaller than a jet, $s_d < s_c$. As in Brueckner (2004), the airline operates flights with a 100% load factor so that all seats are full. Since the quantity on a route is determined by the number of seats in the plane times the number of flights,quantity is equal to $q = sf$. By dividing the quantity of passengers on a route by the number of seats, the frequency of flights can be derived. For the direct flights, the number of passengers is simply the number of direct passengers, while for the flights to and from H and indirect and xH passengers, respectively.

$$f_{AB} = \frac{q_d}{s_d} \tag{2}$$

$$f_{xH} = \frac{q_c}{s_c} \tag{3}$$

Using equation 1, we can now derive the airline's profit function:

$$\begin{aligned} \pi \quad = \quad & (w_h - \frac{\gamma_h s_c}{q_c})N\mu + (w_l - \frac{\gamma_l s_c}{q_c})(1-\mu)N \\ & +(w_h - \frac{\gamma_h s_d}{q_d})\theta_h \mu + (w_l - \frac{\gamma_l s_d}{q_d})\theta_l(1-\mu) \\ & +(w_h - \alpha_h - \frac{\gamma_h s_c}{q_c})N(1-\theta_h)\mu + (w_l - \alpha_l - \frac{\gamma_l s_c}{q_c})(1-\theta_l)(1-\mu) \\ & -\tau_d q_c - 2\tau_c q_d \end{aligned} \tag{4}$$

With the parameters of interest being the routing of AB passengers, the profit function in equation 4 is maximized with respect to the proportion of high and low passengers on the direct flight, θ_h and θ_l. The first order conditions with respect to θ_h and θ_l are

$$\begin{aligned}
\frac{\partial \pi}{\partial \theta_h} &= \frac{s_c N}{q_c^2}\mu(\gamma_h - 2(\mu\gamma_h + (1-\mu)\gamma_l)) \\
&+ \frac{s_c}{q_c^2}\mu(1-\mu)(1-\theta_l)(\gamma_h - \gamma_l) \\
&- \frac{s_d}{q_d^2}\theta_l \mu(1-\mu)(\gamma_h - \gamma_l) \\
&+ \mu(\alpha_h + 2\tau_c - \tau_d)
\end{aligned}$$

$$\begin{aligned}
\frac{\partial \pi}{\partial \theta_l} &= \frac{s_c N}{q_c^2}\mu(\gamma_l - 2(\mu\gamma_h + (1-\mu)\gamma_l)) \\
&+ \frac{s_c}{q_c^2}\mu(1-\mu)(1-\theta_l)(\gamma_h - \gamma_l) \\
&- \frac{s_d}{q_d^2}\theta_h \mu(1-\mu)(\gamma_h - \gamma_l) \\
&+ (1-\mu)(\alpha_l + 2\tau_c - \tau_d)
\end{aligned}$$

To ensure profit maximization and to check for interior solutions, second-order conditions must be solved. The second-order condition with respect to θ_h, is positive when $\gamma_h > 2(\mu\gamma_h + (1-\mu)\gamma_l)$, which is a result when γ_h is significantly larger than γ_l. Regardless of the values of schedule delay, in a profit maximizing setting, optimally results in a corner solution for business travelers, where they all either take the direct route or indirect route. The second-order condition with respect to θ_l, is always negative. Thus, with a profit function concave in θ_l, an interior or corner solution is always possible. With this result, all business passengers will take the direct flight when the following conditions hold:

Condition 1 *Given* $\theta_h = 1$, $\theta_l = 0$

This condition holds when the following is true:

$$(\alpha_l+2\tau_c-\tau_d)+\frac{s_d}{q_d^2}\mu(1-\mu)(\gamma_h-\gamma_l)+\frac{s_cN}{q_c^2}(1-\mu)(\gamma_l-2(\mu\gamma_h+(1-\mu)\gamma_l)<0 \quad (5)$$

Condition 2 *In optimally, all business travelers are allocated to the direct route when* $\theta_l = 0$

This condition holds when the following is true:

$$\mu(\alpha_h+2\tau_c-\tau_d)-\gamma_h s_d+\frac{\mu s_s}{(N+1)(N+1-\mu)}[(1-\mu)(\gamma_h-\gamma_l)+N(\gamma_h-2(\mu\gamma_h+(1-\mu)\gamma_l)]>0 \quad (6)$$

Holding τ_c and τ_d constant, these conditions hold when s_d is small. While these two conditions appear to be contradictory, they are in-fact complimentary. In actuality, it is not necessary for all leisure passengers to travel indirectly in the airline's profit maximizing solution. Condition 1 suggests that leisure travelers will not travel direct when equation 5 holds. Likewise, condition 2 states when there are no leisure travelers on the direct route, all business travelers will travel directly if equation 6 holds. The next section presents evidence of the impact regional jets are having on network structure.

3 Empirical Analysis

3.1 Data

To analyze the trends of regional jet influence on airline networks, data from the Department of Transportations's Bureau of Transportation Statistics T100 schedule is used. The T100 is the transportation schedule of the Form 41 data that large carriers are required to submit to the DOT every quarter. Prior to the third quarter of 2002, only large scheduled carriers[4] were required to

[4]The BTS defines large certificated air carriers as airlines that hold Certificates of Public Convenience and Necessity issued by the U.S. Department

submit the required data. In July, 2002, the DOT issued a ruling that required all carriers, including small and regional air carriers to submit Form 41 data. We get around the short time span of data by observing that regional jet carriers owned by large carriers start reporting to the FAA in 1997. These airlines are presented in the following table:

Major Carrier	Regional Carrier
American (AA)	American Eagle (MQ)
	Executive Airlines (OW)
Continental	Expressjet (XE)
Delta	Atlantic Southeast (EV)
	Comair (OH)
Northwest	Mesaba (XJ)
	Pinnacle (9E)

The T100 is comprised of two parts, the T100 market data, which contains all Origin-Destination pairs, and the T100 segment which contains data for market segments. T100 segment data is the Data Bank 28DS of Form 41, which contains aircraft type and configuration, passengers, freight and mail transported, scheduled and performed departures, and distance. This study uses the segment data to analyze the use of each aircraft type. In order to separate markets that are point to point versus hub-spoke, annual 10K reports filed each year with the Securities and Exchange Commission for each company are analyzed. From this, the following hub airports are defined.

of Transportation (DOT) and operate aircraft with seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds. (http://www.bts.gov/publications/airport_activity_statistics_of_certificated_air_carriers/)

	Hub City and Airport	Years
American	Chicago (ORD)	1997-2005
	Dallas-Ft Worth (DFW)	1997-2005
	Miami (MIA)	1997-2005
	St Louis (STL)[5]	1997-2005
	San Juan, PR (SJU)	1997-2005
Continental	Cleveland (CLE)	1997-2005
	Newark (EWR)	1997-2005
	Houston (HOU)	1997-2005
Delta	Atlanta (ATL)	1997-2005
	Cincinnati (CIN)	1997-2005
	Dallas-Ft. Worth (DFW)	1997-2004
	New York-JFK (JFK)	2005
	Salt Lake City (SLC)	1997-2005
Northwest	Detroit (DTW)	1997-2005
	Memphis (MEM)	1997-2005
	Menniapolis-St Paul (MSP)	1997-2005

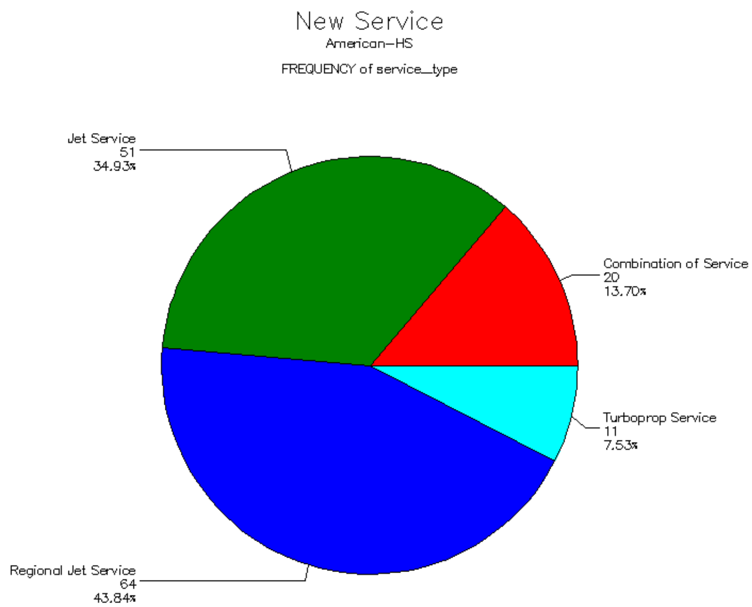
Each airline is analyzed on a case by case basis. To remain consistent with the theoretical model and for simplicity, market directionality is removed by taking the mean values of the outbound and return segment data of a return trip. We drop markets where there is no route trip traffic. While this results in some observations being lost, in actuality less than 10routes, or less than 2% of the observations are dropped due to this restriction.

3.2 Observations

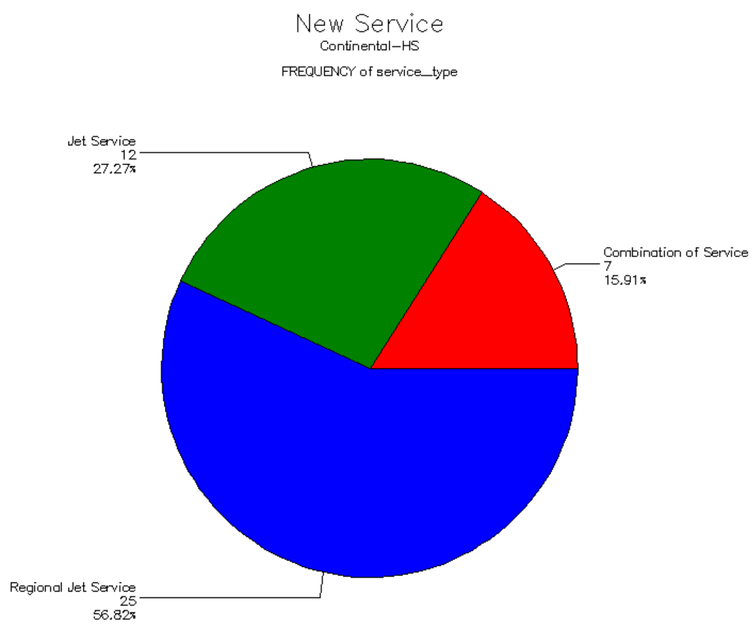
3.2.1 New Markets

New service is defined as service between city pairs that, once started, continues uninterrupted through the end of the study period. Here, two cases are presented, hub-spoke markets and later point to point markets. The following four graphs show the types of planes used on new hub and spoke service.

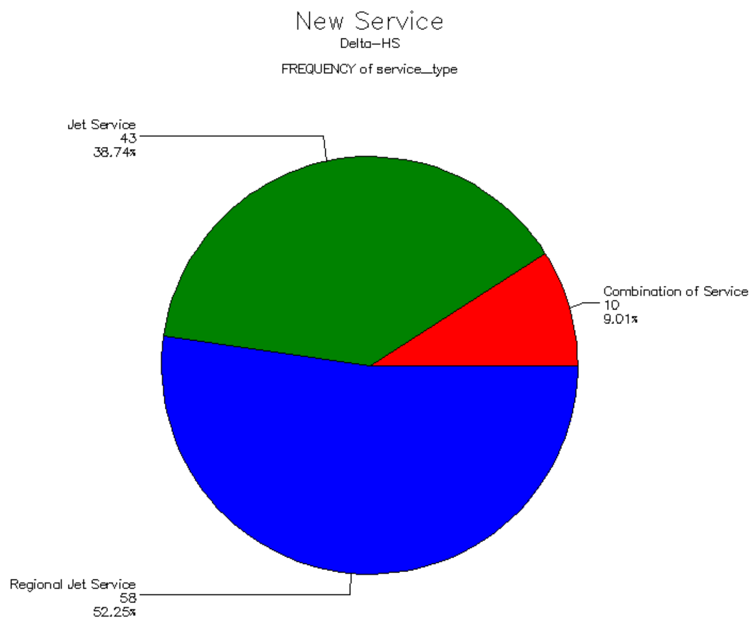
[5] St Louis became an American hub when it took over Trans World Airlines (TWA).



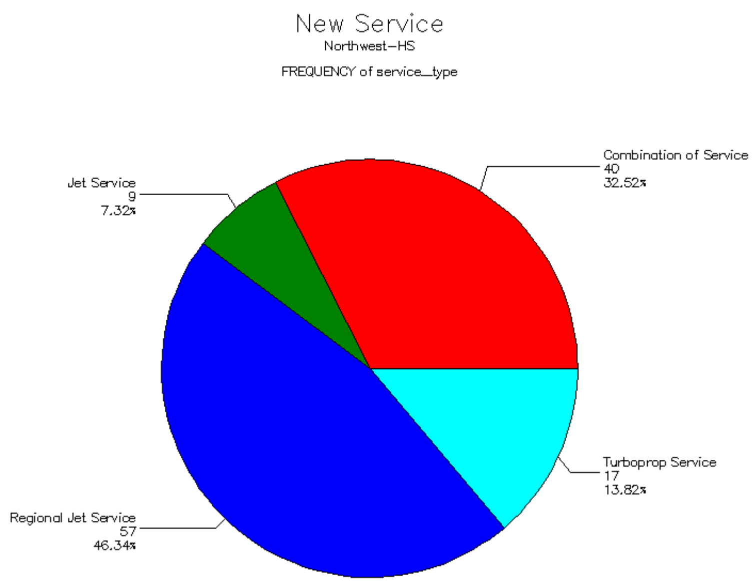
New American Hub-Spoke Service



New Continental Hub-Spoke Service



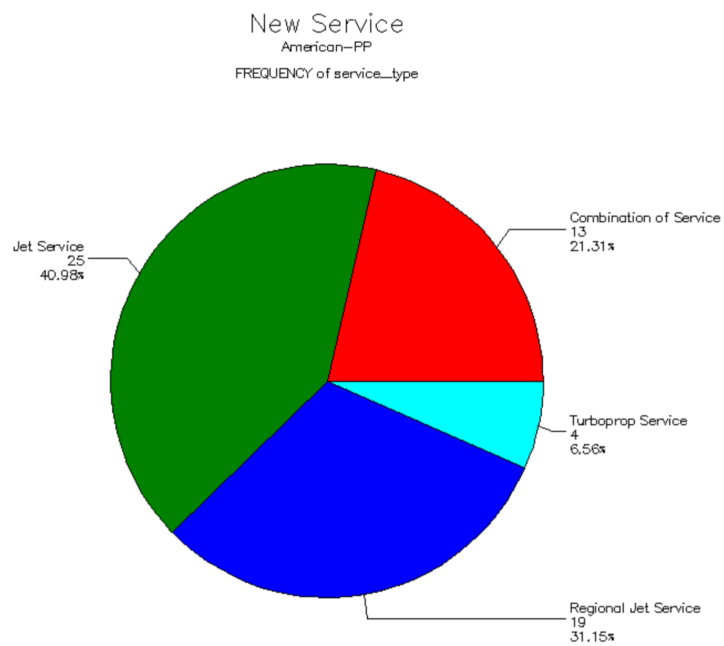
New Delta Hub-Spoke Service



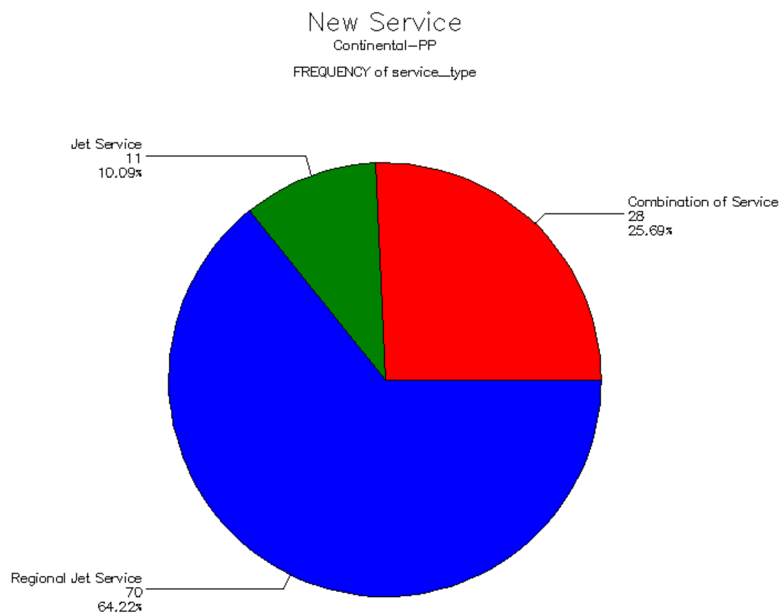
New Northwest Hub-Spoke Service

The graphs above show that the airlines use regional jets on a majority of new hub-spoke routes. In a sense, this can be thought of as a hedge against risk. Barla and Constantatos (1999) suggest that an airline may choose a particular network type as a hedge against unknown demand. In the same light, airlines may view the use of regional jets as a hedge against unknown demand, as they would need fewer passengers to make a route flown by a regional jet profitable.

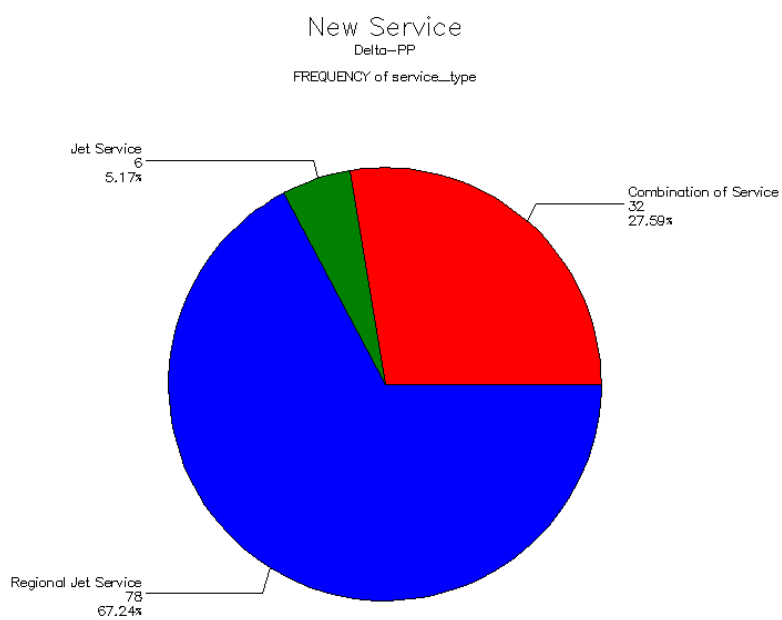
The following graphs show the types of planes used on new point to point routes.



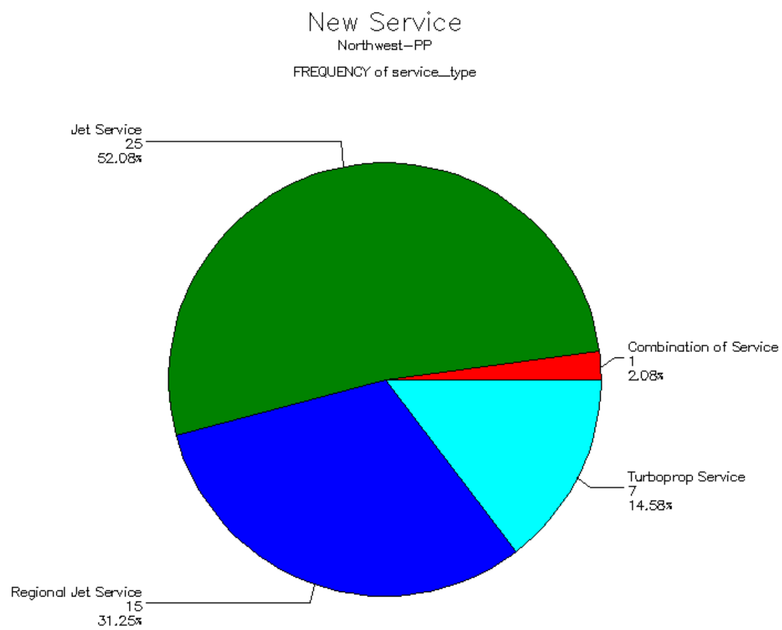
New American Point to Point Service



New Continental Point to Point Service



New Delta Point to Point Service

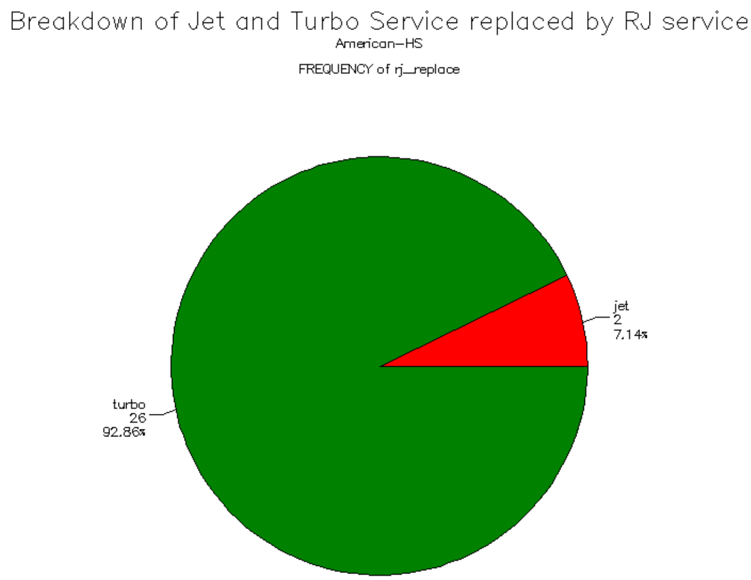


New Northwest Point to Point Service

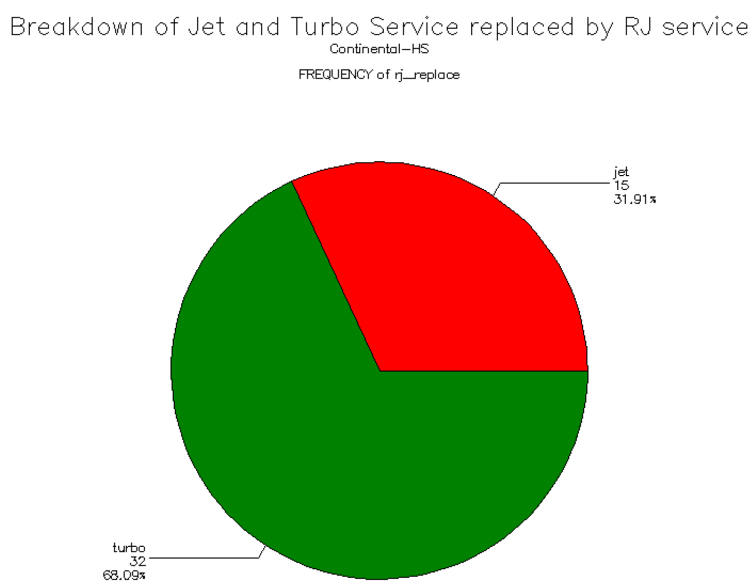
Unlike service to the hub, each airline uses a different combination of plane types on new point to point service. Northwest and American dominantly use jets on new point to point routes, while Delta and Continental dominantly use Regional Jets on new point routes. In this situation, it is possible that the airlines know the demand between two points, and launch new jet service only when it is profitable. Another explanation for such a divergence in plane use may be due to a carrier's strategy to offer greater frequency on routes where frequent jet service would not be feasible and overwhelm turboprops.

3.2.2 Technology Replacement

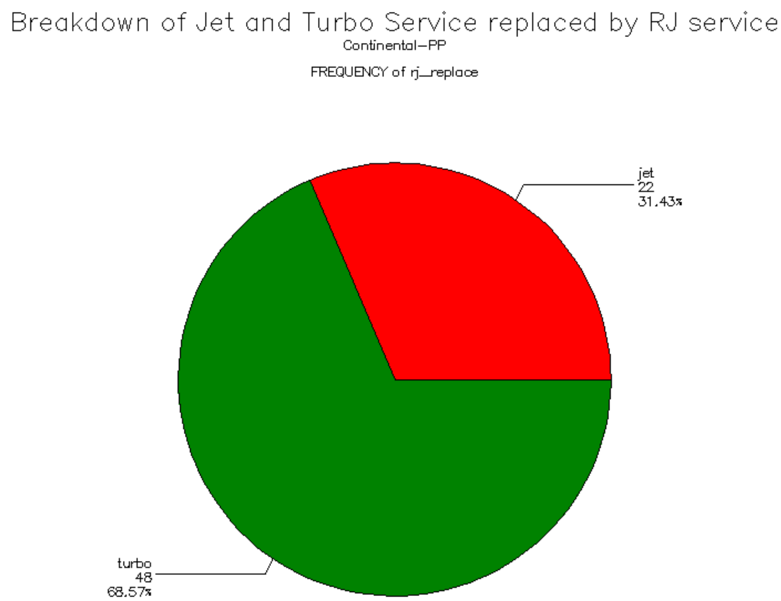
Here technology replacement is considered. From a quality perspective, regional jets are faster than turboprops and offer the convenience of jet travel for markets that are not able to support jet service. The following graphs shows which type of planes regional jets replace if there is replacement on a route.



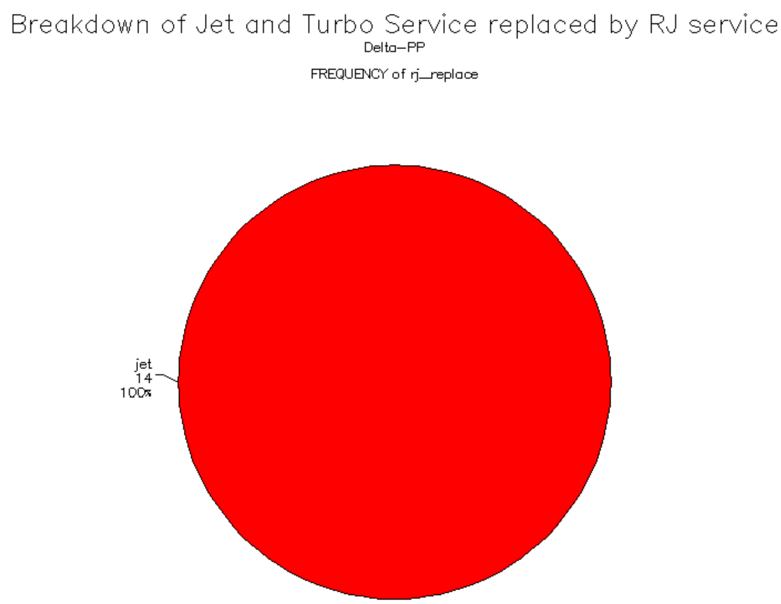
American Airlines Hub-Spoke Route Plane Replacement



Continental Hub-Spoke Route Plane Replacement

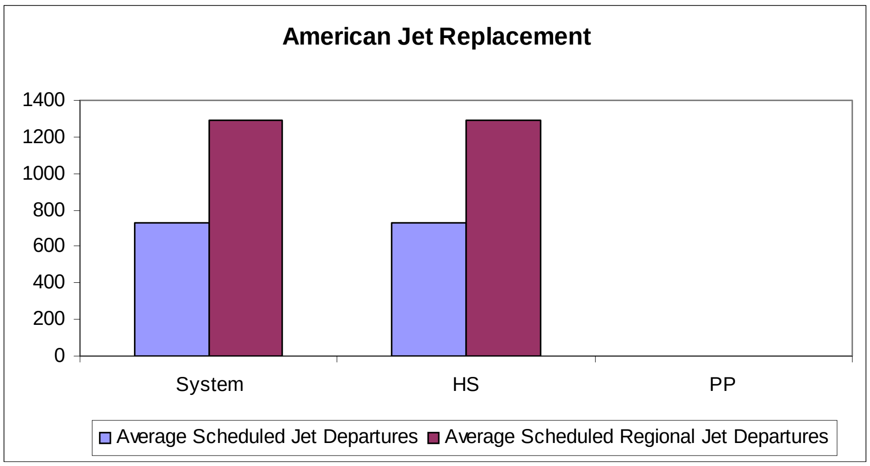


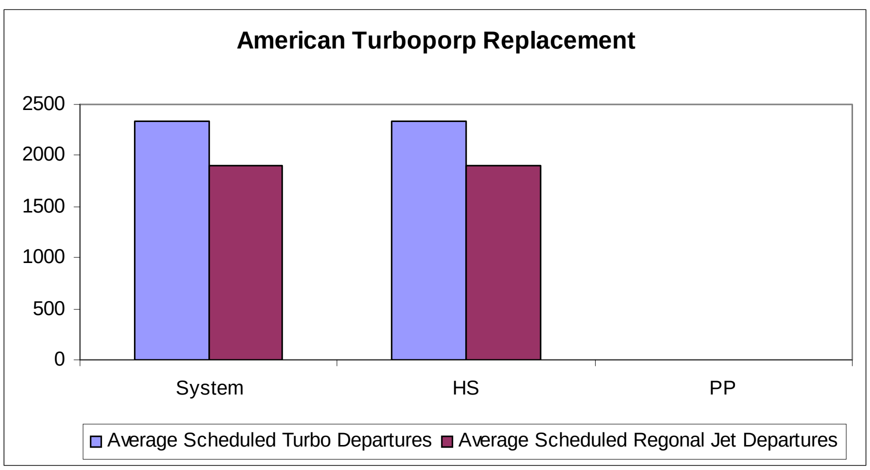
Continental Point to Point Route Plane Replacement



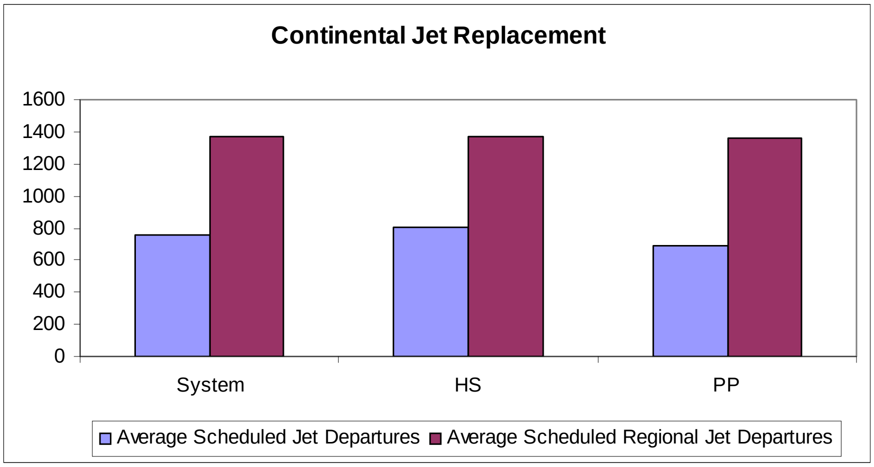
Delta Point to Point Route Plane Replacement

As evident from the graphs, if replacement occurs, regional jets often replace turboprops over jets. This suggests that airlines view regional jet service as an improvement in service quality over turboprops. This can be supported by analyzing frequency changes. As shown below, when a regional jet replaces a jet, average scheduled departures increase, and when a turboprop is replaced, average scheduled departures decrease.





Delta is a notable expectation in Jet replacement from a hub, where average schedule departures rise marginally relative to the other airlines or even Delta's own point to point routes. This suggests that for the most part, airlines view regional jets less as a replacement technology and more of a unique technology.


Continental Jet Replacement
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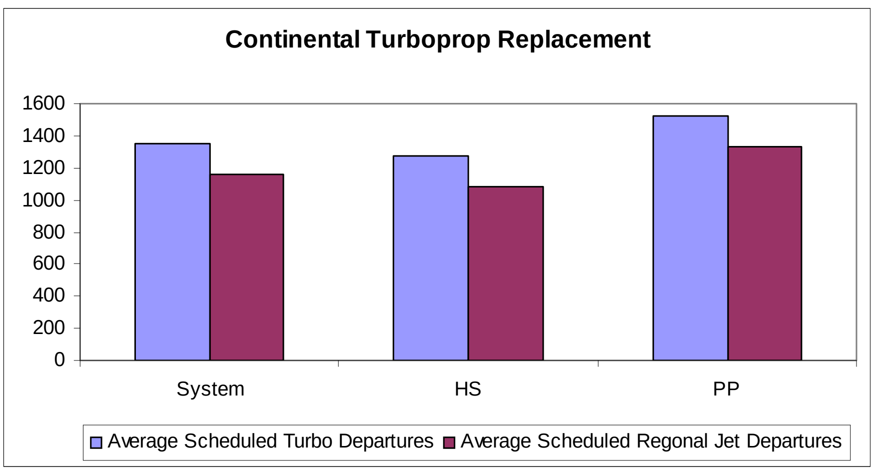
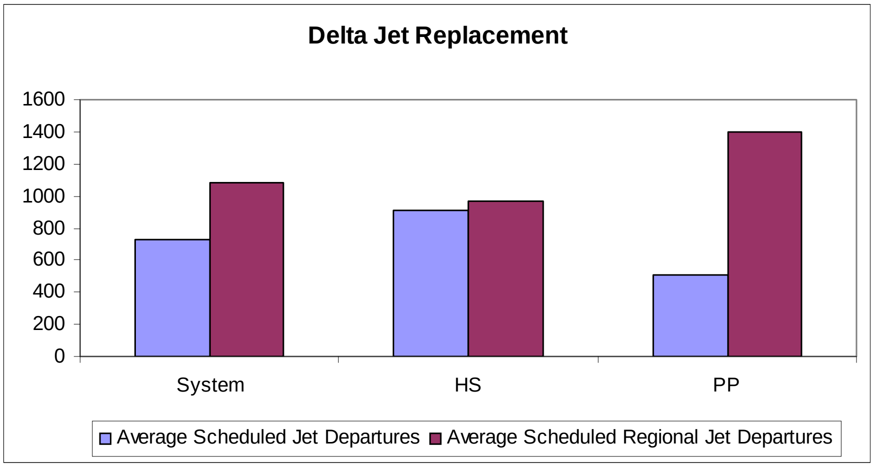
200
0
System
HS
PP
Average Scheduled Jet Departures
Average Scheduled Regional Jet Departures


Continental Turboprop Replacement
1600
1400
1200
1000
800
600
400
200
0
System
HS
PP
Average Scheduled Turbo Departures
Average Scheduled Regonal Jet Departures


Delta Jet Replacement
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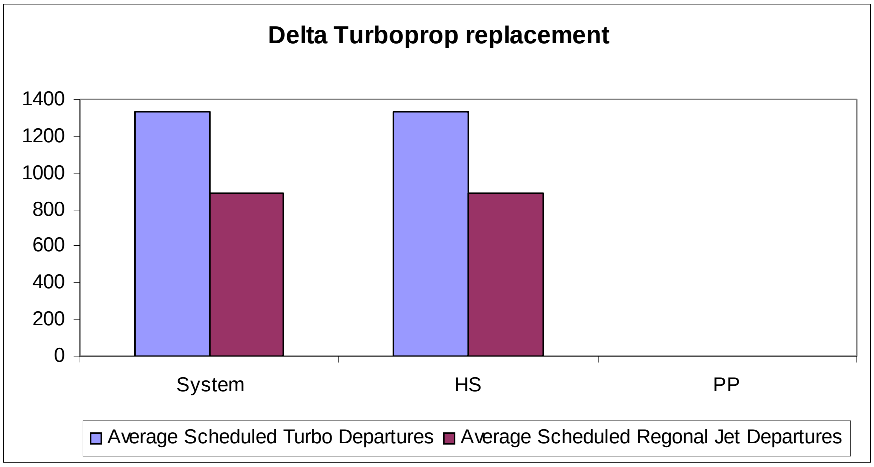
Average Scheduled Jet Departures
Average Scheduled Regional Jet Departures


Delta Turboprop replacement
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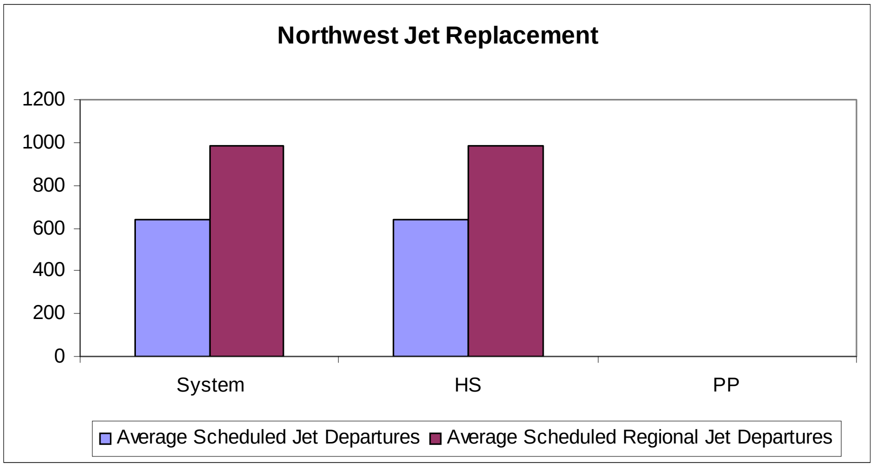
Average Scheduled Turbo Departures
Average Scheduled Regonal Jet Departures


Northwest Jet Replacement
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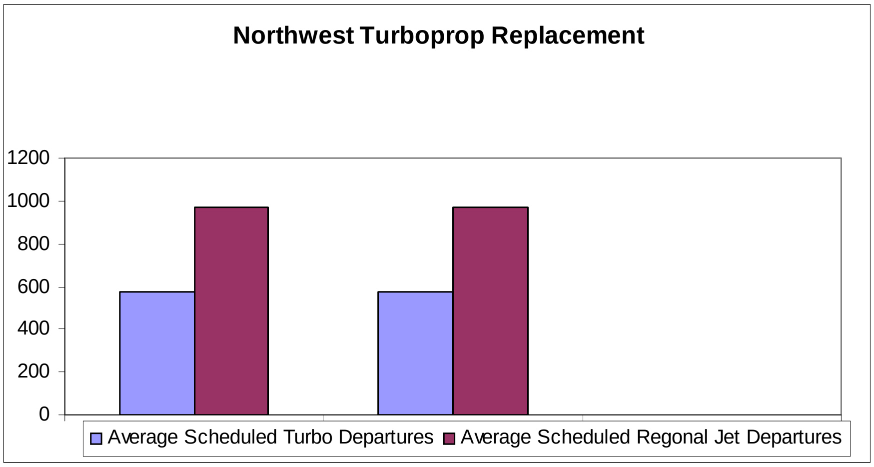
System
HS
PP
Average Scheduled Jet Departures
Average Scheduled Regional Jet Departures


Northwest Turboprop Replacement
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Average Scheduled Turbo Departures
Average Scheduled Regonal Jet Departures

4 Conclusion

The prevalence of regional jets has made a significant impact on the airline industry. With the introduction of regional jets, airlines have been able to offer more direct flights than with jet or turboprop planes. The model presented in this paper suggests that direct service compliments indirect, or hub-spoke, service. A result of the model is that business travelers will use direct routes due to the time costs involved in indirect travel. As confirmed by data, regional jets enables an airline to offer new service or offer improved service quality in terms of frequency. Additional research into demand characteristics would provide further evidence on the impact of regional jets, namely do regional jets allow for service that would not have been viable before. The dataset refined for this project will also allow future research into factors that influence the use of specific plane types on different routes. The increased use of regional jets also has potential implications on air traffic and congestion. With the introduction of new flights, the number of planes flying in the air increase, and along with it additional air traffic. In addition, airports must be able to handle the additional jets. The lower capacity of regional jets may lead to underutilization of airport terminal infrastructure. For example, slot constrained airports such as New York LaGuardia will be underutilized as the number of passengers traveling through the airport will be lower, with the same amount of plane landings. While beyond the scope of the model presented, such issues nevertheless warrant exploration.

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