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Optimizing Air Transportation Service to Metropolitan Airports

Part 1: Analysis of Historical Data

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EXECUTIVE SUMMARY

Context

This report summarizes work done for NASA Langley Research Center as part of the Airspace Systems Program (Airportal Project), under Contract number NNX07AT23A. The air transportation system is a significant driver of the U.S. economy, providing safe, affordable, and rapid transportation. During the past three decades airspace and airport capacity has not grown in step with demand for air transportation (+4% annual growth), resulting in unreliable service and systemic delays. Estimates of the impact of delays and unreliable air transportation service on the economy range from \$32B/year (NEXTOR, 2010) to \$41B/year (Schumer, 2008).

Government and industry are collaborating to address the capacity-demand imbalance via three approaches:

Increasing Capacity. Several initiatives are underway to increase the capacity of the airports and airspace to handle additional flights. The Airport Improvement Plan (2010) is designed to relieve the bottlenecks at U.S. airports by adding runways, taxiways, gates, terminal buildings and service facilities to key nodes of the air-transportation system. Plans are also underway to improve landing and takeoff technologies that will allow “all weather” operations.

The impact of these initiatives on the most capacitated airports is limited due to the lack of additional real-estate to accommodate needed infrastructure.

Special use airspace (e.g. military use only) is also being made available to increase the number of flights that can be handled during periods of peak demand.

Increasing Effective-Capacity and Productivity. Modernization of U.S. Air Traffic Control (ATC) infrastructure, known as NextGen, is a \$37B program. NextGen will improve productivity and the utilization of existing airspace. This will yield increases in the effective-capacity of the airspace and airports. Improvements in flow management, airborne re-routing, 4-D coordination of flights, and super-dense operations will increase the number of flights that can be handled during peak-periods. Estimates for increasing effective capacity at the bottlenecks range from a total increase of 10% to 30%. These increases are significantly lower than a compounded 4% annual growth rate in demand.

Increasing Seat Capacity. This approach incentivizes airlines to increase the size of aircraft to transport more passengers per runway/airspace slots. To create these incentives the government or port authority regulates the number of scheduled flights to match the number of runway slots and gates available. The slots are allocated to ensure competition between airlines to maintain competitive airfares and service, as well as to provide economies of scale and network integrity for airline networks. Allocation schemes range from administrative (e.g. grandfathering or political allocations) to market-based mechanisms (e.g. congestion pricing, auctions). Care must be taken to ensure the most efficient economic and socio-political use of the slots, and to avoid monopolies and ensure competition.

Problem

Currently there is not enough emphasis is being placed on the third approach, improved utilization through increased aircraft size.

The idea of improved utilization of runway/airspace capacity through increased aircraft size gained some traction in 2007 and 2008. A Department of Transportation initiative coordinated capacity limits at the three New York airports: at JFK the limit was set at 81 operations per hour (1/18/2008), EWR at 81 per hour (5/21/2008), and at LGA was decreased from 75/hour + 6 unscheduled to 71/hour + 3 unscheduled (1/15/2009).

The slots at each of the airports were allocated by grandfathering. The concept of auctioning the slots to maximize the economic efficiency in the allocation and to ensure competitive airfares met strong criticism and was withdrawn.

The objections to the concept were based on concerns that the introduction of capacity limits and market-based allocation schemes would affect:

Geographic access to air transportation service (i.e. elimination of service at smaller markets)

Economic access to air transportation service (i.e. increased operational costs leading to increased airfares, leading to pricing-out segments of the population)

Airline finances in a negative manner (i.e. reduced profits due to additional costs of operation)

Objective & Method

This report describes the results of an analysis of airline strategic decision-making with regards to: (1) geographic access, (2) economic access, and (3) airline finances. This analysis evaluated markets-served, scheduled flights, aircraft size, airfares, and profit from 2005-2009. During this period, airlines experienced changes in costs of operation (due to fluctuations in hedged fuel prices), changes in travel demand (due to changes in the economy), and changes in infrastructure capacity (due to the capacity limits at EWR, JFK, and LGA).

This analysis captures the impact of the implementation of capacity limits at airports, as well as the effect of increased costs of operation (i.e. hedged fuel prices). The increases in costs of operation serve as a proxy for increased costs per flight that might occur if auctions or congestion pricing are imposed.

The “design of the experiment” with the percent changes in national Gross Domestic Product (GDP), hedged fuel prices, and capacity limits at the airports is summarized below. Since the analysis is based on what actually occurred historically, this analysis is a “quasi-experiment” where only four of a possible 27 treatments are examined. A companion study using a model of airline operations describes the full “design of experiment” with all combinations of fluctuations.

- Airports included the three major New York airports (LaGuardia Airport (LGA), John F. Kennedy International Airport (JFK), and Newark Liberty International Airport (EWR)), Philadelphia International Airport (PHL), and San Francisco International Airport (SFO)
- Fuel prices ranged from -47% to +72% annual change
- GDP ranged from -2.4% to +2.7% annual change
- Capacity limits were added to JFK and EWR in 2008. And Capacity limits were reduced at LGA in 2008. These effects can be observed in the airline behavior changes from 2008 to 2009.

- Only domestic markets examined
- The first treatment (2005-2006) show effects from an increase in fuel prices, an increase in GDP, and no changes to capacity limits.
- The second treatment (2006-2007) show effects from no change in fuel prices, an increase in GDP, and no changes to capacity limits.
- The third treatment (2007-2008) show effects from an increase in fuel prices, no change in GDP, and no changes to capacity limits.
- The fourth treatment (2008-2009) show effects from a decrease in fuel prices, a decrease in GDP, and reduced capacity limits.

Results

The following results represent statistically significant trends with a 95% confidence interval.

Geographic Access. The number of domestic markets served directly by an airport is primarily affected by the demand for air transportation. The number of flights per day to a market is also primarily determined by passenger demand.

Capacity limits at airports did result in a small reduction in domestic markets served and flights per day. Airline network restructuring (e.g. Delta's expansion at JFK), airlines financial restructuring (e.g. USAirways bankruptcy filing impacted PHL), and inter-airline competition also affected domestic markets served and flights per day.

1. The growth/decay in demand for air transportation (as measured by the Gross Domestic Product (GDP)) is the primary determinant of the number of domestic markets served. A linear regression showed that for every +1% change in GDP, there is a +1.44% change in the number of domestic markets with direct service. The linear regression also showed that for every 1% change in GDP, there is a 1.83% change in the number of flights per day serving these markets. As the economy slowed, the number of markets with direct service decreased.
2. The introduction of Capacity Limits at congested airports also affected the number of domestic markets served. In response to the economic down-turn (2008 and 2009), airports without capacity limits (SFO, PHL) experienced a reduction in the number of domestic markets served by an average of -7% (SFO -8%, PHL -6%). During the same period, heavily congested airports that had capacity limits implemented (EWR) or reduced (LGA), experienced a loss of an additional 4% of markets served (EWR -12%, LGA -10%) versus (SFO -8%, PHL -6%) and 9% reduction in flights per day (LGA -16%, EWR -16%, JFK – None) versus (SFO -4%, PHL -7%).

Economic Accessibility. Passenger accessibility to air transportation through airfares at these airports followed established patterns of passenger demand during this period. Changes in the economy significantly affected demand for air transportation. The economic downturn had an order of magnitude greater effect on airline airfares than did the change in airlines' operating costs (as measured by changes in fuel costs).

1. Cumulative elasticity at the airports ranged between -3.1 to -1.8 during this period. Specifically, a -3 elasticity means a 1% increase in airfare (e.g. \$300 to \$303) resulted in a 3% reduction in demand for air service at that fare. This result is consistent with prior studies that showed passenger demand to be elastic.

2. The change in airfare was driven by changes in travel demand (reflected by changes in the GDP) and changes in hedged fuel prices. This correlation accounted for 79.6% (i.e. $R^2=79.6$) of the observed variation in airfares. At the five airports studied (LGA, JFK, EWR, PHL, and SFO), airfares changed on average +1.84% for every +1% change in GDP and +0.12% for every +1% change in hedged fuel prices. A \$1 increase in hedged per-gallon fuel prices resulted in an average of \$16 increase in airfares, which yielded an average reduction in passenger demand of 1.5%.

Airline Profitability. Airline profitability for the routes serviced at these five airports is a complex phenomenon driven by demand for air transportation, passenger responses to price increases, and operating costs. During this period, airline profitability was primarily determined by the industry's ability to raise airfares relative to the cost of operations (i.e. when hedged fuel prices were escalating dramatically). During the spike in fuel costs, the airlines were faced with significantly greater operating costs and decreased demand due to the economic downturn. During this period:

1. airline profitability decreased as airlines were unable to increase airfares as fast as hedged fuel prices increased.
2. airlines shed less profitable domestic markets in order to improve profitability. The decrease in markets was driven primarily by reduced economic demand for air transportation and the sensitivity of passengers in certain markets to increased airfares.
3. airlines decreased aircraft size in order to maintain profitability as demand decreased.
4. the change in airport congestion was driven by changes in domestic markets served, scheduled flights per day, and by aircraft size ($R^2=76.5\%$). At the five airports studied (LGA, JFK, EWR, PHL, and SFO), congestion changed on average 2.16% for every 1% change in markets served, 1.64% for every 1% scheduled flights per day and -4.04% for every 1% increase in aircraft size.
5. the change in airline profitability was driven by changes in airfare and changes in aircraft size ($R^2=75.6\%$). At the five airports studied (LGA, JFK, EWR, PHL, and SFO), airline profitability decreased an average of 0.28% for every 1% increase in hedged fuel prices.

Implications of Results

The historic data paints a complex, nuanced picture of the airline strategic decision-making in the presence of changes in economic demand for air travel, fluctuations in hedged fuel prices, and regulatory adjustments to airport capacity limits.

There are two main implications:

1. A stable or growing economy with non-fluctuating operating costs (i.e. hedged fuel prices) provides the optimum balance between geographic and economic accessibility for passengers (sought by regulatory authorities) and airline financial stability (sought by airlines).
2. Airport Capacity Limits (at congested airports) provide a critical mechanism for providing balanced geographic and economic access with profitable operations during periods of economic growth and fluctuating operating costs (i.e. hedged fuel prices)

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1 Introduction

The air transportation system is a significant driver of the U.S. economy, providing safe, affordable and rapid transportation.

During the past three decades airspace and airport capacity has not grown in step with demand for air transportation (+4% annual growth), resulting in unreliable service and systemic delays (Sherry, 2008).

Estimates of the impact of delays and unreliable air transportation service on the economy range from \$32.3B/year (NEXTOR, 2010) to \$41B/year (Schumer, 2008).

Government and industry are collaborating to address the capacity-demand imbalance via three initiatives: Increasing Capacity, Increasing Effective-Capacity and Productivity, and Increasing Seat Capacity.

Increasing Capacity

Several initiatives are underway to increase the capacity of the airports and airspace to handle additional flights. The Airport Improvement Plan (2010) is designed to relieve the bottlenecks at U.S. airports by adding runways, taxiways, gates, terminal buildings and service facilities to key nodes of the air-transportation system.

The Airports Improvement Program (AIP) is administered by the FAA and funded from the Airport and Airway Trust Fund (A&ATF). The A&ATF is created from user fees (e.g. 7.5% ticket tax) and fuel taxes.

The AIP provides about 18% of the capital funds for improvements that include enhancements of capacity, safety, and other aspects of airport infrastructure. AIP funds are also applied toward projects that “support aircraft operations including runways, taxiways, aprons, noise abatement, land purchase, and safety, emergency or snow removal equipment” (Kirk, 2003; p. 3). To be eligible for AIP funding, airports must be part of the National Plan of Integrated Airport Systems (NPIAS), which imposes requirements on the airport for legal and financial compliance (Wells & Young, 2003; p. 329).

The NPIAS has two goals: To ensure that airports are able to accommodate the growth in travel, and to keep airports up to regulatory standards (FAA, 2008; p. v).

The AIP funds are distributed to passenger, cargo, and general aviation airports, in two categories (Kirk, 2003; pp. 6-7):

1. Formula funds: Formula funds (also known as “apportionments”) are apportioned according to formulas based on the volume of throughput (e.g. enplaned passengers) and location. The formulas vary depending on the type of airport.
2. Discretionary funds: Discretionary funds are approved by the FAA and are distributed based on factors such as project priority and congressional mandates. Although it is not the sole determinant factor, project selections are based on a project’s score in the National Priority Rating (NPR) equation, which assigns projects a rating from 0 to 100 (high or 100% aligned with agency goals) (FAA, 2000; p. 5). Projects with safety and security purposes receive higher ratings than those focused on capacity (Dillingham, 2000; p. 32).

Special use airspace (e.g. military use only) is also being made available to increase the number of flights that can be handled during periods of peak demand.

The impact that these initiatives will have on system-wide bottlenecks at the most capacitated airports is limited due to the lack of additional real-estate to accommodate needed infrastructure.

Increasing Effective-Capacity and Productivity

Modernization of U.S. Air Traffic Control (ATC), known as NextGen, is a \$37B program. NextGen will improve productivity and the utilization of existing airspace yielding increases in the effective-capacity of the airspace and airports. Improvements in flow management, airborne re-routing, 4-D coordination of flights, and super-dense operations will increase the number of flights that can be handled during peak-periods.

NextGen is an umbrella term for the ongoing, wide-ranging transformation of the National Airspace System (NAS). At its most basic level, NextGen represents an evolution from a ground-based system of air traffic control to a satellite-based system of air traffic management. This evolution is vital to meeting future demand, and to avoiding gridlock in the sky and at our nation's airports (FAA, 2010; p. 4).

NextGen will realize these goals through the development of aviation-specific applications for existing, widely-used technologies, such as the Global Positioning System (GPS) and technological innovation in areas such as weather forecasting, data networking, and digital communications. Hand in hand with state-of-the-art technology will be new procedures, including the shift of certain decision-making responsibility from the ground to the cockpit.

When fully implemented, NextGen will allow more aircraft to safely fly closer together on more direct routes, reducing delays and providing unprecedented benefits for the environment and the economy through reductions in carbon emissions, fuel consumption and noise.

FAA estimates show that by 2018, NextGen will reduce total flight delays by about 21 percent while providing \$22 billion in cumulative benefits to the traveling public, aircraft operators and the FAA. In the process, more than 1.4 billion gallons of fuel will be saved during this period, cutting carbon dioxide emissions by nearly 14 million tons. These estimates assume that flight operations will increase 19 percent at 35 major U.S. airports between 2009 and 2018, as projected in the FAA's 2009 traffic forecast.

Estimates for increasing effective capacity at the bottlenecks range from a total increase of 10% to 30%. These increases are significantly lower than a compounded 4% growth rate in demand.

Increasing Seat Capacity

This approach incentivizes airlines to increase the size of aircraft to transport more passengers per runway/airspace slot. To create these incentives the government or port authority regulates the number of runway slots and gates available to match the available supply. The distribution of the available slots is then allocated through some combination of administrative (e.g. grandfathering) and market-based mechanisms (e.g. congestion pricing, auctions) in order to ensure the most efficient economic and socio-political use of the slots, and to avoid monopolies and ensure competition.

Problem Statement

Currently there is not enough emphasis is being placed on improved utilization of the air transportation system through increased aircraft size.

The idea of improved utilization of runway/airspace capacity through increased aircraft seat capacity is mired in uncertainty about the impacts on the airlines, on domestic markets served and on costs to both the airline industry and passengers. Access to airlines has been shown to have significant effect on local economies, and delays at airports have been shown to alter the economy of a region. Elected officials, representing their constituents, have been very sensitive to these consequences.

In 2008, the concept of market-based methods gained some traction at the congested New York airports. The Department of Transportation (DOT) published a rule to limit the number of arrival and departures at the New York airports and to allocate a small proportion of the available slots via an auction (Federal Registry volume 73, pages 60544-60601).

An agreement was reached with incumbent airlines to set capacity limits at the three New York airports. After sharp debates about how those capacity limits should be set and about how the limited capacity would be allocated, capacity limits at JFK were set at 81 per hour (1/18/2008) and at EWR were set at 81 per hour (5/21/2008). The capacity limits at LGA were decreased from 75/hour + 6 unscheduled to 71/hour + 3 unscheduled (1/15/2009). No equivalent capacity restrictions were placed on other congested airports with similar congestion during peak operations (e.g. Philadelphia, Atlanta).

The slots at each of the airports were allocated by grandfathering only.

The concept of auctioning the slots to maximize the economic efficiency in the allocation and to ensure competition that would lead to lower airfares was roundly criticized (Schumer, 2008; LaHood, 2009; Bethune, 2008; Air Transport Association, 2008; Regional Airline Association, 2008).

The objections to the concept were based on concerns that the introduction of capacity limits and market-based allocation schemes would affect:

1. Geographic access to air transportation service by elimination of service at smaller domestic markets
2. Economic access to air transportation service as a result of increased operational costs that would in turn lead to increases in airfares to the point where a segment of the population could no longer afford to fly
3. Negative financial impact to airlines through additional costs of operation

This DOT concept of auctioning the slots for the New York airports was put into law in the federal registry in October 2008 (Federal Registry volume 73, pages 60544-60601). This rule established procedures to address congestion in the New York City area by assigning slots at airports in a way that allows carriers to respond to market forces to drive efficient airline behavior. The rule also extended the caps on the operations at the two airports, assigns to existing operators the majority of slots at the airports, and develops a robust secondary market by annually auctioning off a limited number of slots in each of the first five years of this rule. Auction proceeds would be used to mitigate congestion and delay in the New York City area. The rule also contained provisions for minimum usage, capping unscheduled operations, and withdrawal for operational need. The rule would sunset in ten years. This rule was due to go into effect October 2009, but was rescinded in May 2009 (Federal Registry volume 74, page 22714) for JFK and EWR and in October 2009 (Federal Registry volume 74, pages 52132) for LGA.

The rule proposed the FAA would auction 10% of slots at EWR and JFK and 15% of the slots at LGA above the 20-slot baseline annually for the first 5 years of the rule. As a result, 96 of the total 1,219

slots at the airport would be auctioned over the 10-year span of the proposal; between 91 and 179 slots out of 1,245 total slots at JFK would be affected.

Three categories of slots were proposed: Common Slots, Limited Slots and Unrestricted Slots. Most would be Common Slots, which would be leased for ten years and revert to FAA when the rule sunsets. Carriers would have property rights to Common Slots, allowing the slots to be collateralized or subleased to another carrier for consideration, but Common Slots would revert to FAA under the rule's minimum usage provision and could be withdrawn for operational reasons. Limited Slots would consist only of slots operated on a daily, year-round basis, and leases for Limited Slots would also be assigned by cooperative agreements between the FAA and carriers. However, during each of the first 5 years of the rule, a percentage of Limited Slots would be made available by auction, at which point they would be converted to Unrestricted Slots, which are slots leased directly from FAA under the auction process.

Five protests were filed on August 14, 2008 by airline carriers. On the same date, a protest also was filed by the Air Transport Association. Two additional protests were filed by the Port Authority of New York and New Jersey on August 28, 2008 and another by the New York Aviation Management Association (NYAMA) on August 29, 2008. The NYAMA protest was dismissed as the organization is not considered a legitimate stakeholder.

The protests presented legal arguments contending that the FAA lacks legal authority to conduct the slot auction. According to the protesters, the slots are not actual "property," and as such, cannot be subject to a lease. According to the protests, the auction transaction involves not a lease, but rather the sale of a license by the FAA to a carrier to use a designated flight departure and/or flight landing time. Arguing that only a license - rather than a tangible property interest - is involved, the protests maintain that the FAA's Property Management Authority does not permit this auction effort. The protests also contend that the slot auction is not authorized under the FAA's "Airspace Management Authority," which is frequently cited as providing the Administrator's management authority over the United States' navigable airspace (FAA, 2008; pg 5.).

Objective of this Research

The objective of this research is to inform the policy-makers, research and technology entities, and decision-makers on the concept of better utilizing the seat capacity per runway-slot. Specifically, this research answers the following questions in Table 1:

Stakeholder	Factor
Congress, Department of Transportation, Department of Commerce, and Department of Justice as advocates for consumers and the U.S. economy	<u>What happens to Geographic access</u> to air transportation service by introduction of capacity limits at certain highly-congested airports and an increase in airlines costs (to pay for the slots). Would this result in an elimination of service at smaller domestic markets?
Congress, Department of Transportation, Department of Commerce, and Department of Justice as advocates for consumers and the U.S. economy	<u>Economic access</u> to air transportation service as a result of increased operational costs. Would this in turn lead to increases in airfares to the point where a segment of the population could no longer afford to fly?
Airlines	What is the <u>financial impact to airlines</u> through additional costs of operation

Table 1 Stakeholders Research Questions

Research Approach

During the period between 2005 and 2009, the economy and hedged fuel prices fluctuated. This provided an opportunity to answer questions about how airline operating costs, economic conditions and an airlines’ access to an airport impact the markets it serves, ticket prices and aircraft sizes.

This analysis, summarized in the factorial design in Table 2, represents four of the possible 27 treatments possible (3 GDP % change possibilities x 3 Fuel Price % change possibilities x 3 Airport Capacity Limit % change possibilities).

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		

Table 2 Historic Design of Experiment

This analysis examined airline schedule behavior in the presence of application of airport capacity limits and fluctuations in fuel prices and Gross Domestic Product (GDP). Figures 1 and 2 respectively show that that between 2005 and 2009 fuel prices and GDP changed a lot. Therefore, this is an excellent time period to examine airline behavior. The following metrics will be used to examine airline’s behavior in response to these exogenous factors: (a) Aircraft size, (b) Flights per day, (c) Daily domestic markets served and (d) average load factors. It also tracks airline (e) average ticket airfare on departures and arrivals. The impacts of these behaviors are examined by tracking (f) Airport congestion and (g) Profitability of the airports.

Two types of analysis were applied. In the first study, a statistical analysis of trends for the New York and San Francisco airports from 2005 to 2008 was conducted.

In the second study, a regression analysis of these trends from 2005 through 2009 was conducted, to evaluate airlines’ business and operational behaviors in response to economic and policy changes at the New York, Philadelphia and San Francisco airports.

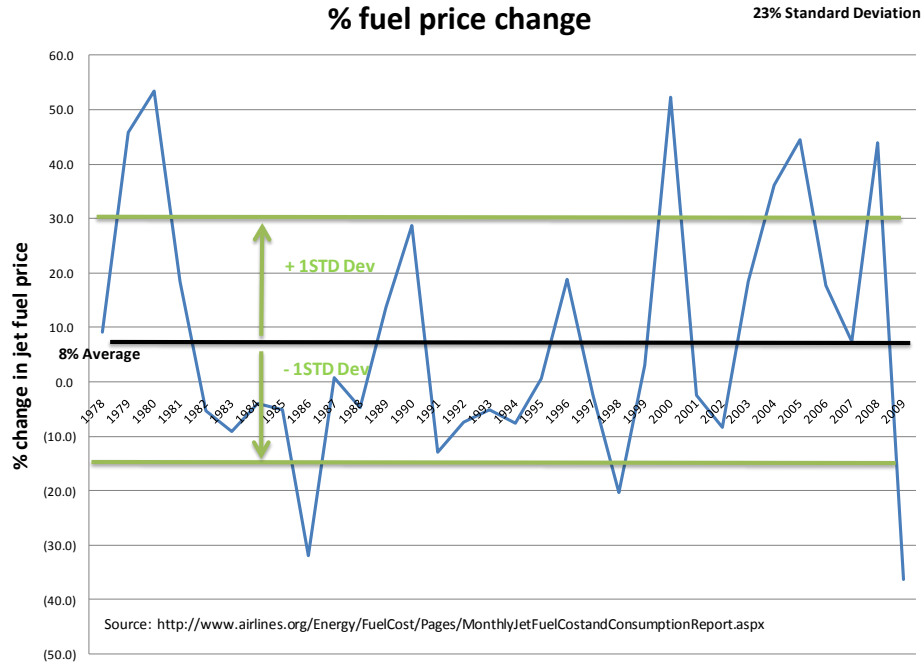


Figure 1 Fluctuations in year-over-year annual changes in Hedged Fuel Prices from 1978 to 2009. Black-line shows the average (+8% annual growth). Green lines show one standard deviation.

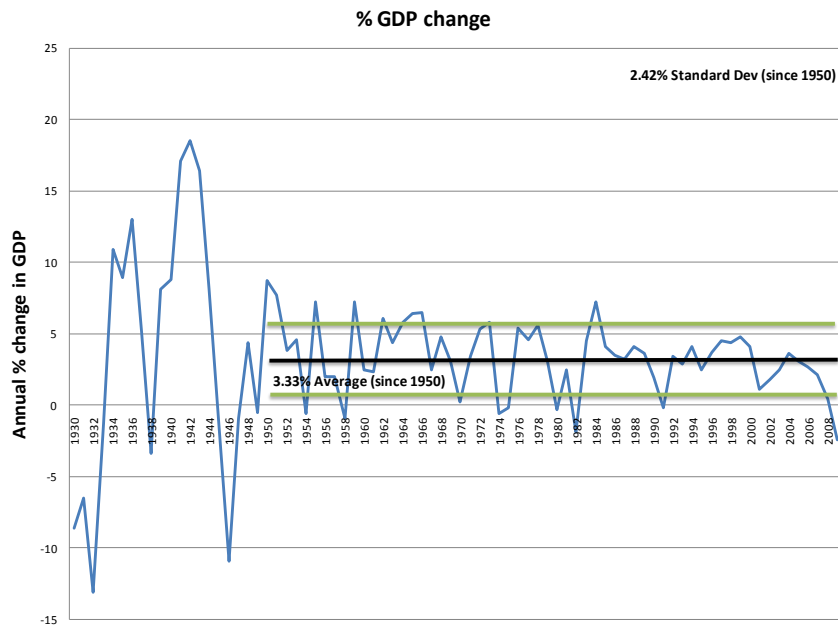


Figure 2 Fluctuations in year-over-year annual changes in Gross Domestic Product from 1930 to 2008. Black-line shows the average from 1950 to 2008 (3.3% annual growth). Green lines show one standard deviation.

Benefits of This Research

Multiple stakeholders for the US air transportation system can benefit from modeling and understanding airline behavior in the presence of economic, regulatory, & technological changes.

Government policy-makers will be provided a quantitative analysis of impact of changes to airline scheduling and pricing behavior from changes in economic conditions like Gross Domestic Product and hedged fuel prices. The government policy-makers will also be provided insight into how airline scheduling and pricing behavior changes with changes in airport capacity limits or with additional fees. This model built on 5 years analysis of historical data will provide the ability to forecast expected airline scheduling and pricing behavior for non-historical economic and regulatory scenarios.

Research Managers (e.g. NASA) will be provided insights into impacts of improved technologies (e.g. aircraft fuel efficiency). The economic analysis identifies the aircraft and engine performance requirements that would be required to incentivize up-gauging to larger aircraft.

This research complements the NextGen research, since 49 of 131 NextGen OI's involved upgrades in aircraft capabilities (Sherry, 2007). Airline up-gauging increases effective-capacity to the system, just like the NextGen initiatives do through improvements in air traffic flow management, reduced airline separation and more efficient use of current TRACON airspaces.

2 Functional Model of Airline Strategic Decision-making

Airlines are continuously adjusting their operations in the presence of economic, regulatory, & technological changes (Figure 3). Demographics, social values, and the economic benefits of rapid, affordable transportation afforded by airlines determine the demand for airline operations. Regulatory changes incentivize airline behavior and can also alter or curtail airline operations. Technological changes increase productivity and the range and performance of the air transportation service.

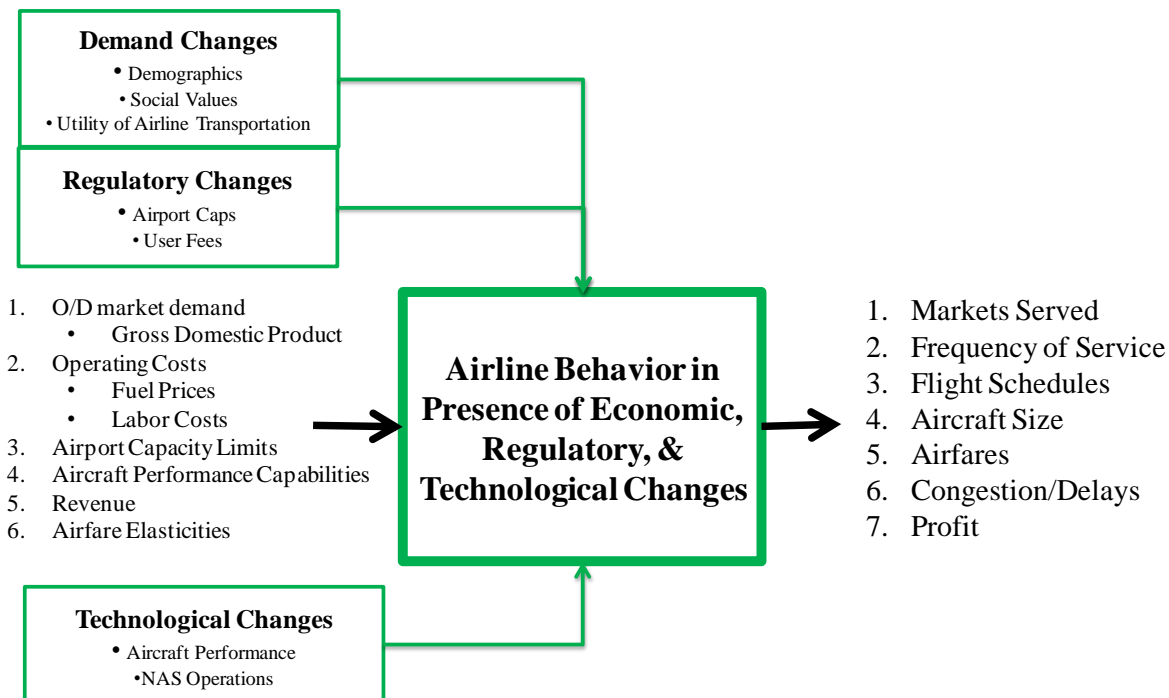


Figure 3 Airline behavior in the presence of demand, regulatory, and technological changes

Airlines make the following choices:

- Domestic markets Served
- Frequency of Service
- Flight Schedules
- Aircraft Size
- Airfares

The following metrics are affected by airline behavior or decisions:

- Profit
- Congestion/ Delays

These decisions are made in the presence of:

- National and regional economic conditions
- Operational costs (e.g. fuel prices, crew costs, aircraft costs)
- Airport capacity limits (e.g. slot controls, gate and ground operations access)
- Aircraft Performance Capabilities
- Origin and Destination domestic market demand, revenue, airfare vs demand elasticities

Figure 4 shows a functional representation of airline business planning, scheduling, and operational functions and decisions. The green boxes represent the impact of the exogenous factors on these decisions. Other key factors which influence airline decision making includes access to airport facilities, regional economic conditions, aircraft costs, and anticipation of regulation. The diamonds in the figure represent a simplified view of airline strategic decisions. The arrows show the functions and decision impacted by strategic decisions.

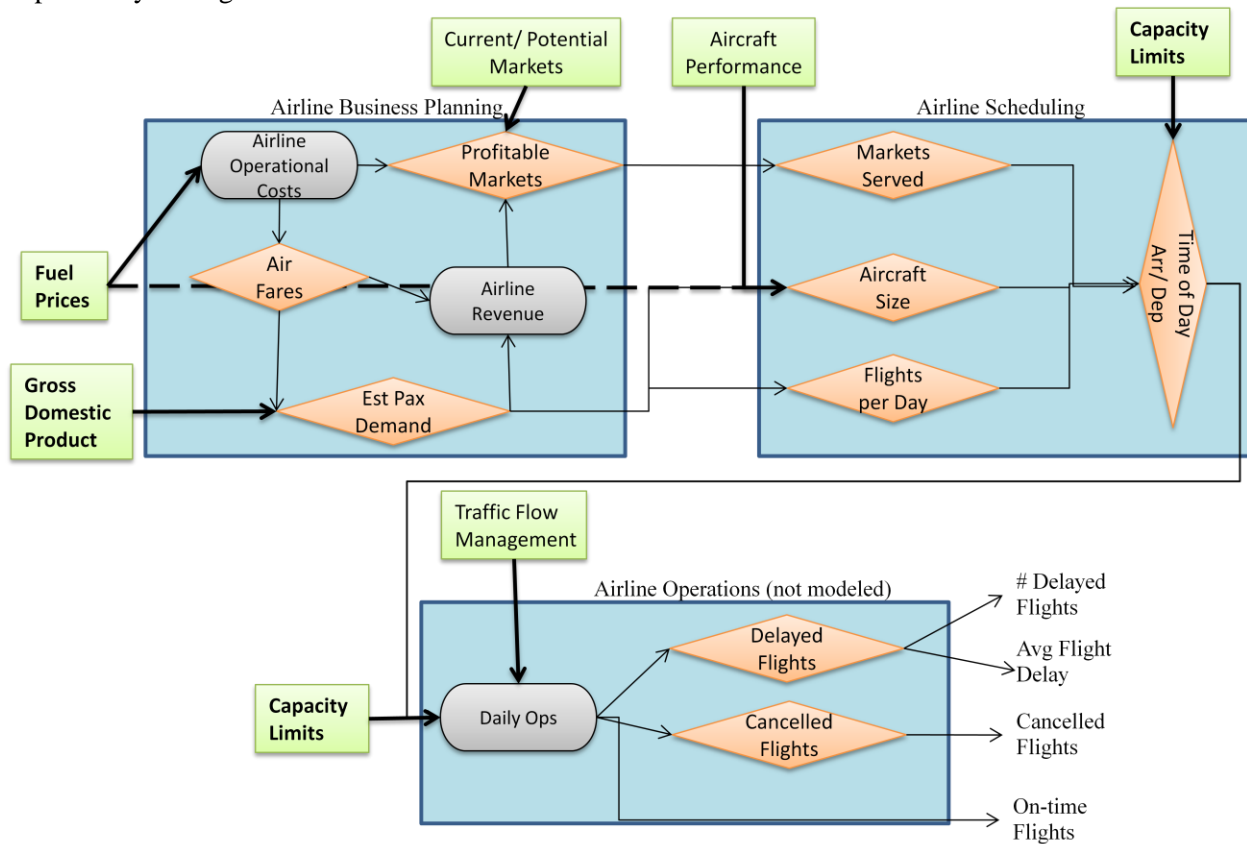


Figure 4 Airline decision-making: Business Planning, Scheduling, and Operations

The Airline Business Planning function sets airfares based on expected operational costs, estimated demand and a variety of strategic decisions related to maintaining or growing market share. An airline must determine if an increase in operational costs such as hedged fuel prices must be absorbed or can be passed on to the consumer through increased airfares. Often, because of competition and because demand for air travel is highly elastic, the airlines may not be able to recover all of the additional costs they might incur when operational costs (such as fuel costs, crew or maintenance costs, additional fees imposed through regulation) increase.

As the figure shows there is a two-way relationship between airfare and the airlines' estimated market demand. Demand is also influenced by overall economic conditions. In our analysis, we have used National Gross Domestic Product to evaluate the state of the economy. When the economy is good, potential travelers have more disposable income to buy airline tickets. During recessions, both business travel and vacation travel are reduced.

After the airlines determine the potential demand within a given market at various ticket prices, they then evaluate the likely revenue, costs, and competition within a market in order to determine whether to serve the market and if so, with what frequency.

Airlines then use a variety of optimization tools to determine the overall schedule of service, the allocation of aircraft to markets, and the allocation of crews to the aircraft. Other models determine the maintenance schedule and the dynamic pricing of tickets based (revenue management) on competition and relative demand.

On the day of service, other models are used to determine the operational decisions to mitigate congestion and delay while at the same time trying to serve the maximum amount of passengers possible and maintain their network structure. Airlines make decisions to delay flights, cancel flights or let flights fly on time based upon traffic flow management constraints. These constraints might be from weather or congestion-driven ground delay programs or may be from capacity limits applied to airport operations.

3 Method

This section describes how data for our analysis was collected, the methods used to track trends and the methodology used to determine if the changes observed were statistically significant.

3.1 Data Sources

The following metrics are used in the analysis to measure airline behavior in response to economic and policy changes.

Aircraft size: The average number of seats per aircraft for various O/D pairs as reported to BTS. (BTS, 2009)

Flights per day: The number of arrivals per day from other airports as reported to the Bureau of Transportation Statistics (BTS). (BTS, 2009)

Domestic markets Served: A count of the number of destinations served from a NY/NJ airport with at least sixty or more arrivals and departures per month, as reported to BTS. (BTS, 2009)

Load Factor: The number of passengers on a given aircraft divided by the seat capacity of that aircraft, as reported to BTS. (BTS, 2009)

Average Airfare: The average airfare during a given quarter, as reported in the 10% price sample provided to BTS. (BTS, 2009) This analysis does not completely include the passenger's cost of travel since it does not reflect any baggage, fuel fees, or other incidentals (e.g. blanket, movie, food).]

The response to these airline actions is recorded by the following metrics:

Flight Delay: The number of delayed flights (flights with delays of 15 minutes or more), as reported to BTS. (BTS, 2009)

Flight Cancellations: The total number of flights cancelled for each O/D, as reported to BTS. (BTS, 2009)

Congestion: Percentage change in the number of flights delayed more than 15 minutes plus percentage change in the number of flights cancelled divided by two. The measure of congestion is based on a weighted average of both delays and cancellations.

Airline Revenue: For each market, total revenue is determined by multiplying the average single segment fare for that O/D pair by the total passengers flown in that quarter. Thus, revenue does not include any additional fees charged by the airline.

Airline Costs: For each market, we collect the reported operational costs (personnel, fuel, insurance, taxes, maintenance, and depreciation per flight hour) by aircraft type as reported to BTS. The operational costs reported to BTS do not include any additional costs that the airline might incur due to delays or cancellations. The costs reported to BTS are per flight hour. We therefore multiply the per hour cost by the average flight time as reported in the Aviation System Performance Metrics (ASPM), and then multiply that result by the number of flights of that type flown that quarter, as reported in the BTS database. (BTS, 2009)

Profitability: Operational profitability is defined as the difference between airline revenue and airline cost for a given market. When examining changes between periods, we calculate the percentage change in airline profit. (BTS, 2009)

Delay Costs: In addition, the operational cost of delay is estimated by using a model derived from the EuroControl 2004 study of airline delays. (Eurocontrol, 2004) For more on these calculations see the paper on a domestic delay cost model by Kara, et.al. (Kara, et. al., 2010) The model is additive with four components to the overall cost: fuel costs, crew costs, maintenance costs, and all other costs. The costs are segmented into short, medium, and long delays.

The BTS data was examined for the following timeframes:

- Airline On-Time Performance Data (Jan 05 – Dec 09)
- Air Carrier Financial: Schedule P-52 (1QTR05-3QTR09)
- Origin and Destination Survey : DB1BMarket (1QTR05-3QTR09)
- Air Carriers : T-100 Segment (Jan 05 – Dec 09)
- Aviation System Performance Metrics (ASPM) (Jan 05 – Dec 09)

The following additional metrics are used in the analysis to measure significant trends in airline behavior in response to economic and policy changes.

Average Flight Delay: Average flight delay is computed by dividing the total delay from delayed flights by the total number of flights.

Load Factor: Load factor is the ratio of passengers flown to the average seat capacity for each O/D pair studied, as reported to BTS.

3.2 Statistical Trend Analysis

The metrics were analyzed to determine statistically significant trends in longitudinal historic data. The analysis of significant trends was necessary to understand the different thresholds of significance for a variety of different factors. For example, a 1% reduction in aircraft size for the San Francisco airports from 2005 to 2007 was found to be significant, while a 34% increase in cancellations for the New York airports from 2005 to 2007 was found not to be significant.

The analysis of statistically significant trends for the New York and San Francisco airports required the following multi-step process:

1. The data was processed into the metrics of interest at the metroplex level.
2. The monthly data was tested for normality conditions using the Kolmogorov-Smirnov (K-S) test in Minitab. Since the data analyzed had seasonal trends embedded, most of the data sets examined failed the K-S test for normality. For such instances, non-parametric tests were applied. The Kolmogorov-Smirnov normality test was used to test for normality. When data sets were found to be normally distributed the Student's t-test was used.
3. The Wilcoxon Signed Rank test was used whether differences in two sets of data (either two related samples or repeated measurements on a single sample) were statistically significant. This test is a non-parametric test. Significant trends among metrics for the airports were examined.
4. Because very small trends can be found to be significant using the Wilcoxon Signed Rank test, trends were not considered significant unless greater than 2% in magnitude.
5. Trends that were found to be statistically significant were aggregated to determine general airline scheduling and pricing behavior relationships with the exogenous factors to the system.

3.3 Method for Regression Analysis of Trends

A stepwise regression was conducted on all of the metrics that were found to be statistically significant to determine the strength and sign of statistical correlations between the exogenous factors and airline scheduling and pricing behavior, and the impacts of these behaviors on airport congestion and airline profitability.

The analysis of statistically significant trends required the following multi-step process:

1. The data was processed into the metrics of interest at the airport and metroplex level.
2. A regional or metroplex level analysis was performed to identify the relationships between the exogenous factors and the resulting airline behavior.
3. Because of the confounding of intra-regional airport behavior, the trends were de-aggregated to the airport level to identify the significant relationships between the exogenous factors and the resulting airline scheduling and pricing behavior and the significant relationships between airline behavior and airline profitability and airport congestion.
4. First a correlation analysis of factors was done to identify the individual relationships between factors. The Pearson Product moment correlation coefficient was used to measure the degree of linear relationship between two variables. The correlation coefficient assumes a value between -1 and +1. If one variable tends to increase as the other decreases, the correlation coefficient is negative. Conversely, if the two variables tend to increase together the correlation coefficient is positive. For a two-tailed test of the correlation:
 $H_0: r = 0$ versus $H_1: r \neq 0$ where r is the correlation between a pair of variables.
5. Next a step-wise regression was performed to identify the factors that most impact the independent variable. Thus, stepwise regression adds variables sequentially, choosing the most significant variable first and continues until the adding of another variable degrades the relative R2 coefficient (i.e. the R2 adjusted for the number of independent terms in the regression equation).
6. Then these separate individual regression model results were aggregated to develop a picture of the statistically significant relationships between the exogenous factors, the airline scheduling and pricing behavior, and the impacts of these behaviors on airport congestion and airline profitability.

3.4 Scope

This paper describes two longitudinal studies. The first study is a statistical analysis of trends for the New York and San Francisco airports from 2005 to 2008 to identify statistically significant trends.

The second study is a regression analysis of trends from 2005 through 2009 that evaluates airlines' business and operational behaviors in response to economic and policy changes to the New York, Philadelphia and San Francisco airports. This analysis established how airline behavior is affected by three specific impulses: tightened slot controls, changes in hedged fuel prices, and national economic conditions. When any of these three factors were varied historically, the airlines' responses, in terms of changes to their schedules, to ticket prices, to domestic markets served and to aircraft size chosen for a given market, were examined.

In addition, the effect on changes to an airlines' profitability was measured, as was the overall usage/congestion of the airspace as measured by amount of delay and cancellations.

3.5 Design of Experiment

A partial “Design of Experiment” is illustrated in Table 3. This analysis examined airline schedule behavior by tracking (a) aircraft size, (b) flights per day, (c) daily domestic markets served and (d) average load factors. It also tracks airline (e) average ticket airfare on departures and arrivals. The impacts of these behaviors are examined by tracking (f) airport congestion and (g) profitability of the airports. The trends in these metrics are measured from summer to summer to capture the impacts from changes in hedged fuel prices, economy (as measured by national gross domestic product) and capacity limits.

		Hedged fuel prices		
		Up	Constant	Down
Economy	Up	2005-2006	2006-2007	
	Constant	2007-2008		
	Down			2008-2009 Airport capacity limits introduced at EWR, LGA, JFK

Table 3 Historic partial “Design of Experiment”

The effects of new and adjusted capacity limits placed on the NY airports in 2008 can be seen in the summer 2008 to summer 2009 trends (see Table 4). These trends were calculated by taking the weighted average change from January to September data to the next years January to September data for each respective metric. This methodology eliminates seasonality from the trends and captures the greatest fluctuation in hedged fuel prices as they peaked in third quarter 2008. At the time of this analysis the fourth quarter 2009 data was unavailable.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		

Table 4 Historic partial “Design of Experiment”

4 Results

This section describes the results of the analyses. Section 4.1 describes the results of the statistical trend analysis; section 4.2 describes the relationship between parameters from the regression analysis.

4.1 Statistical Trend Analysis Results (2005-2008) (NY, SF)

Airline schedule behavior can be observed by examining the trends in geographic access, economic access, and airline profitability.

The annual changes, 2005-2007 and 2007-2008, for the New York and San Francisco Metroplexes were tested for significance at the 95% level (Ferguson, et. al., 2009a; 2009b). Since most of the data, measured as monthly observations, did not pass the Kolmogorov-Smirnov test assumption of normally-distributed data, the Wilcoxon Sign Rank Test (a non-parametric test) was used to test these trends for significance. A summary of the results of this analysis are shown in Table 5.

Fuel Prices	Slot Controls	Market	**Economic	Flight Performance
+57% 2005-2007	Yes – LGA No – EWR, JFK	Markets reduced 3%	Operating Cost increased 20%	*Flight Delays increased 39%
		*Aircraft Size reduced 3%	Airfare increased 8%	*Average Delay increased 48%
		*Flights/ Day increased 4%	Revenue increased 22%	Cancellations increased 34%
				*Load Factors increased 3%
	No – SFO, SJC, OAK	*Markets increased 4%	Operating Cost increased 9%	*Flight Delays increased 30%
		*Aircraft Size reduced 1%	Airfare increased 10%	*Average Delay increased 29%
		*Flights/ Day increased 4%	Revenue increased 15%	*Cancellations increased 47%
				Load Factors remained the same
+70% 2007-2008	Yes – LGA, EWR, JFK	Markets reduced 2%	Operating Cost increased 24%	*Flight Delays decreased 18%
		Aircraft Size increased 1%	Airfare increased 7%	*Average Delay decreased 14%
		*Flights/ Day decreased 6%	Revenue increased 5%	*Cancellations decreased 18%
				*Load Factors decreased 3%
	No – SFO, SJC, OAK	Markets remained the same	Operating Cost increased 28%	Flight Delays decreased 7%
		Aircraft Size remained the same	Airfare increased 2%	Average Delay increased 9%
		*Flights/ Day decreased 5%	Revenue increased 3%	Cancellations increased 6%
				*Load Factors decreased 3%

* 95% Statistically Significant w/ Wilcoxon Sign Rank Test

** Too few data points for statistical tests

Table 5 Summary of statistical trend analysis for the New York and San Francisco Metroplexes

The results indicate that slot controlled airports yielded improved throughput performance (i.e. flight delays and cancelled flights) through reductions in frequency and de-peaking schedules. Even in the presence of fluctuations in passenger demand and economic shocks, passengers saw an improvement in service (i.e. a decrease in delays and cancellations) without any significant loss in markets served or frequency to those markets.

4.1.1 Domestic markets Served

There was little change to the number of domestic markets served by the New York and San Francisco Metroplex airports since January 2005. Although New York serves over 100 markets, the number of markets served by at least 60 flights per month (i.e. having at least one arrival and departure daily) is approximately 70. Similarly, the number of San Francisco markets served by at least 60 flights per month is approximately 50.

The number of domestic markets served by one, two or three of the metroplex airports remains unchanged from 2005 through 2008 for San Francisco; however this is not the case for New York as seen in Figure 5. The analysis shows a sharp decrease in markets served by two or more airports in the New York Metroplex starting in the spring of 2008, when fuel costs were high.

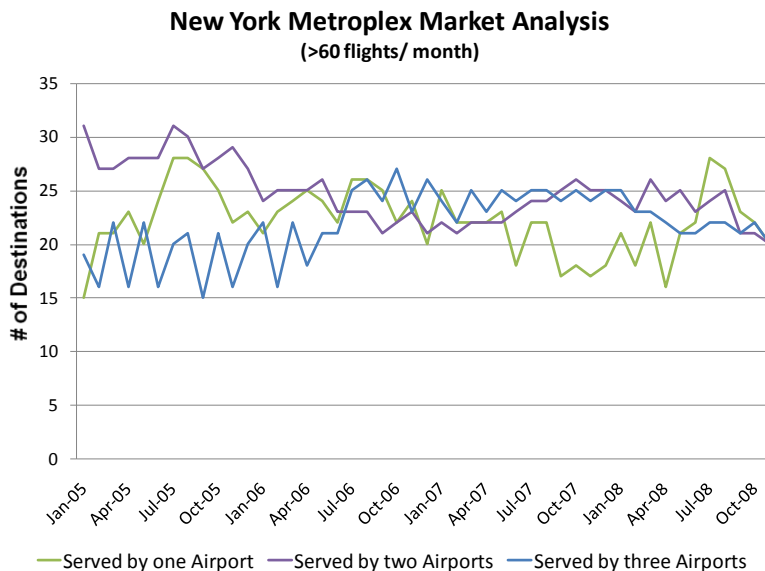


Figure 5 Number of Destinations served with daily service from either one, two or three airports in the NY Metroplex

4.1.2 Flights per day

There was a 4% increase of flights to the New York Metroplex from 2005 to 2007 and a 6% decrease in flights from 2007 to 2008, bringing the number of flights per day in 2008 to 3% less than the 2005 levels. There was a 5% increase of flights to the San Francisco Metroplex from 2005 to 2007 and a 4% decrease in flights from 2007 to 2008, bringing the number of flights per day in 2008 back to the 2005 levels.

The increase in fuel costs and the downturn in the economy influenced the decision of airlines to reduce their schedules in 2008. This is observed in the reductions in scheduled flights for both the New York and San Francisco airports.

The imposition of slot controls by Department of Transportation (DOT) in 2008 clearly contributes to the reductions in scheduled flights in 2008 for the New York Metroplex. Close examination of the changes in hourly operations show that the change to airline schedules exactly match the regulations set by DOT. The significant fluctuations in fuel costs did not change airline schedules as suggested by earlier

arguments against market based management of airline operations. These arguments against market based management of airline operations included:

- Small domestic markets would stop being served
- Airfares would be increased
- Airline profits would go down

Although the number of flights per day remained relatively constant, seasonality trends exist for the New York major domestic markets (see Figure 6). More flights are observed to Miami in the colder months and more flights to overseas locations in the summer. This seasonality was not observed for the San Francisco major markets, see Figure 7.

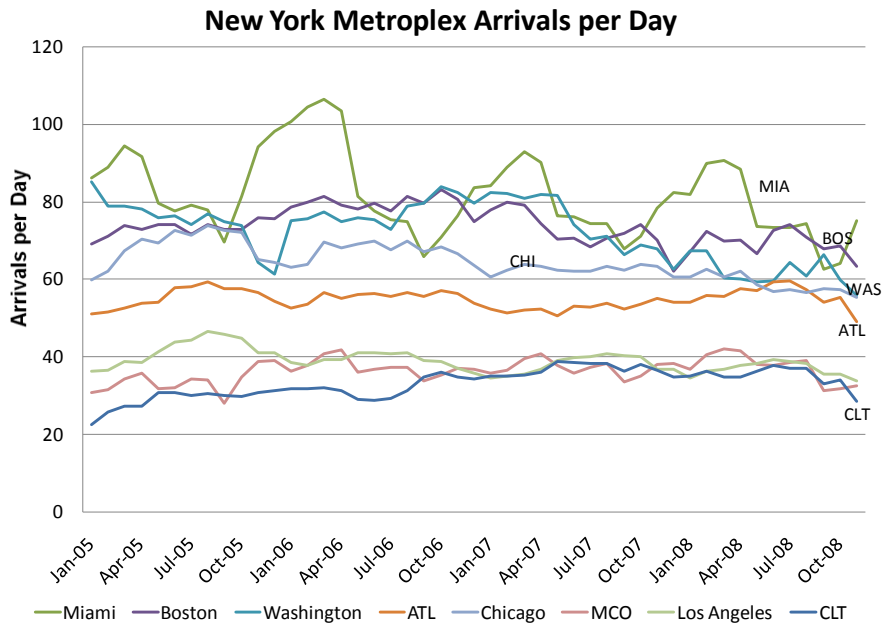


Figure 6 NY Metroplex Arrivals per Day

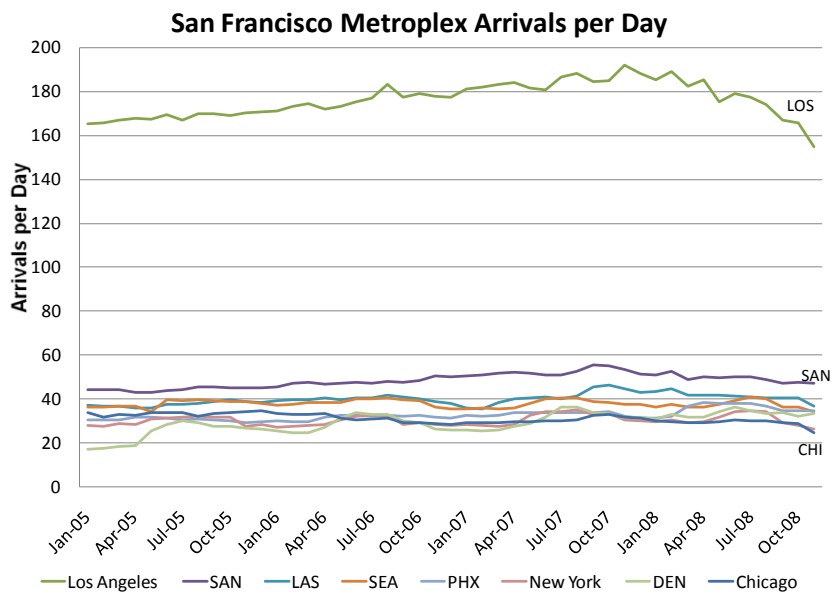


Figure 7 SF Metroplex Arrivals per Day

Two other changes in the markets served during this period were: (a) a drop of 25 arrivals per day from the Washington D.C. metroplex to EWR, and (b) a reduction in the number of arrivals per day at EWR and LGA from the Chicago Metroplex.

4.1.3 Aircraft Size

Two important events occurred in 2008: capacity limits were imposed at the New York airports and hedged fuel prices increased. Either of these events might have triggered a reduction in frequency coupled with an up-gauging to larger, more efficient aircraft since such actions can improve an airline's profitability. However, the data does not show any significant overall up-gauging in aircraft (see Figures 8 and 9). The analysis does indicate that on average, the aircraft size used to service shuttle markets (NY-BOS, NY-WAS, SF-LOS, and SF-SAN) has increased, but is still significantly smaller than aircraft used to service other metroplexes. A slight down-sizing in seat sizes to other locales has kept the average aircraft size constant over time with little seasonal differences.

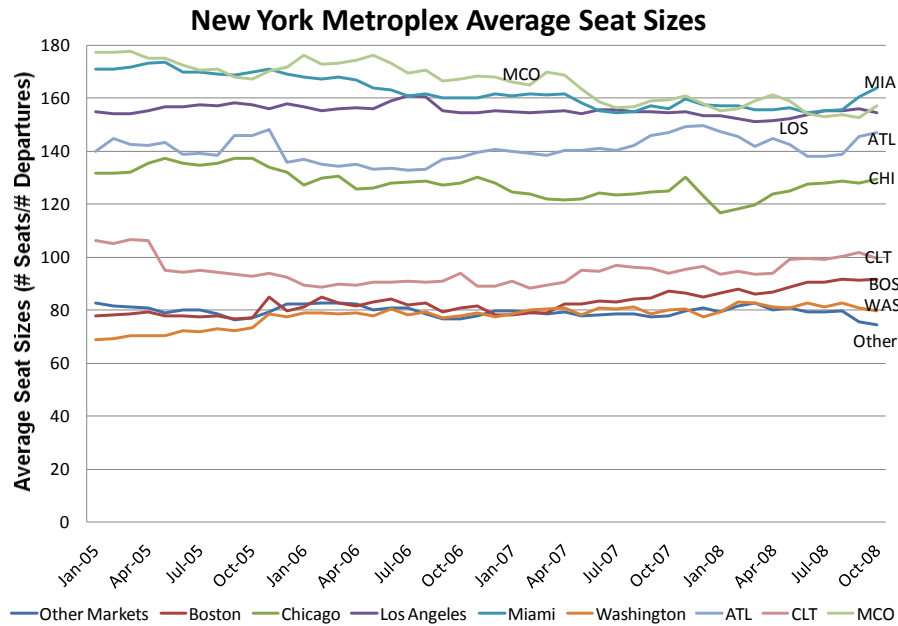


Figure 8 NY Metroplex Average Aircraft Size

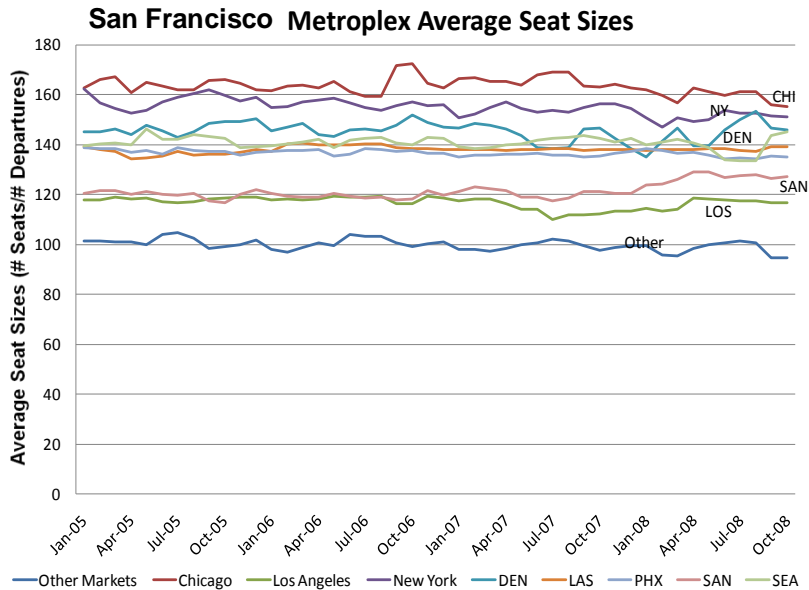


Figure 9 SF Metroplex Average Aircraft Size

4.1.3 Airline Profitability

To better understand the economic impact of increased hedged fuel prices, slot controls and/or congestion, ticket prices over time at both the New York and the San Francisco airports were examined. This study examines the airline profitability for the New York and San Francisco airports as a whole, on shuttle service markets, on major hubs, and on long haul markets. Finally the estimated revenue generated by flights to a variety of locations is graphed.

4.1.3.1 Airline Costs – The airline costs per flight hour were analyzed beginning with data from the first quarter (1Q) of 2005, and reflect the changes to hedged fuel prices, but show no seasonality. While personnel, training, maintenance, and depreciation costs have remained level, the fuel costs have increased 166% since first quarter 2005. The air carriers have experienced over 70% of this increase fuel since the first quarter 2007. Thus, the only significant variability in airline costs over this period is fuel costs.

When applying these cost factors to operations at the New York and San Francisco Metroplexes the analysis shows a 49% and 39% increases in costs, respectively. The estimated operating cost for flights into and out of the New York and San Francisco Metroplexes since 1Q 2005 shows seasonality (see Figure 10).

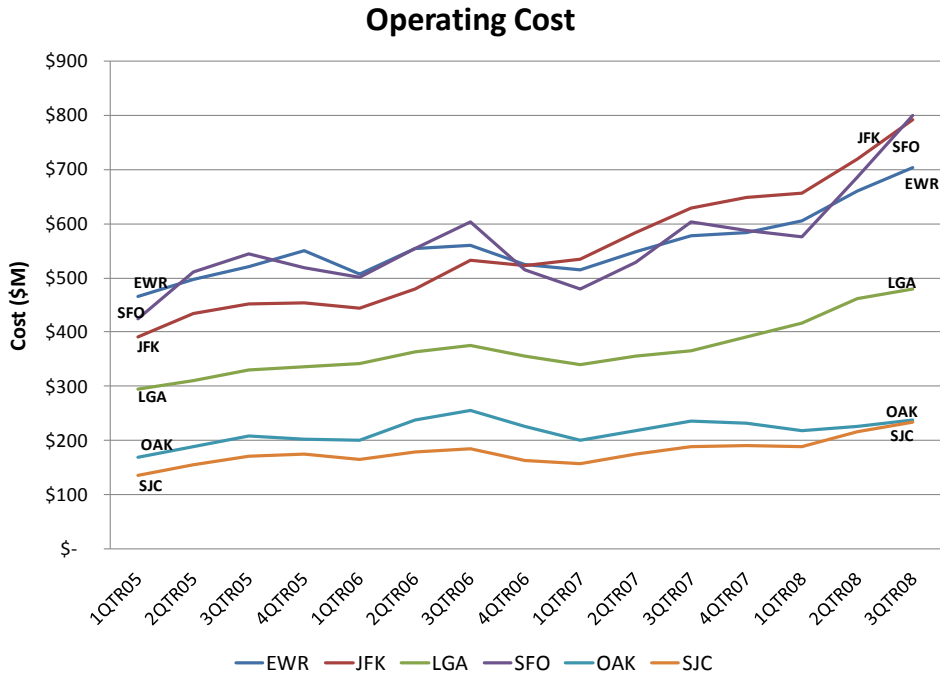


Figure 10 NY & SF Metroplex Cost

4.1.3.2 Airfare – The average airfares paid by passengers since 1Q 2005 reflect the changes to hedged fuel prices and show no seasonality (see Figure 11). This analysis showed that the average airfare for the New York and San Francisco Metroplexes increased 15% and 12% respectively in this timeframe.

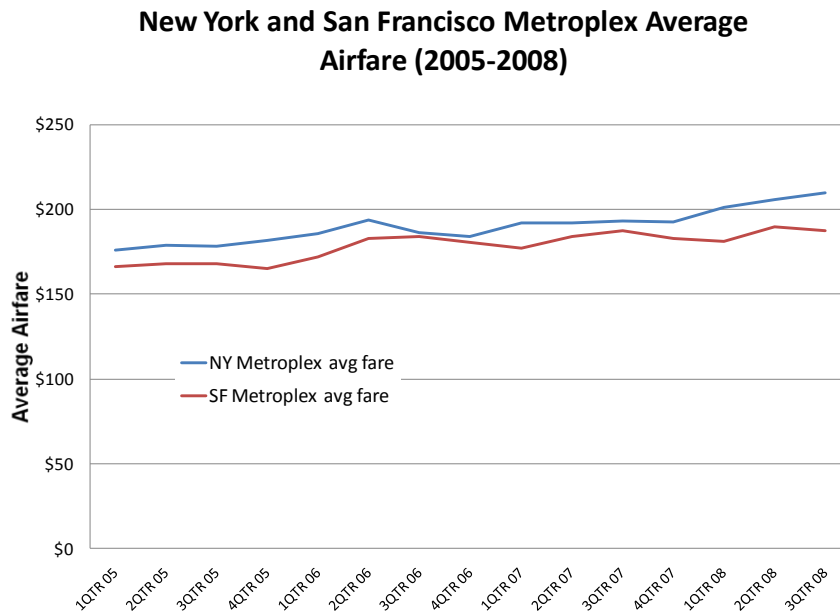


Figure 11 NY & SF Metroplex Average Airfare

4.1.3.3 Airline Revenue – The estimated revenue generated by flights into and out of the New York and San Francisco Metroplexes since 1Q 2005 shows seasonality similar to the trends seen in airline costs

(Figure 12). The analysis shows that airlines have compensated for the increased operational costs. Even without the additional revenue generated from new fees for fuel, baggage, food, blankets, movies and other similar charges, the airlines have increased revenue 28% from 2005 through 2008 in New York and 18% in San Francisco.

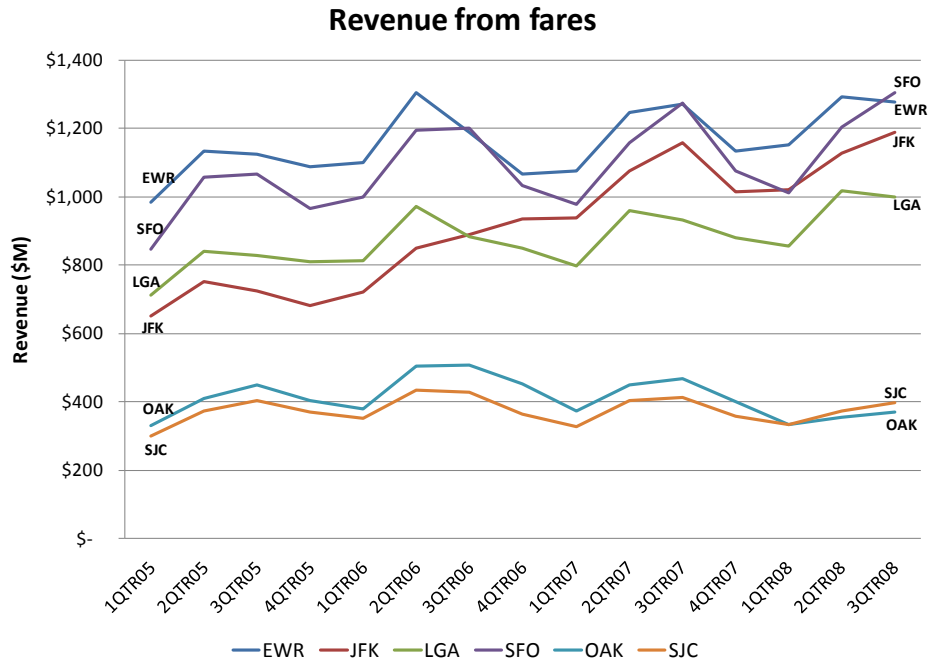


Figure 12 NY & SF Metroplex Revenue from Fares

When evaluating the average annual revenue realized by different-sized aircraft serving the New York and San Francisco Metroplexes, the airlines’ revenues are derived primarily from aircraft in the 113-187 seat ranges (see Figures 13 and 14). However in New York 14% of the revenue is generated from aircraft with seats ranging from 38-62, which is not the case for San Francisco.

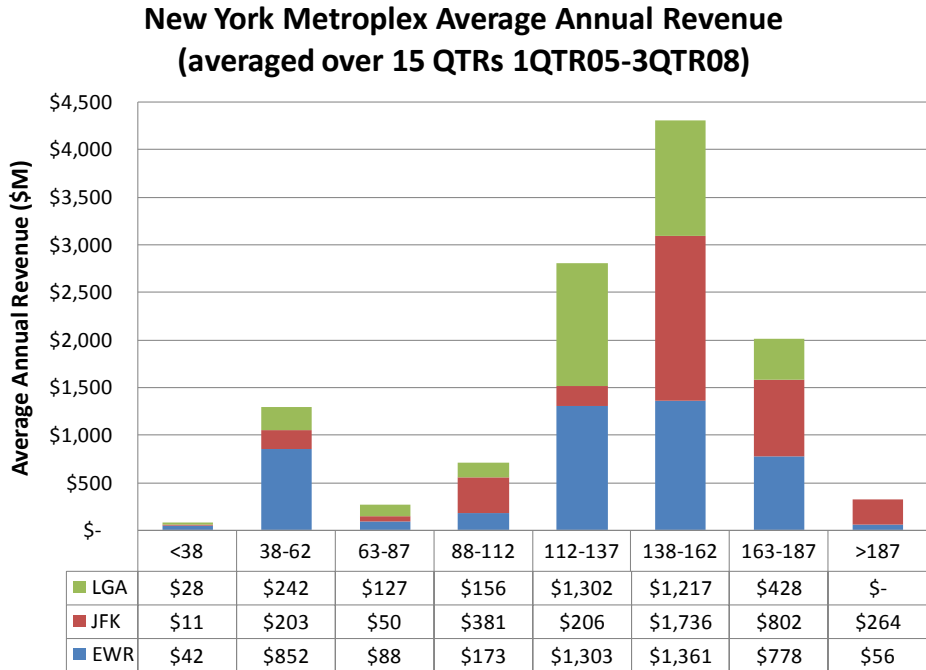


Figure 13 NY Average annual revenue by aircraft size

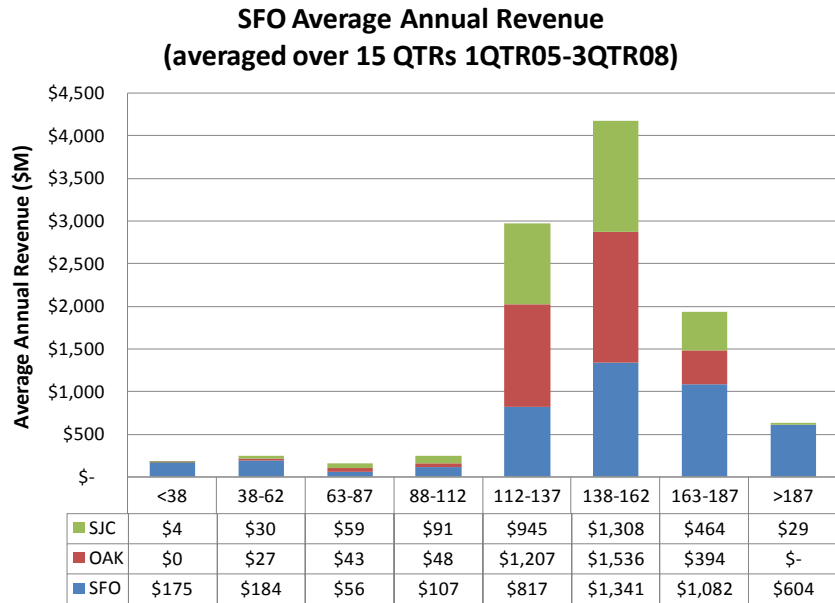


Figure 14 SF Average annual revenue by aircraft size

4.1.3.4 Flight Performance – From 2005 to 2007 the reduced aircraft size combined with an increase in arrivals per day increased load factors, delays and cancellations for the New York and San Francisco Metroplexes (see Table 6). However, analysis of the New York Metroplex shows a reversal in this trend in 2008, with airlines reducing the number of flights (-6%) and increasing aircraft size (1%). As a result from airline schedule changes (-6% flights per day) from 2007 to 2008 the New York Metroplex showed significant reductions in the number of flights delayed (-18%), the average amount of time flights were delayed (-14%), the number of flight cancellations (-18%), and overall passenger trip delay (-16%) from both cancellations and delayed flights.

Metric	% Change 2005 to 2007		% Change 2007 to 2008		% Change 2005 to 2008	
	NY	SF	NY	SF	NY	SF
Fuel Prices	57%	57%	70%	70%	166%	166%
Markets	-3%	4%	-2%	0%	-4%	4%
Operating Cost	20%	9%	24%	28%	49%	39%
Revenue	22%	15%	5%	3%	28%	18%
Average Fare	8%	10%	7%	2%	15%	12%
Aircraft Size	-3%	-1%	1%	0%	-2%	-1%
Arrivals per Day	4%	4%	-6%	-5%	-3%	0%
Load Factors	3%	0%	-3%	-3%	1%	-3%
# of Flight Delays	39%	30%	-18%	-7%	14%	21%
Average Flight Delay	48%	29%	-14%	9%	27%	41%
Flight Cancellations	34%	47%	-18%	6%	10%	55%
Passenger Delay	66%	61%	-16%	1%	39%	63%

Table 6 Longitudinal Changes in Metrics

In contrast, from 2007 to 2008, the San Francisco Metroplex reduced flights (-5%) and showed reduced flight delays (-7%), increased average flight delay (9%), increased flight cancellations (6%), and increased overall passenger delays (1%). The fact that DOT imposed slot controls at all three NY Metroplex airports probably contributes to this contrast in system behavior.

Overall from 2005 to 2008 there were significant increases in the number of flights delayed, average amount of time flights were delayed, the number of flight cancellations, and in the delay incurred by the passenger from both cancellations and delayed flights.

4.2 Regression Analysis of Trends (2005-2009) (NY, SF, PHL)

This analysis compares the behavior of the air transportation system (e.g. markets served, airfares, delays, load factors, aircraft size) during the recent run-up in hedged fuel prices at capacity-limited New York airports and non-slot controlled San Francisco and Philadelphia airports (Ferguson, et. al., 2010).

The results indicate:

- i. Airfares change in proportion to changes in hedged fuel prices and gross domestic product
- ii. Flights per day and domestic markets served change in proportion to changes in gross domestic product
- iii. Flights per day and domestic markets served change in proportion to changes in airport capacity limits

- iv. Delays and cancellations change in proportion to flights per day and domestic markets served and negatively proportional to aircraft size
- v. Airline profitability changes negatively proportional to aircraft size, airfares and domestic markets served

This study expands on prior efforts to analyze the behavior of airlines at congested airports. It compares the performance at the New York airports to the performance at the Philadelphia and San Francisco airports from 2005 through 2009. During this time period, there were significant fluctuations in hedged fuel prices and in the overall economic condition of the country. In addition, tighter regulations on the scheduling of flights at the three New York airports were imposed.

The results indicate that capacity limited airports yielded reduced congestion (i.e. fewer delayed and cancelled flights) through reductions in schedules and de-peaking schedules. There was no significant change in domestic markets served. While airfares were affected by changes in hedged fuel prices, they did not significantly increase at New York airports after capacity limits were applied.

San Francisco and Philadelphia airports reduced schedules during the economic downturn. Congestion was reduced due to these reductions in schedule. The overall conclusions are shown in Table 7.

	Annual Changes			Observations			
	Caps	Economy	Fuel Prices	Airfare	Schedule	Congestion	Profit
05-06	Yes	Up	Up	Up	No Δ	Up	Down
05-06	No	Up	Up	Up	Up	Up	Down
06-07	Yes	Up	No Δ	No Δ	No Δ	Up	Down
06-07	No	Up	No Δ	No Δ	Up	Up	No Δ
07-08	Yes	Constant	Up	Up	No Δ	No Δ	Down
07-08	No	Constant	Up	Up	Down	Down	Down
08-09	Reduced	Down	Down	Down	2xDown	2xDown	Up
08-09	No	Down	Down	Down	Down	Down	Up

Table 7 Economic and Policy Impacts

The key observations from this analysis are as follows (Table 7):

- Airfares increase when hedged fuel prices increase and when the gross domestic product decreases.
- Flights per day and domestic markets served decrease when gross domestic product decreases.
- Flights per day and domestic markets served decline when airport capacity limits are imposed.
- Delays and cancellations decrease as flights per day and domestic markets served are decreased; delays and cancellations increase as aircraft size is decreased.
- Airline profitability decreases as aircraft size, airfares or domestic markets served increases.
- Up-gauging of airline fleets is unlikely to occur without the introduction and purchase of a new class of aircraft that has better efficiency for aircraft carrying between 100-150 passengers. Currently, the aircraft stock in the 100-120 seat size is the oldest and least fuel-efficient portion of the fleet.
- With the imposition of slot controls in 2008, LGA and EWR reduced schedules while JFK was capable of keeping the same number of flights as were flown prior to the imposition of slot controls. Because of a peaked schedule at JFK, there was opportunity to move flights from peak times to off-peak times rather than having to remove the flights. LGA and EWR were at capacity

at virtually all times and so had to remove flights from the schedule in order to adhere to the new regulations.

- In 2008, the airlines were less profitable. Even though delays and the resultant cost of delays were reduced, the increase in fuel costs was considerably greater. Thus, overall, airlines’ operational costs increased in 2008. These costs were greater than the increase in ticket prices.
- Airports with capacity limits reduced operations and congestion. Airlines’ profitability at these airports (as measured by operational revenue minus operational costs) increased.

The analysis showed a positive correlation between:

- airfare and hedged fuel prices
- Gross Domestic Product and airline schedule
- capacity limits and airline schedule
- airline schedule and airport congestion

A negative correlation was found between:

- airfare and airport profitability
- airport congestion and airport profitability.

The analysis showed no significant change in load factors, or aircraft size.

4.2.1 Geographic Access

4.2.1.1 Domestic markets Served

The results of an analysis of the domestic markets served by the three metroplexes (NY, SF, and Philadelphia) are shown in Table 8. When the economy was expanding (2005-2007) the number of markets served by each metroplex (except Philadelphia) remained unchanged. Philadelphia saw a contraction in service due to the bankruptcy and reorganization of USAirways.

When the economy began its slide into recession in the 2008-2009 time period, the number of domestic markets serving these metroplexes decreased; hedged fuel prices did not have any impact on the markets they served.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Markets Served	No Δ	-10%	No Δ	No Δ	No Δ	No Δ	No Δ	No Δ	No Δ	-7%	No Δ	-6%

Table 8 Analysis of the domestic markets served by the three metroplexes (NY, SF, and Philadelphia).

The results of an analysis of the domestic markets served by the airports at each of the Metroplexes (NY, SF, and Philadelphia) are shown in Table 9. These results show a more nuanced view of the dynamics.

Examination of the individual airports shows that domestic markets served tracked well with changes in the national economy and the introduction of new or reduced capacity limits. During an expanding economy (2005-2007), the number of markets served increased. When the economy was contracting (2008-2009), the number of markets served decreased. At the New York airports, the reduction in markets served was twice that at the San Francisco airports. The effect of the capacity limits at the New York Metroplex airports contributed to this trend.

The effect of airport capacity limits is observed at LGA and EWR. These airports are congested throughout the day. To meet the capacity limits, airlines serving these airports must reduce the number of domestic markets served. Markets served at JFK were not impacted by the capacity limits. The morning and evening peaks were rescheduled and the midday uncongested period increased.

Historical Changes		Longitudi	
Fuel Prices	Economy	Airport	Markets
21% 2005-2006	2.7%	LGA	-3%
		EWR	no change
		JFK	no change
		PHL	-10%
		SFO	8%
1% 2006-2007	2.1%	LGA	no change
		EWR	no change
		JFK	8%
		PHL	no change
		SFO	no change
72% 2007-2008	0.4%	LGA	-4%
		EWR	4%
		JFK	no change
		PHL	no change
		SFO	no change
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	-10%
		EWR*	-12%
		JFK*	no change
		PHL	-6%
		SFO	-8%

Table 9 Analysis of the domestic markets served by the five congested airports.

The total number of domestic markets served by the individual metroplex airports is shown in Figure 15. The reduction in markets served by the airlines at EWR and LGA are highly correlated with the reduction in capacity limits applied in 2008.

The markets served by airlines at SFO & JFK increases during the period 2005 – 2009.

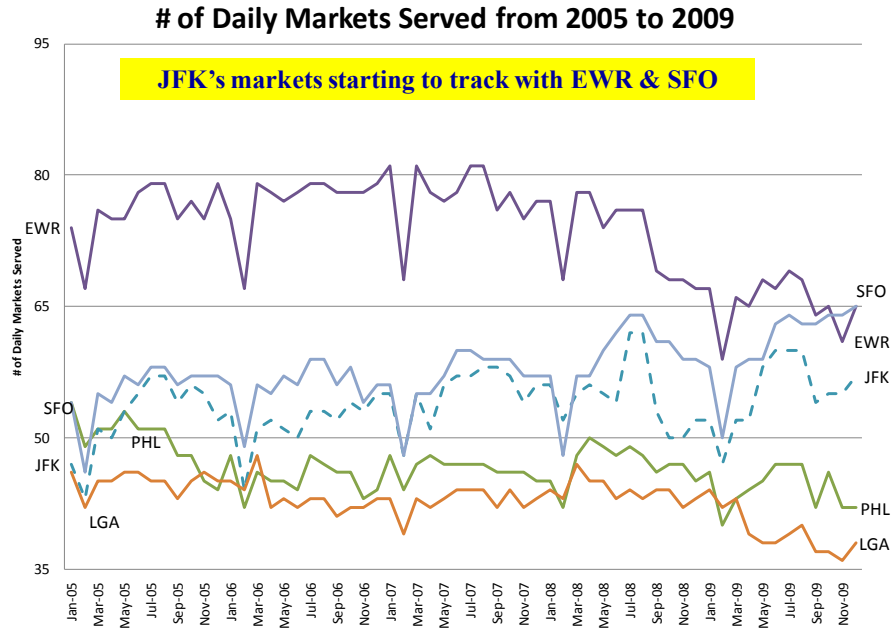


Figure 15 Longitudinal analysis of the domestic markets served by the five congested airports.

The results of a linear regression for domestic markets served for each of the five airports over a period of 4 years provides insights into the correlations between the variables and the significant factors that influence airline decisions on markets served (Table 10).

		Fuel Prices	GDP	Caps
Markets	Pearson correlation	0.44	0.539	-0.452
	P-Value	0.052	0.014	0.046

Table 10 Airport correlation of significant factors that influence airline decisions on domestic markets served

The closer the Pearson correlation coefficient is to +1 or -1 the greater the positive or negative correlation (or relationship) is between the factors.

A P-value of .05 or less means that there is 95% confidence in the statistical correlation.

The analysis shows positive correlation between domestic markets served, the Gross Domestic Product (GDP) and airport capacity limits.

A stepwise regression analysis of the dependent variable percent change in domestic markets served versus percent change in hedged fuel prices, national gross domestic product and capacity limits identified the change in Markets to be a function of changes in national Gross Domestic Product (GDP). This relationship was found to be positive. The correlation accounted for 25.2% (i.e. R-squared) of the observed variation in markets served. The remaining effects are inter-airline competition, changes in airline business models, and airline restructuring when emerging from bankruptcy. The effect of capacity

limits was ambiguous due to the small number of data points reflecting this change. The regression model found for changes in domestic markets is as follows:

$$\Delta \text{Domestic markets} = -0.0266 + 1.44 \Delta \text{GDP}$$

4.2.1.2 Scheduled Flights per Day

The results of an analysis of the scheduled flights per day at the three metroplexes (NY, SF, and Philadelphia) are shown in Table 11. When the economy was expanding (2005-2007) the number of flights per day at the metroplexes remained relatively unchanged. One exception was Philadelphia which saw a contraction in service due to the bankruptcy and reorganization of USAirways. When the economy started shrinking (2009), the number of flights per day at the metroplexes decreased. Hedged fuel prices did not have any impact on flights per day at the metroplex.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change (LGA caps, others no caps)			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Scheduled Flights per Day	No Δ	-16%	+3%	+3%	-4%	No Δ	-5%	-4%	-3%	-11%	-7%	-11%

Table 11 Analysis of the scheduled flights per day at the three metroplexes (NY, SF, and Philadelphia).

The results of an analysis of the flights per day at the individual airports for each of the metroplexes (NY, SF, and Philadelphia) are shown in Table 12. These results show a more nuanced view of the dynamics.

Examination of the individual airports shows that flights per day tracked well with changes in the national economy and the introduction of new or reduced capacity limits. During an expanding economy (2005-2007), the number of flights per day increased. When the economy was contracting (2008-2009), the number of flights per day decreased. At the New York airports, the reduction in flights per day was twice that of the San Francisco airports. The effect of the capacity limits at the New York metroplex airports contributed to this trend.

The effect of airport capacity limits is observed at LGA and EWR. These airports are congested throughout the day. To meet the capacity limits, airlines serving these airports are required to reduce the number of flights per day. Flights per day at JFK were not impacted by the capacity limits. The morning and evening peaks were rescheduled and the midday uncongested period increased.

Historical Changes		Longitudinal	
Fuel Prices	Economy	Airport	Flights/ Day
21% 2005-2006	2.7%	LGA	no change
		EWR	no change
		JFK	4%
		PHL	-16%
		SFO	3%
1% 2006-2007	2.1%	LGA	-3%
		EWR	no change
		JFK	20%
		PHL	-4%
		SFO	4%
72% 2007-2008	0.4%	LGA	no change
		EWR	-8%
		JFK	-5%
		PHL	-4%
		SFO	4%
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	-16%
		EWR*	-16%
		JFK*	no change
		PHL	-7%
		SFO	-4%

Table 12 Analysis of the scheduled flights per day at the five congested airports.

The total number of departures per day by the individual metroplex airports is shown in Figure 16. The reduction in departures per day at EWR and LGA are highly correlated with the reduction in capacity limits applied in 2008 at LGA and new capacity limits applied at EWR in 2008. The departures per day at SFO & JFK increased during the period 2005 – 2009.

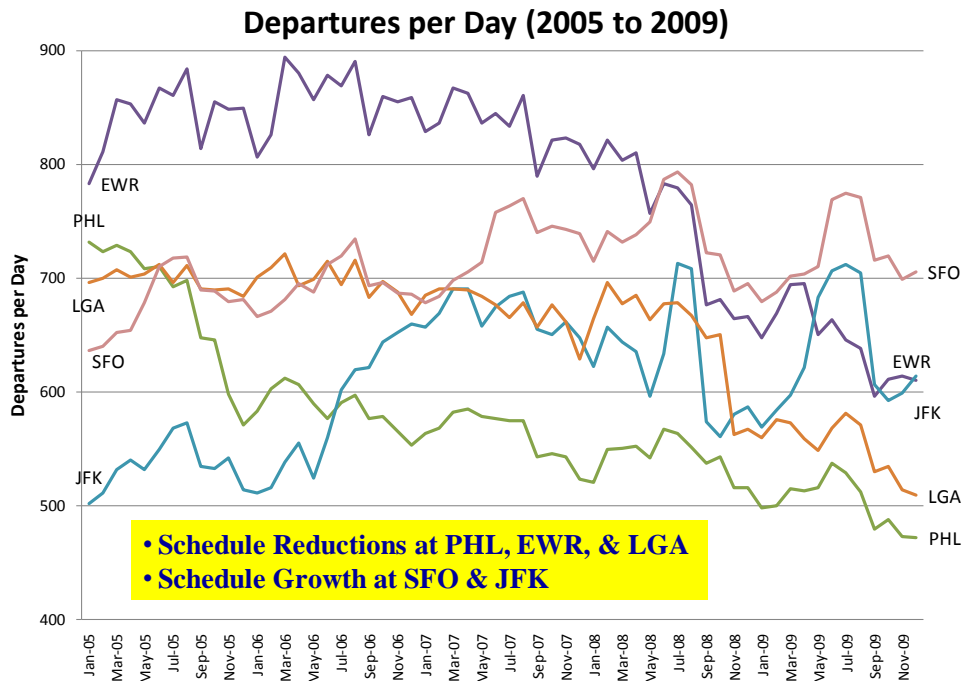


Figure 16 Longitudinal analysis of the scheduled flights per day at the five congested airports.

The results of a linear regression for scheduled flights per day at the airports at each of the five airports over four years provides insights into the correlations between the variables and the significant factors that influence airline decisions on scheduled flights per day (Table 13).

		Fuel Prices	GDP	Caps
Flights/ Day	Pearson correlation	0.214	0.447	-0.43
	P-Value	0.364	0.048	0.058

Table 13 Airport correlation of significant factors that influence airline decisions on scheduled flights per day

The analysis shows correlation between scheduled flights per day, the Gross Domestic Product (GDP) and airport capacity limits. The analysis showed no correlation between hedged fuel prices and scheduled flights per day.

A stepwise regression analysis of the dependent variable percent change in flights per day versus percent change in hedged fuel prices, national gross domestic product and capacity limits identified the change in scheduled flights per day to be a positive correlation to changes in national Gross Domestic Product (GDP). The correlation accounted for 15.6% (i.e. R-squared) of the observed variation in markets served. The remaining effects are inter-airline competition, changes in airline business models, and airline restructuring when emerging from bankruptcy. The effect of capacity limits was ambiguous due to the small number of data-points reflecting this change. The regression model found for changes in flights per day to all markets is as follows:

$$\Delta \text{Flights/ Day} = - 0.0368 + 1.83 \Delta \text{GDP}$$

4.2.1.3 Airport Level Schedule Analysis

This section describes the details of the schedule profiles at the airports, providing insights into the dynamics of the hourly schedules.

Figure 17 shows that even with a 2.0% drop in the economy from 2007 to 2009, airlines increased their operations at SFO. There were 44 additional daily flights added by the airlines at SFO. This included an increase of 10 operations for the 7am hour, 12 operations for the 11am hour, and 7 operations for the 1pm hour; a decrease of 6 operations for the 4pm and 5pm hours, and increases of 10 operations for the 7pm hour, and 7 operations for the 10pm hour. The results of these changes left the airlines with a more peaked schedule.

Figure 18 shows that even with a 4.8% increase in the economy from 2005 to 2007, airlines decreased their Operations at PHL. There were 94 fewer daily flights scheduled by the airlines at PHL. This included increases of 9 operations for the 8am, 9am and 10am hours, decreases of 11 operations for the 11am hour, and 18 operations for the 12pm hours, an increase of 13 operations for the 1pm hour, and decreases of 12 operations for the 5pm hour, 7 operations for the 6pm hour, and 14 operations for the 9pm hour. The results of these changes left the airlines with a reduced schedule.

SFO 3QTR Schedule Adjustments 2007-2009

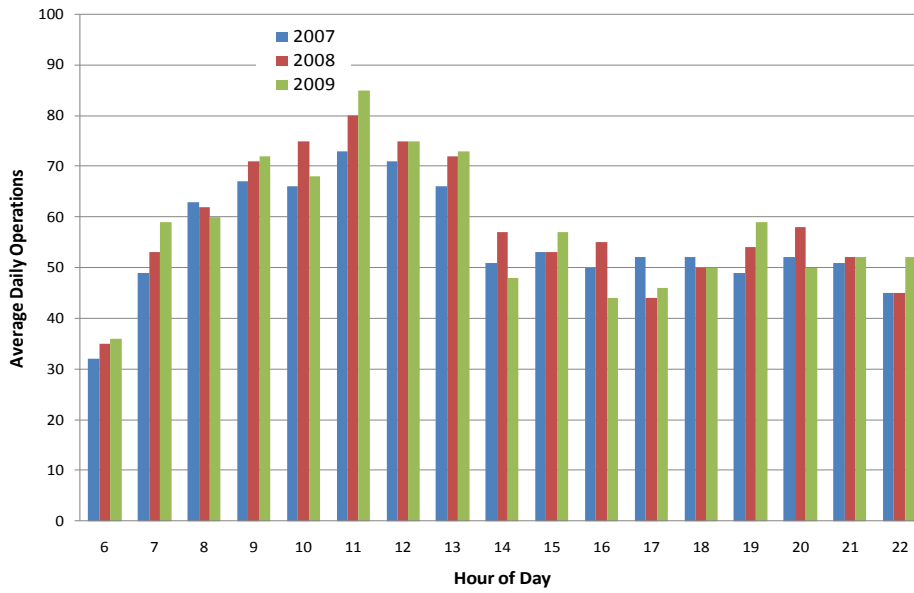


Figure 17 SFO Schedule Adjustments 2007-2009 by time of day

PHL 3QTR Schedule Adjustments 2005-2007

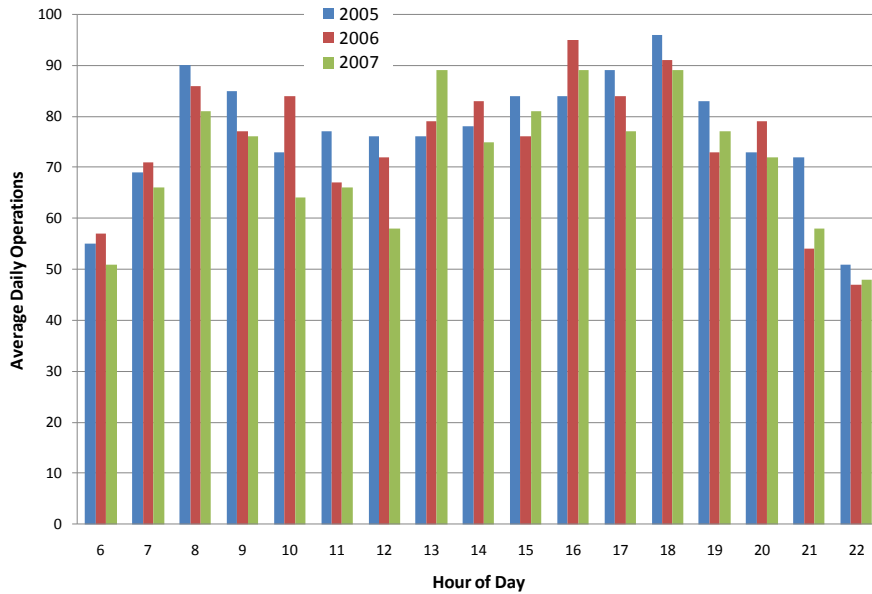


Figure 18 PHL Schedule Adjustments 2005-2007 by time of day

Figures 19-21 highlight how the NY airports reacted to new capacity limits in 2008. The airlines operating out of LGA and EWR reduced operations (since de-peaking was not an option), while the airlines operating at JFK de-peaked and maintained schedule. Specifically airlines operating out of JFK moved flights from the 8am, 4pm and 6pm hours to the 1pm, 2pm and 10pm hours as shown in the chart below.

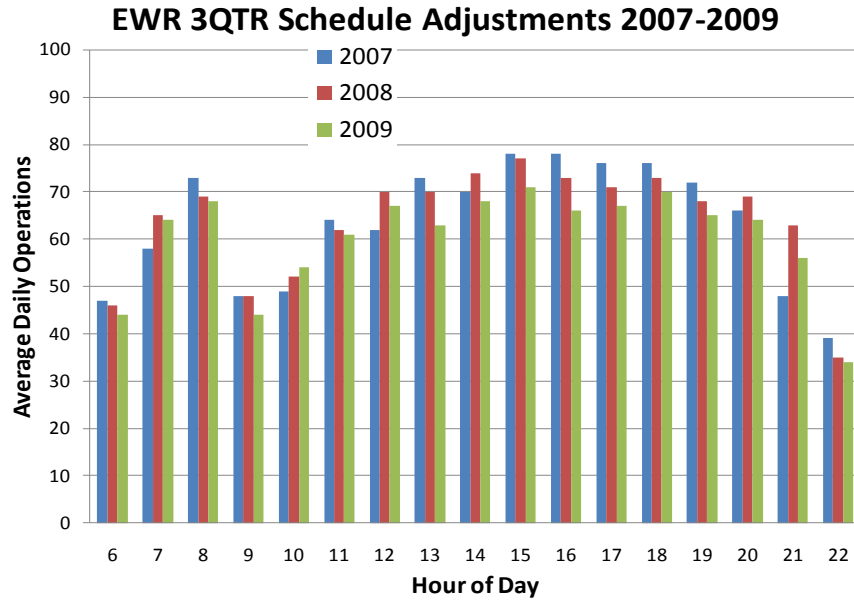


Figure 19 EWR Schedule Adjustments 2007-2009 by time of day

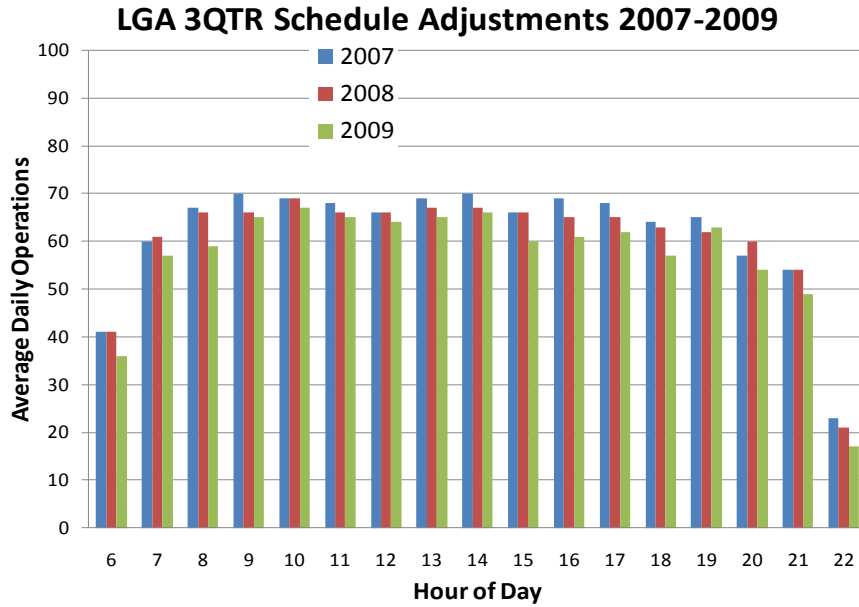


Figure 20 LGA Schedule Adjustments 2007-2009 by time of day

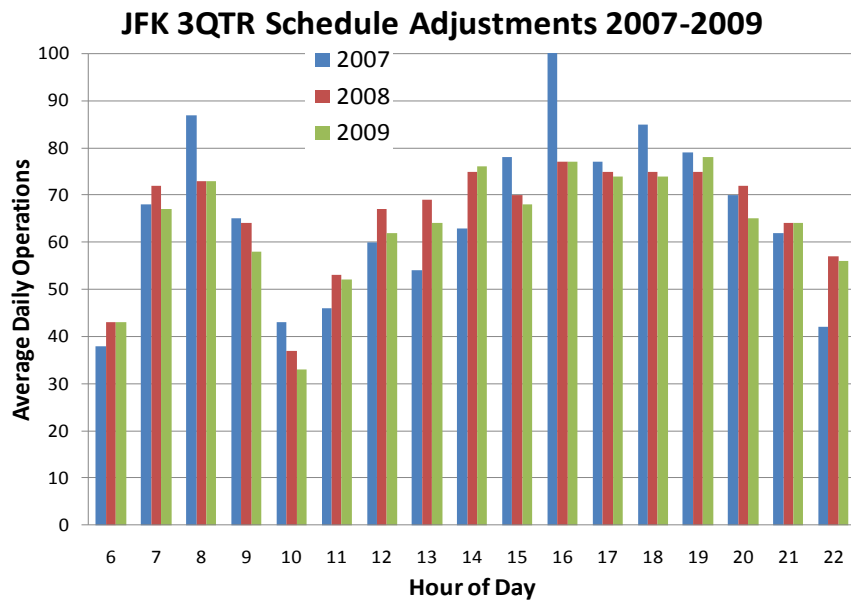


Figure 21 JFK Schedule Adjustments 2007-2009 by time of day

4.2.1.4 Aircraft Size

The results of an analysis of the average aircraft size at the Metroplex (NY, SF, and Philadelphia) are shown in Table 14. The average size of aircraft used did not significantly change throughout this study with the exception of JFK (2007), SFO (2006/2009) and PHL (2006). In 2006-2007 Delta Airlines started using JFK as a hub for international travel. Delta scheduled flights to feed the international flights using smaller aircraft to match the feeder route passenger demand. The size of aircraft serving JFK reflected this change in strategy (decreased).

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Aircraft Size	No Δ	-4%	+3%	-3%	No Δ	No Δ	No Δ	No Δ	No Δ	No Δ	No Δ	-6%

Table 14 Analysis of the average aircraft size at the three metroplexes (NY, SF, and Philadelphia).

The changes in aircraft size in the San Francisco Metroplex can be attributed to the increase of service in 2006 due to an upswing in the economy and a corresponding decrease in service due to a drop in the economy in 2009 and a consolidation of Southwest Airlines (SWA) operations into SFO after the SWA buyout of ATA Airlines.

The results of an analysis of the aircraft size at the airports for each of the metroplexes (NY, SF, and Philadelphia) are shown in Table 15. These results show a more nuanced view of the dynamics.

Examination of the individual airports shows there is a lack of a relationship at the metroplex and airport level of analysis.

Historical Changes			Longitudi
Fuel Prices	Economy	Airport	A/C Size
21% 2005-2006	2.7%	LGA	no change
		EWR	3%
		JFK	no change
		PHL	-4%
		SFO	no change
1% 2006-2007	2.1%	LGA	no change
		EWR	no change
		JFK	-12%
		PHL	no change
		SFO	no change
72% 2007-2008	0.4%	LGA	no change
		EWR	no change
		JFK	3%
		PHL	no change
		SFO	no change
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	no change
		EWR*	no change
		JFK*	no change
		PHL	no change
		SFO	no change

Table 15 Analysis of the average aircraft size at the five congested airports .

The results of a linear regression for aircraft size at the airports at each of the five airports over four years provides insights into the correlations between the variables and the significant factors that influence airline decisions on aircraft size (Table 16).

		Fuel Prices	GDP	Caps
A/C Size	Pearson correlation	0.12	-0.169	0.071
	P-Value	0.615	0.476	0.765

Table 16 Results of correlation analysis of aircraft size, hedged fuel prices, Gross Domestic Product, and airport capacity limits

The analysis shows no correlation between aircraft size, hedged fuel prices, Gross Domestic Product, and airport capacity limits.

A stepwise regression analysis of the dependent variable percent change in aircraft size versus percent change in hedged fuel prices, national gross domestic product and capacity limits identified no correlation between any of them.

The hypothesis that when congestion increased substantially, or when slot controls were imposed, airlines would respond by up-gauging the airplanes used on these routes was not observed. A closer examination of the data shows that there are economies of scale related to crew and maintenance costs. However, there are no such economies of scale related to fuel costs. The newest part of the airline industry fleet is regional jets that are more fuel efficient than the larger aircraft in the overall fleet. As hedged fuel prices increase, there is more incentive for the airlines to move to smaller aircraft. Figure 22 illustrates this point where it can be seen that the smaller aircraft have better average fuel usage per seat hour. By using smaller aircraft the airlines can assure higher demand (and load factors) through increased frequency.

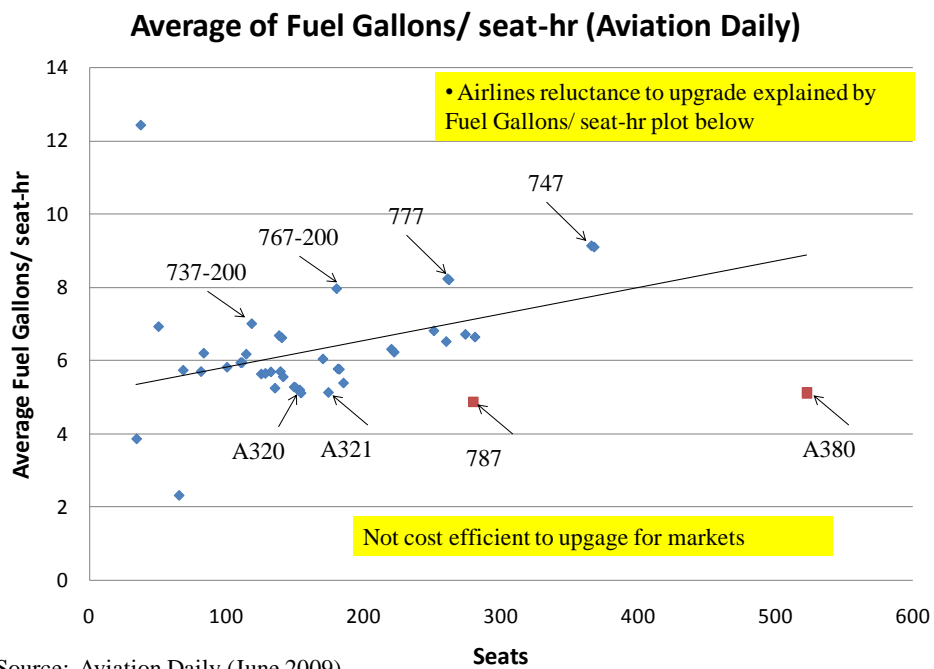


Figure 22 Aircraft fuel burn rate/seat-hr versus seat size

4.2.2 Economic Access

4.2.2.1 Airfares

The results of an analysis of the airfares at the metroplex (NY, SF, and Philadelphia) are shown in Table 17. Analysis of changes in the airfares for flights servicing the Metroplex airports in this study indicates that airfares are primarily a function of changes in hedged fuel prices (and not capacity limits).

Specifically a positive relationship was found between hedged fuel prices and airfares. Increases in hedged fuel prices leads to increased airfares, and decreases in hedged fuel prices leads to decreased airfares. Gross Domestic Product and capacity limits seem to have no effect on airfare, as shown in the table.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Airfares	+8%	+13%	+13%	No Δ	No Δ	No Δ	+10%	+11%	+3%	-12%	-10%	-6%

Table 17 Analysis of the average airfares at the three metroplexes (NY, SF, and Philadelphia).

The results of an analysis of the airfares at the airports for each of the metroplexes (NY, SF, and Philadelphia) are shown in Table 18. These results show a more nuanced view of the dynamics.

Increases in hedged fuel prices lead to increased airfares and decreases in hedged fuel prices leads to decreased airfares. Gross Domestic Product and capacity limits seem to have no effect on airfare, as shown in the table. The analysis at the airport level shows more clearly the positive relationship between hedged fuel prices and airline airfare.

Historical Changes		Longitudi	
Fuel Prices	Economy	Airport	Airfare
21% 2005-2006	2.7%	LGA	10%
		EWR	no change
		JFK	12%
		PHL	13%
		SFO	7%
1% 2006-2007	2.1%	LGA	no change
		EWR	no change
		JFK	4%
		PHL	no change
		SFO	no change
72% 2007-2008	0.4%	LGA	11%
		EWR	11%
		JFK	8%
		PHL	11%
		SFO	no change
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	-13%
		EWR*	-10%
		JFK*	-13%
		PHL	-10%
		SFO	-9%

Table 18 Analysis of the average airfare at the five congested airports .

Figure 23 shows the average airline airfare for the five congested airports over the five years examined. This analysis highlights the significant airline airfare growth for JFK and how the airline airfares at JFK are starting to track with EWR & SFO.

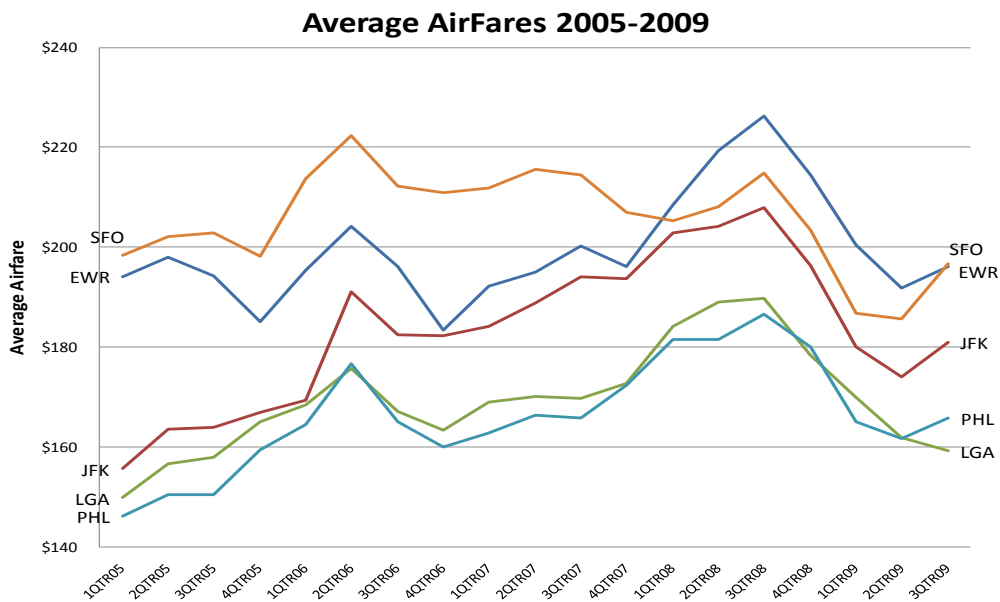


Figure 23 Average airfares by airport (2005-2009)

The results of a linear regression for airline airfares at the Airports at each of the 5 airports over 4 years provides insights into the correlations between the variables and the significant factors that influence airline decisions on airfare (Table 19).

		Fuel Prices	GDP	Caps
Airfare	Pearson correlation	0.826	0.73	-0.666
	P-Value	0	0	0.001

Table 19 Analysis of correlation between airfare, hedged fuel prices, Gross Domestic Product, and airport capacity limits

The analysis shows correlation between Airfare, Hedged fuel prices, Gross Domestic Product, and Airport Capacity Limits.

A stepwise regression analysis of the dependent variable percent change in airline airfares versus percent change in hedged fuel prices, national gross domestic product and capacity limits identified the change in airfare to be a positive correlation function of changes in national Gross Domestic Product (GDP) and hedged fuel prices. The correlation accounted for 79.6% (i.e. R-squared) of the observed variation in domestic markets served. The remaining effect is inter-airline competition, changes in airline business models, and airline restructuring when emerging from bankruptcy. The effect of capacity limits was ambiguous due to the small number of data-points reflecting this change. The regression model found for changes in average airfare to all markets is as follows:

$$\Delta\text{Airfare} = - 0.0114 + 1.84 \Delta\text{GDP} + 0.124 \Delta\text{Hedged fuel prices}$$

4.2.3 Airline Profits

4.2.3.1 Profitability of airlines – The results of an analysis of the airline profitability at the metroplex (NY, SF, and Philadelphia) are shown in Table 20. The analysis shows a negative relationship between airline airfares and airport profitability. When airfares are increased, airport profitability is reduced. When airfares are reduced, airport profitability is increased.

The analysis showed hedged fuel prices increased more than airfares. Also note that extra baggage fees and other new fees introduced by the airlines are not included in this analysis so the conclusions may be misleading since these fees now account for a considerable addition to the airline revenue.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Airfares	+8%	+13%	+13%	No Δ	No Δ	No Δ	+10%	+11%	+3%	-12%	-10%	-6%
Airline Profits	-5%	+5%	No Δ	-5%	No Δ	-4%	-26%	-18%	-26%	+10%	+9%	+20%

Table 20 Analysis of the airline profits at the three metroplexes (NY, SF, and Philadelphia).

Some caveats to the analysis are as follows:

- NY airports do not have strong competition between airlines.
- Airlines may be strategically lagging airfare response to fuel price fluctuations since there is only so much airlines can raise airfares before getting a very negative response from the markets price elasticity curves.

The results of an analysis of the airlines profitability at the airports for each of the metroplexes (NY, SF, and Philadelphia) are shown in Table 21. These results show a more nuanced view of the dynamics.

The analysis at the airport level shows the positive relationship between hedged fuel prices and airline airfare. This level of analysis also highlights the negative relationship between airfare and airline profitability and the negative relationship between congestion and airline profitability.

Historical Changes			Longitudinal	
Fuel Prices	Economy	Airport	Airfare	Profit
21% 2005-2006	2.7%	LGA	10%	-5%
		EWR	no change	no change
		JFK	12%	-9%
		PHL	13%	5%
		SFO	7%	no change
1% 2006-2007	2.1%	LGA	no change	-13%
		EWR	no change	-12%
		JFK	4%	4%
		PHL	no change	no change
		SFO	no change	no change
72% 2007-2008	0.4%	LGA	11%	-17%
		EWR	11%	-32%
		JFK	8%	-22%
		PHL	11%	-18%
		SFO	no change	-20%
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	-13%	9%
		EWR*	-10%	10%
		JFK*	-13%	11%
		PHL	-10%	9%
		SFO	-9%	25%

Table 21 Analysis of the airline profit at the five congested airports .

The results of a linear regression for airline profitability at the airports at each of the five airports over four years provides insights into the correlations between the variables and the significant factors that influence airline profitability (Table 22).

	Fuel	GDP	caps	Airfare	Markets	A/C Size	Flights/Day	Congestion
Profitability	-0.877	-0.396	0.424	-0.664	-0.454	-0.211	-0.13	-0.092
	0	0.084	0.062	0.001	0.044	0.371	0.584	0.698

Table 22 Analysis of correlation between profitability, airfare and domestic markets

The analysis shows correlation between profitability, airfare and markets.

A stepwise regression analysis of the dependent variable percent change in airline profitability versus percent change in hedged fuel prices, national gross domestic product, capacity limits, markets served, flights per day, aircraft size, airline airfare, and airport congestion identified the change in airline profitability to be a function of changes in hedged fuel prices. Hedged fuel prices were found to have negative relationships with profitability. The correlation accounted for 52.5% (i.e. R-squared) of the observed variation in markets served. The remaining effect is inter-airline competition, changes in airline

business models, and airline restructuring when emerging from bankruptcy. The regression model found for changes in airline profitability to all markets is as follows:

$$\Delta\text{Profitability} = -0.004712 - 0.280 \Delta\text{Hedged Fuel Price}$$

4.2.3.2 Congestion

The results of an analysis of the airport congestion at the metroplex (NY, SF, and Philadelphia) are shown in Table 23. Congestion is clearly a function of flights per day.

The longitudinal analysis of the congestion at these metroplexes highlights the differences between these metroplexes. For example, SFO has excess capacity and can grow without increasing congestion. As the economy slowed down in 2008, SJU and OAK lost flights while SFO increased flights by 20%. Some hypothesis for this metroplex behavior: (1) airlines operating in SFO are ramping up flights in anticipation of capacity limits; (2) SFO local wages incentivizing switch to SFO (San Jose City Council Study Session, 2010) to improve options for their passengers; and (3) SWA purchase of ATA enabled consolidation at SWA operations to SFO (out of OAK and SJU).

This metroplex analysis is also confounded by airport growth at JFK with the introduction of significant Delta Airline Operations by the summer of 2007, the Southwest Airlines purchase of ATA lead to consolidation of services in SFO from SJC and OAK in 2008, and the PHL consolidated operations in 2006. Therefore these airports will not always track with the observed trends from economic and policy changes.

	2005-2006			2006-2007			2007-2008			2008-2009		
Regions	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF	NY	PHL	SF
Fuel Prices	+21%			No Change			+72%			-47%		
Gross Domestic Product	+2.7%			+2.1%			+0.4%			-2.4%		
Capacity Limits	No Change			No Change			No Change			Effect of 2008 caps at EWR, JFK and LGA seen here		
Scheduled Flights per Day	No Δ	-16%	+3%	+3%	-4%	No Change	-5%	-4%	-3%	-11%	-7%	-11%
Congestion	+6%	-34%	+27%	+37%	+32%	+3%	-11%	-25%	+9%	-27%	-20%	-31%

Table 23 Analysis of the congestion at the three metroplexes (NY, SF, and Philadelphia).

The results of an analysis of the airport congestion for each of the metroplexes (NY, SF, and Philadelphia) are shown in Table 24. These results show a more nuanced view of the dynamics.

As expected growth in airline schedules leads to increased congestion (delays and cancellations) and reductions in schedule reduce airport congestion.

The capacity limits applied at New York airports have reduced congestion for EWR and LGA, since reductions in congestion are 50% higher than that observed at JFK and PHL. Additional analysis of the schedules shows that EWR and LGA reduced their schedules and JFK de-peaked its schedule as a result of the new or changed capacity limits, as shown in previously in Figures 19-21.

This should serve as a warning to the US air transportation community, that when the economy recovers, expect congestions at major airports to get worse unless these airports are capped.

Historical Changes		Longitudinal Metrics		
Fuel Prices	Economy	Airport	Flights/ Day	Congestion
21% 2005-2006	2.7%	LGA	no change	5%
		EWR	no change	11%
		JFK	4%	-3%
		PHL	-16%	-34%
		SFO	3%	40%
1% 2006-2007	2.1%	LGA	-3%	21%
		EWR	no change	23%
		JFK	20%	111%
		PHL	-4%	32%
		SFO	4%	6%
72% 2007-2008	0.4%	LGA	no change	no change
		EWR	-8%	-13%
		JFK	-5%	-22%
		PHL	-4%	-25%
		SFO	4%	20%
-47% 2008-2009 (*caps in NY)	-2.4%	LGA*	-16%	-30%
		EWR*	-16%	-31%
		JFK*	no change	-16%
		PHL	-7%	-20%
		SFO	-4%	-29%

Table 24 Analysis of the congestion at the five congested airports .

Longitudinal analysis of congestion for the airports examined showed with more clarity the trend that was observed at the metroplex level of analysis. The analysis showed that congestion is a function of flights per day (and peak period scheduling) and that congestion can be mitigated through the application of caps, as seen at EWR and JFK (and lower caps at LGA).

The results of a linear regression for airport congestion at each of the five airports over four years provides insights into the correlations between the variables and the significant factors that influence airport congestion (Table 25).

This analysis illustrates the impact of airline schedules on airport congestion. As expected growth in airline schedules leads to increased congestion (delays and cancellations) and reductions in schedule reduce airport congestion.

	Fuel	GDP	caps	Airfare	Markets	A/C Size	Flights/ Day	Profitability
Congestion	0.111	0.538	-0.352	0.177	0.734	-0.618	0.825	-0.092
	0.642	0.014	0.128	0.456	0	0.004	0	0.698

Table 25 Analysis of correlation of changes in airport congestion with changes in airfare, markets served and flights per day

The correlation analysis shows that changes in airport congestion are correlated with changes in airfare, markets served and flights per day. These relationships shown from the statistics reinforce the understood relationships between congestion and airline schedules. A positive relationship was found between congestion and markets and flights per day. A negative relationship was found between congestion and aircraft size.

A stepwise regression analysis of the dependent variable percent change in airport congestion versus percent change in hedged fuel prices, national gross domestic product, capacity limits, markets served, flights per day, aircraft size, airline airfare, and airline profitability identified the change in congestion at an airport to be a function of changes in markets, aircraft size and flights per day. Markets and flights per day were found to have a positive relationship with congestion. Aircraft size was found to have a negative relationship with congestion. The correlation accounted for 76.5% (i.e. R-squared) of the observed variation in markets served. The remaining effect is inter-airline competition, changes in airline business models, and airline restructuring when emerging from bankruptcy. The regression model found for changes in airport congestion is as follows:

$$\Delta\text{congestion} = 0.0778 + 2.16 \Delta\text{Markets} - 4.04 \Delta\text{A/C Size} + 1.64 \Delta\text{Flights/ Day}$$

5 Conclusions

5.1 Summary of Statistical Trends (2005-2009) (NY, SF, PHL)

This analysis compares the behavior of the air transportation system (e.g. domestic markets served, airfares, delays, load factors, aircraft size) during the recent run-up in hedged fuel prices at capacity-limited New York airports and non-slot controlled San Francisco and Philadelphia airports.

The results indicate:

- i. Airfares change in proportion to changes in hedged fuel prices and gross domestic product
- ii. Flights per day and domestic markets served change in proportion to changes in gross domestic product
- iii. Flights per day and domestic markets served change in proportion to changes in airport capacity limits
- iv. Delays and cancellations change in proportion to flights per day and domestic markets served and in negative proportion to aircraft size
- v. Airline profitability change in negative proportion to aircraft size, airfares and domestic markets served

This study expands on prior efforts to analyze the behavior of airlines at congested airports. It compares the performance at the New York airports to the performance at the Philadelphia and San Francisco airports from 2005 through 2009. During this time period, there were significant fluctuations in hedged fuel prices and in the overall economic condition of the country. In addition, tighter regulations on the scheduling of flights at the three New York airports were imposed.

The results indicate that capacity limited airports yielded reduced congestion (i.e., fewer delayed and cancelled flights) through reductions in schedules and de-peaking schedules as shown in previously in Figures 19-21. There was no significant change in domestic markets serviced. While airfares were affected by changes in hedged fuel prices, they did not significantly increase at New York airports after capacity limits were applied.

San Francisco and Philadelphia airports reduced schedules during the recession. These airports also reduced congestion through the reduction in schedules. The overall conclusions are shown in Table 26.

	Annual Changes			Observations			
	Caps	Economy	Fuel Prices	Airfare	Schedule	Congestion	Profit
05-06	Yes	Up	Up	Up	No Δ	Up	Down
05-06	No	Up	Up	Up	Up	Up	Down
06-07	Yes	Up	No Δ	No Δ	No Δ	Up	Down
06-07	No	Up	No Δ	No Δ	Up	Up	No Δ
07-08	Yes	Constant	Up	Up	No Δ	No Δ	Down
07-08	No	Constant	Up	Up	Down	Down	Down
08-09	Reduced	Down	Down	Down	2xDown	2xDown	Up
08-09	No	Down	Down	Down	Down	Down	Up

Table 26 Economic and Policy Impacts

The key observations from this analysis are as follows:

- Airfares increase when hedged fuel prices increase and when the gross domestic product decreases.
- Flights per day and domestic markets served decrease when gross domestic product decreases.
- Flights per day and domestic markets served decline when airport capacity limits are imposed.
- Delays and cancellations decrease as flights per day and domestic markets served are decreased and delays and cancellations increase as aircraft size is decreased.
- Airline profitability decreases as aircraft size, airfares or domestic markets served increases.
- Up-gauging of airline fleets is unlikely to occur without the introduction and purchase of a new class of aircraft that has better efficiency for aircraft handling between 100-150 passengers. Currently, the aircraft stock in the 100-120 seat size is the oldest and least efficient portion of the fleet.
- With the imposition of slot controls in 2008, LGA and EWR reduced schedules while JFK was capable of keeping the same number of flights as were flown prior to the imposition of slot controls. Because of a peaked schedule at JFK, there was opportunity to move flights from peak times to off-peak times rather than having to remove the flights. LGA and EWR were operating at capacity at virtually all times and so had to remove flights from the schedule in order to adhere to the new regulations.
- In 2008, the airlines were less profitable. Even though delays and the resultant cost of delays were reduced, the increases in fuel costs were considerably greater. Thus, overall, airlines' operational costs increased in 2008, and these costs were greater than the increase in ticket prices.
- Airports with capacity limits reduced operations and congestion. Airlines' profitability at these airports (as measured by operational revenue minus operational costs) increased.

The analysis showed a positive correlation between:

- airfare and hedged fuel prices,
- Gross Domestic Product and airline schedule,
- capacity limits and airline schedule, and
- airline schedule and airport congestion.

A negative correlation was found between:

- airfare and airport profitability and
- airport congestion and airport profitability.

The analysis showed no significant change in load factors, or aircraft size.

5.2 Summary of Functional Relationships (2005-2009) (NY, SF, PHL)

The summary of functional relationships found from the stepwise regression analysis and their multipliers between the exogenous factors, economic access, geographic access and airline profitability are shown in Figure 24. All results are based on statistically significant trends with a confidence interval of 95%. The stepwise regression results are listed below:

$$\Delta \text{Domestic markets} = -0.0266 + 1.44 \Delta \text{GDP}$$

$$\Delta \text{Flights/ Day} = -0.0368 + 1.83 \Delta \text{GDP}$$

$$\Delta \text{Airfare} = -0.0114 + 1.84 \Delta \text{GDP} + 0.124 \Delta \text{Hedged fuel prices}$$

$$\Delta \text{Profitability} = -0.004712 - 0.280 \Delta \text{Hedged Fuel Price}$$

$$\Delta \text{congestion} = 0.0778 + 2.16 \Delta \text{Markets} - 4.04 \Delta \text{A/C Size} + 1.64 \Delta \text{Flights/ Day}$$

Figure 50 identifies the relationships between factors. For example, a one percent change in hedged fuel prices lead to a 0.12% change in airfares. A negative relationship indicates that a positive increase in the source, leads to a decrease in the result.

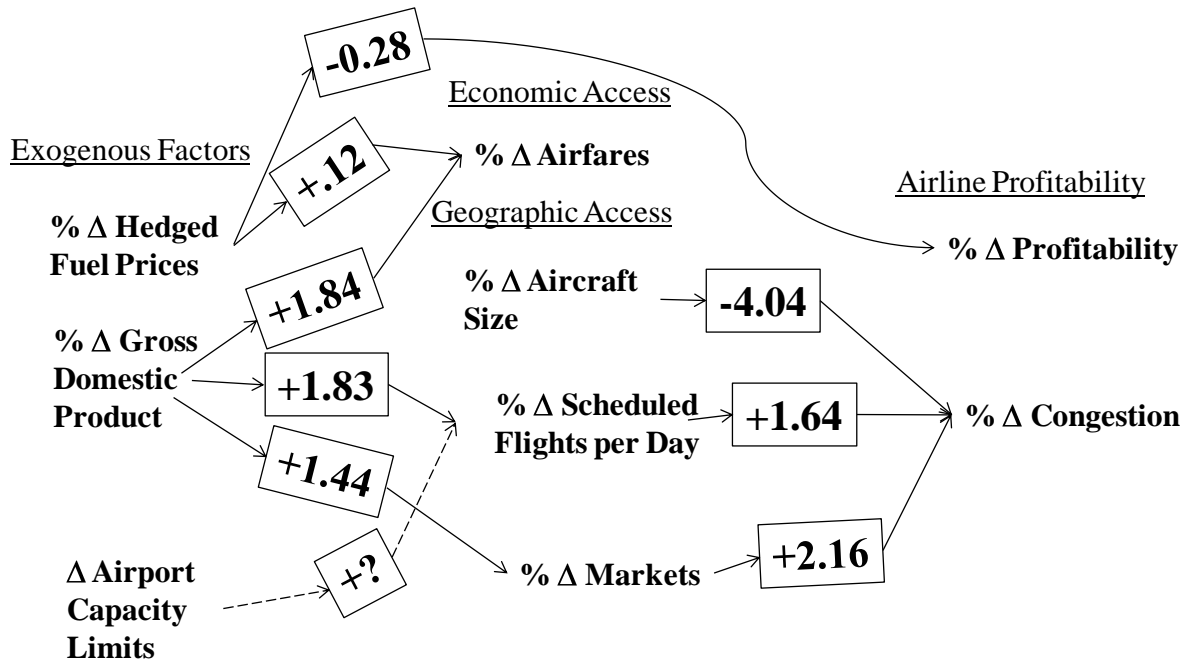


Figure 24 Summary of multipliers between the exogenous, economic access, geographic access and airline profitability factors

5.2.1 Geographic Access.

The number of domestic markets served directly by an airport is primarily affected by the health of the economy as measured by demand for air transportation. Capacity limits at airports did result in a small reduction in domestic markets served, as did airline network restructuring, airline financial restructuring, and inter-airline competition.

The growth/decay in demand for air transportation (as measured by the Gross Domestic Product (GDP)) is the primary determinant of the number of domestic markets served. The results of the stepwise regression show that for every 1% change in GDP, there is a 1.44% change in the number of domestic markets with direct service. The linear regression showed that for every 1% change in GDP, there is a 1.83% change in the number of flights per day serving these markets. As the economy slowed, the number of markets with direct service decreased.

The introduction of capacity limits at congested airports also affected the number of domestic markets served. In response to the economic down-turn (2008 and 2009), airports without capacity limits (SFO, PHL) experienced a reduction in the number of domestic markets served by an average of -7% (SFO -8%, PHL -6%). During the same period, heavily congested airports that had capacity limits implemented (EWR) or reduced (LGA), experienced a loss of an additional 4% of markets served (EWR -12%, LGA -10%).

Airlines' network restructuring (e.g. Delta's expansion at JFK), airlines' financial restructuring (e.g. USAirways bankruptcy filing impacted PHL), and inter-airline competition also affected the number of markets served.

5.2.2 Economic Access

Passenger accessibility to air transportation through airfares at these airports followed established patterns for passenger demand. Changes in the economy significantly affected demand for air transportation.

- Cumulative elasticity at the airports ranged between -3 to -2.7 during this period. Specifically, a 1% increase in airfare (e.g. \$300 to \$330) resulted in a 3% reduction in demand for air service at that fare. This result is consistent with prior studies that showed airfares to be highly elastic.
- The change in airfare was driven by changes in travel demand (reflected by changes in the GDP) and changes in hedged fuel prices ($R^2=79.6\%$). At the five airports studied (LGA, JFK, EWR, PHL, and SFO), airfares changed on average 1.84% for every 1% change in GDP and 0.12% for every 1% change in hedged fuel prices. A \$1 increase in hedged fuel prices resulted in an average of \$16 increase in airfares, which yielded an average reduction in passenger demand of 1.5%.

5.2.3 Airline Profitability.

Airline profitability for the routes serviced at these five airports is a complex phenomenon driven by demand for air transportation, passenger's responses to price increases, and operating costs. During this period, airline profitability was primarily determined by the industry's ability to raise airfares relative to the cost of operations (i.e. when hedged fuel prices were escalating dramatically). During the spike in fuel costs the airlines were faced with significantly greater operating costs and decreased demand due to the economic downturn.

1. During this period, airline profitability decreased as airlines were unable to increase airfares as fast as hedged fuel prices increased.
2. During this period, airlines shed less profitable domestic markets in order to improve profitability. The decrease in markets was driven primarily by reduced economic demand for air transportation and the sensitivity of passengers in certain markets to increased fares.
3. During this period, airlines decreased aircraft size in order to maintain profitability as demand decreased.
4. The change in airport congestion was driven by changes in domestic markets served, scheduled flights per day, and by aircraft size ($R^2=76.5\%$). At the five airports studied (LGA, JFK, EWR, PHL, and SFO), congestion changed on average 2.16% for every 1% change in markets served, 1.64% for every 1% scheduled flights per day and -4.04% for every 1% increase in aircraft size.
5. The change in airline profitability was driven by changes in airfare and changes in aircraft size ($R^2=75.6\%$). At the five airports studied (LGA, JFK, EWR, PHL, and SFO), airline profitability changed on average -0.28% for every 1% increase in hedged fuel prices.

5.3 Relationship between Airports and Metroplexes

No two metroplexes are the same.

Analysis of these metroplexes shows different aggregate airline behavior between the metroplexes, and between the individual airports in a metroplex.

The two metroplexes examined in this study (New York and San Francisco) were found to be comparable in many ways. They both have international hubs. They both have substantial shuttle markets. They both have airports with a primary domestic focus. And they both have cross country markets to connect east coast and west coast travelers to the US domestic air transportation network.

However, the New York airports are controlled by the Port Authority of New York / New Jersey and the San Francisco airports are managed separately. The New York Metroplex has two airports operating at capacity and one airport operating near capacity. All three New York airports are OEP 35

airports. The San Francisco Metroplex has one OEP 35 airport which operates at near capacity, but is still less capacitated than any of the three New York airports.

Airports and metroplexes will respond differently to economic growth.

Airline behavior will depend on how capacitated the airports are within a metroplex. For example, from 2005 to 2007 when the economy experienced a 4.8% growth in national gross domestic product, the two capacitated airports in New York (LGA and EWR) experienced no increase in scheduled operations. During this same time period, JFK experience a 25% increase in scheduled operations, Delta airlines introduced domestic operations into JFK.

Airports and metroplexes will respond differently to economic decline.

Airline behavior will depend on the airline competition within the airports and within a metroplex. For example, from 2007 to 2009 when the economy experienced a 4% drop in national Gross Domestic Product, there was a difference in the response between the San Francisco and New York metroplex. Airline scheduled operations were consolidated into SFO from OAK and SJC. During this same time period New York airports experienced reductions in scheduled operations with no intra-airport interaction.

Airports and metroplexes will respond differently to capacity limits.

This same phenomenon can be observed when capacity limits are introduced in a metroplex. In 2008, capacity limits were introduced at the New York airports. These capacity limits were set or adjusted to the perceived capacity limits at the respective airports. Therefore, since airlines operating at EWR and LGA were operating at or slightly above these capacity limits for most of the day, these airlines had no choice but to reduce schedules. On the other hand the airlines operating at JFK were only operating at or above these capacity limits for a few hours during the day, so these airlines were able to move scheduled operations to non-congested times rather than reduce the overall schedule or the domestic markets served.

Airports and metroplexes will respond differently to capacity limits and market based incentives.

Metroplexes operating at or near capacity will reduce operations in response to reduced capacity limits and maintain operations in response to market based incentives, as seen with increased operational costs from fuel prices. On the other hand, metroplexes like San Francisco with airports of different sizes will consolidate operations to the larger more economically robust airport in response to market based incentives, as seen in San Francisco from 2007 to 2008.

Airlines will up-gauge when policy incentives are matched with available fuel efficient fleet options.

Currently there is insufficient inventory of 80 to 120 seat aircraft to support domestic up-gauging to reduce congestion. The aircraft available at the 85-120 seat capacity are not as fuel efficient per seat as the smaller aircraft between 50 and 80 seats.

5.4 Additional Observations

The historic analysis indicates that slot controlled airports yielded improved performance (i.e., flight delays and cancelled flights) through reductions in frequency and de-peaking schedules without degrading service or frequency. On the other hand, the non-slot controlled airports in the San Francisco region showed an increase in flight delays and cancellations during the same period. The number of domestic markets served and airfares did not change. These results provide some justification for slot-controls at airports that need to manage network congestion. Even in the presence of fluctuations in passenger demand and economic shocks, passengers saw an improvement in service (i.e. a lessening of delays and cancellation) without any significant loss in domestic markets served or frequency to those markets. The only significant reduction in frequency was to the Washington DC, Boston and Chicago shuttle markets

where there was a significant decrease in frequency and an up-gauging of aircraft to accommodate the passenger demand.

Even though the number of markets served in a metroplex are robust to economic changes (GDP, Fuel) and regulatory changes (airport capacity limits), examination of the airports within the metroplex identifies major differences among the airports. At the airport level, increases in Gross Domestic Product resulted in corresponding increases in airport operations and markets; similarly, decreases in Gross Domestic Product result in corresponding decreases in airport operations and markets. Additionally, analysis of the New York airports from 2005 to 2009 showed that capacity limits resulted in reduced operations at capacitated (EWR & LGA) airports and de-peaking of operations at un-capacitated airports (JFK). Reduced airline operations as the result of capacity limits led to reduced airport congestion and increased airline profitability at these airports.

This analysis refutes the concern that congestion pricing is likely to reduce the markets or the profitability of the airlines. Congestion prices are likely to be far less than the change in fuel price experienced by the airlines in 2008. Since markets were relatively insensitive to that spike in costs, we see no reason to believe that a congestion pricing fee would impact markets or airline profitability significantly. Similarly, capacity limits at airports did not impact the domestic markets served, airline profitability or network connectivity when imposed at the NY airports.

Economic and regulatory changes have not incentivized the airlines to increase capacity through up-gauging. Therefore, regulators must determine mechanisms that will incentivize the industry to consider up-gauging, either through the introduction of energy efficient aircraft in the 100-150 seat category and/or through the restriction of access to the most congested airports without up-gauging.

The airlines are capable of adapting relatively quickly to significant economic and regulatory changes. They have responded to increased costs by imposing new fees (baggage handling fees, food charges, higher cancellation fees, etc). They are careful to maintain market share during economic downturns, and respond quickly to threats by low-cost carriers to their most profitable markets. Airlines have also responded to downturns in the economy by maintaining their frequency to small markets through down-sizing of the aircraft flown to these domestic markets.

This analysis indicates that when the economy recovers, airlines will increase schedules. Congestion levels can be expected to increase accordingly.

5.5 Policy Maker's View of Results

What was the impact of Capacity Limits on Geographic Accessibility? Capacity limits at congested airports that forced a reduction in scheduled flights (i.e. EWR and LGA) resulted in a slight reduction in the number of domestic markets served (approx -4%) and a reduction of frequency of service to domestic markets served (-9%). The introduction of capacity limits at JFK had the effect of causing de-peaking in the late afternoon/evening congested period, and an increase in flights arriving and departing during the previously uncongested mid-morning and early afternoon periods.

What was the impact of Capacity Limits on Economic Accessibility? The impact of capacity limits on airfares was not significant, but such effects may have been overshadowed by the larger impacts of fuel costs and the economic downturn. During the period when capacity limits were present there was little change in airfares.

What was the impact of Capacity Limits on Airline Profitability? For those airlines that were grandfathered slots at the capacity-limited airports (EWR, LGA, and JFK), profitability improved at these airports when compared to profits at airports (PHL and SFO) that did not have capacity limits.

What was the impact of Increasing Hedged Fuel Prices on Geographic Accessibility? There was only indirect evidence that hedged fuel prices had any impact on markets served. Markets served are directly determined by the economy and the demand for passenger travel. The airlines were not able to raise airfares to match increased operating costs because passengers were unwilling or unable to accept higher airfares during a period of economic downturn. Regressions on increased hedged fuel prices on markets served did not provide statistically significant results (i.e. the null hypothesis “that increased hedged fuel prices negatively impacted markets served” could not be rejected).

What was the impact of Increasing Hedged Fuel Prices on Economic Accessibility? Changes in airfare were driven by changes in travel demand (reflected by changes in the GDP) as well as changes in hedged fuel prices ($R^2=79.6\%$). At these congested airports, airfares changed on average 1.84% for every 1% change in GDP, and 0.12% for every 1% change in hedged fuel prices. A \$1 increase in hedged fuel prices resulted in an average of \$16 increase in airfares, which yielded an average reduction in passenger demand of 1.5%.

What was the impact of Increasing Hedged Fuel Prices on Airline Profitability? Airline profitability is determined by the dynamics of the economic demand for air transportation and the rate of change of operating costs (as measured by changes in fuel costs, since all other operating costs remained constant). During periods of economic predictability in both demand for air transportation and costs of operations, airlines are profitable. During periods of decreasing demand or increasing operating costs, airlines are no longer profitable.

During periods when hedged fuel prices were constant or when hedged fuel prices dropped (e.g. -47% 2008-2009), the airlines achieved profitability. During the period in which hedged fuel prices rose rapidly (e.g. +72% 2007-2008), the airlines were unable to increase airfares fast enough to maintain profitability.

Did Capacity Limits or Increasing Hedged Fuel Prices affect Aircraft Size? No increase in aircraft size was observed during this period. During periods of increasing fuel costs, aircraft size decreased to take advantage of aircraft with lower labor and fuel costs. At airports with capacity limits, aircraft size remained unchanged.

5.6 Recommendations

1. DOT and FAA evaluate options to relax Pilot Union Scope Clauses that would allow incentives for aircraft manufacturers to produce, and airlines to acquire and deploy, the correct sized aircraft (88 - 112 seats) to match the passenger O/D market demand.
2. Introduce Capacity Limits at congested airports. This has the effect of significantly reducing congestions and delays (across the NAS), without financial penalties to airlines or loss of geographic and economic access.
3. Research and develop aircraft technologies (e.g. engines) to provide improved performance for the 88 - 112 seats class. The use of such aircraft will increase the efficiency of the airspace (i.e. more passenger throughput) and will also reduce emissions.

5.7 Future Work

5.7.1 Airline Schedule Optimization Model (ASOM) to Complete the “Design of Experiment”.

The historical analysis was dictated by the events that occurred during the period under study and provided an analysis of four of a possible 27 treatments (3 GDP % change possibilities x 3 Fuel Price % change possibilities x 3 Airport Capacity Limit % change possibilities).

To examine the effect of the remaining treatments, an optimization model was developed. The Airline Schedule Optimization Model (ASOM), calibrated using the historical data, is used in a follow-up study to evaluate the consequences of alternative combinations of economic conditions, changes in operating costs, runway capacity restrictions and airfare changes. The results of the study will complete the design of experiment and forecast what the airlines are likely to do if the economy has a significant upswing or if the government imposes capacity restrictions at other airports.

5.7.2 Absence of Economies-of-Scale through Up-gauging (or “Cash for Clunkers”).

During the calibration of the ASOM, it was observed that the optimization model failed to show the airlines increasing aircraft size from 80 to 100 seats. The ability to up-gauge in this range is critical to taking advantage of the concept of using the same runway slots to ferry additional passengers.

This behavior is a result of the absence of economies-of-scales in up-gauging in this range. The significantly higher costs of operation at the 100 seat and 200 seat class of aircraft prevent airlines from up-gauging. In the 100 seat range the only aircraft in revenue-service are the older, DC-9 class that is more expensive to operate. No new, efficient aircraft are available in this range. This phenomenon becomes more pronounced as the price of fuel increases.

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