NextGen
Aligning Costs, Benefits and Political Leadership

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Eno Center for Transportation

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About Eno

The Eno Center for Transportation is a neutral, non-partisan think-tank that promotes policy innovation and leads professional development in the transportation industry. As part of its mission, Eno seeks continuous improvement in transportation and its public and private leadership in order to increase the system's mobility, safety and sustainability.

The leader in its field for nearly a century, Eno provides government and industry leaders with timely research and a neutral voice on policy issues. Eno's Center for Transportation Policy (CTP) publishes rigorous, objective analyses on the problems facing transportation and provides ideas for and a clear path toward possible solutions. CTP also publishes a monthly transportation newsletter that reaches 2,000 individuals directly plus another 40,000 through the Transportation Research Board. CTP's policy forums bring together industry leaders to discuss pressing issues and hear from top researchers in the field.

Through its professional development programs, the Center for Transportation Leadership (CTL), Eno cultivates creative and visionary leadership by giving public and private transportation leaders the tools and training the need to succeed together. CTL's leadership Development Conference brings the nation's top transportation students to Washington, DC, each year to meet with top practitioners in the field, while other CTL programs give transportation executives the tools they need to be successful as leaders. Since its inception, CTL has instructed over 3,000 transportation professionals.

Eno was founded in 1921 by Williams Phelps Eno (1859-1945), who pioneered the field of traffic management in the United States and Europe. Mr. Eno sought the promote safe mobility by ensuring that traffic control became an accepted role of government and traffic engineering a recognized professional discipline. His "Rules of the Road", adopted by the City of New York in 1909, became the world's first city traffic plan. He also wrote the first-ever manual of police traffic regulations. In 1921 he chartered and endowed the Eno Center for Transportation to attract the thinking of other transportation experts and specialist, and to provide a forum for unbiased discussions that would lead to improvements in the movement of people and goods.

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The Control tower at Phoenix Sky Harbor International Airport

Introduction

The aviation system that is part of the life-blood of our economy is poised to face rising demand with limited additional capacity and outdated technology. This could put considerable stress on the system in terms of congestion and efficiency. The Next Generation Air Transportation System (NextGen) represents a series of incremental policies, procedures, and technological changes to modernize the air traffic control (ATC) system into a more efficient, state-of-the-art satellite-based system.

On the technology side, NextGen is composed of two main components: aircraft based equipment that records and transmits the exact location of the aircraft using Global Positioning System (GPS), and ground based infrastructure that can receive and analyze the GPS data. Infrastructural improvements also entail devising more direct and fuel-efficient routes, and upgrading the computer and backup system used at 20 Federal Aviation Administration (FAA) air traffic control centers nationwide. The infrastructure implementation is currently in the hands of the FAA and funded by the Airport and Airway Trust Fund (AATF), while aircraft equipage is expected to be paid for by the operators.

On-board equipage could allow improved decision-making capabilities and accessibility during adverse weather, as well as better data communications between cockpit and ATC. This more precise system has the potential to reduce the minimum aircraft separation standard and allow more direct flight patterns, thus decreasing fuel consumption, carbon emissions, and congestion.

On the policy-side, there are several obstacles to NextGen that hinder progress and the likelihood of a timely and cost-efficient implementation. First of all, there are uncertainties regarding the extent of the benefits NextGen can potentially provide. It is difficult to make forecasts about how much congestion or fuel consumption can be reduced to make the infrastructure investment worthwhile. This makes it challenging to create sustained political, financial, and industry support for the project.

Secondly, there are doubts about costs and the FAA's ability to deliver technology solutions of this magnitude. In the early 1980s, aviation modernization projects were projected to cost $12 billion and be ready in 10 years. NextGen infrastructure and equipage is now estimated to cost about $40 billion with expected completion by 2025.[1] Testimony by the US Department of Transportation Inspector General and a recent report by the Government Accountability Office (GAO) have pointed out cost overruns and delays in several NextGen programs. This continued uncertainty

[1] Hearings on the Reauthorization and Reform of the Federal Aviation Administration and the Airport Improvement Program, February 8, 2011. "NextGen" was first announced in 2004 but modernization projects were introduced much earlier, under different names and objectives.

regarding the total infrastructure and equipage cost figure of NextGen has planted seeds of doubt amongst stakeholders and potential NextGen beneficiaries.

Third, the airlines and general aviation users have been hesitant to bear equipage costs due to low profitability, economic turmoil, and a lack of clear incentives to justify investing in NextGen. Operators are unlikely to invest until, at a minimum, the FAA is ready to deliver the promised benefits. This leads to a stalemate: operators are uncertain whether investing in NextGen is worthwhile, when the infrastructure is not yet fully in place, and without equipage the infrastructure by itself is ineffective. The FAA has mandated equipage of Automated Dependent Surveillance-Broadcast Out (ADS-B) that allows the equipped aircraft to send transmission to other equipped aircraft ADS-B ground stations for all operators by 2020. However, there is uncertainty over when other NextGen on-board equipment will be required, particularly ADS-B In which allows the equipped aircraft to receive transmission from other ADS-B ground stations and other aircraft.

Fourth, NextGen faces funding issues that pose some very difficult policy decisions. Work on the ground infrastructure aspect of NextGen is currently funded by the Facilities and Equipment account of the AATF and some progress, albeit slow, has been made on this project. However, recent reports by the Congressional Budget Office and the Government Accountability Office show that current AATF revenues are inadequate to fund NextGen.[2] Despite recent resolution over the long overdue FAA reauthorization bill, little progress has been regarding securing a full-fledged modernization funding plan. The current bill authorizes a flat amount of $2.731 billion over four years for NextGen and funding is still subject to annual appropriation. A project that is already endangered by uncertainties regarding its worth would benefit from a stable and adequate funding source.

A fifth problem facing NextGen is lack of Congressional political leadership in prioritizing a project of such potential value. In July 2011 the House of Representatives passed a short-term extension bill that failed to pass the senate, resulting in a shutdown that lasted a fortnight. The AATF received no tax revenues during the shutdown. As Congressional leaders argued over the Essential Air Services program, the trust fund lost over $400 million in foregone tax revenues. Those are funds that could have potentially been used towards an investment like NextGen. Furthermore, according to the FAA some of the NextGen program delays can be attributed to the furlough of some of the FAA employees in July 2011 and a freeze on contractor funding which resulted in work stoppage orders for several projects.[3] This impact of the impasse on NextGen was also documented on the GAO report on the FAA's NextGen cost-management.[4]

In order for NextGen to succeed, there must be greater certainty about potential benefits and costs. In the highly competitive low profit-margin airline industry, few want to take on the burden of paying for something that spreads speculative benefits so widely. It will also be essential to have a mechanism that raises sufficient capital for NextGen infrastructure in a transparent and equitable manner, while imposing minimal burdens on those who pay for it. Without a sustainable, stable, and reliable strategy for both continued infrastructural improvements and incentives for equipage, there is no guarantee that NextGen can be implemented in a timely and cost-effective manner. Without strong political leadership, a clear and unbiased delineation of costs and benefits, a transparent source of funds, and incentives for operators to equip, it is unlikely that NextGen benefits can be delivered in a timely manner if at all.

This paper serves a dual purpose: First is to shed some light on the uncertainties regarding NextGen's benefits and costs. On the benefit side, we make no attempt to estimate how much the benefits might be in terms of the percentage of delay reduction, or improvement in fuel-efficiency due to NextGen. Instead, the research presented includes an estimate of the cost of the system in terms of current congestion, fuel expenditure, carbon emissions and safety issues. Various scenarios of NextGen's impact are considered and the corresponding benefits are quantified as a percentage of reduction in current costs to the system. This approach has the potential to show that even with the assumption that NextGen's impact on improving the current system is minimal, the resulting cost-savings can be significant. Separate analysis is done for commercial aviation, general aviation, and passengers to highlight the benefits to all users. The second purpose of the paper is to analyze different funding mechanisms for NextGen. These various mechanisms are analyzed based on several factors including adequacy, equitability, transparency, political feasibility, and efficiency in terms of minimizing burden on taxpayers.

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[2] Airport and Airway Trust Fund: Declining Balances Raises Concerns over Ability to Meet Future Demand. United States Government Accountability Office, Testimony Before the Committee on Finance, U.S Senate, February 3, 2011.
[3] http://www.faa.gov/news/media/workstop/(February 2012)
[4] Air Traffic Control Modernization: Management Challenges Associated With Program Costs and Schedules Could Hinder NextGen Implementation. United States Government Accountability Office, Report to Congressional Committees. February, 2012.

Air traffic controllers plot the positions of aircraft on a wall-mounted display, circa 1950.
(Photo by Archive Photos)

NextGen Benefits

NextGen has the potential to reduce congestion and fuel consumption significantly while increasing safety due to more precise location information of air traffic. While most agree that air traffic control would improve under NextGen, there are varying estimates on the magnitude of the potential benefits of NextGen among experts in the airline industry.

One concern is that NextGen might not have a significant impact on increasing the airport acceptance rates (AAR), which is an important factor in reducing congestion, particularly at large hub airports.[5] Even if NextGen increases the number of operations in en route airspace by reducing minimum separation standards and facilitating more direct routes, critics contend that airports can still only allow a fixed number of planes to land per hour.

Another criticism is that the operators cause most of the delays in some airports through flight scheduling for business reasons as opposed to due to airport capacity limitations. As a result it is argued that NextGen could do little to alleviate delays.

In part to counter these concerns, the FAA released its NextGen Implementation Plan in March 2011 where it estimated benefits from NextGen in terms of reduced congestion and increased fuel efficiency based on both simulations and in some case actual data:

In Atlanta, arrivals making use of Performance Based Navigation (PBN) procedures have saved hundreds of thousands of gallons of fuel and thousands of tons of carbon dioxide and air pollutants. Similar fuel savings and reductions in emissions have resulted from the use of precise, continuous descents into Los Angeles and customized descents into San Francisco. Preliminary results from a surface management initiative in Boston point to a fuel savings of 5,100 gallons and a reduction in carbon dioxide emissions of 50 tons during periods of heavy congestion. Shared surface surveillance data coupled with aircraft metering techniques are creating

[5] David Plavin, former President of Airports Council International-North America, in a correspondence with the Eno Center for Transportation on 20th August 2011.
[6] FAA NextGen Implementation Plan, March 2011, pp7

Washington Dulles International Airport main terminal and control tower.

taxi-out time savings of up to 7,000 hours a year at New York's John F. Kennedy airport and 5,000 hours a year at Memphis, Tenn.[6]

On one hand, the criticisms of NextGen might have some valid ground and have yet to be rebuked through published research. On the other hand, NextGen benefits have been demonstrated at certain airports in the US. These conflicting statements make it challenging to reasonably estimate NextGen benefits.

A recent Deloitte LLP report estimates the potential merits of accelerating the NextGen programs, as well as assessing the economic effect of potential implementation delays.[7] The study finds that the net present value for NextGen deployment varies from $161 billion to $1.3 trillion through 2035, depending on how soon modernization is complete and whether the benefits include environmental and economic spillover effects. The study assumed certain levels of benefits based on previous studies and reports. For example, between 2009-2025 fuel efficiency was assumed to be reduced by 25 percent by the end year. Airline delays are assumed to be reduced by 78-85 percent by 2025, based on an earlier estimate by the Joint Planning and Development Office.[8]

Although certainly a valuable contribution to the discourse on the importance of NextGen to aviation, the Deloitte study makes certain underlying assumptions on the impact of NextGen on delays and fuel consumption based on previous findings and is optimistic, much like the FAA's own benefit estimates in its 2011 NextGen implementation report. The Deloitte study does not quantify benefits for general aviation.

This paper presents an alternative methodology for estimating NextGen's benefits. First, current cost of the system is estimated for airlines, passengers, and general aviation. For

[7] Transforming the Air Transportation System- A Business Case for Program Acceleration. Deloitte LLP, July 2011.
[8] JPDO, Concept of Operations for the Next Generation Air Transportation System, June 2007.

Air traffic controller at work.

both commercial and general aviation, costs are estimated in terms of fuel consumption and delays. Safety costs are estimated for general aviation. For passengers, the cost of delays is quantified by estimating the value of time wasted in delays.

Next, a range of potential savings due to NextGen is considered. A low 1-5 percent impact is considered to reflect a very conservative case where NextGen has a minimal impact on improving fuel efficiency, delays and safety. A moderate 5-10 percent impact is considered as well, in addition to a 10-20 percent impact to reflect the "good case" scenario. It should be noted that the delay savings even in the "good case "scenario that are considerably lower than those used by the FAA and in the Deloitte study.

The analysis in subsequent sections attempts to estimate possible ranges of benefits in the following categories:

- Reduced fuel consumption
- Reduced congestion
- Increased safety

Benefits to Commercial Aviation

The FAA maintains that NextGen will benefit operators by increasing fuel efficiency and reducing congestion, potentially saving the industry billions of dollars in the process. First the direct fuel savings are calculated, followed by the congestion savings to operators.

The current aviation system uses radar to scan through an area periodically and reports any nearby operating aircraft to ATC. The lack of continuous precise detection means that aircrafts must maintain a minimum separation distance of at least five miles in the en route airspace and three miles in the terminal airspace for safety. Moreover, airplanes are required to fly through predetermined air corridors similar to imaginary highways in the air, limiting en route flexibility, though this is a procedural requirement by the FAA and not necessarily due to the limits of existing technology. The precision of GPS would allow reduction in the aircraft separation standard, which would greatly enhance air traffic management and flow. NextGen's Area Navigation (RNAV) would allow pilots to choose more direct and shorter routes, to their destination, assuming FAA develops appropriate procedures to allow direct navigation. This could result in substantial fuel savings.

Another procedure through which NextGen would save fuel is during aircraft landing. Under the current system, an aircraft follows a fuel-intensive stepped descending approach where it descends to a lower altitude, levels off to a constant altitude, and then descends further by periodically altering engine power. Optimal Profile Descent (OPD) would allow the aircraft to glide continuously prior to landing instead of using additional engine power.[9]

By reducing fuel consumption, NextGen could provide relief to the airline industry's fuel costs, one of the largest components of total operating cost. Airline profitability in recent years has been stifled in part due to substantial increases in fuel prices: from under $1/gallon between 2000-2004 to over $2.20/gallon in 2010, including record prices of about $3/gallon in 2008 (Figure 8, Appendix A). Prior to jet fuel price hikes starting in 2004, fuel expenses accounted for about a quarter of total operating expenses. Since 2004,

[9] Other NextGen improvements are discussed in Appendix A4.

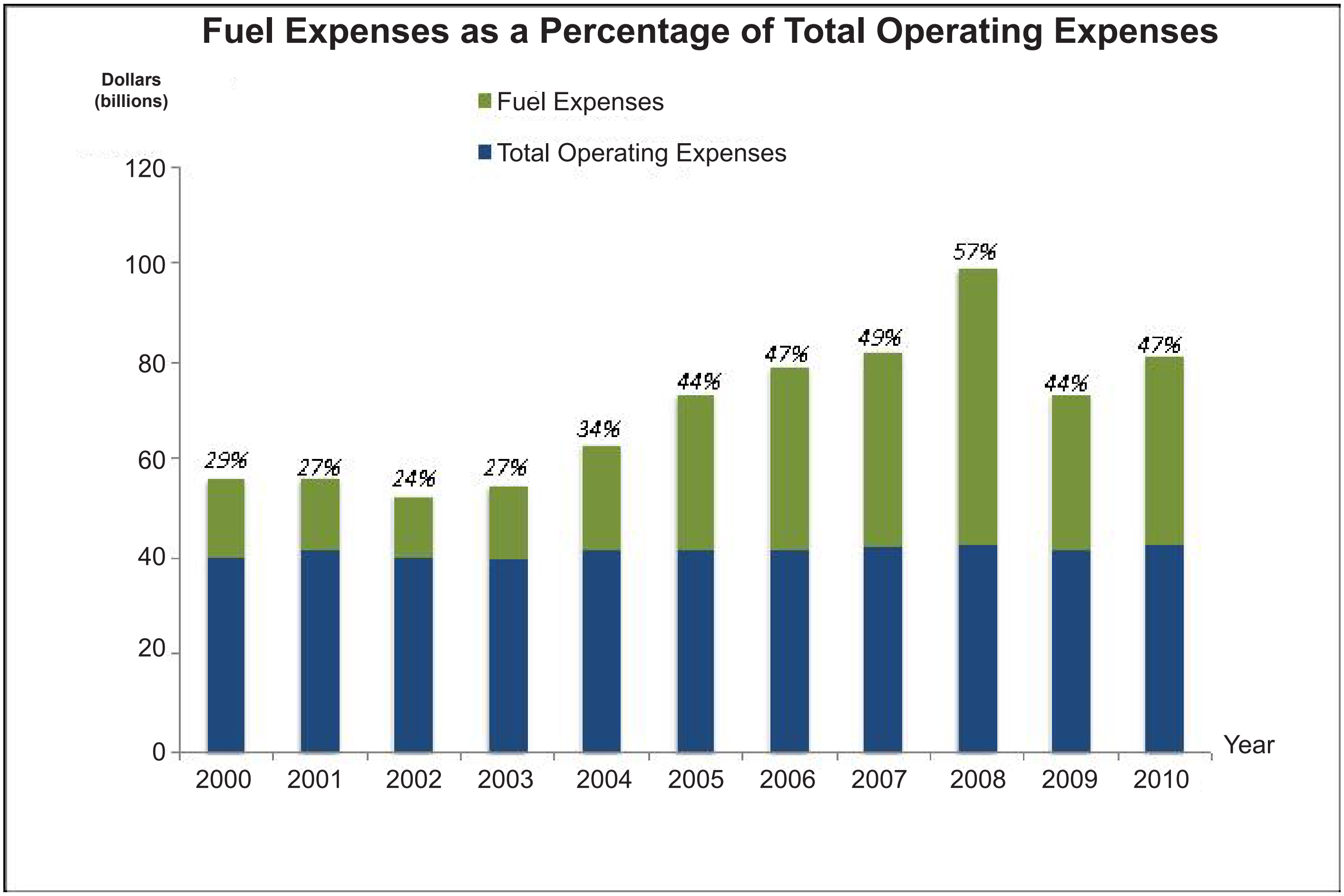

Figure 1: Fuel expenses as a percentage of total operating expenses (2000-2010). **Source:** Form 41, Schedule P-5.2, Bureau of Transportation Statistics and the Research & Innovative Technology Administration

about half of total operating expenses are from fuel costs (Figure 1).

Fuel Cost Savings to Airlines

The burden of increased fuel expenses is further exacerbated by airport congestion and existing inefficiencies in an aviation system that uses outdated technologies and protocols. Congestion is a problem, particularly at certain busy airports where the congestion is caused by capacity constraints, and will likely get worse as the economy recovers from the recession and travel demand rises.[10]

In 2010 major airlines reported that about 40 percent of arrivals and departures are delayed.[11] Every additional minute spent by operators sitting on the tarmac or circling an airport awaiting clearance means additional fuel, equipment depreciation and maintenance, increased labor costs, employee fatigue, and a possible loss of customers.

According to the latest FAA estimate, NextGen could save about 1.4 billion gallons of fuel through 2018.[12] This estimate assumes continued benefits of some of the NextGen capabilities already in place at some airports and timely implementation of the FAA's mid-term goals. This amounts to, on average, about 200 million gallons annually assuming full implementation of NextGen. Using the current jet fuel price of about $2.86/gallon in 2011, total fuel savings to operators would be about $600 million annually.

However, the FAA has not made public the details of their estimation, simulation models, or methodology. Some industry experts may remain skeptical of the FAA's estimates without a clear indication of the methodology or basis behind these figures.

The following is a simple yet plausible independent measure of NextGen's fuel savings. In 2010 the total fuel consump-

[10] Federal Aviation Administration Aerospace Forecast, Fiscal Years 2011-2031
[11] BTS/RITA Airline On-Time Performance data (2010). http://www.transtats.bts.gov/HomeDrillChart.asp (accessed June 2011)
[12] FAA's NextGen Implementation Plan (March 2011)

Fuel Reduction	Fuel Saved (mil gas)	$ Value (mil)	CO2 Reduced (mil tons)	Value of Reduced Emissions (mil $)
1%	102	$229	1.076	7.90
2%	204	$458	2.152	15.80
3%	306	$687	3.228	23.69
4%	408	$916	4.304	31.59
5%	510	$1,145	5.380	39.49

Table 1: Direct Annual Fuel Cost Savings

tion by all US commercial airlines in domestic flights was 10.205 billion gallons of fuel worth $22.84 billion at an average fuel price of $2.24/gallon.[13] Assuming a one percent improvement in fuel efficiency following NextGen implementation, which is a very conservative assumption, the resulting fuel savings amount to about 102 million gallons of fuel annually worth $229 million using the average 2010 fuel price. The savings from fuel also have environmental benefits. The 102 million gallons of fuel saved translates into reduced carbon dioxide emissions by approximately 1.076 million tons.[14] This helps mitigate the airline's industry impact on the environment and has real economic savings in a carbon offset market worth $7.9 million.[15] Table 1 simply expands the figures for higher levels of fuel reduction.

The results show that the benefits could be significant when only considering modest estimates of NextGen' fuel efficiency. A more ambitious five percent fuel consumption reduction leads to about $1.145 billion dollars of fuel saved and 5.380 million tons of reduced carbon emissions annually.

Delay Cost Savings to Airlines

Congestion in aviation is a serious problem with direct quantifiable costs to airlines and other operators.[16] According to the FAA's Cost-Benefit Analysis Guidance,[17] the value of reduced time of aircraft delay can be measured by the aircraft's variable operating costs including crew costs, maintenance, and fuel and oil costs. Fuel costs, which are analyzed separately above, are a part of the congestion savings included in this analysis.

Figure 2 shows the percentage of flights reported by carriers that arrived or departed late.[18] Post 9/11 dips in delays up to 2003 are indicative of decreased demand for flying, as indicated in green, and hence less congestion. Since then the percentage of flights delayed increased progressively as the impact of 9/11 on the airline industry slowly diminished. Towards the end of 2007 about 24 percent of reported flights arrived at least 15 minutes late, while 21 percent departed late. Delay numbers decreased in 2008 significantly following the recession, although they have climbed back up again as the economy began to recover. Today, about 20 percent of flights arrive or depart delayed.

NextGen's delay cost savings to commercial airlines is estimated as follows: First, using the Department of Transportation's airline delay data, the cost of current congestion to all airlines is calculated. Next the value of reduced congestion is quantified for various levels of delay reduction. The value of the FAA's estimate of 20-35 percent delay reduction is calculated and compared to the savings from much lower levels of delay reduction.

Major airlines are required to submit delay data to BTS.[19] The total delay for each reporting airline is calculated, amounting to 1.22 million hours of plane delays in 2010 overall. For every airline, the total cost of delays is calculated using an airline-specific hourly operating cost.[20] Using this data, the total cost of delays to major reporting airlines in 2010 was about $3.58 billion.

Using very modest estimates of NextGen's delay reductions, the delay savings are about $35.8 million annually for a one percent delay reduction and $179 million for a five percent delay reduction. These figures are much lower than the benefits using the FAA's 20-35 percent delay reduction estimates of 715.9 million-$1.25 billion, but still represent substantial annual savings.

Limiting the analysis to only the reporting operators underestimates the true cost to the entire airline industry that includes many smaller low-cost regional operators as well as cargo operators, which are not required to report to the

[16] Data on airline delays is used as a proxy for congestion due to unavailability of actual congestion data.
[17] FAA Cost-Benefit Analysis Guidance Office of Aviation Policy and Plans, Federal Aviation Administration (1999).
[18] In this report, a flight is considered late if it departed (arrived) from (at) the gate 15 minutes after schedule.
[19] Airline On-time Performance Data, Bureau of Transportation Statistics, accessed June 2011.
[20] The analysis is detailed in Appendix A4.

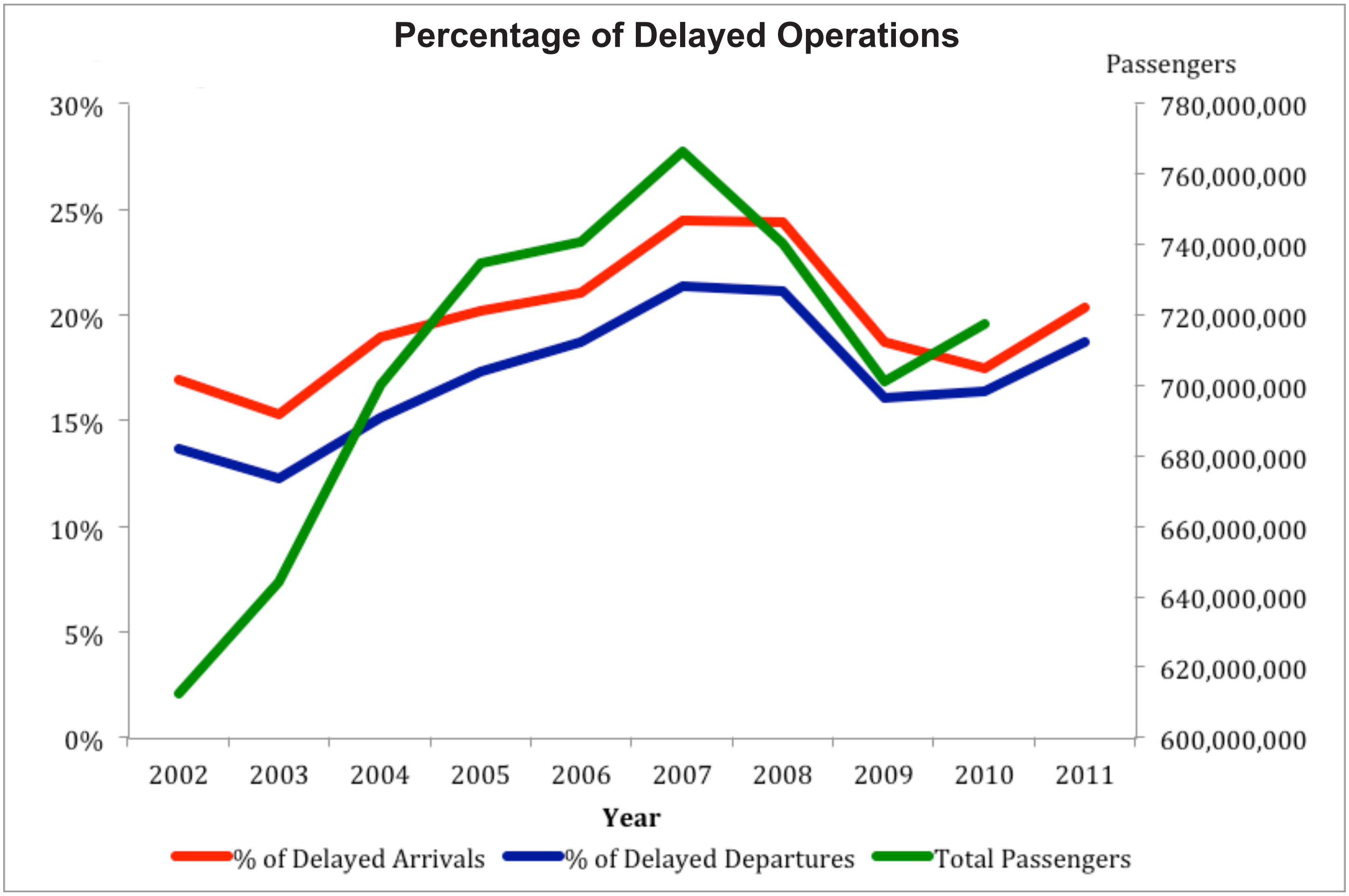

Figure 2: Percentage of delayed operations
Data Source: On-time performance- flight delays at a glance, Bureau of Transportation Statistics/Research and Innovative Technology Administration

BTS. A one percent delay reduction saves the rest of the low cost regional operators $3.33 million, five percent saves $16.67 million, 20 percent reduction of delay saves a total of $66 million while a 35 percent delay reduction saves about $117 million.[21]

Table 2 summarizes the delay savings. Note that a portion of these savings includes fuel savings. The total fuel savings in the previous section include both delay fuel savings as well as fuel savings during regular operation, so delay fuel savings are included in both calculations.

NextGen's Impact	Annual Delay Cost Savings
1% Delay Reduction	$39,130,000
5% Delay Reduction	$195,670,000
10% Delay Reduction	$391,340,000
20% Delay Reduction	$781,900,000
35% Delay Reduction	$1,367,000,000

Table 2: Estimated Reduced Congestion Savings to Operators

Time Savings to Commercial Passengers

In addition to reduced operating costs, passengers will also save time with reduced congestion, which is an economic resource. Any unneeded time spent due to congestion adds to the opportunity cost of foregone work or leisure, as well as any discomfort incurred. Travel time saved can thus be valued to reflect both the opportunity cost and discomfort during travelling.[22] The transportation literature suggests measuring this value of time in terms of, or as a percent-

[21] The analysis is detailed in Appendix A6.
[22] Economic Values for Evaluation of Federal Aviation Administration Investment & Regulatory Programs, FAA and US DOT, January 1998, accessed July 2011. (FAA/DOT 1998)

age of, an hourly wage rate. For this analysis, the FAA "all purpose" hourly rate of $28.60 is used.

The total cost of delays to passengers is estimated to be about $5.37 billion, or about $25.84 per passenger, which is about 7.7 percent of the average nominal ticket price of $336 in 2010.[23]

Table 3 shows the estimated value of the time that NextGen can save passengers under different delay reduction scenarios and the resulting average dollar savings per passenger.[24] The results show that for a one percent reduction in delays, the total value of travel time saved is about $53.7 million, or about 25 cents per passenger. For a five percent delay reduction, total savings is $268.5 million annually or $1.292/passenger. For a moderate 10 percent delay reduction, this is about 5.4 minutes saved per flight per passenger, the total savings amount to $537 million per year, or $2.584 per passenger. The savings are significantly larger using the FAA's delay savings estimates: $1.074 billion per year or $5.167 per passenger for a 20 percent delay reduction, and $1.88 billion/year or $9.042 per passenger for a 35 percent delay reduction.

NextGen's Impact	Total Savings ($)	Saving/Passenger ($)
1% Delay Reduction	53,702,744	0.258
5% Delay Reduction	268,513,721	1.292
10% Delay Reduction	537,027,441	2.584
20% Delay Reduction	1,074,054,883	5.167
35% Delay Reduction	1,879,596,045	9.042

Table 3: Estimated Delay Reduction Benefits to Passengers (2010)

Benefits to General Aviation

General aviation users will benefit from NextGen through improved approach capability at small airports that currently do not qualify for precision navigation aids, and improved safety. There may also be benefits in the form of shorter stage lengths and resulting fuel savings. The following analysis attempts to quantify these benefits for general aviation, starting with the reduced travel time and fuel savings. These can be estimated based on the FAA's database on general aviation and part 135 activity surveys for 2009.

Reduced Travel Time and Fuel Savings

According to the data, there were 23,760,000 all-purpose general aviation flight hours with 1.584 billion gallons of fuel in 2009. The following table shows the possible savings due to NextGen under different circumstances. For the purpose of this analysis, the USDOT recommended value of $45 is used as the per hour value of travel time for general aviation users. The fuel price used is $2.86/gallon. Along with the fuel savings for commercial aviation, reduction in fuel consumption offers real environmental benefits as well. The results in Table 4 show that a modest one percent reduction in travel time leads to total savings of $56 million annually. A larger five percent reduction could potentially bring very large savings to general aviation operators.

There is a difference, however, in the potential for NextGen to benefit commercial and general aviation. The earlier analysis that quantified benefits to airlines was based on a range of 1-35 percent delay reduction. For the general aviation analysis, a much lower range of benefits of 1-5 percent is used because on a system-wide basis, congestion is a less prevalent problem for general aviation.

Safety

With more precise location information on all aircraft, controllers can have a much better sense of their location with respect to the location of other moving and non-moving aircraft in their vicinity. NextGen provides precision vertically guided approaches with no equipment expenditure on the ground. The direct result of the improved information is less of a risk of collisions on the ground or in the air, especially in times of low visibility.

While commercial aviation in the United States has an unparalleled safety record, general aviation still faces substantial flight incidents and casualties annually. An analysis of the National Transportation Safety Board's (NTSB) data for general aviation accidents shows over 1,000 cases in 2010, including 245 casualties.[25] A common probable cause for accident according to the NTSB's investigation reports is pilot error due to lack of situational awareness, particularly during times of poor visibility.

In quantifying the cost of fatalities, the USDOT's recommended value per casualty is $5.8 million, or a range of $3.2-$8.4 million due to uncertainty.[26] Based on this estimate, the

[23] Annual US Domestic Average Itinerary Fare in Current and Constant Dollars, Bureau of Transportation Statistics, http://www.bts.gov/programs/economics_and_finance/air_travel_price_index/html/annual.html, accessed July 2011.
[24] Details of the methodology can be found in Appendix B1, including a robustness check in Appendix B2.
[25] NTSB, Aviation Accidents and Synopses Database (2010).
[26] Revised Departmental Guidance, Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses, U.S. Department of Transportation, Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses, http://ostpxweb.dot.gov/policy/reports/080205.htm, accessed Dec. 5, 2011.

Travel Time Reduced	Hours Saved	Value of Saved Time ($)	Fuel Saved ($)	Total Savings ($)
1%	237625	10,693,137	45,307,682	56,000,819
2%	475251	21,386,273	90,615,365	112,001,638
3%	712876	32,079,410	135,923,047	168,002,457
4%	950501	42,772,547	181,230,730	224,003,276
5%	1188126	53,465,684	226,538,412	280,004,096

Table 4: Estimated NextGen Benefits to General Aviation Through Reduced Travel Times and Fuel Consumption.

cost of general aviation accidents in terms of lives lost is about $1.421 billion or between $784 million-$2.058 billion annually.[27]

The database indicates damage to the aircraft as "substantial" or "destroyed". In 2010 there were 38 cases where the aircraft was completely destroyed, and 981 cases of substantial damage. Using a roughly estimated price of a used Cessna 180 aircraft of $100,000, the cost of destroyed aircraft is approximately $3.8 million. The cost of damaged aircraft is about $24.5 million, assuming the per-aircraft cost to be a quarter of damaged aircraft.

Based on these estimates, the total cost of accidents to the general aviation community in 2010 was about $1.449 billion.

Even with on-board ADS-B, the prospect of greater situational feedback and data could be undermined by human error of judgment. However, a reasonably moderate estimate can be made where greater situational awareness does contribute to preventing some accidents.

Table 5 shows savings to the general aviation community under various levels of NextGen's impact on safety. Even if NextGen plays a small role in improving safety and reducing incidents in general aviation, the potential benefits are substantial.[28]

Summary of NextGen Benefits

Table 6 summarizes the potential annual NextGen benefits to the aviation community, assuming complete infrastructure and equipage. For commercial airlines, reduced delays and fuel consumption could bring up to $1.45 billion/year of benefits. For passengers, the estimated value of reduced delays and travel time is about $852 million/year for a 20 percent delay reduction and $1.5 billion/year for a 35 percent delay reduction. The benefits are quite substantial for the general aviation community as well. One important point to note is that even for a small impact of NextGen, benefits can be very high. The value of reduced travel time is estimated to be $10.69 million/year for a one percent reduction, and $53.47 million/year for a five percent reduction. The value of reduced fuel consumption is about $45.31 million/year for a one percent reduction and $226.54 million/year

NextGen's Impact	Value of Reduced Casualties (million $)	Value of Saved Equipment ($)
1%	14.21	283,250
5%	71.05	1,416,250
10%	142.1	2,832,500
20%	284.2	5,665,000
30%	426.3	8,497,500
40%	568.4	11,330,000
50%	710.5	14,162,500

Table 5: Estimated NextGen Safety Benefits to General Aviation

[27] The cost of injuries is ignored due to lack of data on the type of injuries.
[28] Based on Eno's correspondence with The Aircraft Owners and Pilots Association (AOPA), there is still a concern among general aviation operators that the FAA's NextGen Implementation Plan does not include infrastructure coverage to GA airports that are prone to accidents. Furthermore, there is also a notion that ADS-B-IN, which adds on-board display and situational awareness, would play a stronger role in improving safety than ADS-B-OUT. Currently the FAA has mandated equipage of ADS-B-OUT only. The less-optimistic estimates in table 4 likely reflect a situation where these concerns are valid.

	Benefit	Possible Range	Value mil ($/year)
Airlines	Fuel Savings	1%	229
		5%	458
		10%	687
		20%	916
		35%	1145
	Reduced Congestion	1%	39.1
		5%	195.7
		10%	391.3
		20%	781.9
		35%	1367
Passengers	Reduced Travel Time	1%	53.7
		5%	268.5
		10%	537
		20%	1.074
		35%	1880
General Aviation	Safety		
	(i) Reduced Facilities	1%	14.21
		10%	142.2
	(ii) Reduced Aircraft Damage	1%	0.28
		10%	2.83
	Reduced Travel Time	1%	10.69
		5%	53.47
	Reduced Fuel Consumption	1%	45.31
		5%	226.54

Table 6: Summary of Estimated NextGen Benefits

for a five percent reduction. Safety benefits could range from $14.21 million/year to $142.2 million/year in terms of reduced accident fatalities, while the cost of lost aircraft can be reduced by up to $2.83 million/year.

It should be noted that in addition to these benefits, there are also likely to be substantial environmental benefits that have not been quantified here. Quantifying these environmental benefits would require substantial additional data and analysis that is beyond the scope of this research.

Total annual savings using the one percent impact of NextGen for every benefit category yields $353.19 million. For a moderate case of five percent, total annual benefits are about $1 billion. High end estimates yield up to $3.45 billion annually.

Large jet airliner taking off.

NextGen Costs

This section shifts the focus from benefits to costs of NextGen, which has two distinct aspects- infrastructure and equipage. The infrastructural costs of NextGen involve paying for ADS-B, improved decision-making capabilities during adverse weather, devising more direct routes, better data communications between cockpit and ATC, and replacing the En Route Host computer and backup system used at 20 FAA air Route Traffic Control Centers nationwide with En Route Automation Modernization (ERAM). In order for NextGen to be fully implemented, operators need to install NextGen equipment on their aircraft, which entails a separate equipage cost. Any on-board technological investment to be made by operators is referred to as equipage, which is different from ground infrastructure that is currently being paid for by the facilities and equipment account of the AATF. direct routes, critics contend that airports can still only allow a fixed number of planes to land per hour.

Infrastructure Costs

According to the FAA, the total infrastructure cost of NextGen through 2025 is approximately $15 billion-$20 billion. However, the FAA has not published its cost breakdowns for individual infrastructure projects. To the best of our knowledge, the only published source for the project costs is the recent GAO report that tracks the status of NextGen projects and associated costs. Based on that report, Table 7 shows 30 major NextGen programs with FAA approved budget and schedule,[29] with an estimated total cost of about $14.243 billion.

Equipage Costs

In additional to the infrastructure side of NextGen, operators will also have to install the appropriate on-board equipment to reap the benefits of the modernized infrastructure. This entails further equipage costs. It is difficult to accurately estimate the cost of equipage to operators for a number of reasons. There could be different levels of equipage depending on the aircraft and airline policy. According to industry sources, ADS-B may cost at least $100,000 per jet and at least $10,000 per small aircraft, affecting up to 240,000 aircraft including general aviation depending on FAA regula-

[29] Air Traffic Control Modernization: Management Challenges Associated With Program Costs and Schedules Could Hinder NextGen Implementation. United States Government Accountability Office, Report to Congressional Committees. February, 2012.

NextGen Program	Start Date	Completion Date	Estimated Cost (mil $)
Wide Area Augmentation System (WAAS)	1998	2013	$3,008
Standard Terminal Automation Replacement System (STARS)	1996	2007	$2,719
En Route Automation Modernization (ERAM)	2003	2014	$2,484
Automatic Dependence Surveillance Broadcast (ADS-B)	2007	2014	$1,730
Power Systems Sustained Support (PS3)	2008	2018	$969
Advanced Technologies and Oceanic Procedures (ATOP)	-	2014	$524
Runway Status Lights (RWSL)	2010	2016	$352
Next Generation Air/Ground Communication System (NEXCOM)	1998	2013	$325
System Wide Information Management (SWIM)	2009	2015	$310
Integrated Terminal Weather System (ITWS)	1997	2010	$282
Air Traffic Control Radar Beacon Interrogator (ATCBI-6)	1997	2012	$255
Collaborative Air Traffic Management Technologies (CATMT)	2008	2015	$163
Terminal Automation Modernization and Replacement (TAMR)	2005	2008	$140
Trajectory Management—Arrival Tactical Flow Time Based Flow Management	2010	2014	$115
Ultra High Frequency (UHF) Radio Replacement	2002	2013	$93
Regulation and Certification Infrastructure for System Safety (RCISS)	2010	2016	$91
Voice Switching and Control Switching System (VSCS)	2006	2014	$84
Service Life Extension Program (SLEP)	2003	2017	$77
Terminal Doppler Weather Radar (TDWR)	2003	2013	$75
Aviation Surface Weather Observation Network (ASWON)	2001	2012	$56
Integrated Display Systems (IDS) Replacement	2008	2015	$51
Instrument Flight Procedure Automation (IFPA)	2006	2012	$51
Next Generation Voice Recorder Replacement Program (VRRP)	2007	2013	$46
En Route Communication Gateway (ECG)	-	-	$41
Traffic Flow Management System (TFMS)	2011	2015	$40
Tower Training Simulator Systems	2007	2010	$37
International Flight Inspection Aircraft (IFIA)	2003	2012	$34
Weather and Radar Processor (WARP) Sustain	2009	2012	$28
Next Generation Weather Radar (NEXRAD)	2008	2013	$26
Airport Surveillance Radar (ASR)	2008	2015	$21
Weather Camera Program (WCP)	2007	2014	$20
Total			$14,243

Table 7: NextGen Programs and Estimated Costs to Completion
Source: Air Traffic Control Modernization: Management Challenges Associated With Program Costs and Schedules Could Hinder NextGen Implementation. United States Government Accountability Office, Report to Congressional Committees, February 2012. Date accessed: March 2012.

tions.[30] About 90 percent of current commercial aircraft are already equipped with RNAV, while about half are equipped with Required Navigation Performance (RNP),[31] which reduces their equipage costs compared to their completely unequipped counterparts. Table 8 is a summary of the current size of passenger and cargo fleet that would require NextGen equipage.

If we look only at the commercial airlines, using CBO's industry estimates of $100,000/ large and regional passenger jets and cargo, and $10,000 per small aircraft, total cost of ADSB equipage over the entire modernization process is about $637 million.[32] Including general aviation would of course substantially increase this total, possibly as much as $2.3 billion.[33] Note that the $637 million above only includes ADS-B equipage. The total equipage cost would cover other on-board NextGen equipment. Since it is not certain what these other equipment might be or their market price, we have not attempted to include them in our analysis. The FAA has estimated that total equipage could cost $19

[30] Congressional Budget Office Cost Estimate, H.R 658 FAA Reauthorization and Reform Act of 2011 report, March 2011.
[31] FAA NextGen Implementation, Appendix A, accessed July 2011.
[32] These figures are similar to the $681-$982 million for full ADS-B/RNP equipage or $650-$767 million for partial equipage for commercial operators recommended by the RTCA NextGen Advisory Committee to the FAA in June 2011. Recommendation for the Prioritization of NextGen Mid-Term Operations Dependent on Equipage, RTCA, June 2011.
[33] Author's own calculation using data on total general aviation aircrafts and the $10,000 per aircraft cost of ADSB equipage. Source of Data: General Aviation and Part 135 Activity Surveys- CY 2010, FAA. Accessed: December 15, 2011.

OPERATOR/AIRCRAFT TYPE	Narrowbody	Widebody	Other	TOTAL
Mainline Passenger/Combination (Jet)	3,108	514	91	3,713
Regional Passenger (Jet)	---	---	1,771	1,771
Regional Passenger (Other)	---	---	806	806
All-Cargo	267	539	---	806
Total U.S. Air Carrier Fleet	3,375	1,053	2,668	7,096

Table 8: US Commercial Passenger and Cargo Fleet as of Dec. 31, 2010
Source: Air Transport Association, FAA Aerospace Forecast report (2010)

billion through 2030, although it has not made its methodology public.

Most US operators have been less than enthusiastic about paying for NextGen equipage because the technology does not provide benefits unless the infrastructure and ATC procedures are in place to use it. Investing in new technology for which the infrastructure is not yet in place poses a significant financial risk operators are not incentivized to bear. Equipage is at a standstill due to concerns of rapid technological obsolescence and uncertainty. "If I go first, I'll have to bear the cost of updating the software, and when NextGen is turned on, I'll have the oldest, most obsolete systems out there",[34] is an oft-expressed concern, according to Russell Chew of Nexa Capital, a private financing firm for NextGen equipage. Operators have also expressed concerns regarding the lack of control over benefits arising from NextGen, which can only be reaped if a majority of operators decide to equip. If only some operators equip, that may lead to freeriding by other operators.

Low profitability due to increasing fuel costs and post-9/11 recessionary demand-side shocks is another reason why commercial carriers have been reluctant to pay for NextGen equipage. Some carriers have lobbied in vain for federal stimulus funding for NextGen equipage during this period.[35]

Operators would have an incentive to invest in NextGen if they can be sure it will generate profits by reducing operating costs. As discussed earlier, NextGen could significantly reduce operating costs by reducing delay and fuel consumption. Whether this would increase airline profits depends to some extent on the intensity of competition between operators.[36] However, assuming that the underlying assumptions and analyses are correct and annual airline benefits exceed the total equipage cost, there is a sensible business case for the industry as a whole to invest in NextGen, meaning there is a reason for operators to pay for their own equipage. From a policy side, a strong set of incentives needs to be provided to facilitate this equipage. The FAA has already begun to provide some aid to airlines for equipage, but it has not been enough to counter the continuing risk across the larger industry.[37]

Aligning Costs with Benefits

The benefits of NextGen, as described in Section II, extend to users and operators of both commercial and general aviation. In addition there is real value in congestion reduction to regional economies dependent on airports, although this paper does not attempt to quantify those benefits. An important result of the analysis so far is that even a low estimate of NextGen impacts indicates substantial annual benefits. It is clear that a wholesale overhaul of the system such as NextGen will require funding and some challenging policy decisions. The next section looks at different funding sources and demonstrates how these sources compare in terms of equity, transparency, efficiency, and political feasibility.

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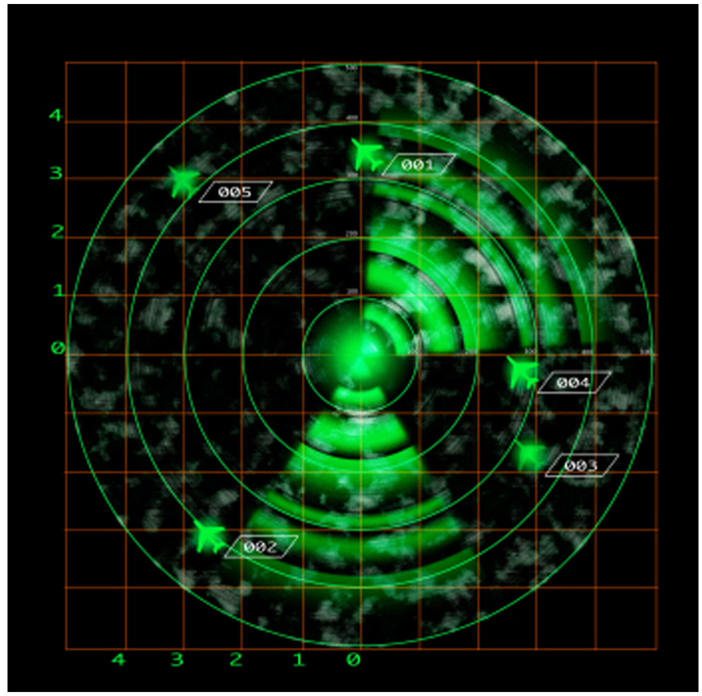
[34] *Washington Post*, Ashley Halsey III. "New guidance system for skies could face delays", July 4, 2011.
[35] "Aviation Lobby Groups Urge: Include NextGen in Stimulus", February 2009, *Aviation International News*.
[36] For example, as operating costs decrease in highly competitive routes, operators are able to reduce fares to attract passengers from other operators, who in turn might retaliate by reducing their own fares. Even if costs go down, a fare war would mean that operators generate no additional profit arising from NextGen. On the other hand, presence of market power and some of tacit collusion or understanding between operators would lead to some or no reduction in fares and generate profits.
[37] Some operators have taken the initiative to install ADS-B in their aircraft due in part to federal incentives. JetBlue operators received $4.2 million federal funding in 2011 to equip and start new routes to the Caribbean from selected east coast cities. Southwest operators, perhaps not surprisingly given their financial record relative to the industry, have also taken part in equipage. Both operators received funding from the FAA.



Air traffic control radar.

Funding NextGen

While reaching consensus on the costs and benefits has been a contentious issue, little progress has been made towards devising a funding strategy for NextGen. This section explores options for aligning the burden of paying for NextGen with those who benefit from it.

This looks at funding for two aspects of NextGen: infrastructure and equipage. Under the current program, the FAA is responsible for funding and implementing the infrastructure side of the program and the airlines and general aviation operators are left to equip their own aircraft with the appropriate technologies. This section will review funding options for infrastructure and then discuss ways to incentivize and finance equipage.

Infrastructure Funding

This analysis stems from the premise that funding levels in the AATF are neither adequate to implement neither NextGen nor effective at accelerating modernization, which is crucial to making the most out of AATF funds. According to the FAA:

By 2022, we estimate that this failure [to implement NextGen in a timely manner] would cost the U.S. economy $22 billion annually in lost economic activity. That number grows to over $40 billion by 2033 if we don't act. Even as early as 2015 our simulation shows that without some of the initial elements of NextGen we will experience delays far greater than what we are seeing today.[38]

The results of the Deloitte study that showed significant additional costs by delaying implementation buttress the FAA's estimates above.

The AATF has been the primary funding source for NextGen to date. It receives revenues from a variety of user fees and taxes paid by both commercial and general aviation operators as well as passengers (Table 9). According to a report by GAO,[39] current sources of revenue in the Airport and Airway Trust Fund might be inadequate to cover anticipated future costs of NextGen without drawing from other revenue sources, and this is likely unfeasible given ongoing fiscal and political constraints. Total trust fund expenditures have

[38] "Why now?" FAA NextGen Factsheet, February 2007.

[39] Airport and Airway Trust Fund: Declining Balances Raises Concerns over Ability to Meet Future Demand. United State Government Accountability Office, Testimony Before the Committee on Finance, U.S Senate, February 3, 2011.

Source	Rates
Domestic passenger Ticket Tax	7.50%
Domestic flight segment tax	$3.7/passenger/segment
Domestic commercial Fuel Tax	$.043/gallon
Domestic general Aviation Gasoline tax	$.218/gallon
Domestic cargo/mail	6.25%

Table 9: Domestic Revenue Sources of the Airport and Airway Trust Fund
Source: AATF, Federal Aviation Administration [40]

gone up since 2000 from under $10 billion to about $14 billion in 2010 (Figure 3). However, trust fund revenues have not increased proportionately to keep up with rising expenditures. Several economic studies have shown that inflation-adjusted fares in the airline industry have been declining for several reasons such as expansion of low-cost carriers and two major demand-side shocks in the past decade.[41] In fact, the Congressional Budget Office earlier this year adjusted its projection of the trust fund revenues to $25 billion less than its 2007 forecast for through 2017.

Past shortfalls have been fulfilled by increasing general fund contributions, covering 34 percent of the FAA's expenditures in 2010 and 24 percent in 2009. The current fiscal crisis and Congressional discourse on debt-reduction seriously besets the possibility of continued general fund transfers to the AATF.

Furthermore, the trust fund's end-of-year uncommitted balance, the surplus of revenues after spending commitments from FAA's appropriations, has also decreased dramatically from $7.07 billion in 2000 to only $770 million in 2010. This was partly due to Airport Improvement Program (AIP) funding and due to revenues not rising sufficiently to meet expenditures as discussed above. A low uncommitted balance means inadequate FAA funding to cover new projects and programs. Even though the FAA has been able to initiate some work on NextGen infrastructure, a diminishing uncommitted balance leaves very little room for other unforeseeable expenses.[42] And the current trend of outlays growing faster than revenues could mean further decreases in that balance.

In order for NextGen modernization to reach completion, determining an adequate funding source is essential.

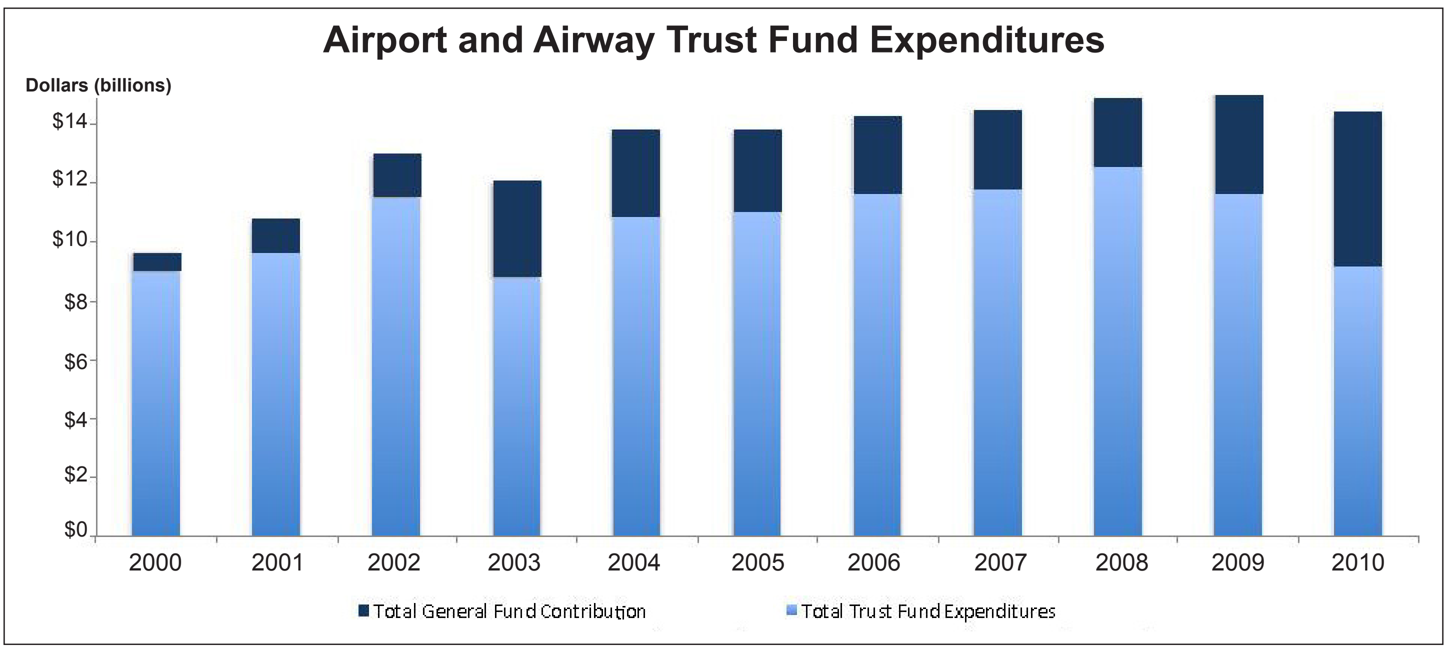


Figure 3: Airport and Airway Trust Fund Expenditures, FY 2000-2010.
Source: Federal Aviation Administration[43]

[40] http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf (Date accessed: July 2011)
[41] For example, Severin Borenstein (2005), US Domestic Airline Pricing 1995-2005, Institute of Business and Economic Research, Competition Policy Center, University of California, Berkeley, Paper CPC05'048.
[42] For example, as of early 2011 the NextGen information-sharing program called System-Wide Information Management (SWIM) was $105 million over budget and completion was postponed two years until 2015 (CBS Atlanta, "Key Part of New Air Traffic System in Trouble", June 2011)
[43] http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/historical_data (Date accessed: June 2011)

Although the recent FAA reauthorization bill authorizes a fixed funding for NextGen over the next four years, it is unclear whether the current revenue sources are adequate to fund NextGen, particularly with no new law on aviation taxes or fees. If NextGen continues to be funded through the AATF, it is likely necessary to consider future sources of revenues or there needs to be greater prioritization of NextGen to allow general funds to supplement the AATF. The following is an analysis of the relative merits and weaknesses of each revenue source, and they might propel or stagnate NextGen progress. An effective funding mechanism behind NextGen should be equitable, transparent, efficient and politically feasible. The following explains each of these criteria and how they help alleviate the obstacles facing NextGen.

Criteria for Analysis

Equity. NextGen benefits will likely be greater for both operators and passengers in more heavily congested airports than in uncongested areas. An equitable funding mechanism requires that those who benefit most from NextGen should also pay a greater share towards funding NextGen. In other words, congested airports and routes where operators and passengers benefit the most should generate more revenues towards funding NextGen.

Transparency. Despite an awareness of its merits, and the need for modernization of the aviation system, there is no clear plan that shows where the funds for NextGen will come from, who is paying, or where the money is going. Transparency will help those that are paying for NextGen accept the additional cost.

Efficiency. Taxes can distort free-market outcomes by imposing an additional cost burden on passengers and operators. If the combined losses to both passengers and operators exceed the tax revenue, the net is called dead weight loss or social welfare loss.

An efficient funding mechanism should aim at generating sufficient revenue for NextGen while minimizing market distortions and loss to society.

Political Feasibility. No matter how effective and optimal a policy measure in theory, it is impractical unless it can generate Congressional support. This paper aims to propose a funding mechanism that is practical in the existing political environment. Any potential funding mechanism needs to be able to gain support from lawmakers, who have shown strong opposition to tax increases in recent times. However the unavoidable fact is that upgrading the air traffic control system to NextGen is going to require real funding. A policy that minimizes the cost burden while still equitable and transparent is more likely to gain political support.
The most effective policy will provide the best balance between equity, transparency, impact on the aviation users and political feasibility. The focus in this discussion is on effective ways of funding NextGen, rather than on analyzing exactly how much revenue should be raised. This analysis covers multiple options for funding NextGen, including:

- Taxing baggage fees
- Increasing jet fuel tax
- Increasing passenger ticket tax
- Imposing a NextGen fee
- Dedicating general funds
- Privatization of Air Traffic Control

Each potential revenue source is analyzed for its equity, transparency, market efficiency and political feasibility.

The Baggage Tax

One possible way of raising NextGen funds is by taxing baggage fees. In recent years, commercial operators have started charging for ancillary services such as baggage fees as alternative sources of revenue. According to the 2011 GAO report on the AATF, applying the current 7.5 percent excise tax to baggage fees would have raised an additional $248 million in revenues in 2010, potentially increasing if operators continue to increase such fees in subsequent years. Substantially higher baggage fees since 2007 suggest that the demand for baggage services might be fairly inelastic. This implies that such a tax can potentially be passed on to passengers in the form of higher fees without eliciting any

reduction in demand for baggage services. For example, a 7.5 percent excise tax on the typical $25 first luggage fee would raise it to about $27, which might not be enough to force a passenger's decision to fly or to check his/her luggage, meaning that the baggage tax could have minimal market distortions.

From an equity standpoint, it would place the entire burden on passengers that check baggage. Another potential difficulty in implementing an equitable and transparent baggage tax is that there is no direct connection between baggage and NextGen. Passengers of congested urban routes, who would benefit the most from NextGen and thus should be paying more, might be mostly business class fliers on short trips who do not need to check any luggage. With the same percentage excise tax nationwide, a baggage tax would fail to extract additional revenues from more congested airports. Differentiating the tax rate based on congestion would not be effective either due to free ridership from passengers with no baggage. The possibility of a baggage tax has received mixed reactions from policymakers. A baggage tax was considered in a previous FAA reauthorization proposal, but did not receive any substantial bipartisan support.

Commercial Jet Fuel Tax

The commercial jet fuel could be a direct way of collecting the operators' contribution to NextGen infrastructure or an indirect way of paying for equipage where airlines are taxed first and then the revenues are used to buy the necessary equipment for the aircraft. Commercial operators currently pay 4.3 cents/gallon in federal jet fuel tax.[44] Figure 4 shows the contribution of the fuel tax revenues to the AATF. The following analysis examines how such a fuel tax might be implemented to fund NextGen.

- Raising the current flat jet fuel tax of 4.3 cents/gallon
- Replacing the existing tax with a percentage tax

Increasing the commercial jet fuel flat tax from 4.3 cents per gallon could potentially raise sufficient revenues to pay for airline equipage. Figure 5 shows that US domestic airline fuel consumption has been on a decline from about 14 billion gallons in 2000 to 11 billion gallons in 2010 at an annual average rate of about two percent. This has been in part due to rising fuel costs as operators switch to more fuel-efficient practices and also in response to post 9/11 and recessionary shocks. It is reasonable to assume that fuel consumption might rise in the near future as the economy recovers from recession. It should also be noted that NextGen would also reduce fuel consumption. For the purpose of analyzing the impact of raising the flat fuel tax, it is assumed that the fuel consumption levels remain fairly unchanged in the near term.

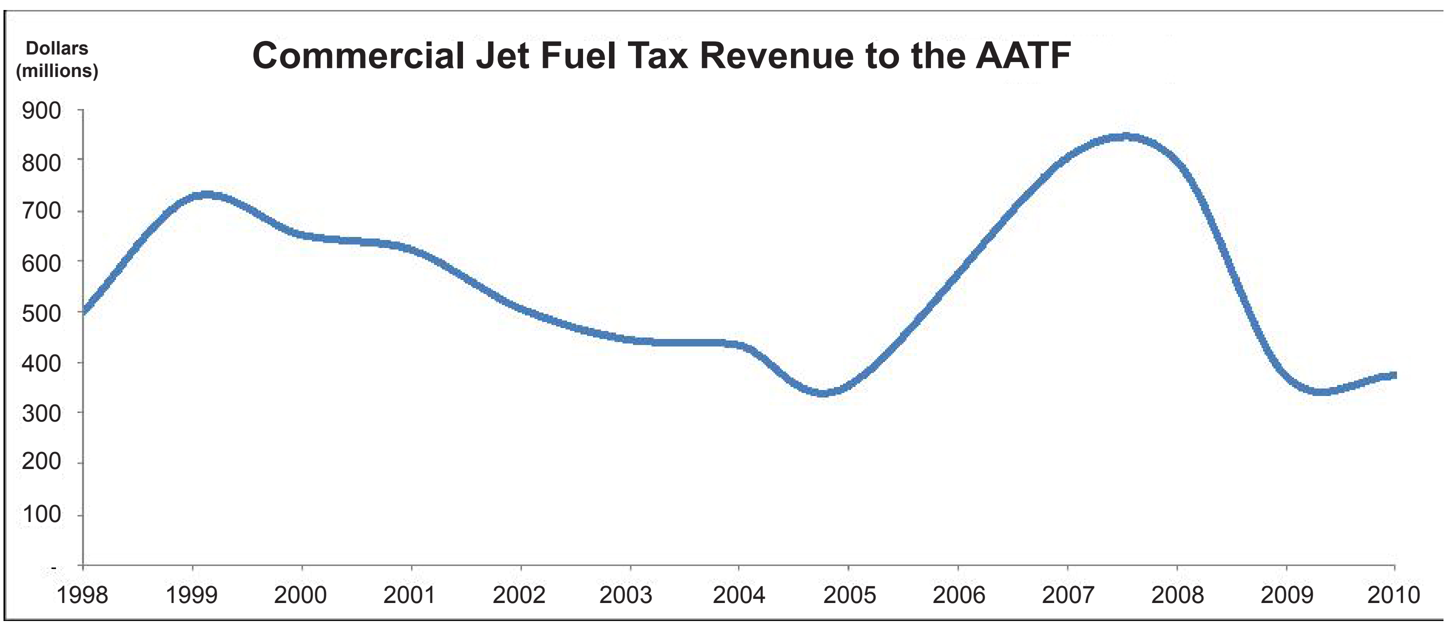


Figure 4: Commercial Jet Fuel Tax Revenues (FY 1998-2010)
Source: FAA Airport and Airway Trust Fund Revenue Data

[44] Commercial tax receipts for FY06 include $223 million transfer from the Highway Trust Fund to the AATF as a result of fuel tax provisions from SAFETEA-LU. Due to fuel tax provisions in the American Jobs Creation Act, some fuel used in commercial aviation is initially taxed at the higher non-commercial rate, with taxpayers having to file for refund for the difference. The initial tax revenue is credited as non-commercial fuel tax receipts, and the refund is deducted from commercial fuel tax receipts. Source: http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/historical_data/. Date accessed: March 2012.

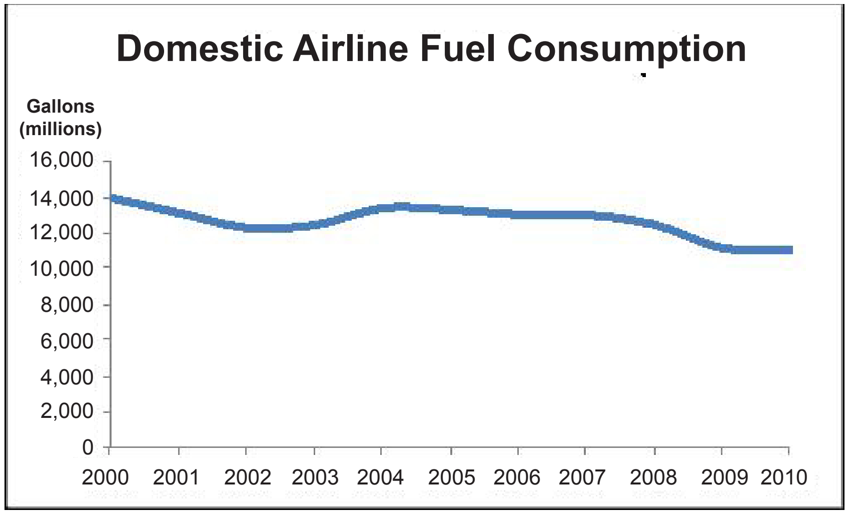


Figure 5: US Domestic Airline Fuel Consumption, 2000-2010
Source: Bureau of Transportation Statistics, Airline Fuel Cost and Consumption [45]

Tax Rate ($/gal)	Max Revenue: Year 1	Year 2	Year 3	Year 4	Year 5	NPV
0.043	$475,416,600	$448,125,742	$410,098,535	$364,367,237	$314,306,379	$2,012,314,494
0.08	$884,496,000	$833,722,311	$762,974,019	$677,892,534	$584,756,055	$3,743,840,919
0.12	$1,326,744,000	$1,250,583,467	$1,144,461,029	$1,016,838,801	$877,134,082	$5,615,761,379
0.14	$1,547,868,000	$1,459,014,045	$1,335,204,534	$1,186,311,935	$1,023,323,096	$6,551,721,609

Table 10: Estimated commercial jet fuel tax revenues

Table 10 shows the net present value (NPV) of revenues generated in the short run by different levels of the jet fuel tax. At the current rate of 4.3 cents per gallon, the maximum revenue generated is about $476 million, the present value of which declines to about $314 million five years later if a nominal three percent discount rate is applied. However, these revenue levels are insufficient to fund equipage as discussed earlier. Raising the fuel tax to eight cents per gallon raises an additional $1.7 billion in NPV over the next five years. Revenues associated with further increases in the jet fuel tax are also estimated. For the sake of transparency, this increase in the fuel tax could be administered for a fixed period of time after which the tax rate could roll back to current levels.

An increase in the commercial jet fuel tax by four cents per gallon over five years would be more effective than higher increases over shorter periods of time. First, higher tax rates are unnecessary as a simple four-cent tax increase could raise sufficient revenues for equipage. Second, it will be easier to gain political and private sector support for a smaller increase in the fuel tax than a larger increase. A small increase in the fuel tax spread over about five years would have less impact on the market than a higher tax over a shorter period of time.

From an equity perspective, it is unreasonable to assume that any additional taxes will be borne entirely by operators. The airline industry is characterized by fairly low profit margins, implying that fares reflect operating costs. If costs go up, fares also rise. Increasing the commercial jet fuel tax would raise operating costs, which might trigger fares to go up. As a result, passengers would ultimately bear a portion of the tax burden. The jet fuel tax needs to be raised with this consideration in mind. A simple analysis (Appendix C1) estimates that a four-cent increase in the jet fuel tax increase could raise fares paid by passengers by about $350-$600 million. Therefore, a higher jet-fuel tax is not a sole burden on operators, but passengers would indirectly pay as well.

An alternative to increasing the flat jet fuel tax is switching to a percentage tax where the tax is paid as a percentage of the fuel price. The current level of fuel consumption at about 11 billion gallons and the 4.3-cent/gallon-fuel tax yields a maximum of $475.4 million. Using the average jet fuel price of $2.86/gallon in 2011, 1.51 percent fuel tax would generate the same amount of revenues. The main advantage of a percentage tax over a flat fuel tax is that it is self-adjusting- revenues increase proportionately with inflation, negating any need for periodic renewal of the tax that is subject to politics and bureaucratic delays.

However, there are several obstacles facing a percentage tax. As Figure 5 demonstrates, the price of jet fuel is volatile and expected revenues can fluctuate dramatically. If fuel prices rise faster than inflation, the operators' tax burden also increases. With recent hikes in jet fuel prices, this is an obvious concern for operators. A sharp fall in fuel prices on

[45] http://www.transtats.bts.gov/fuel.asp. Date Accessed: July 2011

the other hand could hurt the FAA in the form of inadequate revenues to fund its projects. Furthermore, jet fuel consumption is subject to state fuel taxes in many places.

These issues can potentially be dealt with using a revenue-neutral percentage tax, so that operators pay the same amount in taxes initially, with a minimum and maximum tax cap to safeguard both the operators and the FAA from volatile fuel prices.

In sum, increasing the commercial airline jet fuel tax to eight cents per gallon over five years could raise $1.7 billion towards NextGen equipage, about $350-$600 of which would be borne by passengers. This means that ultimately operators are liable for about $1.1-$1.35 billion. However, owing to its distortionary nature and the likelihood of alienating airlines from pursuing NextGen due to higher fuel taxes, implementation of a fuel tax increase would face substantial challenges.

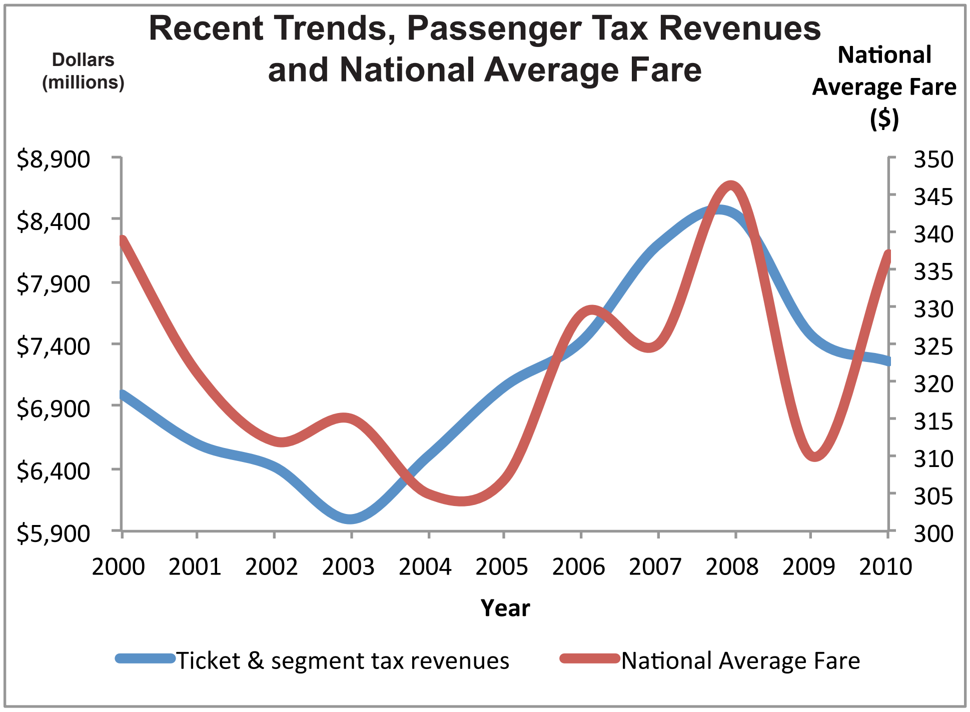


Figure 6: Recent Trends in the Passenger Tax Revenues and the National Average Fare.
Source: Bureau of Transportation Statistics/Research and Innovative Technology Administration[47]

Passenger Ticket Tax

The passenger ticket tax is a direct means of collecting the passengers' share of funding the FAA's projects. The 7.5 percent ticket tax is presently the largest contributor to the AATF. In 2010, ticket tax revenues in addition to passenger segment fees amounted to $7.261 billion, about 65 percent of total trust fund revenues.[46] As a revenue source that is already in place, a temporarily increased ticket tax is potentially a feasible source of funding NextGen.

Figure 6 shows the close cyclical relationship between the passenger ticket tax revenues and the national average fare, with slight deviations because the blue line also includes passenger segment fees, which do not depend on airfares. This implies that the ticket tax revenues can be expected to fluctuate in line with trends in fares in the future.

For equity considerations, it is necessary to analyze whether airfares are a good proxy for NextGen benefits. It is possible that routes in heavy demand and experiencing higher congestion and delays would have higher fares. In such a case a percentage ticket tax is equitable because passengers paying higher fares benefit more from NextGen's delay reduction and pay higher taxes to fund NextGen. However, fares can also be high in routes involving rural airports or in long-haul routes connecting relatively uncongested airports. In such cases, the ticket tax imposes an unfair tax burden on passengers who do not necessarily benefit from NextGen but are required to pay a tax towards funding it on top of already high fares.

There are other equity issues as well. Raising the existing ticket tax in a transparent manner from 7.5 percent for the purpose of collecting revenues from passengers towards their share of funding NextGen could potentially be unfair if ticket prices increase. For example, skyrocketing fuel prices following a supply shock would unnecessarily increase the tax burden for passengers. Also, due to the possibility of unfair tax burdens, it will be difficult to gain political support behind raising the passenger ticket tax. Even though the passenger ticket tax could potentially be a reliable source of NextGen funding, it could pose considerable problems regarding both equity and political feasibility.

Separate NextGen Fee

Another alternative funding source is to implement a flat NextGen fee aimed at passengers flying through the most congested airports. Proposing a new revenue source for the purpose of funding US aviation projects is not uncom-

[46] Federal Aviation Administration, http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/historical_data/ (Date accessed: July 2011).
[47] http://www.bts.gov/programs/economics_and_finance/air_travel_price_index/html/annual.html and http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/historical_data. (Date accessed: July 2011)

LARGE HUBS

Year	Passengers (mils)	$.50 NextGen Fee	$1.00 NextGen Fee	$1.25 NextGen Fee	$1.50 NextGen Fee
1	500	$250,000,000	$500,000,000	$750,000,000	$1,000,000,000
2	513	$256,250,000	$512,500,000	$768,750,000	$1,025,000,000
3	525	$262,656,250	$525,312,500	$787,968,750	$1,050,625,000
4	538	$269,222,656	$538,445,313	$807,667,969	$1,076,890,625
5	552	$275,953,223	$551,906,445	$827,859,668	$1,103,812,891
Total		$1,314,082,129	$2,628,164,258	$3,942,246,387	$5,256,328,516

OTHER AIRPORTS

Year	Passengers (mils)	$.50 NextGen Fee	$1.00 NextGen Fee	$1.25 NextGen Fee	$1.50 NextGen Fee
1	300	$150,000,000	$300,000,000	$450,000,000	$600,000,000
2	308	$153,750,000	$307,500,000	$461,250,000	$615,000,000
3	315	$157,593,750	$315,187,500	$472,781,250	$630,375,000
4	323	$161,533,594	$323,067,188	$484,600,781	$646,134,375
5	331	$165,571,934	$331,143,867	$496,715,801	$662,287,734
Total		$788,449,277	$1,576,898,555	$2,365,347,832	$3,153,797,109

Table 11: Estimated NextGen fee Revenue Generation

mon. The Passenger Facility Charge (PFC) for example, was enacted in 1990 as a funding solution to anticipated revenue shortfalls to future infrastructure needs of US airports.

A flat NextGen fee could be similar to a PFC: it could be collected from passengers flying through designated congested airports. This would allow revenue collection to be highest where users benefit the most from NextGen. The current PFC, with a cap of $4.50 per passenger and $18 per round-trip regardless of the number of connecting airports, raised $2.7 billion in 2010 from 353 airports and is expected to collect $2.67 this year.[48] This means that asides from being equitable, a small NextGen fee per passenger has the potential for raising a significant amount of revenues. A small, temporary fee also has the potential to be approved by Congress with minimal tax burden on users.

However, unlike a PFC that goes directly to the airport, the NextGen fee could be deposited in an FAA administered NextGen Fund, a dedicated pool of money to fund NextGen. Funds from the NextGen Fund could be appropriated and authorized for the FAA till 2018 to meet its infrastructure goals, and the fee terminated once modernization is complete. This has the potential to achieve two very important advancements towards NextGen. First, separating NextGen from the FAA's authorization and appropriation process could help expedite the funding process and rid of the uncertainty with NextGen's funding. Second, this leads to a transparent transfer of resources from users towards building a system that will eventually benefit them. This "user-fee" approach to funding NextGen does not ignore positive externalities that might merit general fund contributions, but rather acknowledges that proposing general tax revenues will be very difficult given the current fiscal environment.

For the purpose of collecting the NextGen fee in an equitable manner, airports could be ranked by the FAA by potential for NextGen benefits based on current congestion delays through a hub-based classification.[48] According to the FAA in FY 2010, there are 28 large hub airports, 35 medium hub airports, 67 small hub airports and 218 non-hub airports in use by commercial aviation. The 29 largest hub airports in 2010 carried about 500 million passengers out of the total of roughly 800 million passengers.[49] Table 11 shows estimated revenues generated by different NextGen fees from the large hubs, using a three percent discount rate to generate the net present value of total revenues generated over five years.

The idea would be to charge a higher fee in large hub airports and a smaller charge in smaller airports. Suitable NextGen fees can be determined by the FAA based on their evaluation of which airports would benefit the most from NextGen and by how much compared to smaller

[48] FAA Key Passenger Facility Charge Statistics, March 1, 2012. www.faa.gov/airports/pfc/monthly_reports/media/stats.pdf. Date Accessed: August 2011
[49] This categorization is for illustrative purposes. Other classification is also possible, for example based on delay data per airport. A hub-based classification is based on the size of an airport hub as a proxy for its congestion.
[50] Bureau of Transportation Statistics T-100 Market data. Date accessed: July 2011.

airports. Using the requested FY 2012 NextGen budget of $1.24 billion as the baseline funding requirement, a $1.50 NextGen fee in large hub airports and a $1.00 fee at smaller airports could potentially generate $1.3 billion annually, with revenues increasing in following years, if total passengers continue to rise as forecasted by the FAA, to keep up with inflation and unexpected increases in outlays.

This NextGen fee could be targeted solely at funding NextGen, and hence could end when modernization is complete. This can be achieved by allowing airports to apply for waiver from the fee once certain performance goals, such as timely installation of infrastructure and airline equipage are reached.

Regarding political feasibility, it has to be acknowledged that any increase in fees will be difficult to pass through Congress. However, a NextGen fee that is equitable, transparent, and proposes a small increase in fees with minimal burden on users could imbue more firepower in the Congressional bargaining and negotiations arsenal

General Funds

The present fiscal constraints are such that the general fund contributions are often not considered an option. But faced with funding an expensive modernization project with dim prospects of raising and taxes or fees might ultimately leave policy-makers with no other option. As the benefits of NextGen extend beyond aviation users and operators and affect the efficiency of regional economies, safety, and the environment, justification to use general fund contributions warrant consideration.

The public benefits of congestion and fuel reduction are likely to be large. Delays in one airport could affect delays in other airports, implying that any delay reduction at a target airport might alleviate delays at a distant airport connected by the same airline. Additionally, reduced fuel consumption and carbon emissions could potentially yield external environmental benefits. These benefits often warrant the use of general funds to solve a public problem. However as stated before these merits are confronted by the political reality of constrained federal resources.

Privatization of Air Traffic Control

The private sector could also potentially be a driving force behind funding NextGen. Private sector modernization efforts could be in the form of a full-fledged privatized ATC system to a public-private financing partnership.

Privatization of ATC is a controversial topic. Proponents of privatization invoke free-market competitive efficiencies

Regional jet parking at Chicago O'Hare International Airport.

and optimal pricing that alleviates congestion and is self-sufficient in raising adequate operating revenues without need for bureaucratic delays and the appropriation process. Some have argued for privately funding NextGen by separating ATC from the FAA and funding its operations by charging private user fees to all aviation users.[51] The idea is that the long-term trend of declining ticket prices due to increased market share for low-cost carriers means that the passenger ticket tax cannot be relied on as a source of funding for NextGen. Furthermore, political stagnancy is a hindrance to bringing about changes in a timely fashion. Finally, there are examples of successful privatized ATCs from countries such as Canada and the United Kingdom. Arguments against privatizing ATC make the general case that the private sector might not cater to an outcome that is in the interest of society. A privatized ATC would still require some form of government oversight to ensure safety standards are met and pricing practices are fair.

Making a case for or against privatization is not the focus of this paper, as it deserves more thorough analysis. In any case, due to its controversial nature, privatization talks in Congress would likely cause more friction than fluency towards modernization efforts.

Equipage Funding

The preceding sections analyzed potential revenue sources for NextGen infrastructure funding. In this section we consider possible funding solutions to equipage. Under the current program, operators are expected to fund their own equipage. As long as the FAA implements the infrastructure in a timely manner the private operators will have real benefits to equipping. As a financing solution to equipage,

[51] "The Urgent Need to Reform the FAA's Air Traffic Control System", Robert W. Poole, The Reason Foundation (2007).

Air traffic control monitor.

a private-public partnership (P3) would not require raising additional taxes or fees and offer a solution to help operators pay for the equipage portion of NextGen modernization. A P3 is in theory a more efficient way of facilitating equipage than collecting taxes from the operators and using the revenues to pay for equipage. It is more realistic to focus on private sector financing options coupled with incentivizing operators to invest in equipage instead of employing an indirect funding method of taxing them to pay for equipage.

Operators and investors need a clear set of incentives to make use of this financing opportunity and expedite equipage. Federal loan guarantees and a "best equipped best served" approach have been proposed as means of incentivizing airline equipage and mitigating risk for investors. In fact, the recent reauthorization bill FAA Modernization and Reform Act of 2012 authorizes the FAA to use loan guarantees. A loan guarantee could use revenues collected from users as cover if a borrower operator defaults on its payments to the NextGen Equipage Fund. Under a "best equipped best served" measure, equipped operators could be given take off and landing priorities, thus a financial incentive to equip. As a further incentive for operators, any repayments can be deferred until expected benefits emerge in the short run.

The federally guaranteed loans from the NextGen Equipage Fund is a mitigation of the financial risk of NextGen from operators and private investors by ultimately transferring the risk to taxpayers. This can actually be equitable and justified if some of the risk is transferred to operators and passengers through a transparent funding mechanism. Operators should be liable to pay their share of equipage costs, while revenues collected from passengers can form the basis for a loan guarantee.

A NextGen P3 could be implemented as follows:
• Operators submit their equipage needs
• A P3 purchases the required equipment
• Equipment is leased to the airline. Financing terms are negotiated.
• Incentive clauses are added as discussed below.

The NextGen Fund P3 is an effective financing solution as previously discussed that has the potential to resolve the two main equipage dilemmas:

1. Operators are uncertain about NextGen's benefits and the FAA's ability to deliver those benefits in a timely fashion.

2. The "First-Equipage" dilemma: There is a concern that operators that equip early might lose out to those who are the last to equip due to technological obsolescence.

Incentive measures could be:
• Postponing loan repayments until NextGen benefits are realized might resolve the first equipage dilemma.
• Federal loan guarantees encourages private sector investors to lend to operators for equipage. A portion of funds from the NextGen fee can be used as a separate pool of money as basis for the loan guarantees.
• Takeoff and landing priorities for equipped operators: This incentive could be used to deal with the second dilemma above. Takeoff and landing priorities would give operators a huge cost advantage particularly in congested airports by enabling them to quickly load and unload passengers.

Air traffic controller directing plane with light signs.

Conclusion

NextGen is faced with four major hurdles:

Uncertainty Regarding NextGen's Benefits. These is still disagreement among industry experts regarding to what extent NextGen can improve aviation. This is one of the reasons behind the failure to make a sufficient business case for operators to invest in on-board equipage.

Uncertainty Regarding the FAA's Ability to Deliver. Even though a lack of strong political stimulus is certainty an issue, at the core of the problem is the uncertainty whether the FAA can efficiently deliver NextGen. "NextGen" has been around since the 1980's under various different names and modernization projects with very little progress. Today, there is no certainty regarding how long it will take for NextGen benefits to be delivered, and how much it will cost. This uncertainty exacerbates the lack of incentives for operators to invest in equipage.

Securing funding for infrastructure. The AATF has relied on increasing general fund contributions in recent years to meet increasing outlays. This has led to a rapidly depleting uncommitted funds level. In this fiscal climate, it is not reasonable to continue to expect general fund injections. Furthermore, there is no clear source of funds for NextGen in the upcoming years to ensure its continuity. There is a lack of an equitable long term funding mechanism for FAA's portion of NextGen's capital investment needs.

Equipage. Operators have shown little progress towards equipping their aircraft. This is primarily due to the first two problems discussed above- uncertainty regarding NextGen's benefits and a lack of clear incentives to invest, and uncertainty about the FAA's ability to deliver efficiently. There is a concern that equipping early will cost them more in the long run due to technological obsolescence. Operators want to see more "skin in the game" from the FAA than promises of benefits. However, airlines have lobbied in the past for federal stimulus funds to cover equipage costs. While revenues generated from the system have been and should continue to be used to fund NextGen's infrastructure and capital needs, operators will eventually have to invest in equipage particularly if there are benefits involved.

This paper provides evidence that NextGen benefits, even at low levels, could yield significant tangible benefits to users. It is inevitable that NextGen will require additional funds to become a reality. The decision about funding sources will ultimately be a complex political decision reached by negotiation and compromise with government and industry. This paper has attempted to outline some criteria and initial analysis to aid in that conversation. The next step will be to convene the appropriate stakeholders, and conduct more independent research on costs and benefits, in order to begin these negotiations and generate the impetus for the political leadership necessary to make NextGen happen.

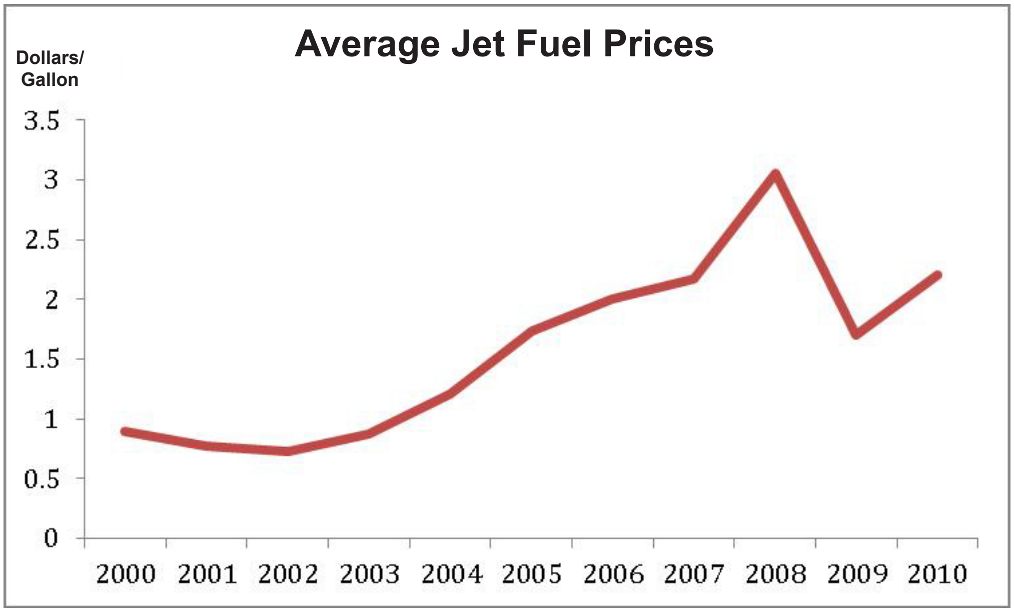


Figure 7: Average Jet Fuel Prices (2000-2010).
Source: US total refiner petroleum product prices, Energy Information Administration (2010).

Appendix A: Benefits to Operators

A1. Soaring Fuel Prices Have Had a Serious Impact on Operators

The increased fuel cost over the past decade, as shown in Figure 7, has played a substantial role in reshaping pricing practices in the airline industry as well as airline behavior. At least some of this additional burden of higher fuel costs has been passed on to consumers, which has led to a steep increase in average fares across the industry.[52] Operators have also increased baggage and other ancillary fees.[53] To lower operating costs, carriers have withdrawn from unprofitable routes and grounded less fuel-efficient aircraft.[54] Low profitability has forced several operators to file for bankruptcy or leave the industry. [55] Several key operators have merged over the past two years for efficiency gains.[56] Some carriers, in particular Southwest airlines, have managed to survive or avert financial turbulence in part through fuel hedging, although in several cases it has backfired and caused hefty losses to the industry.[57]

A2. NextGen Reduces Congestion and Fuel Consumption

The current aviation system uses radar to scan through an area periodically and report any nearby operating aircraft to ATC. The lack of continuous precise detection means that planes must maintain a minimum distance of at least three miles between each other for safety. Moreover, airplanes are required to fly through predetermined air corridors like imaginary highways in the air. The precision of GPS would allow reduction in the aircraft separating standard, which greatly enhances air traffic management and flow, and NextGen's RNAV would allow pilots to choose more direct and shorter routes to their destination.

Airline pilots have to rely on the dated radar ATC system for semi-precise information on their location and navigation of other planes in their vicinity. NextGen-cockpit display of traffic information (CDTI) would allow pilots to for the

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[52] "Annual U.S Domestic Average Itinerary Fare in Current and Constant Dollars, Bureau of Transportation Statistics. Date accessed: July 2011
[53] Bureau of Transportation Statistics, Schedule P-12, Date accessed July 2011
[54] Federal Aviation Administration Aerospace Forecast, Fiscal Years 2011-2031. Date accessed: June 2011
[55] US Airways, Delta, and United Airlines filed for chapter 11 bankruptcies in 2002 and 2004, 2005 and 2002 respectively. Maxjet Airways, Skybus Airlines, Eos Airlines, Primaris Airlines, and Arrow Air have discontinued service after declaring bankruptcy. History of Airline Bankruptcies, Fox Business, http://www.foxbusiness.com/travel/2011/11/29/history-us-airline-bankruptcies, Date access: November 2011
[56] Recent Mergers: Delta and Northwest Airlines in 2008, United and Continental Airlines in 2010, and Southwest Airlines and Airtran Airways in 2011. Other mergers include Midwest and Frontier Operators, Arctic Circle Operators and ERA Aviation, and ExpressJet with SkyWest operators.
[57] "United May Not Be Alone With Fuel Hedge Losses", September 2008, Aviation news on MSNBC.

first time know precise location of every aircraft around them and have direct access to the information that was previously only available to ATC. This improves the pilot's situational awareness and flexibility. NextGen digital data communication between pilots and ATC reduces chances of verbal miscommunication that is quite common in many international airports in the US today. NextGen also allows for OPD, allowing the aircraft to glide prior to landing instead of using additional engine power during the current stepped descending approach.

A3. BTS's Definition and Measurement of Congestion

The Bureau of Transportation Statistics classifies reported delays into the following categories:

- Air carrier delays caused by crew/aircraft maintenance, baggage handling, and fuelling.
- Extreme weather delays
- National Aviation System (NAS) delays caused by heavy traffic volume
- Late arriving aircraft
- Security delays

A4. Quantifying Benefits of Delay Reduction

Every year, major operators are required to submit congestion data to the BTS.[58] Based on this data, there were 1.2 million delayed arrivals reported by major carriers in 2010 averaging of 54.2 minutes per delayed flight. This amounts to 1.07 million hours of plane delays in 2010.

Forecasting how much operators save from reduced congestion is more complicated than calculating benefits from direct fuel savings and requires an estimation of the cost to an airline per minute of congestion. Even though there are several studies on the passenger value of time and airport congestion pricing in the transportation literature, work on the congestion cost to the airline is relatively sparse. Some operators have privately analyzed their own congestion costs, although such reports are not published publicly because of confidentiality.

According to the FAA's Cost-Benefit Analysis Guidance,[59] the value of reduced time of aircraft delay can be measured by the aircraft's variable operating costs including crew costs, maintenance, fuel and oil costs. The FAA's 1998 report "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs" also has estimates of airline operating costs for different types of aircraft. However, these values are quite outdated and not adjusted for inflation. Furthermore, no values are reported for smaller regional jets.

The Massachusetts Institute of Technology (MIT) provides a dataset of operating costs for major operators using the data submitted by individual operators to the Department of Transportation.[60] Using the operating costs for each airline and their respective shares of operators congestion in 2010 (Figure 8) gives the total savings for each reporting airline for two cases: when NextGen reduces delays by 20 percent and by 35 percent. The results, summarized in Table 12, show that depending on how much NextGen reduces delays major reporting operators could save between $716 million and $1.253 billion per year.[61] One advantage of using this method is that benefits are calculated airline by airline and are weighted by how much each airline experiences delays and their respective variable operating costs per unit time, as opposed to using total amount of delays and using an average measure of operating costs.

A5. Verifying Robustness of Estimates

In order to add robustness to these figures, three other studies of congestion costs to operators in Europe are considered. According to a 1999 study conducted by a French transportation institute, Institut du Transport Aerien (ITA), congestion costs operators between 39.4-48.6 Euros (€)/minute.[62] Other studies conducted on the Madrid airport[63] and by the University of Westminster[64] found the cost to be 83.3 €/min and 72€/min respectively.[65]

[58] Airline On-time Performance Data, Bureau of Transportation Statistics. Date Accessed: July 2011.

[59] Office of Aviation Policy and Plans, Federal Aviation Administration, 1999.

[60] The Global Airline Industry Program Airline Data Project, http://web.mit.edu/airlinedata/www/default.html. Date accessed: August 2011.

[61] In cases where the MIT dataset does not have any data for a reporting carrier, an inflation-adjusted FAA operating cost estimate is used assuming a narrow-bodied two engine aircraft. Due to their low share of total delays, this assumption does not distort the estimation significantly. Another possible drawback of this analysis is not differentiating between the cost of departure delays and arrival delays, and also not incorporating airline 'buffer delays'- Commercial operators are known to add some extra time to their schedules in addition to normal block hours. It typically costs operators more if the delay is caused while the aircraft is airborne, than if it waits on the tarmac with engines idle, thereby consuming less fuel. Although the data for separate arrival and departure delays is available, the data for operating costs does not differentiate between being air-borne and on the tarmac.

[62] Institut du Transport Aerien (2000), "Costs of Air Transport delay in Europe".

[63] Nombela, G., de Rus, G. and O. Betancor (2002); "Evaluation of Congestion Costs for Madrid Airport", UNITE.

[64] University of Westminster (2004), "Evaluating the true cost of one minute of airborne or ground delay", Performance Review Commission, Eurocontrol.

[65] There are limitations with applying these figures from the European airline industry to analyze benefits of reduced air congestion in the US because of the differences in aviation infrastructure and data in the two regions. In France, about 25% of flights are delayed with an average delay of 43 minutes. In the US, about 40% of flights are delayed by 15 minutes or more, with an average delay of about 54 minutes. Differences in the cost of congestion can also be attributed to aircraft size and load factor. Setting aside these possible limitations, both US and European operators bear a similar burden of increasing fuel prices, which are a significant component of airline operating expenses. As a result, congestion costs across the two regions could be comparable.

Airline	Total Delay	OC/min	20%	1% Delay Savings	5% DR	20% DR	35% DR
AirTran Airways	2,531,138	44.6	506228	$1,127,622	$5,638,110	$22,552,440	$39,466,769
Alaska Airlines	892,509	67.0	178502	$598,130	$2,990,649	$11,962,596	$20,934,542
American Airlines	6,176,587	59.6	1235317	$3,681,246	$18,406,229	$73,624,917	$128,843,605
American Eagle Airlines	5,303,681	41.7	1060736	$2,209,867	$11,049,335	$44,197,342	$77,345,348
Atlantic Southeast Airlines	4,167,454	41.7	833491	$1,736,439	$8,682,196	$34,728,783	$60,775,371
Comair	3,848,262	41.7	769652	$1,603,443	$8,017,213	$32,068,850	$56,120,488
Continental Airlines	2,425,284	54.7	485057	$1,326,630	$6,633,152	$26,532,607	$46,432,062
Delta Airlines	9,169,167	58.2	1833833	$5,334,927	$26,674,635	$106,698,540	$186,722,445
ExpressJet Airlines	4,837,239	41.7	967448	$2,015,516	$10,077,581	$40,310,325	$70,543,069
Frontier Airlines	847,058	42.1	169412	$356,611	$1,783,057	$7,132,228	$12,481,400
Hawaiian Airlines	532,524	64.6	106505	$344,099	$1,720,496	$6,881,985	$12,043,474
JetBlue Airways	2,935,949	49.1	587190	$1,440,572	$7,202,862	$28,811,446	$50,420,031
Mesa Airlines	1,622,973	41.7	324595	$676,239	$3,381,194	$13,524,775	$23,668,356
Pinnacle Airlines	2,908,135	41.7	581627	$1,211,723	$6,058,615	$24,24,458	$42,410,302
SkyWest Airlines	6,986,819	41.7	1397364	$2,911,175	$14,555,873	$58,223,492	$101,891,110
Southwest Airlines	11,507,620	50.3	2301524	$5,792,169	$28,960,844	$115,843,375	$202,725,906
United Airlines	2,900,848	51.5	580170	$1,492,486	$7,462,431	$29,849,726	$52,237,020
US Airways	3,443,417	56.2	688683	$1,935,200	$9,676,002	$38,704,007	$67,732,012
TOTAL	**73,036,664**		**14607333**	**$35,794,095**	**$178,970,473**	**$715,881,892**	**$1,252,793,310**

Table 11: Total Delay Savings, By Airline.
Data Sources: MIT Airline Data Project, Bureau of Transportation Statistics/Research and Innovative Technology Administration (2010)

Before using the European measures of congestion costs, it is necessary to perform a number of conversions. First, the 1999 French congestion cost/minute is converted from Euros to the 1999-dollar amount,[66] giving $37.84/min. Because fuel prices have increased considerably since then, this dollar amount needs to be inflated to reflect current costs. As shown in the historical jet fuel prices in Figure 8, fuel costs were about a quarter of total operating costs around that time period. The fuel cost component of the $37.84/min figure is thus $9.46/min. This fuel cost is then doubled to reflect the increase in jet fuel price, which has gone up from roughly 1$/gallon to about 2$/gallon. The resulting $18.92 is added to the non-fuel cost component of the original $37.84/min figure, giving $47.3/min as the adjusted congestion delay cost per minute to operators. Applying similar conversions to the other cost estimates gives $89.5 and $77.41 respectively. The congestion costs above vary quite significantly; the latter figures are almost twice the $47.3/min cost. This might be attributed to underlying assumptions in the models or model misspecifications which over/underestimate the cost of delays.

The cost of delays to airline used in the ITA paper most closely reflects the values used in this paper. The adjusted cost of delay of $47.4/min is actually quite close to most US airline variable operating costs, except for those of legacy carriers and Hawaiian and Alaskan operators (Table 11). ITA's use of operating costs also most closely follows the FAA recommendation of using operating costs as a proxy for delay costs. However, this per minute cost figure was conjured from previous studies and not estimated by the ITA researchers.

The study by Nombela et al on the Madrid airport is an improvement from the ITA study in that they actually estimate a simple model to estimate congestion costs of €83.3/min. This figure is also comparable to the University of Westminster estimate of €72. However, as Villemeur et al (2005) argue, this value is most likely overestimated. The total delay for operators used in their study comes from the average delay used in private airline studies, which might introduce an overestimation bias. This is probably right, as the adjusted $89.5/min cost is significantly higher than that in the MIT ADP data.

The University of Westminster study is quite rigorous in terms of covering several factors that may affect delay costs, including different lengths delays in congestion under different circumstances: airborne, tarmac, gate, during taxiing. The study also accounts for depreciation and financing. They find that the average cost per delay is around €1 for delays less than 15 minutes, and about €84 for longer delays.

[66] Historical $/€exchange rates, Oanda.com. Date Accessed June 2011.

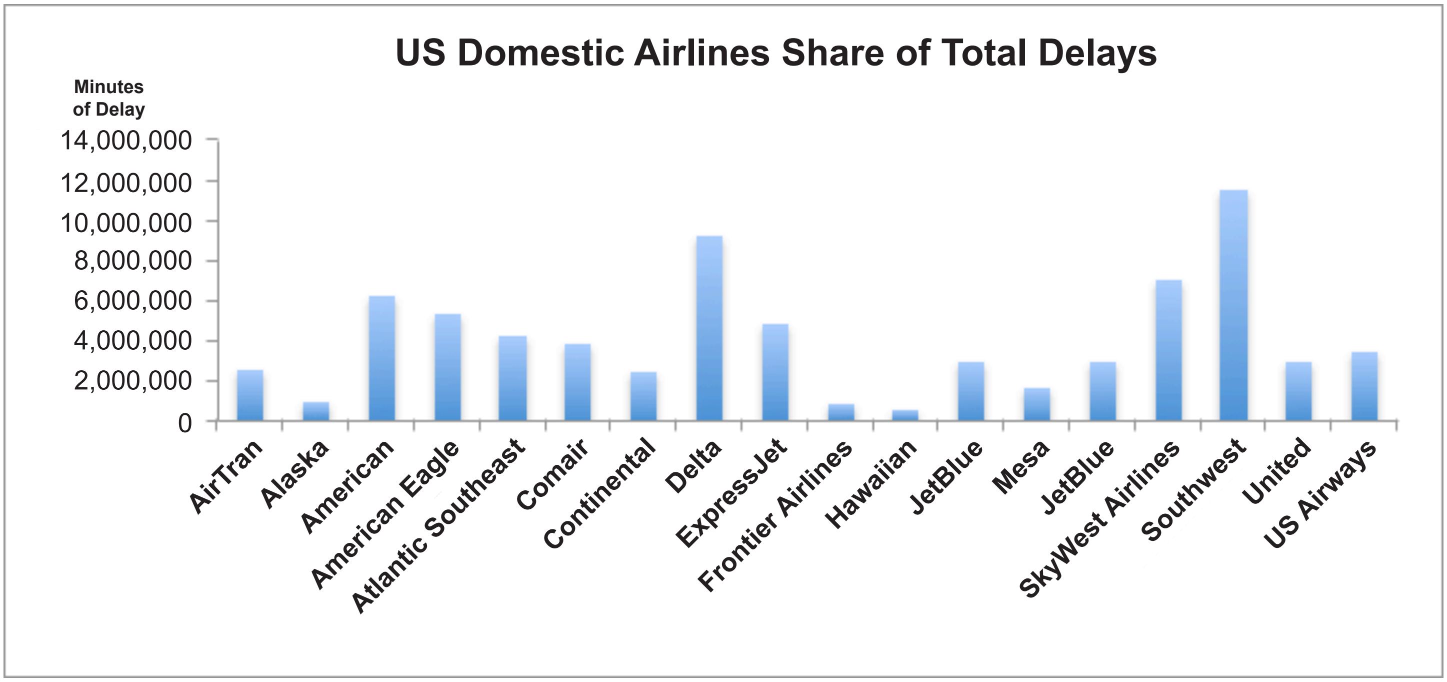

Figure 8: Airline Share of Total Delays (2010)
Data Source: Bureau of Transportation Statistics/Research and Innovative Technology Administration analysis of Operators On-Time Data (2010)
Note: Delta Operators delays include Northwest Operators delays after merger

However, despite what appears to be a fairly comprehensive model of congestion costs, the cost per minute of delay from this study ($77.4) is still quite larger than the reported operating costs by US operators. A possible reason for this might be the that the data for this study was obtained through interviews with airline staff, which like the Nombela et al study may have been an overestimation.

A6. Quantifying Benefits to Non-reporting Carriers

In 2010 there were about 10 million total flight operations according to the BTS,[67] of which reporting carriers accounted for about 6.45 million flights. The remaining 3.55 million operations consist of non-reporting operators and low cost regional jets. Estimating benefits for these remaining operators quickly becomes quite complicated. Firstly, the per minute cost of delay is likely much less for these low cost carriers than the reporting carriers. Secondly, these local jets might experience similar delay periods if they share the same airports as the reporting carriers. They might not experience delays if operating out of local, smaller airports. Thirdly the non-reporting operators also include cargo carriers like FedEx and UPS, who might actually experience similar delay costs as regular passenger carriers, especially if they share an airport with other carriers. Finally due to unavailability of delay data from these operators, any analysis of delay-reduction benefits has to rely on making some assumptions, including variable operating costs. While these assumptions might significantly over/underestimate the estimates, it would severely undermine the total benefits to the airline industry by excluding these carriers, which account for about 30 percent of total flights.

For the purpose of this analysis, it is assumed that about 20 percent of these remaining flights are also delayed and that each flight is delayed on average by the same duration, 52 minutes, as the reporting carriers.[68] This leads to 582,000 delayed flights with a total of 30.3 million minutes of delays. For simplicity, it is also assumed that the typical local airline uses a turboprop with 20 or more seats, since data for regional jet variable operating costs is not available in the 1998 FAA report. While this definitely leads to an estimation of the costs to the remaining non-reporting operators, it still buttresses the argument that even an underestimation of the benefits of NextGen provides significant financial benefits for the operators.

Using this adjusted operating cost for turboprops with 20 or more seats of $11/min, a one percent delay reduction saves the rest of the low cost regional operators $3.33 million, five percent saves $16.67 million, 20 percent reduction of delay saves a total of $66 million while a 35 percent delay reduction saves about $117 million.

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[67] Bureau of Transportation Statistics T-100 segment data. Date accessed: July 2011.

[68] FedEx and UPS had about 400,000 operations. Also, about 240,000 operations were removed from the remaining analysis due to too few passengers.

Passengers inside the cabin of a commercial airliner during flight.

Appendix B: Benefits to Passengers

B1. Estimating Passenger Benefits

Total passenger savings from NextGen delay-reduction are estimated as follows. First, the number of passengers affected is calculated from the total number of delayed flights, the average aircraft capacity, and load factor. Next, the total value of this delay reduction to passengers is calculated using the per hour value of time and the average delay of a flight.[69] Finally, the value of saved time is calculated for 20-35 percent reductions in delays due to NextGen.

Using the BTS/RITA data on airline delays, there were about 1.18 million delayed operations in 2010. Average aircraft size and load factor are 139.7 seats/aircraft-mile and 81.8 percent respectively (FAA).[70] Each delayed flight experienced, on average, about 54.2 minutes of delays.

For simplicity, FAA's 2003 all-purpose value of time estimate of $28.60 per hour is used. Using this and 54.2 minutes as the average delay faced by a passenger in a flight gives almost $700 million annually as the value of saved time for a 20 percent reduction in delays. Similarly for a 35 percent delay reduction, the value of saved time to passengers is about $1.22 billion.

The calculations are then repeated for the non-reporting operators as well, assuming about 18 percent of the remaining 3.55 million flights in 2010 are also delayed with the same average delay of 54.2 mins/flight as operators sharing the same runways as the reporting carriers are also subject the same delays.

B2. Robustness of Results

In a recent study, researchers at the University of California at Berkeley found the total cost to passengers due to all air transportation delays to be about $16.7 billion in 2007.[71]

Commissioned by the FAA, this is the most comprehensive study to date modeling the monetary costs of delays by accounting for different types of delays and how they affect passengers differently. In their model the total cost of delays to passengers is based on not only passenger time lost, but also the cost of cancelled flights and missed-flight connec-

[69] This assumes that every passenger faces the same length of delay (54.2 minutes).
[70] Review of 2010, FAA Aerospace forecast fiscal year 2011-2031.
[71] Total Delay Impact Study- A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States. Final Report, October 2010.

Pilots working during a commercial flight, interacting with air traffic control at a nearby airport.

tions, the cost of hidden delays due to airline buffering, and the cost of additional time spent away from home due to anticipated delays.

Given that the focus in this section is only on the value of time saved, it is not surprising that the 35 percent delay reduction savings of $1.5 billion is less than what 35 percent of the Berkeley study costs suggests ($5.85 billion). This analysis uses an accounting approach while the Berkeley estimates are based on an econometric model. The Berkeley study considers all costs of delays to passengers, while this study only looks at the benefits of reduced delays because of NextGen based on the value of time. Finally, the value of time in this study comes from a 2003 FAA estimate, which may need to be updated to reflect inflation and other macro-economic changes and passengers' preferences over time.

It is also unreasonable to assume that passengers completely sit idle during delays especially with better on-flight facilities and technology such as wireless Internet service that are more prevalent nowadays. Business passengers might utilize delays efficiently by working on their laptop computers, for example. As a result, the actual cost of delays to passengers could be lower than the 2003 figures provided by the FAA. However, delays still hurt passengers, particularly business class passengers due to schedule conflicts and missed appointments. Furthermore, no-frill low-cost carriers and even some network carriers generally do not generally provide facilities such as electrical outlets or wireless Internet connections on-board.

Cost of delays, and therefore any benefits of delay reductions are often estimated to be higher for passengers than the operators.[71] The 2009 Partnership for New York report on congestion estimated the total cost of delays to be about $834 million to operators compared to $1.7 billion for passengers in New York in 2008. The Berkeley study also found the cost to operators to be about half of the costs to passengers; $8.3 billion compared to $16.7 billion. This current study finds that for a 20 percent delay reduction, passengers could save about $850 million compared to $226.3 million for operators and $1.5 billion compared to $850 billion to operators for a 35 percent delay reduction, which is consistent with what previous studies found.

[72] "Grounded- The High Cost of Air Traffic Congestion", Partnership for New York City, 2009.

Jet being fueled before departure.

Appendix C: Funding NextGen

C1. Tax burden to Passengers Following a 4-Cent Increase in the Commercial Jet Fuel Tax

Between 2010 and 2011, 93 of the top 100 US domestic routes ranked by total originating passengers experienced significant fare increases by about eight percent on average.[73] This increase might be attributed to increases in fuel prices and higher demand for flying following economic recovery from the recession.[74]

During that period, fuel cost per gallon went up by about 27 percent.[75] Total passengers carried increased about 1.84 percent.[76] Total available seat miles have gone up by about 2.1 percent.[77] Because the increase in fuel costs was much more significant than the percentage increase in passengers, it is reasonable to assume that fuel prices played a stronger role in driving fares up.

A 4-cent increase in the jet fuel tax increases the 2011 fuel cost from 2.86 cent/gallon to 2.90 cent/gallon, a 1.4 percent increase. Based on the figures above, a reasonable estimate is that fares might go up by small amount, roughly about .3-.5 percent.

Assuming that it is insignificant to have any impact on the total number of passengers significantly, a .3-.5 percent increase in fares would raise operating revenues by about $350-$600 million paid by the passengers.[78] This is another reason why any increases in the jet fuel tax needs to be low because larger increases would raise fares even further and cause further tax burdens both for operators as well as passengers.

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[73] Bureau of Transportation Statistics, Origin and Destination Survey: DB1BTicket, first quarter of 2011.
[74] Other important factors that might affect fares are airport slot restrictions and holiday or tourist routes.
[75] Bureau of Transportation Statistics F41 Schedule P12A. Date accessed: July 2011.
[76] Bureau of Transportation Statistics T-100 Market data. Date accessed: July 2011.
[77] Bureau of Transportation Statistics T-100 Segment data. Date accessed: July 2011.
[78] Using $119 billion total operating revenue in 2010., Bureau of Transportation Statistics F41 Schedule P12 data. Date accessed: July 2011.

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