YOUR FLIGHT HAS BEEN DELAYED AGAIN

FLIGHT DELAYS COST PASSENGERS, AIRLINES, AND THE U.S. ECONOMY BILLIONS

A REPORT BY THE JOINT ECONOMIC COMMITTEE MAJORITY STAFF
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THE JOINT ECONOMIC COMMITTEE, ESTABLISHED UNDER THE EMPLOYMENT ACT OF 1946, WAS CREATED BY CONGRESS TO REVIEW ECONOMIC CONDITIONS AND TO ANALYZE THE EFFECTIVENESS OF ECONOMIC POLICY.

EXECUTIVE SUMMARY

The economic costs of air traffic delays to the U.S. economy are large and far-reaching. As air traffic has grown over the last two decades, the number of domestic flights and air flight delays has reached record levels. Increasing flight delays and cancellations are placing a significant strain on the U.S. air travel system and costing both passengers and airlines billions of dollars each year.

For this report, the majority staff of the Joint Economic Committee (JEC) used U.S. Department of Transportation data to analyze more than 10 million individual U.S. domestic scheduled flights in 2007. These passenger flights were operated by more than 400 different carriers – both national and regional – and traveled through more than 1,100 airports. The JEC found that:

- **The total cost of domestic air traffic delays to the U.S. economy was as much as $41 billion for 2007.**
  - Air-traffic delays raised airlines' operating costs by $19 billion. With each delayed flight, airlines paid extra for crew, fuel, and maintenance costs while planes sat idle at the gate or circled in holding patterns.
  - Delays cost passengers time worth up to $12 billion. Delayed travelers, their employers, and others lost productivity, business opportunities and leisure activities when air travel took extra time. Costs cascaded when delayed flights resulted in other late flights. These costs to passengers could be even higher than JEC estimates, as a result of missed connections, cancelled flights, disrupted ground travel plans, forgone pre-paid hotel accommodations, and missed vacation times.
  - Indirect costs of delay to other industries added roughly $10 billion to the total burden. In particular, industries that rely on air traffic, such as food service, lodging, general retail, and public transportation suffered.

- **Delayed flights consumed about 740 million additional gallons of jet fuel.**
  - Delayed flights cost the airlines (and customers) an additional $1.6 billion in fuels costs, assuming an average wholesale price of $2.15 per gallon in 2007.
  - Burning fuel during flight delays released an additional 7.1 million metric tons of climate-disrupting carbon dioxide into the atmosphere.

- **Almost 20 percent of total domestic flight time in 2007 was wasted in delay.**
  - In 2007, flight arrivals were delayed by a total of 4.3 million hours, after accounting for padding in airline schedules. These delays cost travelers 320 million hours of lost time delays.
  - Planes arrived later than their scheduled arrival by more than 2.8 million total hours; however, because airlines have built the most predictable delays into their schedules calculating delays with respects to schedules significantly underestimates the problem. In fact, when padding is removed from the analysis, total delays are actually 57 percent higher than the airlines report.

  - Flight delays were longest during months when many people take vacations. Flight delays during the months of June, July and August – popular vacation months – averaged approximately 414,000 total hours of delay per month. Flights during December – the height of holiday traveling – totaled almost 438,000 hours of delay.

- **Seventy-eight percent of flight delays in 2007 occurred before take-off.** Almost 60 percent of flight delays occurred at the gate, and 20 percent of delays occurred during the taxi to the runway. Airborne delays, the most costly for airlines accounted for 15 percent of all delays.

- **Delays at the nation's largest airports disproportionately contributed to total passenger delays in 2007.** Flights to and from the 35 largest U.S. airports accounted for about half of the total passenger delays, even though flights in and out of these airports accounted for only 33 percent of the flights in this study. Passengers departing from airports in the Northeast and Midwest experienced the longest per passenger delays.

Certainly, some air traffic delay is unavoidable. Flights can and should be delayed if safety issues arise due to severe weather or mechanical problems. However the staggering levels of delays experienced in 2007 and the significant costs these delays had on the U.S. economy are troublesome.

As air travel is expected to increase – the Federal Aviation Administration forecasts that the number of U.S. air travelers will grow by at least 2.7 percent per year through 2025, from more than 689 million passengers today to more than 1.1 billion in 2025 – delays will continue to worsen without important reforms to the system.

Introduction

Air travel delays in the U.S. are at record levels and getting worse. With the exception of a dip in travel following the September 11, 2001 attacks, the number of domestic flights has steadily grown over the last two decades, leading to increased air congestion and delays. As a result, flight delays and subsequent cancellations are costing both passengers and airlines billions of dollars each year. With the Federal Aviation Administration (FAA) predicting that the number of paying U.S. air passengers will likely increase through 2025 at an annual rate of at least 2.7 percent,[1] the costs to passengers, airlines, and the overall economy can only be expected to rise in the coming years. To alleviate the growing costs of congestions and delays, it is clear systematic reform is needed.

To help policy makers understand the true economic ramifications of delayed flights in the United States, the majority staff of the Joint Economic Committee (JEC) has estimated the total costs of air travel delays to the U.S. economy in 2007. To compute the total cost of delay, the JEC estimated the operating costs of airlines, the value of delayed passenger time, and the spillover costs to other industries. The JEC also estimated the environmental ramifications of jet fuel wasted as a result of delay. The JEC used U.S. Department of Transportation (DOT) data to analyze more than 10 million individual U.S. domestic scheduled flights in 2007. These passenger flights were operated by more than 400 different carriers – both national and regional – and traveled through more than 1,100 airports. This report excludes the costs of delay for international, freight, military, and general aviation flights, including corporate non-commercial flights. Additionally, this report excludes the costs of cancelled or missed connecting flights due to the delay of an initial leg of a flight. Cost estimates in this report are based on airline delays only and do not include the additional lost passenger time spent getting through security. Finally, this cost estimation accounts for expected delays built in to airline schedules. The appendix provides an in-depth explanation of the scope and methodology used for this analysis.

Air Traffic Delays Cost the U.S. Economy Up To $41 Billion in 2007

The economic costs of air traffic delays to the U.S. economy are vast and far-reaching. Delayed flights affect not only the airline industry and the traveling public, but also businesses that depend on air traffic to generate revenue. In addition to the economic costs of delay, burning jet fuel during delays emits climate-disrupting carbon dioxide and local air pollutants. Delayed passenger flights in 2007 emitted an additional 7.1 million metric tons of carbon dioxide into the atmosphere. In total, the JEC found that delayed domestic passenger flights cost the U.S. economy close to $41 billion in 2007 alone.

Figure 1: Air Traffic Delay Costs Totaled Up to $41 Billion in 2007

Airline Operating Costs	Value of Passenger Time	Spillover Costs to the Economy	Total
$19.1 Billion	$12.0 Billion	$9.6 Billion	$40.7 Billion

Of the 10 million domestic scheduled passenger flights analyzed, the JEC found that delays accounted for 19.5 percent of total flight time, measuring from scheduled departure to actual arrival. The JEC calculated that planes arrived later than their scheduled arrival by more than 2.7 million total hours. However this measure of delay significantly underestimates the true burden of growing congestion. As delays have become routine, airlines have changed published schedules to include predictable delays. After accounting for the padding in schedules for routine congestion by measuring delays relative to estimated flight durations in uncongested conditions, the JEC found that delay is actually 57 percent higher, or more than 4.3 million hours in total. These delays cost travelers 320 million hours of lost time. To account for all delays in its cost estimates, the Committee calculated total economic costs by incorporating schedule padding into its calculations.

Delayed Flights Cost an Already Struggling Airline Industry As Much As $19 Billion in Additional Operating Costs

Air-traffic delays raised airlines' operating costs by $19 billion.[2] With each delayed flight, airlines paid extra for crew and fuel while planes sat idle at the gate. Airborne delays added to airplane maintenance costs and increased depreciation as planes circled in holding patterns. System-wide delays also boosted requirements for aircraft, personnel, and other factors that enable the airlines to provide a given level of transportation services. Additionally, delays resulted in airlines incurring broader costs, such as the opportunity cost of the delayed aircraft and extra personnel. These costs accrued most directly to airlines, but ultimately passengers have likely borne them through higher ticket prices or reduced service.

Passengers Affected by Delayed Flights Lost Time Valued at Over $12 Billion

Delays cost passengers time worth up to $12 billion. Delayed travelers, their employers, and others lost productivity, business opportunities and leisure activities when air travel took extra time. Delay costs cascaded when flights resulted in other late flights. Costs were likely higher due to missed connections, cancelled flights, disrupted ground travel plans, forgone pre-paid hotel accommodations, and missed vacation times.

Analysts of air traffic delay costs have used a number of approaches in accounting for the value of travelers' time since the value of passenger time is revealed through travelers' choices rather than market prices. Different travelers may have different valuations for their time and indeed, the same traveler may value his or her time differently depending on the purpose of the travel, work conditions, or other factors affecting the burden of delays.[3] In calculating the economic cost of passenger time, the JEC followed the guidance DOT uses for its policy analysis and applied a value of $37.60 per passenger per delay hour. JEC calculations do not include delays to passengers who missed connecting flights, delays resulting from cancelled flight, or delays from post-September 11th security procedures.[4]

Other Industries that Rely on the Airline Industry Suffered As the Result of Delay—By as Much as $10 Billion

Indirect costs of delay to other industries added another $10 billion to the total burden. In particular, delays raised production costs and lowered demand for food service, lodging, retail, and ground transportation, which purchase or otherwise rely on air travel for supplies or customers. To calculate the total costs to other industries, the JEC applied macroeconomic modeling results that estimate an additional $0.50 effect on gross domestic product.[5] These calculations did not include delays in air cargo shipments although delays in this segment are likely costly to manufacturing and other industries.

Jet Fuel Consumed as a Result of Delay Cost More than $1.6 Billion in 2007

The JEC found that airlines consumed an additional 740 million gallons of jet fuel in 2007 as a result of airline delays. At an average wholesale price of $2.15 per gallon in 2007, the delay-induced fuel consumption cost more than $1.6 billion. This report calculated the excess fuel burn for each flight by applying a known rate of fuel burn by the aircraft type during the phases of flight in which each minute of delay occurred.

The report finds that air traffic delay-related burn of jet fuel led to the emission of about 7.1 million metric tons of carbon dioxide, or about 5 percent of the 142.1 million metric tons of carbon dioxide from domestic commercial aircraft in 2006.[6] To put this figure in context, according to Toyota, the aggregate CO_2 emissions reductions resulting from the one million Prius hybrid automobiles sold so far is 4.5 million metric tons, or 63 percent of JEC estimates for delayed passenger aircraft in the U.S. in one year.[7]

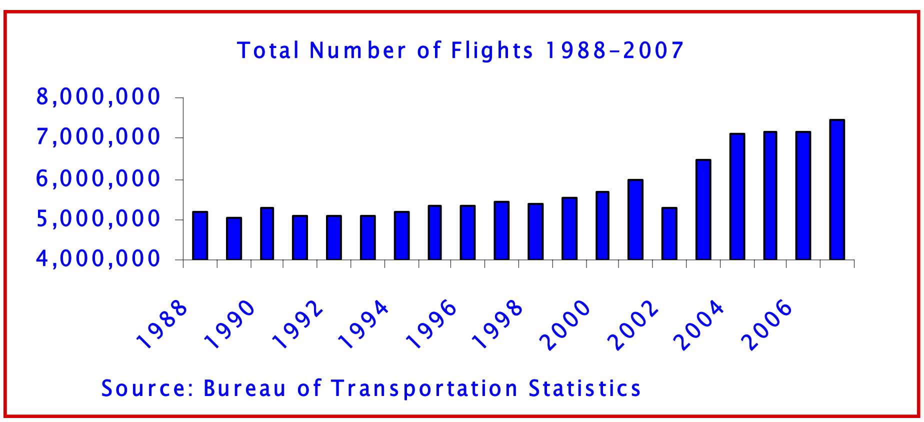
FIGURE 2: EXCESS JET FUEL CONSUMED DURING DELAYS IN 2007 COST THE ECONOMY $1.6 BILLION

CO_2 Emissions	Excess Jet Fuel Consumption	Cost of Excess Jet Fuel Consumption
7.07 million metric tons	740 million gallons	$1.6 billion

AS THE NUMBER OF FLIGHTS HAS INCREASED, FLIGHT DELAYS HAVE REACHED RECORD LEVELS

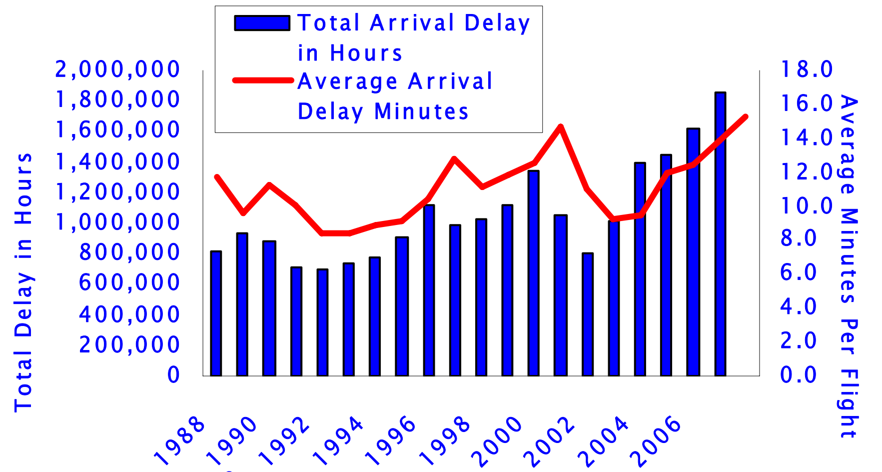
With the exception of a small dip in airline travel following the attacks of September 11, 2001, the number of passengers and domestic flights has steadily increased over the last two decades. According to DOT Bureau of Transportation Statistics reports on flights by carriers with more than $100 million in annual revenue, domestic air traffic volume increased by more than 2.2 million flights in the past 19 years – jumping from just 5..2 million domestic passenger flights in 1988 to more than 7.4 million domestic passenger flights in 2007. The FAA forecasts that this trend is likely to continue and predicts a steady growth in the number of paying U.S. air travelers through 2025 at an average annual growth rate of at least 2.7 percent from 689 million passengers today to over 1.1 billion in 2025. Although airlines can accommodate some of these travelers with larger or fuller planes, some increase in air traffic is inevitable as the number of travelers rises.

FIGURE 3: THE TOTAL NUMBER OF DOMESTIC FLIGHTS HAS INCREASED BY 43 PERCENT SINCE 1998



Not surprisingly, as the volume of air traffic has increased, total delay and the average delay per flight have also increased. According to the Bureau of Transportation Statistics, domestic passenger flights were delayed by more than 1.8 million total hours and average delays were up to 16 minutes per flight in 2007.[8] These figures account only for delays as measured against scheduled arrival times, and therefore do not account for expected delays that airlines have incorporated into their schedules. Because these numbers do not account for routine airline delays, these figures underestimate the true amount of time air travel passengers were delayed in 2007.

FIGURE 4: INDIVIDUAL AND TOTAL FLIGHT DELAYS HAVE INCREASED OVER THE LAST 20 YEARS



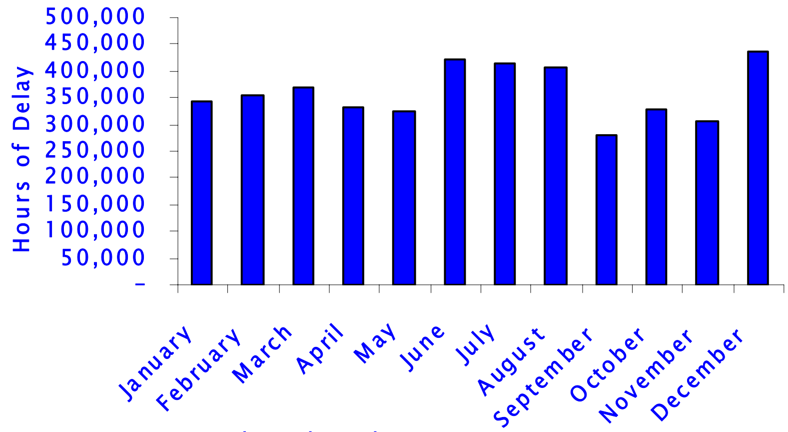
Source: Bureau of Transportation Statistics

Although there was a small decrease in delays following September 11, 2001, total delays and average delays per flight now exceed pre-September 11 numbers. The figures show that the post-September 11 drop in delays was proportionately greater than the drop in the total number of flights. This finding suggests that congestion delays are quite sensitive to changes in traffic levels, and thus future expected increases in total number of flights will negatively impact total delays.

FLIGHT DELAYS PEAKED DURING THE BUSIEST TRAVELING SEASONS

When analyzing total hours of delay across the year, the JEC found that the periods with the largest total delays corresponded to periods when many people take vacations. Flight delays during the busy summer vacation months of June, July and August averaged approximately 414,000 total hours of delay per month. Flights during December – the height of holiday traveling – totaled almost 438,000 hours of delay.

FIGURE 5: FLIGHT DELAYS IN 2007 PEAKED DURING THE BUSY SUMMER TRAVEL SEASON

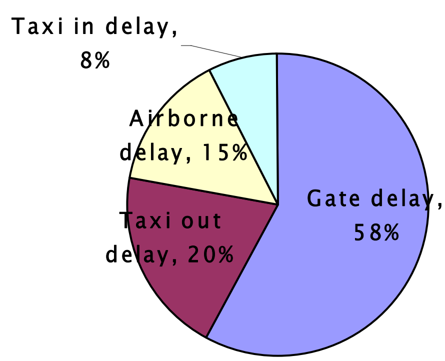


Source: JEC Analysis based on Data

MOST AIR TRAFFIC DELAY OCCURS ON THE GROUND

The vast majority of air-traffic delays in 2007 occurred before airplanes took off for flight. Almost 60 percent of delays occurred at the gate, while 20 percent of flight delays occurred while taxiing out to the runway. Only about 15 percent of the JEC estimated total delay occurred during airborne minutes. Airborne delays, the most costly delays to airlines because of high rates of fuel consumption and greater wear and tear to the airplanes, include time to circumvent storms or congested airspace and time upon arrival to await landing approval from air traffic controllers. Less than 10 percent of all delays occurred after airplanes had landed.

FIGURE 6: ALMOST 60 PERCENT OF ALL FLIGHT DELAYS OCCURRED AT THE GATE



Source: JEC Analysis based on Data from the DOT

Delays Persist From Coast to Coast

Delays at the nation's largest airports disproportionately contributed to total passenger delays in 2007. While delays are not confined to the largest airports, delayed flights there affect relatively more passengers. Flights to and from the top 35 U.S. airports represented about 33 percent of the sample and 34 to 37 percent of the total hours of delayed planes. However, given the relatively larger planes involved, the flights to and from large airports comprised about half of the total passenger delay hours.

Figure 7: Across the Country Passengers Wastesd Millions of Hours Due to Delay

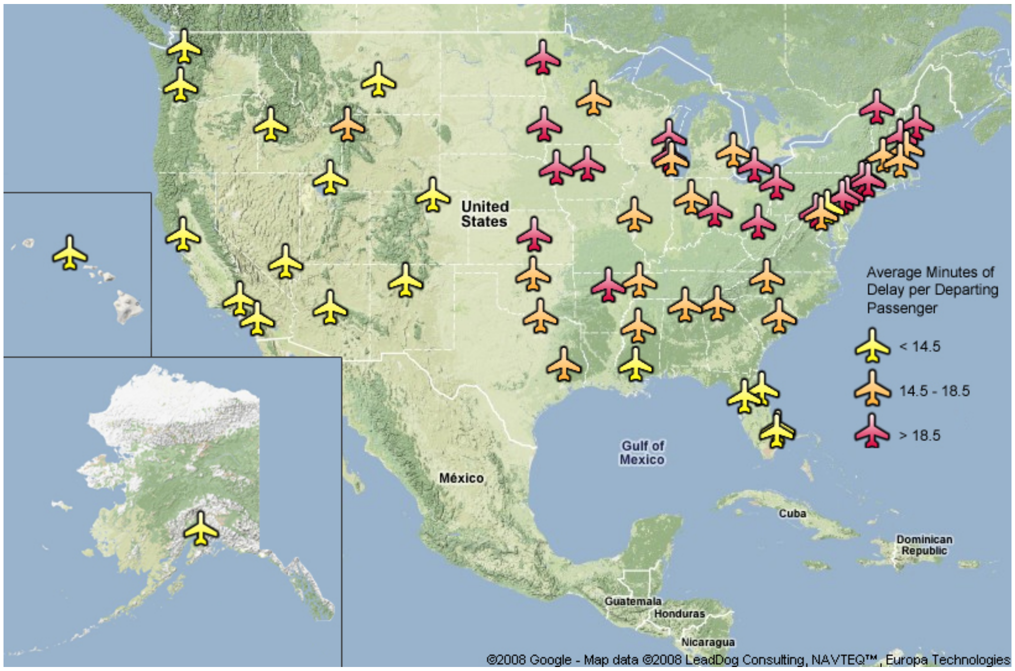
Airport	Total Est. Ground-Based Passenger Delay Hours (Includes Arrival Delay)	Total Est. Domestic Departing Passengers	Est. Minutes of Departure Delay Per Passenger
Atlanta Hartsfield-Jackson International, GA (ATL)	18,996,152	41,945,140	16.15
Chicago O'Hare International, IL (ORD)	17,749,859	32,705,606	21.25
Dallas-Fort Worth International, TX (DFW)	12,628,406	27,370,009	15.03
New York John F. Kennedy International, NY (JFK)	10,408,536	13,808,842	26.83
Denver International, CO (DEN)	9,364,240	24,909,795	13.72
Philadelphia International, PA (PHL)	9,084,470	15,375,846	24.98
Newark Liberty International, NJ (EWR)	9,022,480	13,722,618	26.16
Los Angeles International, CA (LAX)	8,689,587	24,029,982	10.58
Las Vegas McCarran International, NV (LAS)	8,382,613	22,856,398	11.36
New York LaGuardia, NY (LGA)	7,762,236	12,683,010	29.66
Phoenix Sky Harbor International, AZ (PHX)	7,584,878	21,731,487	11.07
Charlotte-Douglas International, NC (CLT)	7,213,054	17,450,847	16.85
George Bush Intercontinental, TX (IAH)	6,883,717	18,015,101	15.71
Minneapolis-St Paul International, MN (MSP)	6,628,018	16,494,770	14.94
Detroit Metropolitan, MI (DTW)	6,575,147	16,529,991	15.48
Orlando International, FL (MCO)	5,516,367	16,822,329	9.93
San Francisco International, CA (SFO)	5,228,316	14,353,465	12.82
Boston Logan International, MA (BOS)	5,171,799	12,526,880	18.11
Seattle-Tacoma International, WA (SEA)	4,634,625	13,897,447	10.76
Washington-Dulles International, VA (IAD)	3,878,318	9,466,094	22.73
Miami International, FL (MIA)	3,824,975	8,853,130	12.33
Salt Lake City International, UT (SLC)	3,687,805	12,119,469	12.77
Chicago Midway, IL (MDW)	3,623,353	9,856,776	15.31
Baltimore-Washington International, MD (BWI)	3,557,716	11,204,172	12.33
Ronald Reagan National, DC (DCA)	3,537,532	9,658,749	16.88
Fort Lauderdale-Hollywood International, FL (FLL)	3,514,704	9,869,811	11.16
Tampa International, FL (TPA)	2,537,263	9,442,762	10.20
Cincinnati-Northern Kentucky, KY (CVG)	2,465,634	8,317,864	18.52
San Diego International Lindbergh, CA (SAN)	2,398,449	9,445,349	9.24
Lambert-St. Louis International, MO (STL)	2,219,283	7,706,011	14.95
Memphis International, TN (MEM)	1,925,259	6,464,272	15.99
Cleveland-Hopkins International, OH (CLE)	1,903,652	5,784,726	20.13
Greater Pittsburgh International, PA (PIT)	1,665,284	5,098,282	19.61
Portland International, OR (PDX)	1,589,843	6,844,396	9.82

Figure 7 Continued on following page

Airport	Total Est. Ground-Based Passenger Delay Hours (Includes Arrival Delay)	Total Est. Domestic Departing Passengers	Est. Minutes of Departure Delay Per Passenger
Ted Stevens Anchorage International, AK (ANC)	1,478,319	4,557,154	14.43
Honolulu International, HI (HNL)	1,355,836	7,768,547	5.60
Indianapolis International, IN (IND)	1,354,713	4,399,702	16.18
General Mitchell International, WI (MKE)	1,234,556	3,766,407	24.69
Louis Armstrong New Orleans International, LA (MSY)	1,066,618	3,969,953	10.93
Bradley International, CT (BDL)	1,035,060	3,379,491	15.29
Albuquerque International, NM (ABQ)	939,548	3,849,373	10.49
Providence-T.F. Green, RI (PVD)	815,605	2,599,242	17.13
Eppley Airfield, NE (OMA)	722,452	2,421,203	20.07
Manchester-Boston Regional, NH (MHT)	674,788	2,062,983	21.17
Will Rogers World, OK (OKC)	581,742	2,106,883	15.00
Birmingham International, AL (BHM)	546,202	2,077,098	17.33
Charleston International, SC (CHS)	415,478	1,341,750	18.33
Little Rock National, AR (LIT)	374,764	1,304,548	18.75
Portland International Jetport, ME (PWM)	370,825	902,630	27.77
Burlington International, VT (BTV)	357,556	833,780	28.55
Des Moines International, IA (DSM)	341,441	1,031,752	24.22
Boise, ID (BOI)	326,798	1,477,663	11.81
Wichita Mid-Continent, KS (ICT)	252,865	826,375	22.49
Jackson-Evers International, MS (JAN)	210,439	840,039	15.25
Sioux Falls Regional, SD (FSD)	156,926	462,617	19.61
Hector International, ND (FAR)	116,600	344,136	20.11
Jackson Hole, WY (JAC)	109,312	313,853	18.05
Yeager, WV (CRW)	102,424	370,116	28.90
Billings Logan International, MT (BIL)	98,005	427,808	12.10
New Castle, DE (ILG)	11,223	30,926	55.13

When measuring delays per airport per passenger, the JEC found that those passengers departing from airports in the Northeast and Midwest experienced the longest delays. Passengers departing from New Castle Airport in Delaware experienced the longest per passenger delays at approximately 55 minutes per passenger, while travelers departing from Honolulu International airport experienced roughly a 6 minute per passenger delay on average.

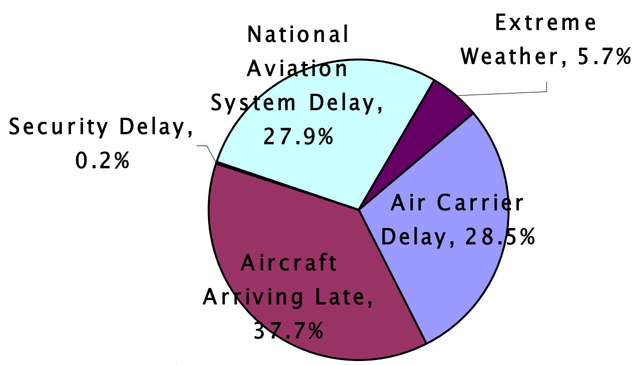
FIGURE 8: AVERAGE FLIGHT DELAYS PER PASSENGER WERE LONGEST IN THE NORTHEAST AND MIDWEST



THE VAST MAJORITY OF FLIGHT DELAYS RESULT FROM SYSTEMIC PROBLEMS IN THE AIRLINE INDUSTRY

According to the DOT Bureau of Transportation Statistics, the top reason that flights were delayed – accounting for almost 40 percent of all delayed flights – was that other flights arrive late, creating a cycle of delay that leaves passengers distressed and airlines in deeper financial difficulty. Other top reasons for delay point to a system under strain. Circumstances within the airlines' control, such as baggage handling and fueling account for 29 percent of delayed flights, and problems within the aviation system such as air traffic congestion and disruption from non-extreme weather conditions comprise another 28 percent. Accounting for less than 6 percent of total delays, extreme weather was a tiny and declining reason for flight delays in 2007.[9]

FIGURE 9: MOST FLIGHT DELAYS WERE CAUSED BY OTHER FLIGHTS ARRIVING LATE



Source: Bureau of Transportation Statistics

Neglected U.S. Aviation System Needs Reform

Seven long years of laissez-faire government policies have left the U.S. aviation system in need of significant improvements and reform; exacerbating the number of flights delayed and the total cost to the U.S. economy. Inaction by the administration has only worsened the problem. Failure to fund equipment upgrades, particularly new air traffic control systems, such as Next Gen, which would convert the nation's radar-based aviation tracking system to a satellite based one, has added to the volume of flight delays. Additionally, the administration has failed to act upon the recommendations of the New York Aviation Rulemaking Committee,[10] which among other things, called for an opening of 15-20 mile band of air space directly off the coast of the eastern seaboard that is currently used for military training purposes. Opening up a portion of this underutilized space would allow commercial airlines to avoid congested areas over New York City, Washington, Atlanta and Florida or bypass bad weather when it arises on the east coast, thus significantly reducing delays.

Conclusion

Certainly, some air traffic delay is unavoidable. Flights can and should be delayed if safety issues arise as a result of severe weather or mechanical problems. Additionally, some level of air traffic congestion is desirable, particularly at "hub airports," to allow airlines to cluster arrival and departure times to offer passengers the most efficient connections.[11] However the staggering levels of delays experienced in 2007 and the significant costs associated with these delays are clearly troublesome and suggest substantial room for cost effective improvements.

As the number of traveling passengers and air traffic congestion is expected to continue to increase, steps must be taken to alleviate pressures on the U.S. air traffic system. Government inaction over the last eight years has left the U.S. aviation system in need of reform. Without such reform, the total costs to the U.S. economy of air traffic delay – including costs to the airline industry, the flying public, the environment, and travel dependent businesses – are sure to increase.

Works Cited

[1]U.S. Department of Transportation, FAA Aerospace Forecast Fiscal Years 2008-2025, Table 5, p. 64. Available at http://www.faa.gov/data_statistics/aviation/aerospace_forecasts/2008-2025/media/Forecast%20Tables.pdf.

[2]The $19 billion represents 19.5 percent of the $97.7 billion in total estimated operating costs of domestic scheduled passenger services in 2007.

[3]Kenneth A. Small, Urban Transportation Economics, in Fundamentals of Pure and Applied Economics, Jacques Lesourne and Hugo Sonnenschein (eds.), Harwood Academic Publishers, 1992.

[4]Researcher has estimated security-related travel time costs to be $25 billion annually, assuming travelers arrive at the airport an hour earlier than before new security measures were imposed. Steven A. Morrison and Clifford Winston (2008), "Delayed! U.S. Aviation Infrastructure Policy at a Crossroads," in *Aviation Infrastructure Performance*, Clifford Winston and Gines de Rus (eds.), Brookings Institution Press.

[5]DRI-WEFA, Inc. "The National Economic Impact of Civil Aviation" p. 13 Table 5. July 2002

[6]Environmental Protection Agency "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006," p. 309. Available at
http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf. Includes consumption of jet fuel and aviation gasoline.

[7]Yuri Kageyama, "Toyota Prius sales top one million units" available at http://ap.google.com/article/ALeqM5iewrO6UxyIuc_ggx8prrcZa7sjogD90M1LU81

[8]The DOT Bureau of Transportation Statistics report analyzed fewer flights than the JEC analyzed in calculating total hours of flight delay.

[9]Understanding the Reporting of Causes of Flight Delays and Cancellations, http://www.bts.gov/help/aviation/html/understanding.html. Figures do not add to 100% due to rounding.

[10]Aviation Rulemaking Committee, "New York Aviation Rulemaking Committee Report," December 2007, available at http://www.dot.gov/affairs/FinalARCReport.pdf

[11]Christopher Mayer and Todd Sinai, "Network Effects, Congestion Externalities, and Air Traffic Delays: Or Why Not All Delays Are Evil," *American Economic Review* 93, No. 4 (2003): pp. 1194-1215. Available at http://www2.gsb.columbia.edu/faculty/cmayer/Papers/Air_Traffic_Delays.pdf.

TECHNICAL APPENDIX

Measuring Air Travel Delay

To measure delay, one must compare an actual elapsed flight time against some alternative trip duration we deem to be "not delayed." While seemingly a simple concept, reasonable choices of how to do this abound, and the results can vary dramatically across different reasonable approaches. Further, one can aggregate the delays of individual flights to get a total across carriers, airports, or the whole system in a number of ways.

For example, the Bureau Transportation Statistics (BTS) measures flight delay relative to the airlines' scheduled times of departure and arrival. The BTS also characterizes flights arriving less than 15 minutes beyond scheduled arrival as "on time" in its computation of performance metrics, so delay could be measured against a 15 minute grace period.

Delays measured relative to scheduled arrivals are increasingly poor measures for assessing the costs to the economy of delays in the air traffic system as airlines add more time to their schedules to account for predictable delays, for example in peak travel periods and at chronically congested airports. Schedule adjustments are necessary to give travelers more realistic estimates of the duration of the trip and arrival times. The adjustments also improve airlines' measures of on-time performance. However, the full cost of air traffic delays includes even predictable delays. Indeed, routine delays may be a large share of overall delays in the system. Thus, to measure delay properly one must compute them relative to travel durations that would be reasonable in the absence of undue delay in the system. These alternative unimpeded travel times are called "nominal" travel times.

Delay measures relative to nominal travel times provide better information for policymakers than delays relative to scheduled arrival times. For example, investments to reduce routine delays (such as building a new runway) could produce real benefits that might not be captured by assessments that measure delay only relative to published schedules. Researchers of air traffic delay have computed delay relative to nominal travel times in a number of ways, but generally have not examined how their results differ from delays relative to scheduled arrivals. The JEC offers just such a comparison below.

Although more useful for policymakers, delays relative to nominal travel times are necessarily more subjective than delays relative to scheduled arrival times. Nominal travel times should exclude systematic and preventable delays, but at the same time not be so tight that only flights with perfect conditions are deemed on time. Analysts studying delay have used a number of approaches. For example, Mayer and Sinai (2003) define a "minimum travel time" for a flight segment as the shortest observed total travel time on a given nonstop route in a particular month.[1] Using the absolute minimum observed travel time as the nominal travel time makes the results sensitive to measurement error in the data and registers all but the very fastest trips as delayed. Other analysts measure delays in each phase of flight (at gate, taxiing, and airborne) and sum them to determine the total delay. Morrison and Winston (2007), for example, measure delay as the sum of delays within different phases of flight.

Delays at the gate are straightforward; the ideal departure time is the scheduled departure time, and the gate delay is the difference the scheduled time and the actual time. Delays during taxi are a little more challenging. Morrison and Winston (2003) measure taxi times relative to the lowest observed taxi times by a given carrier in a given season. Again the minimum approach biases the results towards positive delay and makes the results sensitive to measurement error in the taxi times. Another approach would be to use FAA estimates of nominal, uncongested taxi times. FAA experts estimates different values for taxiing out from the gate to the runway and taxiing in from the runway to the gate upon arrival, taking into account things like carrier gate locations and de-icing upon winter departure at northern airports. In the nominal taxi times, FAA experts include sufficient time for a plane to wait for one aircraft ahead in the takeoff queue. Thus planes may beat nominal taxi times in completely uncongested conditions.

The least straightforward phase of flight in which to measure delay is in the air. Airborne times naturally vary due to weather, wind, and airspace congestion conditions. One could measure delay against the shortest observed airborne time for a given segment in a given month, but then the basis of comparison is a flight that likely had unusually good conditions, such as a strong tailwind. One could measure actual airborne time relative to the flight plan, but the available flight plan data for estimated airborne minutes is from the final flight plan, after updates during the flight.[2] Thus the flight plan may already incorporate airborne delays. Indeed, on flights with large airborne delays the flight plan's estimated airborne minutes can be larger than the entire scheduled time for the flight.

Mindful of these issues, the technical appendix shows the delays of individual flights in four ways: one relative to airlines' scheduled arrival times (Measure A) and three relative to different estimates of how long the flight "should" take in the absence of undue congestion (Measures B, C, and D). Figure A1 summarizes them.

Given that it misses predictable delays, Measure A results in the lowest estimate of total delay. Measures B, C, and D are higher by an amount that approximates those routine delays already built into the published flight schedules. Measure B compares flight times to the 5th percentile of all observed total travel times for a given segment in each month. Using the 5th percentile rather than the absolute minimum makes the measure more robust to measurement error, and excludes comparison to flights that had very unusually good conditions. However, using the 5th percentile as the nominal travel time ensures that 95 percent of flights will register at least some positive delay. Measure B represents an upper bound on delays, and the JEC presents the results as a sensitivity test for these measures.

Measures C and D add up delays for each phase of flight in which delay occurs, but apply different measures of delay for the airborne portion of the trip. Measure C estimates airborne delay using information from the flight plan and the published schedule. The nominal airborne time in Measure C is the minimum of two estimates of airborne time: (1) the estimated airborne minutes from the flight plan; and (2) the scheduled block (gate to gate) time minus the nominal taxi times. Either measure alone might be on the high side. The flight plan's estimated airborne time, having been updated during the flight, may already incorporate some airborne delays, and the scheduled block time minus the nominal taxi times can include schedule padding for routine congestion. However, the minimum of the two is likely to be reasonable, particularly in aggregate across many flights.

Measure D uses a tighter measure of nominal air time, computing airborne delay relative to the fifth percentile of the observed airborne time for the segment for the given month. As Measure B does for the entire travel time, Measure D represents an upper bound on airborne delay.

For all measures of delay, the JEC zeroed out negative values, so that flights traveling faster than nominal times do not net out delays from flight traveling slower than the nominal time. For Measures A and B, that means flights with total travel times less than the basis of comparison have zero delay. For Measures C and D, only non-negative delays within each phase of flight appear in the total delay sum. This approach means that the JEC is implicitly assuming that flights traveling unusually fast do not produce economic benefits that offset the economic costs of flights that are delayed.

In this report, the JEC emphasizes the results for Measure C, the most moderate approach. In this technical appendix, we focus attention on two of the measures of delay: Measure A, which for descriptive convenience we hereinafter refer to as "Arrival Schedule Delay Measure", and measure C, referred to as "JEC Inclusive Delay Measure". However, for completeness, values derived from the other potential measures of delay, Measures B and D, are also reported.

Figure A1: Measures of Delay

Measure of Delay	Basis of comparison	Description
A – Arrival Schedule Delay Measure	Scheduled Arrival	Actual arrival time – scheduled arrival time.
B	Nominal Total Travel time	Actual elapsed time – 5th percentile of observed elapsed time for given segment in a given month
C – JEC Inclusive Delay Measure	Nominal Travel Times by Phase of Flight	delay leaving the gate + delays during taxi (relative to FAA nominal taxi times) + (airborne delay relative to smaller of flight plan and block time minus nominal taxi times)
D	Nominal Travel Times by Phase of Flight	delay leaving the gate + delays during taxi (relative to FAA nominal taxi times) + (airborne delay relative to 5th percentile of observed airborne time for given segment in a given month)

Previous Studies of Air Traffic Delay

The degree to which airlines pad their schedules to account for predictable delays is not well-documented, but some evidence suggests that schedule padding increased substantially in the years before 9/11 and again in the years since. Thrasher and Weiss[3] estimate schedule padding for flights between Laguardia and Boston in the springs of 1998 to 2001. They compare the shortest scheduled trip time (gate to gate) to the longest for the segment and found that while the minimum rose by 7 minutes, the maximum rose by 24. They find that the apparent improvement in on-time arrival (late flights were down from 16 percent to 5 percent from 1998 to 2001) was due to longer scheduled trip times rather than lower travel times.

Increases in scheduled travel times probably offer a reasonable measure of systematic delays, even though airlines might be accused of over-padding to improve their on-time statistics. Airlines compete in part by offering shorter travel durations. Further, although many travelers prefer not to arrive late, excessive earliness is undesirable, too. Thus in setting schedule times airlines must strike a balance between better on-time performance statistics and lower published travel times.

Aircraft delay minutes and passenger delay minutes

The JEC reports two categories of delay for each flight: the number of minutes the plane is delayed and the plane delay times the estimated number of passengers aboard. Some costs of delay, such as the airline's crew and maintenance cost per minute, are not a function of the number of passengers but rather a function of the type of aircraft. In contrast, the overall cost to passengers' time is very much a function of how many passengers are delayed. Some costs are semi-fixed. For example, jet fuel use by an aircraft per minute is influenced by the total weight hauled, which is in turn a function of the number of passengers. To simplify the analysis we assume fuel burn is independent of the number of passengers on each flight.

Flight Data and Measures of Total Delay

Data Sources for Measures of Delay

The JEC analyzed individual flights recorded in the FAA's Enhanced Traffic Management System. The data include schedule and flight plan information, along with FAA estimates of nominal taxi times out and in for each flight. The observations in the JEC data included over 10.01 million individual scheduled domestic passenger flights in 2007. The data include flights through over 1,100 U.S. airports with over 30 different kinds of aircraft flown by over 400 different major, national, and regional carriers. Given the size of the dataset, the JEC analyzed each month within 2007 separately and then totaled the results.

The ETMS flight data do not include information on the number of passengers transported, a key factor for assessing delay costs to travelers. To estimate the number of passengers on each scheduled passenger flight, the JEC turned to BTS's Form 41 Air Carrier Statistics T-100 Domestic Segment Schedule, which includes monthly data on the total number of passengers carried by each carrier on each flight segment (an origin/destination pair) with each kind of aircraft. The T-100 includes information by aircraft type, service class, available capacity and seats, and aircraft hours gate-to-gate and airborne, covering a wide range of carriers.

The JEC matched month, carrier, airport, and equipment codes in the two data sets and merged them, then divided the total number of passengers traveling per month from T-100 (on a given carrier on a given aircraft type on a given segment) by the number of such flights in that month from the ETMS. This approach populated about half of all the flights in the ETMS with an estimated number of passengers. One limitation to a merge like this is that the BTS and the FAA use different aircraft equipment codes that do not translate directly.

For the remainder of flights not populated directly by the T-100 data, the JEC imputed an estimated number of passengers by matching as many of each flight's characteristics to data in the T-100 as possible. For example, the JEC filled in some missing passenger data by assuming that such flights had the same number of passengers as other flights on that segment on that carrier in the same month. For remaining missing values, the analysis imputed passengers by taking the average passengers per flight by segment and month only, or by carrier, equipment type, and month only. The JEC bounded all estimates by the total number of seats on the aircraft. This approach produced an estimate of the number of passengers aboard almost all of the 10.0 million commercial passenger flights in the 2007 data.

Delays not analyzed by the JEC

The JEC included in its analysis only completed scheduled passenger flights between two U.S. airports on U.S. carriers.[4] This approach captures the majority of commercial flights in the U.S., but may leave out economically important sectors. For example, international flights are a small share of total flights landing or departing in the U.S., but represent an important profit center for airlines.[5] Thus, JEC may underestimate the delay costs to the U.S. economy by excluding the costs to U.S. airlines and U.S. travelers of delays in international flights.

Likewise, the JEC analysis excluded cancelled, military, freight, and general aviation flights, all of which may be affected by congestion and delays and contribute to economic costs accordingly. For example, controllers may require general aviation flights to travel circuitous routes to avoid high traffic areas. Congestion and delays may also raise costs for or otherwise impede overnight and same-day cargo services. Further, the JEC has not considered the effects of delayed mail and cargo aboard the delayed passenger flights in its data. However, some air taxi firms may actually benefit from congestion and delays at major hubs because the hassle there leads business customers to unscheduled air transport services from convenient secondary airports.

JEC estimates leave out some important costs to passengers of the congested system. The data on individual flight segments do not capture delays to passengers who miss connecting flights, and data also exclude delays from post-9/11 security procedures.[6] Further, the JEC includes only flights that actually travel; the share of scheduled flights that are canceled has risen from 1.2 percent in 2002 to 2.2 percent in 2007.

Plane Delays

Figure A2 shows the total delay across all of the flights in the JEC data as measured against scheduled arrival, Measure A, and with the JEC Inclusive Delay Measure, Measure C. The JEC finds that measuring delays with respect the published schedule (Measure A) significantly underestimates the true burden of growing congestion. In 2007, planes arrived later than their scheduled arrival by over 2.7 million total hours. After accounting for the padding in schedules for routine congestion, the JEC finds that delay is actually between 57 and 96 percent higher, or between 4.3 and 5.3 million total hours. Measure B reports plane delay of 4.9 million hours (1.8 million for the top 35 airports), and Measure D reports plane delay of 5.3 million hours (2.0 for the top 35 airports). Measure C, the preferred JEC estimate, reports plane delay of 4.3 million hours, with 1.6 million of those at the top 35 airports.

Figure A2 Plane Delay, in millions of hours, 2007

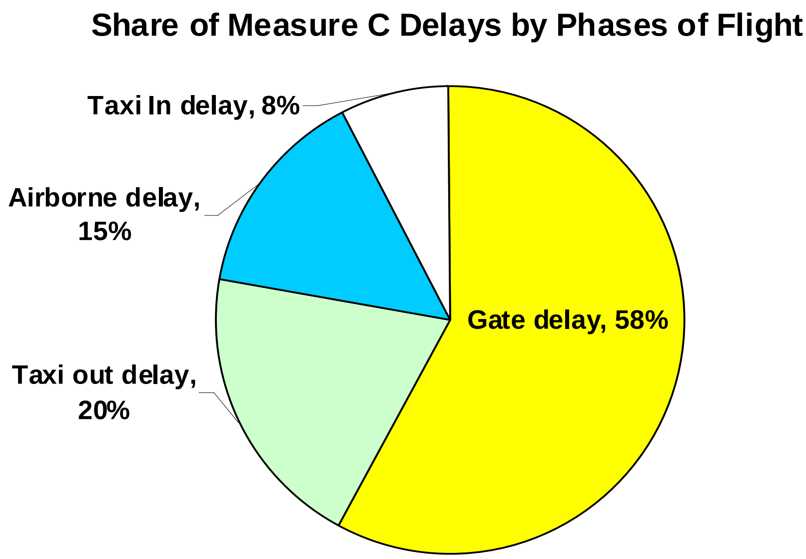
	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Hours of Delay, All Airports: 10.01 million flights	2.75	4.3
Hours of Delay, Top 35 Airports[14]: 3.26 million flights	0.94	1.6

Most Delays are on the Ground

JEC Inclusive Delay Measure, Measure C, sums delays across the four phases of flight: at the gate, taxiing out to the runway, in the air, and taxing into the gate upon landing. Figure A3 shows that a large majority of the total delay occurs on the ground, with the largest component (58 percent) being delay leaving the gate. Flights leaving the gate late (either because the plane or crew were late arriving) would be consistent with BTS statistics that show that the largest cause of delay is other delayed aircraft. Taxi out delays are significantly larger in aggregate than taxi in delays (20 percent of the total compared to 8 percent of the total), in part reflecting longer queues waiting for takeoff.

The composition of delays for Measure D is different than for the JEC Inclusive Delay Measure, Measure C, in precisely the way one would expect given its tighter measure of nominal airborne time. Airborne delays are 15 percent of the total for Measure C but 30 percent of the total for Measure D.

Figure A3 Plane Delays by Phase of Flight



One might be concerned that measures of delay that sum delays across phases of flight may overestimate total delays by not offsetting delays in one phase with faster performance in other phases. Our data suggest that delays across phases of flight are uncorrelated, and that while cross-phase delay offsets are common, they are not systematic. The correlation coefficients between delays in different phases of flight all fall below 0.1 in absolute value. This independence suggests airlines do not generally make up delays at the gate or during taxi by flying the plane faster. It also suggests that leaving the gate late does not generally make a taxi delay more likely. One way to gauge the magnitude of cross-phase delay offsets is to compare the results of Measure B with those from Measure D. Measure B amalgamates delays in all phases and allows cross-phase offsets, while Measure D does not. This explains why Measure D is about 10 percent higher than Measure B.

Plane Delays as a Share of Total Operating Time

The JEC summed the entire operating time for flights in 2007, measuring each flight from the scheduled departure time to the time of actual arrival. Total delay as a share of total operating times appears in Figure A4. Measuring delays relative to schedule arrival (Measure A) suggests delays only comprise 12.4 percent of the total operating time. However, results from Measure C suggest that 19.5 percent of the flight duration is squandered in delay. The other delay measures report upper bounds of 22.2 percent (Measure B) and 23.9 percent (Measure D).

Figure A4 Delay as a Share of Total Operating Time

	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Share of Delay in Total Operating Time	12.4%	19.5%

Results: Passenger Delays

Using JEC estimates for the number of passengers aboard each delayed flight, the JEC calculated the number of passenger delay hours. See Figure A5.

Figure A5 Passenger Delay, in millions of hours, 2007

	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Hours of Passenger Delay, All Airports	196.2	319.9
Hours of Passenger Delay, Top 35 Airports	96.6	160.6

The results in Figure A5 show that delay is not confined to just the largest airports, but delayed flights there carry relatively more passengers, inflicting a disproportionate share of the burden on travelers. Flights to and from the top 35 U.S. airports represented about 33 percent of our sample and 34 to 37 percent of the total hours of delayed planes. However, given the relatively larger planes involved, the flights to and from large airports comprised about half of the total passenger delay hours.

Measures B and D produced higher estimates of passenger delay by an amount reflecting the higher levels of plane delay. Measure B reported 367.2 million hours of passenger delay (186.0 million at the top 35 airports), and Measure D reported 400.8 million hours of passenger delay (205.7 million at the top 35 airports).

Delays Vary by Month

Figure A6 shows plane delay by month through 2007, with scheduled arrival delays (in black) falling consistently below the JEC Inclusive Delay Measure. On the right hand axis the chart reports the total number of observed flights in the month. One might expect total number of flights and total delay to track each other quite closely, both because high traffic causes more congestion and delays and because greater traffic means more flights that can be delayed. The data show a more complicated relationship. For example, in February the number of flights dipped relative to the month before, but delays rose. Delays fell from April to May, while the number of flights climbed. Weather-related delays could partly drive the results for ice and thunderstorm seasons.

Figure A6 Plane Delays by Month

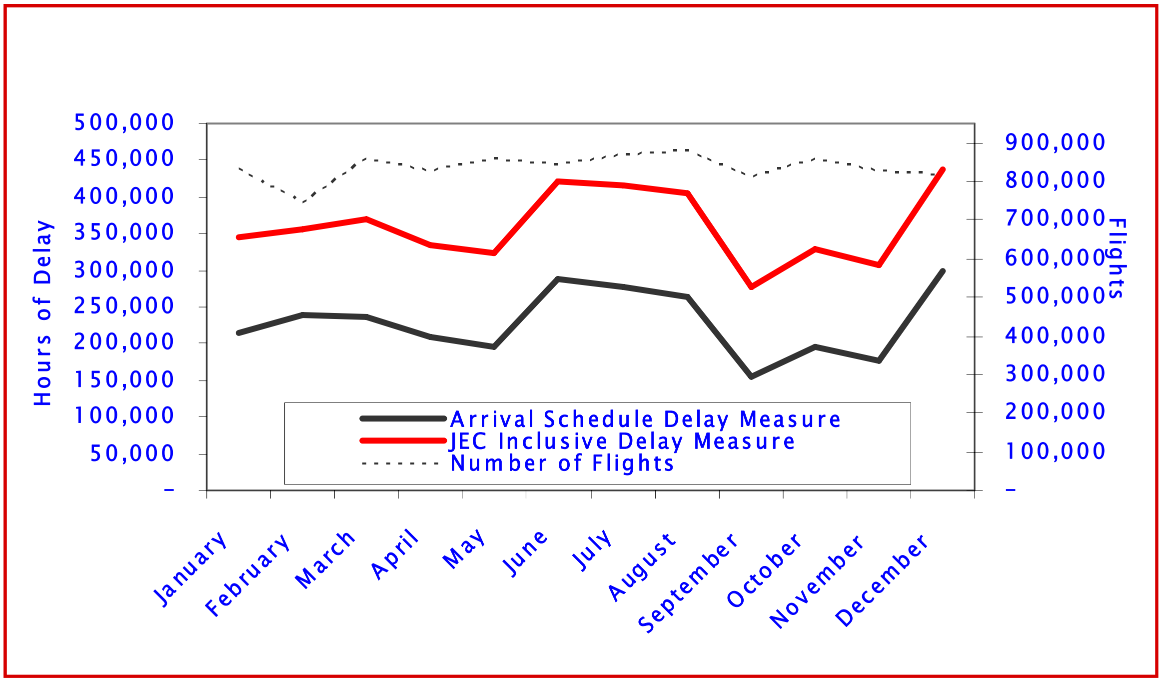
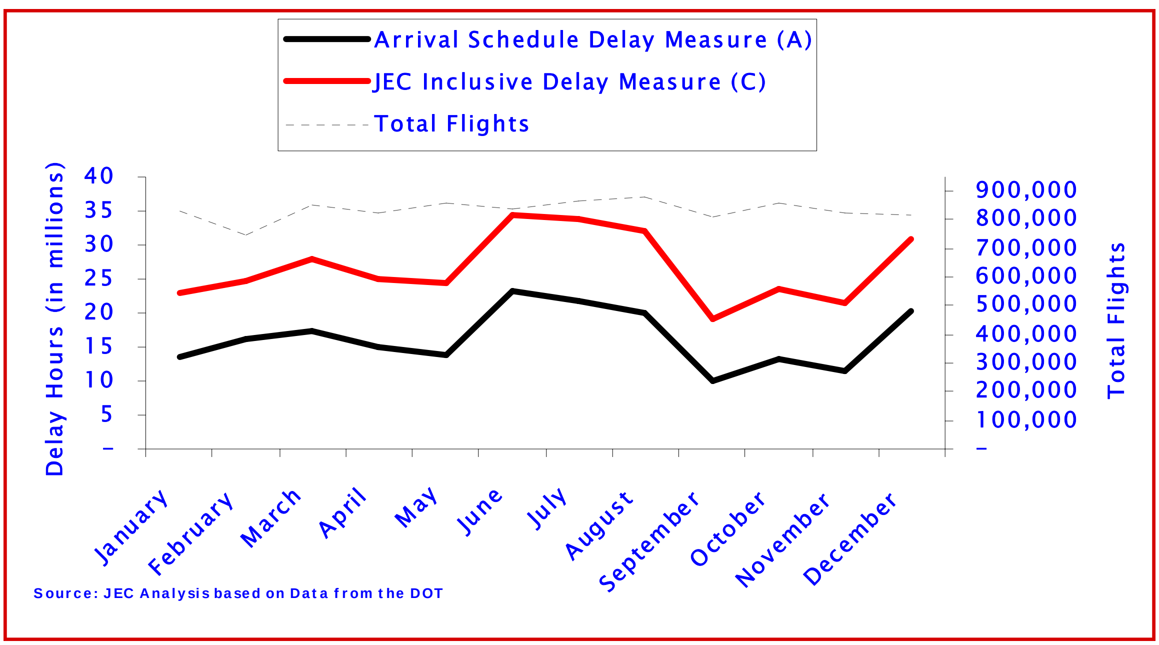


Figure A7 shows passenger hours of delay by month, predictably tracking the pattern of plane delays in Figure A6. However, it shows that passenger delays are more variable than plane delays, which is expected since they include both variation in plane delays and variation in the average number of passengers per plane. The higher amplitude of the graph suggests that the average number of passengers per plane is correlated with (but does not necessarily cause) higher levels of delay.

Figure A7 Passenger Hours of Delay by Month



The Economic Costs of Delay

The JEC computed the costs of delays to the economy as the sum of three values: the operating costs of airlines during the delays; a multiplier on those operating costs to account for spillovers to other industries; and the value of passengers' time.

Analysts of air traffic delay costs have assessed these costs in a variety of ways. A common approach is to follow the guidance the DOT provides to its regulatory agencies for analyzing policies that can affect air travel costs and time.[7] In general the JEC followed this guidance, but in certain instances departed from it to test the sensitivity of results to assumptions and to examine certain cost components in more detail.

Direct Operating Cost to Airlines

Each minute a plane is delayed can result in extra fuel, crew time, and aircraft maintenance, and the magnitude of those costs can depend on whether the delay occurs at the gate, on the tarmac, or in the air. DOT guidance cautions that in some studies incremental costs are more appropriate for economic analysis than average costs.[8] This may be particularly applicable to estimating the incremental cost associated with an additional minute of delay. On the other hand, widespread delays can raise airlines' fixed costs by requiring more aircraft, more employees, and more gates to provide a given level of service. Thus looking only at incremental costs by flight likely understates the burden of delays.

Some studies of the cost to airlines of delays combine the variable costs and fixed costs into an average cost per minute of delay. For example, the Air Transport Association (ATA) calculates that the average cost per minute of delay to major airlines (including fuel, crew, maintenance, and ownership) totaled $60.46 in 2007.[9] The two largest components of the ATA measure are variable costs: $27.86 per minute for fuel and $12.71 per minute for crew.

To span the range of reasonable estimates, the JEC used two quite different approaches to estimate the increased airline operating expenses as a result of delay. The first approach estimates, by flight, the incremental costs for fuel, crew salaries, and maintenance costs strictly applicable to the minutes of delayed operation. The second, much more inclusive, approach first calculates the share of total operating time that was spent in delay. The JEC then applied that proportion to the total domestic passenger-related operating costs of airlines for the year.

Given the data demands, only the JEC Inclusive Delay Measure (Measure C) and Measure D are suitable for computing the narrowest measures of operating costs. That is because Measures C and D break down total delay into delays at the gate, on the tarmac taxiing, and in the air. The phase of flight is critically important for fuel costs and can affect other costs such as depreciation and maintenance of the aircraft.

To calculate the pilot salary, maintenance, and depreciation costs of flight delay, the JEC used data from Schedule P-5.2 from the BTS's Air Carrier Financial Reports (Form 41 Financial Data). The JEC included P-5.2 Schedule information on quarterly aircraft operating expenses for large certificated U.S. air carriers such as flying expenses (including payroll expenses for pilots but not flight attendants), direct expenses for maintenance of flight equipment, and equipment depreciation costs. JEC applied crew salary data to delays during all phases of flight, but maintenance and depreciation applied only to airborne minutes of delay. Since the P-5.2 does not include data on the total number of flight hours (gate-to-gate), the JEC supplemented the P5.2 data with total gate-to-gate times from Schedule T-2 from the Form 41 data.

This analysis presented some of the same challenges of merging BTS data with FAA data that arose in estimating the number of passengers aboard each flight. So the JEC matched characteristics as closely as possible. First, the JEC estimated operating expenses per minute in the ETMS data using the relevant costs for the same carrier on the aircraft in the same quarter, or failing that the same aircraft on other carriers in the same quarter. Where an aircraft type match was not possible, the JEC made an estimate of operating costs by matching with costs in the same quarter for aircraft with a similar number of seats. Since fourth quarter data were not available, the JEC assumed third quarter costs applied in the fourth quarter. This is likely reasonable given that fuel costs, which rose most in 2007, were estimated with other data.

To account for flight attendant expenses, the JEC estimated the number of flight attendants on each flight using information on the number of seats on each delayed aircraft, FAA rules about how many attendants are required for a given number of seats, and information on median hourly wages for flight attendants.[10]

To calculate fuel expenditures, the JEC used data from the FAA for the jet fuel burn and CO_2 emissions per minute by type of aircraft by the phase of flight (on tarmac and at altitudes over 3000 ft). The FAA derived the fuel burn data using its Aviation Environmental Design Tool System for Assessing Aviation's Global Emissions, analyzing flights in 2004.[11] For each 2007 flight, the JEC applied the applicable fuel burn rates for the appropriate aircraft to taxi and airborne delays to compute the incremental jet fuel use as a result of the delays. Given data limitations, the JEC assumes no jet fuel is used at the gate, which likely understates the jet fuel consequences of delay given that gate use of auxiliary power units induces some fuel burn. The JEC calculated the costs of total fuel burn by multiplying the number of gallons burned by the national average wholesale price of jet fuel in the month of the flight.

The JEC analyzed the incremental fuel, salary, and maintenance costs strictly applicable to the minutes of delayed operation of individual flights. The JEC finds that approach produces total incremental operating costs of delay between $3.6 (for the JEC Inclusive Delay Measure, Measure C) and $6.1 billion (for Measure D). These numbers are somewhat lower than other analysts' because they exclude all overhead expenses on labor and capital, such as employee health care and the opportunity cost of aircraft ownership.[12] Also, the measures take into account the phase of flight during which delay accrues, and since a large share of delays occurs at the gate or during taxi, JEC estimates of fuel costs may be lower than others that do not make such distinctions. In particular, since (because of data limitations) the JEC assumes no fuel burn during gate delays, and because 58 percent of the delay occurs at the gate, one expects lower fuel costs for this approach than for others that do not account for the phase of flight in which delay occurs and the associated different fuel burn rates per minute.

A serious limitation of the narrow approach is that it does not account for higher overhead and capital costs to airlines that result from a system in which almost 20 percent of operating time is squandered in delay. As the DOT points out in its analytic guidance, if "...an initiative improves system efficiency, an operator may be able to provide the same service with fewer aircraft."[13] Likewise a system with greater delays requires more aircraft to provide a given level of service, along with more flight attendants, more ground personnel, and other factors of production.

This broader interpretation of the cost to airlines of delay suggests a much costlier picture of delays than the narrow approach. Rather than make detailed assumptions as to which specific operating cost categories rise as a result of widespread delay, the JEC estimated more inclusive operating costs to airlines by applying the share of operating time lost in delay (19.5 percent for the JEC Inclusive Delay Measure, Measure C) to an estimate of the total operating expenses for domestic passenger flights. To estimate the total operating expenses attributable to domestic scheduled passenger flights, the JEC used domestic carrier data from Schedule P6.0 of BTS Form 41 Financial Reports, dropping all-cargo carriers. Since fourth quarter 2007 data were not available, the JEC assumed that fourth quarter expenses were the same as first quarter 2007 expenses. The resulting total 2007 expense estimate was $97.7 billion.[14] On the other hand, the figure may overstate the relevant costs because it includes not just fuel, crew salaries, maintenance, and depreciation, but also advertising, ticket agents, landing fees, legal fees, and other factors that may be less affected by delays.

Then JEC applied the shares of delay in total operating time (reported in Figure 3.4) to airlines' total operating expenses in 2007. The results are reported in Figure 4.2 and report operating costs over five times higher than the narrow approach. The JEC Inclusive Delay Measure reports operating costs of $19.1 billion, and Measures B and D report operating costs of $21.7 and $23.4 billion, respectively.

Figure A8 Estimated Operating Costs of Delay
(Billions of U.S. dollars, 2007)

	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Estimated Operating Cost of Delay	12.2	19.1

Indirect costs to the Economy of Delay

In addition to the direct increase in operating costs due to delay, some analysts assess the indirect and induced costs to the rest of the economy due to air travel delay. Indirect costs include the costs of goods and services bought from the rest of the economy by the civil aviation industry. Air travel delays increase the production and distribution costs of other segments of the economy that rely on air travel as an input into their product or use air travel to provide a service.[15] For example, in the case of commercial passenger airline delays, higher air passenger transportation costs increase business and entertainment expenses, as well as delays in mail and other cargo costs. These additional costs cause higher prices to consumers, which leads to a decrease in general economic activity and real GDP.[16] Further, induced costs include costs to goods and services that are induced from the spending of income generated of industries of which transportation provided. For example, tourism is affected by airline delays, and the reduction in passenger travel will reduce expenditures of visitors in the food service, lodging, general retail, entertainment, public transportation, and auto rental industries.[17]

One study, using an input-output model, measured the indirect and induced impact of commercial airline travel delay to be 1.5, meaning that every dollar of direct impact on airlines has an additional effect on GDP of $0.50.[18] Assuming that the relationship between U.S. industries remains unchanged since the DRI/WEFA study, the JEC used the results of the DRI/WEFA input-output model, multiplying the delay costs to airlines by 1.5 to obtain an additional indirect impact due to delay.[19]

Figure A9 Indirect Effects of Inclusive Estimates of Airline Operating Costs (Billions of U.S. dollars, 2007)

	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Indirect Costs	6.1	9.5

The indirect costs associated with the narrow operating costs of delay for the JEC Inclusive Delay Measure and Measure D are $1.8 and $3.0 billion, respectively. The indirect costs associated with more inclusive operating costs for Measures B and D are $10.8 and $11.7 billion, respectively.

Value of Travelers' Time

Analysts have used a number of approaches in accounting for the value of travelers' time. Since travel time is not something that is purchased or sold, its value is revealed through choices made by travelers, for example by choosing airlines with better on-time performance or paying more for direct flights instead of connections. However unobservable, traveler time is certainly valuable and carries the opportunity cost of travelers' next highest-valued activities. Different travelers may have different valuations for their time and indeed, the same traveler may value his or her time differently depending on the purpose of the travel, work conditions, or other factors affecting his or her tolerance for delays.[20] If travel itself is unpleasant, a premium applies to traveler’s time spent in delays. Although many analysts use hourly wage rates to value business travelers' time, the hourly cost of the traveler to his or her employer (including benefits) may be a better measure since workers often choose between a mix of wages and fringe benefits in selecting their jobs.

Since a travel delay limits the productivity of a worker, their wage is a reasonable basis for the economic loss (to themselves, their employer, and the economy). Factors determining what the proportion of the wage should be considered lost due to a delay. Cell phones, laptops and mobile e-mail make some business people nearly as productive when stuck at the airport as they would be at their desks. On the other hand, being late to or missing a meeting or event can greatly impair a traveler's productivity. The employer clearly believed that the face-to-face interaction, which a delayed flight could easily prevent or complicate, was worth *more* than the foregone productivity of having his or her employee at their desk. Otherwise the employee would not have been sent on the trip. Further, the value of time exceeds the wage rate if time spent at work is enjoyed (relative to traveling), and falls short of it if time at work is relatively disliked.[21]

The economic impact of an individual losing vacation time to flight delays is likely to be smaller than the loss of time of a business traveler since the delay does not also affect an employer. Further, personal travelers are more likely prefer traveling to work, suggesting that the wage rate may overestimate the value of time for leisure travelers.

The Department Of Transportation analytical guidance supports using travelers' before-tax wage rates, including fringe benefits, as a value of travel time.[22] DOT derived its recommended hourly values of travel time savings from a survey conducted by the Air Transport Association (ATA) of America in 1998 and updated it with changes in median annual income from 1998 to 2000, as reported in the U.S. Census Bureau, Income 2000, Table 1. The ATA survey measured annual income for business and leisure travelers and calculated an hourly wage. Travelers' values of time factor in 70 percent of the hourly wage for personal travelers and 100 percent of the hourly wage for business travelers, including fringe benefits.[23] DOT guidance also includes a high and low value of each type of passenger, based on advice from a panel of transportation economists, as well as an average value per passenger, based on the ratio of personal to business travelers.[24] The JEC takes the central value for its analysis and uses the weighted average across business and personal travelers.

The Joint Economic Committee follows the guidance provided by the DOT for cost benefit analyses regarding savings in travel time. Since the Census Bureau's Income 2007 tables are not yet out, and because the cost of a traveler's time should include fringe benefits, the JEC adjusted the DOT guideline numbers by using the Bureau of Labor Statistics, Employer Costs for Employee Compensation Summary for March 2007 versus March 2000. Figure A10 below updates those DOT values to 2007, inflating at the rate of hourly earnings growth including fringe benefits.

Figure A10 DOT Recommended Hourly Value of Travel Time Savings (Inflated by JEC from 2000 to 2007 U.S. dollars per person)

	Central Recommended Value
All Purposes: weighted average of business and personal travelers	$37.60

Some analyses of the cost of delays to airline passengers include a multiplier effect which measures the impact on the economy because of foregone purchases by delayed travelers. In this report, the JEC adheres to the guidelines suggested by DOT and does not include a multiplier to reflect a loss in expenditures by passengers.

Value of Passenger Time: Results

The JEC took the hourly value of traveler time for all purposes as described above and applied them to the measures of passenger delay in Figure A11.[25] The JEC finds that costs of passenger time lost to air traffic delay were at least $7.4 billion in 2007 if delay is measured relative to scheduled arrival. Those costs amounted to $12.0 billion when schedule padding was accounted for.

Figure A11 Estimated Cost of Lost Passenger Time (billions of U.S. dollars, 2007)

Delay Measure	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Value of Delayed Passenger Time	7.4	12

The values of lost passenger time were $13.8 and $15.1 billion for upper bound delay Measures B and D, respectively.

Total Costs

The overall results for assumptions reflecting a moderate estimate of delay (the JEC Inclusive Delay Measure) along with a relatively inclusive approach to assessing operating costs appear in Figure A12, along with the analogous results for a measure of delay that excludes delays already built into airline schedules (Measure A). The JEC finds that those routine delays add an additional 58 percent to the overall costs of delay.

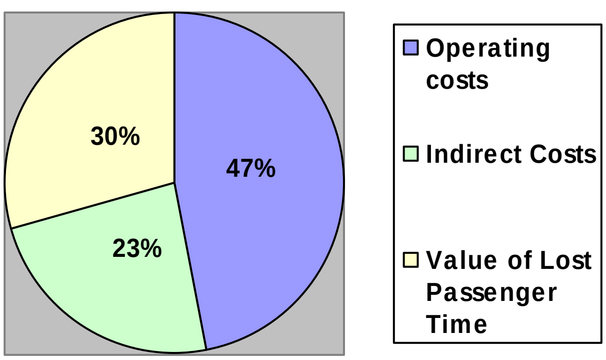
Figure A12 Total Costs of Delay (billions of U.S. dollars, 2007)

	Arrival Schedule Delay Measure	JEC Inclusive Delay Measure
Operating Costs	12.2	19.1
Indirect Costs	6.1	9.5
Passengers' Time	7.4	12
Total	25.7	40.6

The total costs of delay for Measure D were $24.2 billion using the narrow approach to estimating operating costs, and $50.2 billion using a more inclusive approach. Total costs for The JEC Inclusive Delay Measure or Measure C using narrow operating costs were $17.4 billion, and the total costs for Measure B with inclusive operating costs were $46.3 billion.

Figure A13 depicts the shares of the three components of cost in the total for the results for the JEC Inclusive Delay Measure.

Figure A13 Composition of Total Cost of Delay



Initial vs. Final incidence of air travel delay costs

The analysis above describes how costs of delay accrue initially to various participants in the air travel system. However, the initial incidence of delay costs is likely very different from the final incidence, particularly once airlines pass along costs to travelers in the form of higher ticket prices and/or reduced service. Depending on the relative market power of firms and consumers, air carriers will bear some share of the burden as demand for air travel declines as a result of longer travel times and higher ticket prices. However, to the extent they can, airlines will pass along the $19.1 billion in higher operating costs as a result of delay to their customers. Likewise, costs may be passed along to consumers in industries burdened indirectly by air traffic delays.

Jet Fuel and Environmental Costs

An important element of the costs of delay is the excess consumption of jet fuel, not only because fuel is costly but also because it produces pollution when burned. The operating cost analysis discussed above involved a careful estimate of the fuel burn by phase of delay. Since carbon dioxide (CO_2) emissions are fixed relative to the total volume of fuel burned, the data allow an estimate of CO_2 emissions from flight delays. CO_2 is the dominant gas implicated in the risk to the global climate from human-induced greenhouse gas emissions.

Figure A14 Jet Fuel Quantity Burned, Costs, and Emissions From Delay, 2007

Jet Fuel Burned (millions of gallons)	Cost of Fuel Burned (billions of dollars 2007)	CO_2 Emissions (millions of metric tons)
740	1.6	7.1

Delays consumed at least 740 million (the JEC Inclusive Delay Measure or Measure C) and up to 1.4 billion (Measure D) gallons of jet fuel. At an average wholesale price of $2.15 per gallon in 2007, the delay-induced fuel cost totaled at least $1.6 billion.

In computing the jet fuel-related costs to airlines of delay, the JEC multiplied excess jet fuel consumption for each delayed flight by the national average wholesale price for a gallon of jet fuel for the month in which the flight departed (See Figure A15). The price of jet fuel rose significantly over the course of 2007, so monthly fuel price data provide a more accurate estimate of costs than an annual average would.

Airlines' actual average cost of fuel may have been significantly lower than the national wholesale average because airlines frequently hedge against fuel price shocks through futures contracts.[26] However, the wholesale price captures the opportunity cost of the fuel to airlines even if it does not reflect the actual prices they paid. Further, airlines may not contract for 100 percent of their fuel use, so the wholesale price may better reflect their costs on the margin.

Figure A15

Month 2007	Jet Fuel US Wholesale Price per Gallon
January	$1.73
February	$1.77
March	$1.85
April	$2.02
May	$2.08
June	$2.11
July	$2.17
August	$2.15
September	$2.26
October	$2.35
November	$2.66
December	$2.66

Source: Department of Energy

The Joint Economic Committee estimated carbon dioxide (CO_2) emissions from the delay-related jet fuel burn using data from the FAA. The JEC finds that delay-related jet fuel burn emitted at least 7.1 and up to13.4 million metric tons of carbon dioxide (MMTC), or about 5 to 9 percent of all carbon emissions from domestic commercial aircraft in 2006. According to the inventory compiled by the U.S. Environmental Protection Agency (EPA)[27] aggregate U.S. jet fuel combustion produced 142.1 million metric tons of carbon emissions in 2006.

In addition to CO_2, airplanes emit local air pollution such as carbon monoxide, unburned hydrocarbons, oxides of nitrogen, fine particulate matter, and oxides of sulphur.[28] These pollutants are of particular concern in EPA-designated non-attainment or maintenance areas that may violate or risk violating clear air standards. Unlike carbon, local pollutants are not a simple factor of fuel consumption but rather depend on weather conditions and the exact type of engine and airplane body combination. Thus the JEC did not include them in its analysis. However, local criteria air pollutants can contribute to the costs of delays both in the damage they cause directly to human health and the environment and by increasing the requirements of emissions reductions outside the airline sector in order to meet EPA standards. Lowering ground-based delays can reduce such costs and can be considered in analysis of the benefits of reducing delays.

Works Cited

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[2]Personal communication with FAA experts. April, 2008.
[3]Theodore Thrasher and William Weiss, "A Proposed Method for Measuring Air Traffic Delay," CSSI Inc., 2001. available at http://www.cssiinc.com/public/technicalpapers/docs/24-A%20Proposed%20Method%20for%20Measuring%20Air%20Traffic%20Delay.doc
[4]By U.S. law, foreign carriers can fly between two U.S. airports but cannot sell tickets for such flights.
[5]For example, in February 2007, only about 90,000 flights arrived from or departed to a foreign airport out of a total of over 870,000 flights traveling through at least one U.S. airport.
[6]Researchers have estimated security-related travel time costs to be $25 billion annually, assuming travelers arrive at the airport an hour earlier than before new security measures were imposed. Steven A. Morrison and Clifford Winston (2008), "Delayed! U.S. Aviation Infrastructure Policy at a Crossroads," in *Aviation Infrastructure Performance*, Clifford Winston and Gines de Rus (eds.), Brookings Institution Press.
[7]See "Economic Values For FAA Investment And Regulatory Decisions, A Guide", Revised Oct. 3, 2007, FAA Office of Aviation Policy and Plans, available at
http://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/ECONOMICVALUESFORFAAINVESTMENTANDREGULATORYDECISIONS10032007.pdf.
[8]Economic Values, page 4-2.
[9]Air Transport Association, Economics and Energy, "Costs of Delay". Available at: http://www.airlines.org/economics/specialtopics/ATC+Delay+Cost.htm
[10]Hourly wages for flight attendants are not available from U.S. government sources, and annual salaries are problematic given the widely variable number of hours flight attendants may work each year. The JEC estimated an average hourly wage per flight attendant of $25.20, or $.42 per minute, from information at www.payscale.com. http://www.payscale.com/research/US/Job=Flight_Attendant/Hourly_Rate
[11]For more information see http://www.faa.gov/about/office_org/headquarters_offices/aep/models/sage/.
[12]For example, the Air Transport Association estimates the economic costs of delay. See http://www.airlines.org/economics/specialtopics/ATC+Delay+Cost.htm. The ATA applies a single estimated per minute operating cost of $60.46, 46 percent of which is fuel costs, to an estimated 134 million minutes of system delay to find $8.1 billion in estimated operating cost for 2007.
[13]GRA, *Economic Values*, p. 4-1.
[14]This estimate may be on the low side since fuel prices were climbing through the year, but the first quarter was closer in total number of flights to the fourth quarter than the third quarter was.
[15]DRI/WEFA, Inc., A Global Insight Company, "The National Economic Impact of Civil Aviation," July 2002.
[16]*Ibid.*, p. 25.
[17]*Ibid.*, Tables 2 and 3. Some of the impacts measured in Table 3 include general aviation and cargo. These costs are only for commercial passenger air traffic.
[18]*Ibid.*, Appendix A.
[19]*Ibid.*, Appendix A.
[20]Kenneth A. Small, Urban Transportation Economics, in Fundamentals of Pure and Applied Economics, Jacques Lesourne and Hugo Sonnenschein (eds.), Harwood Academic Publishers, 1992.
[21]Small, Urban Transportation Economics, p. 40.
[22]See US Department of Transportation, Office of the Secretary of Transportation, The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations, issued April 9, 1997, available online at http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf; and 2003 update available on line at http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf.
[23]These numbers are much higher than average hourly earnings reported by the Bureau of Labor Statistics because airline travelers were found to have much higher annual incomes than the general population. Consistent with other recently published work, the JEC assumes that incomes for airline travelers in 2007 remain substantially higher than the average population. See Stephen A. Morrison and Clifford Winston (2007), "Another Look at Airport Congestion Pricing," *American Economic Review*, Vol. 97, No. 5, pp. 1970-1977.
[24]See GRA, Incorporated, Economic Values for FAA Investment and Regulatory Decisions, A Guide," Contract No. DTFA 01-02-C00200, Final Report, Revised Oct. 3, 2007, prepared for FAA Office of Aviation Policy and Plans.
[25]Because a breakdown between business and personal travelers on each flight was infeasible, the JEC uses the all-

purpose value reported by DOT, updated to 2007 dollars. That all-purpose value used the ratio of business to personal travelers to calculate the overall value of passengers' time. Thus, to the extent that the ratio of business to personal passengers is higher (lower) today than in 2000, the JEC measure will underestimate (overestimate) the value of lost passengers' time.

[26]Ameet Sachdev, "United's hedge on jet fuel not best bet in 3rd quarter," *Chicago Tribune*. Chicago, Ill.: Sep 16, 2006.

[27]U.S. Environmental Protection Agency,"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006" p 3-9. Available at http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf. Includes consumption of jet fuel and aviation gasoline.

[29]Ohsfeldt, M., Thrasher, T., Waitz, I., Ratliff, G., Sequeira, C., Thompson T., Graham, M., Cointin, R., Gillette, W., and Gupta, M., "Quantifying the Relationship Between Air Traffic Management Inefficiency, Fuel Burn, and Air Pollutant Emissions," presented at the 7th USA/Europe Air Traffic Management Research and Development Seminar, Barcelona, 2007. Available at http://www.atmseminar.org/all-seminars/atm-seminar-2007/papers_calendar, line 65.