

## **Air Transportation in the Northeast Corridor: Challenges for the Future**

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### **Introduction**

The goal of this paper is to provide an overview of air transportation in the Northeast Corridor, with an eye to identifying the most crucial challenges faced in the next few decades. It is organized into two parts: Part I which provides an overview and Part II which looks specifically at two major challenges: congestion and environmental mitigation.

Part I begins with some facts and figures describing both passenger and freight movements in the Corridor and the current state of its most important airports. It also reviews some industry trends that are likely to affect developments in the near future. In order to provide some context, a review of the economic role of air transportation follows, both in general and in the context of the Northeast Corridor. Because the corridor comprises a set of large urban areas with a high degree of intercity interaction, there are extraordinary demands on air transportation and high-speed rail to facilitate face-to-face interaction and to move high-value goods. The last section of Part I reviews the environmental impacts of air travel and likely environmental constraints to come.

There are a number of important challenges that face the air transportation system in the corridor, but two dominant ones are the focus of Part II: first, the management of congestion in the face of growing demand with limited opportunities for infrastructure expansion, and second, environmental constraints that may increasingly impinge on air transportation over the coming decades. Of course, the two challenges are interrelated because it is the environmental impacts of air transportation that have limited the possibilities for airport expansion.

At the outset, a comment with respect to definitions is in order. I have used a traditional definition of the Northeast Corridor as extending from Boston to Washington DC (Bosnywash.) Where state level data are presented, I have used the line of contiguous states from Massachusetts to Virginia and including Pennsylvania. Where data are presented for airports I have excluded those that are in the states just mentioned but clearly outside the corridor. I have had to make some rather arbitrary decisions in the process – for example including Syracuse while excluding Rochester. An argument can be made that the Corridor as a functional regions now extends into New Hampshire and Maine at the northern extent and perhaps into North Carolina at the southern extent, but no data for those states have been included state level data. However, I have included Raleigh-Durham International among the large airports in the Corridor.

## **Part I: Overview**

### **Passenger Traffic**

Table 1 provides data on 2005 enplanements in the ten states that are, at least in part, included in the Northeast Corridor. Overall these states account for about 19% of US enplanements. The same states account for about 22.5% of the US population. Arranging the same data in a different way, we find that annual enplanements per capita are about 2.1 in the Corridor vs. 2.46 nationally. By this measure the Northeast Corridor is *less* air transport intensive than the US as a whole. This may at first seem surprising, but bear in mind that the probability of flying as opposed to choosing another mode is generally increasing in the length of trip. The large number of urban areas in the Northeast Corridor gives rise to a large number of relatively short intercity trips that can be made by car or rail.

The enplanements in Table 1 are broken into four carrier types: large certified; commuter and small certified; air taxi commuter and foreign. It is interesting to note that two categories – small commuter and foreign carriers – are overrepresented in the Corridor in the sense that their shares are larger than the corresponding national level shares. The

large share of foreign carriers is clearly due to trans-Atlantic flights. The large share of small carriers probably reflects the high proportion of short-distance flights.

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**Table 1: Enplanements in Northeast Corridor States**

(For airports with scheduled service and 2,500 or more passengers enplaned)

State	Large certified air carriers	Commuter and small certified air carriers	Air taxi commuter operators	Foreign air carriers	Total enplanements
Connecticut	3,567,752	80,703	86	34,054	3,682,595
Delaware	NA	NA	NA	NA	NA
District of Columbia	NA	NA	NA	NA	NA
Maryland	9,565,762	145,627	256	187,414	9,899,059
Massachusetts	11,731,321	512,124	179,167	1,313,889	13,736,501
New Jersey	15,357,185	1,624	2,045	1,560,508	16,921,362
New York	34,674,105	985,088	6,798	6,276,521	41,942,512
Pennsylvania	20,507,207	1,378,768	3,090	397,549	22,286,614
Rhode Island	2,798,944	37,352	93	9,613	2,846,002
Virginia	24,282,670	507,598	4,448	1,376,660	26,171,376
Corridor Total	122,484,946	3,648,884	195,983	11,156,208	137,486,021
U.S. total (incl. U.S. territories)	690,172,101	10,780,710	1,016,827	34,232,623	736,202,261
Corridor share	17.91%	34.79%	19.43%	33.00%	18.87%

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SOURCE: U.S. Department of Transportation, Federal Aviation Administration, Airports Planning, CY 2005 Enplanement Activity at U.S. Commercial Service Airports

Table 2 provides the same type of enplanement data but at the level of airports. It includes only those ten airports in the Corridor that are among the top 50 nationally. It also excludes Pittsburg, which is included in the state level data, while it includes Raleigh-Durham, which is not. Direct comparison of the aggregate numbers across tables 1 and 2 is therefore not very meaningful. An interesting point, however is that the share of small commuter airlines is closer to the corresponding national share in this table and

the share of air taxi services nearly disappears, which indicates that a large proportions of enplanements in these categories occurs in smaller airports.

Table 3 presents forecasts for enplanements at the eight largest Corridor airports in 2025. These forecasts are generated based on statistical models for individual airports that relate growth in enplanements to regional growth in levels of population and economic activity. There is no direct imposition of constraints on infrastructure expansion in this method, although restraint on expansion is captured indirectly in the parameters of the model. For example an airport that has not been able to expand as rapidly in the past in response to regional growth will have experienced slower growth in enplanements than one that has been relatively free to expand. Since the growth-expansion-enplanement relationships are reflected in parameters that are estimated separately for each airport, those that have experienced capacity constraint in the past have, *ceteris paribus*, slower projected growth in enplanements.

To anyone who has observed the politics of urban airport expansions, such large increases in enplanements will not seem realistic – at least not if they are to be achieved by expansion in runway capacity. In this sense, table 3 points to a looming challenge in terms of accommodating growth in demand. I will return to this topic below.

The failure to match growth in demand with growth in capacity has already given rise to significant congestion throughout the US air travel system. The simplest way to measure congestion is as an inverse of on-time performance, which is shown in Table 4 for major Northeast Corridor airports. Not unexpectedly, the weighted average on time performance for these airports (72%) is substantially lower than the corresponding national performance (77%). But this aggregate comparison conceals significant variation within the corridor. Clearly, if Laguardia and Newark were excluded, on-time performance in the Northeast Corridor would be close to the national level.

**Table 2: Largest Airports in the Northeast Corridor**  
**(For airports with scheduled service and 2,500 or more passengers enplaned)**

<b>Airport and state</b>	<b>Rank</b>	<b>Large certificated air carriers</b>	<b>Commuter and small certificated air carriers</b>	<b>Air taxi commuter operators</b>	<b>Foreign air carriers</b>	<b>Enplanements 2005</b>
John F. Kennedy International, NY	8	14,505,745	0	175	5,754,439	20,260,359
Newark Liberty International, NJ	13	14,882,789	1,624	97	1,560,449	16,444,959
Philadelphia International, PA	15	14,411,235	594,270	884	370,180	15,376,569
General Edward Lawrence Logan International, MA	19	11,707,622	193,259	302	1,313,740	13,214,923
Washington Dulles International, VA	20	11,602,668	153,460	1,368	1,275,006	13,032,502
La Guardia, NY	21	12,122,942	389,234	81	502,057	13,014,314
Baltimore/Washington International, Thurgood Marshall, MD	25	9,565,720	76,103	195	187,414	9,829,432
Ronald Reagan Washington National, VA	29	8,507,707	14,584	0	101,616	8,623,907
Raleigh-Durham International, NC	42	4,663,040	26,027	233	34,689	4,723,989
Bradley International, CT	49	3,542,051	41,287	65	34,050	3,617,453
Northeast Corridor		105,511,519	1,489,848	3,400	11,133,640	118,138,407
U.S. total (incl. U.S. territories)		690,172,101	10,780,710	1,016,827	34,232,623	736,202,261
Northeast Corridor Share		15.3%	13.8%	0.3%	32.5%	16.0%

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**Table 3: Projected Growth at Largest Airports in the Northeast Corridor**

<b>Airport and state</b>	<b>US Rank</b>	<b>Enplanements 2005</b>	<b>Projected Enplanements 2025</b>	<b>Projected Growth</b>
John F. Kennedy International, NY	8	20,260,359	38,381,000	89.4%
Newark Liberty International, NJ	13	16,444,959	30,503,000	85.5%
Philadelphia International, PA	15	15,376,569	30,382,000	97.6%
General Edward Lawrence Logan International, MA	19	13,214,923	21,477,000	62.5%
Washington Dulles International, VA	20	13,032,502	30,433,000	133.5%
La Guardia, NY	21	13,014,314	17,494,000	34.4%
Baltimore/Washington International, Thurgood Marshall, MD	25	9,829,432	19,263,000	96.0%
Ronald Reagan Washington National, VA	29	8,623,907	11,978,000	38.9%

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Source: U.S. Department of Transportation, Federal Aviation Administration, *Terminal Area Forecast Summary: fiscal years 2006-2025*, FAA-APO-07-1, March 2007

**Table 4: On Time Performance**

<b>Airport and state</b>	<b>On time %</b>
John F. Kennedy International, NY	70.2
Newark Liberty International, NJ	64.1
Philadelphia International, PA	71.8
General Edward Lawrence Logan International, MA	72.5
Washington Dulles International, VA	79.0
La Guardia, NY	66.7
Baltimore/Washington International, Thurgood Marshall, MD	80.2
Ronald Reagan Washington National, VA	78.7
Bradley International, CT	77.0
NE Corridor average (weighted by enplanements)	72.3
U.S. total (incl. U.S. territories)	77.0

Source: Derived from U.S. Department of Transportation series: *Air Travel Consumer Report* available online at <http://airconsumer.ost.dot.gov/reports/atcr07.htm>

### **Freight Traffic**

Before looking specifically at the Northeast Corridor, a few comments about the measurement of air freight are in order. It is customary to express freight data in tons, in which case the air mode generally accounts for only a miniscule share of freight movements. From an economic perspective, however, it is the value rather than the weight of goods moved that is important. As table 5 indicates, the value per ton of goods shipped by air is much higher than for goods shipped by other modes – 114 times as high as for truck and 448 times as high as for rail. There are a number of reasons for this. First, for higher value per ton goods, the high cost of air transportation will represent a smaller share of the total delivered prices. Second, since air transportation is the fastest mode it yields savings in terms of inventory carrying costs, which naturally are highest for high value goods. Finally, the rate at which the value of goods depreciates with time is often greatest for high order goods such as high fashion garments.

**Table 5: Value Per Ton of U.S. Freight Shipments by Transportation Mode: 2002**

Transportation mode	Value per ton (dollars)
Air (incl. truck and air)	88,618
Parcel, U.S.P.S, or courier	37,538
Truck and rail	1,480
Truck (2)	775
Water	401
Pipeline (3)	241
Rail	198
Other multiple modes (4)	148
Unknown modes	908

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *Freight in America* (Washington, DC: 2006), table 11.

**Table 6: Value and Weight of U.S. Commercial Freight: 2002**

	value (billions)	value (percent)	tons (millions)	tons (percent)
	Total		Total	
<b>All Modes</b>	13,052	100.0%	19,487	100.0%
<b>Single modes</b>	11,599	88.9%	18,894	97.0%
Truck	9,075	69.5%	11,712	60.1%
Rail	392	3.0%	1,979	10.2%
Water	673	5.2%	1,668	8.6%
Air (incl. truck and air)	563	4.3%	6	0.0%
Pipeline	896	6.9%	3,529	18.1%
<b>Multiple modes</b>	1,121	8.6%	229	1.2%
Parcel, post, or courier	1,022	7.8%	27	0.1%
Truck and rail	77	0.6%	52	0.3%
Other multiple modes	22	0.2%	150	0.8%
<b>Unknown modes</b>	331	2.5%	365	1.9%

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *Freight in America* (Washington, DC: 2006), table 3.

Because of this, air transportation accounts for a much larger share of total US freight activity if measured by value than if measured by weight. As table 6 shows, it accounts for less than .1% by weight but more than 4% by value, and this is an underestimate

because some proportion of the 7.8% by value in the “parcel, post or courier” category uses air for at least part of the shipment.

Table 7 Lists the top freight airports (by weight of landings) in the Northeast Corridor. Three large airports (Kennedy, Newark and Philadelphia) account for well over half of the total freight. It is interesting to note, however, that the list includes a number of smaller airports. This may reflect the tendency for freight operations to avoid competing with passenger operations for terminal capacity.

**Table 7: Top Freight Airports in the Northeast Corridor by Weight**

US Rank	ST	City	Airport Name	Hub	2005 Landed Weight (lbs.)
6	NY	New York	John F Kennedy International	L	5,622,506,380
9	NJ	Newark	Newark Liberty International	L	3,740,721,280
12	PA	Philadelphia	Philadelphia International	L	2,801,700,462
29	MA	Boston	General Edward Lawrence Logan International	L	1,148,881,400
32	CT	Windsor Locks	Bradley International	M	967,385,010
47	DC	Washington	Washington Dulles International	L	609,997,900
58	MD	Baltimore	Baltimore/Washington International Thurgood Marshal	L	514,993,500
59	NC	Greensboro	Piedmont Triad International	S	500,225,543
60	NC	Raleigh/Durham	Raleigh-Durham International	M	495,393,120
66	VA	Richmond	Richmond International	S	404,237,494
72	NY	Syracuse	Syracuse Hancock International	S	373,569,800
88	VA	Norfolk	Norfolk International	M	235,580,740
95	NY	Albany	Albany International	S	205,630,700
100	VA	Roanoke	Roanoke Regional/Woodrum Field	N	200,074,040
104	NY	Newburgh	Stewart International	N	188,093,300
110	RI	Providence	Theodore Francis Green State	M	155,171,000
119	ME	Bangor	Bangor International	S	23,173,600
122	NH	Portsmouth	Portsmouth International at Pease	N	1,893,004
			Sum of Corridor Airports		18,189,228,273
	US		All reporting airports		152,537,230,547
		Corridor Share			11.9%

Source: U.S. Department of Transportation, Federal Aviation Administration, table available online at: [http://www.faa.gov/airports\\_airtraffic/airports/planning\\_capacity/passenger\\_allcargo\\_stats/passenger/mediacy05\\_cargo.pdf](http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/passenger/mediacy05_cargo.pdf)

Air freight accounts for a much larger share of international merchandise trade than it does of domestic goods movement. Furthermore, it accounts for a larger share of exports than of imports—roughly 30% by value in 2002, which is larger than the share of water transportation (USDOT, 2005). The reason for the higher share of international trade is that for many trade partners, road and rail transportation are not options, so air freight only competes with ocean freight. The higher air freight share of exports reflects the fact that the value per ton of US non-agricultural exports is higher than the value per ton of imports.

**Table 8: International Freight Gateways, Ranked by Value of Shipments: 2004**

(Current \$, billions)

Rank	Port name	Mode	Total U.S. trade	Exports	Imports	Exports as % of total
1	JFK International Airport, NY	Air	125.3	52.7	72.6	42.0
2	Los Angeles, CA	Water	121.4	16.4	105.1	13.5
3	Long Beach, CA	Water	121.3	18.6	102.8	15.3
4	Detroit, MI	Land	113.8	58.2	55.6	51.1
5	Port of New York and New Jersey	Water	113.5	23.1	90.4	20.4
6	Laredo, TX	Land	89.5	38.4	51.1	42.9
7	Los Angeles International Airport, CA	Air	68.7	33.9	34.8	49.3
8	Buffalo-Niagara Falls, NY	Land	68.3	31.7	36.6	46.5
9	Houston, TX	Water	66.4	29.2	37.2	44.0
10	Port Huron, MI	Land	65.9	23.6	42.3	35.8
11	Chicago, IL	Air	65.4	25.2	40.1	38.6
12	San Francisco International Airport, CA	Air	54.6	24.3	30.3	44.5
13	Charleston, SC	Water	46.7	15.4	31.3	32.9
14	El Paso, TX	Land	42.8	18.3	24.4	42.9
15	Norfolk, VA	Water	33.5	12.0	21.5	35.8
16	Baltimore, MD	Water	31.3	6.9	24.4	22.0
17	Dallas/Ft. Worth, TX	Air	31.2	14.6	16.6	46.7
18	New Orleans, LA	Air	30.0	15.2	14.8	50.6
19	Seattle, WA	Water	29.6	6.7	22.9	22.6
20	Tacoma, WA	Water	28.9	5.3	23.6	18.3
21	Oakland, CA	Water	27.3	8.5	18.8	31.1
22	Savannah, GA	Water	26.3	9.7	16.6	36.9
23	Anchorage, AK	Air	26.3	5.7	20.5	21.8
24	Miami International Airport, FL	Air	25.3	16.2	9.1	64.0
25	Atlanta, GA	Air	24.9	10.4	14.6	41.6
<b>Total U.S. merchandise trade by all modes</b>			<b>2,286.2</b>	<b>816.5</b>	<b>1,469.7</b>	<b>35.7</b>
<b>Top 25 gateways</b>			<b>1,478.3</b>	<b>520.1</b>	<b>958.2</b>	<b>35.2</b>
<b>Top 25 gateways as share of U.S. total (%)</b>			<b>64.7</b>	<b>63.7</b>	<b>65.2</b>	

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *Freight in America* (Washington, DC: 2006), table 24.

Table 8 reflects this fact, showing that JFK International Airport is the single largest international trade gateway in the United States, exceeding even the largest port and land gateways. The fact that this dominant air gateway is located in the Northeast Corridor perhaps reflects the higher value to weight ratio of European as opposed to Asian trade, but also the fact that merchandise exports from the Northeast Corridor are of relatively high value goods. Note that exports from JFK are about twice as high as exports from the Port of New York and New Jersey, while imports to that port are actually higher than imports to JFK. In part, this reflects the fact that shipping containers often arrive at the port with relatively high value goods and depart with low value goods such as scrap metal.

A completely new category of air freight transportation may be introduced over the next decade or so: Unmanned Aerial Vehicles (UAVs) have been used by the military for various surveillance and attack operations. They can be operated by remote control or with pre-programmed flight plans. There is now an increasing push by firms who have produced UAVs for the military to apply them to commercial applications. Early applications are mostly in various forms of surveillance, such as monitoring pipeline corridors or aerial damage assessment.

The current potential to use of UAVs for freight is limited by the fact that they generally carry payloads of 2000 lbs. or less. However, if institutional barriers could be overcome (in particular, if UAVs could be permitted in civilian airspace) there may be a niche for using such vehicles to make high priority deliveries from point of origin to point of destination without involving airports. UAVs can take off from short runways that could be constructed at industrial parks or on properties controlled by firms specializing in rapid delivery of emergency cargoes. Such cargoes which might include documents, medical supplies, machinery components and other goods whose speed of delivery is so critical as to justify the cost of such a specialized service. Given their small payloads, UAVs will not have a major impact on the volume of freight movements, but they may add a new dimension to air freight and pose a variety of institutional challenges.

### **Industry Trends and Implications**

Two airline industry trends that may have serious implications for air travel in the Northeast Corridor are the well-established move to hub-and-spoke networks and the possible shift to larger airplanes.

The hub-and-spoke network was an outcome of deregulation. Free to offer whatever services they chose, airlines soon discovered that it was more economical to design their network of interconnecting flights around one or more hubs than to offer a large number of point-to-point services. Benefits to the airlines included economies of scale, higher load factors and the ability to centralize repair and maintenance. Consumers benefited from greater air travel opportunities as the number of city pairs served by scheduled flights roughly doubled. However, there are downsides. The scheduling of flights in “banks” to make connections efficiently has led to higher congestion in hub airports. Also, there is evidence that airlines that become dominant in their hub airport are able to charge a premium on trips that begin and end there.

The use of the term “hub” has been somewhat obscured by the FAA’s designation of airports as “large hubs” based solely on the number of enplanements. By their definition, La Guardia is a “large hub” despite the fact that it does not serve a hub function for any major airline. A more functional definition of whether or not an airport is a hub should be based on the proportion of “through” passengers – that is passengers who pass through an airport but whose trips neither begin nor end at that airport. A study at the Boston University Center for Transportation Studies (Gong, 2006) calculated “hubness” as the proportion of through passengers and found that only Baltimore-Washington International and Philadelphia (both of which serve as regional hubs for US Airways) are hubs<sup>1</sup>. Thus, congestion in the Northeast Corridor is not predominantly the outcome of hub-and-spoke operations.

It is interesting to speculate as to why few hub airports have been established in the Corridor. The most likely explanation is that in order to establish a hub an airline must

command a large number of gates in a single airport. This will be possible only where there is either significant slack capacity or the potential for terminal and runway expansion. Neither of these conditions is typical of large airports in the corridor. Also, a number of the airports have many international flights and within-corridor shuttles, all of which may have crowded out hub operations.

Another possible trend is the move to larger planes such as the new Airbus A380, which will seat 550 to 850 people depending upon configuration. Such a trend might be positive in the sense that it could relieve congestion by moving more people through a single runway slot, but might also require some capital expenditures, especially at gates. Such a large plane would logically fit into a hub-and-spoke rather than point-to-point strategy (Mason, 2007) so it would have little role in domestic traffic within the corridor. It might, however, be used on some trans-Atlantic services.

There is a fair bit of skepticism about the future role of very large planes except in very specialized international or transcontinental applications. In fact, the industry move has been mostly in the opposite direction, with the share of 747 operations declining in the most crowded airports over the past twenty years. While a large airplane can move more people through a runway slot, it takes much longer to “turn” at the gate, which greatly diminishes its potential to address congestion problems (Swan, 2007.)

### **The Economic Role of Air Transportation**

Accessible and affordable air transportation is critical for regional economic development. Recent econometric studies have established a strong relationship between the level of air transportation activity in a city and its rate of employment growth, especially in service and high-tech industries (Button *et al*, 1999; Bruekner, 2003.) In a related vein, a recent paper by Cohen and Morrison-Paul (2003) measures significant labor productivity benefits in regional manufacturing due to airport infrastructure expenditures.

In part the economic benefits of air travel activities derive from the fact that they employ a lot of people. For example, the complex of air freight related industries on the grounds of and surrounding JFK International has been reported as employing 60,000 people (NYT, 2004.) But a more important benefit arises because firms whose business requires either rapid goods delivery or frequent face-to-face contact need a high level of air service accessibility. They will therefore locate only in those metropolitan areas with large airports.

It may seem that modern communication technologies should make face-to-face interaction decreasingly important. Research indicates, however, that the more complex a transaction is, the less effective is written or even telephone communication (Daft and Lengel, 1986; Olanian, 1996.) This explains why firms that deal with highly complex information transfer such as financial institutions and corporate law firms are willing to pay high rent premiums to locate in downtown office districts close to their clients and service providers. Because producer services and high technology industries generate very complex information, they require a lot of face-to-communication and are therefore intensive consumers of air services.

This relationship between information-intensive activities and air transportation is especially important in the Northeast Corridor, where a number of major metropolitan areas are linked by frequent point-to-point (shuttle) air services, making it possible for people from different cities to attend the same meeting without the expense and inconvenience of overnight lodging. In fact, this capability for frequent intercity face-to-

face communication is one of the main characteristics of the Northeast Corridor that define it a multi-city agglomeration, rather than just a set of interrelated by independent cities. Anyone who frequents the shuttle departure lounges at Logan, La Guardia, Reagan-National and Dulles airports is familiar with a community of people working in business and government whose normal field of activities straddles the entire Northeast Corridor. Perhaps no other phenomenon better typifies the unique nature of the Northeast Corridor as urban agglomeration writ large.

### **Air Transportation and the Environment**

Air transportation has environmental impacts that are felt at the local, regional and global scales. Noise pollution, which is the greatest single impediment to siting new airports and expanding existing airports, is basically a local phenomenon. Airplane emissions, especially those that are precursors to ground level ozone, affect air quality at the regional level. Contributions to  $CO_2$  and other greenhouse gasses will affect climate at the global scale.

Noise pollution has always been the most prominent environmental problem associated with air transportation. Federal regulations on airplane noise were imposed as early as 1968 and were tightened on several occasions thereafter. As a result, the number of people exposed to airport noise above 65 dB has declined from about 7 million in the 1970's to 500,00 today (USDOT, 2004.) Despite this, noise pollution is still a major source of annoyance to the public and the main deterrent to locating new airports and expanding existing ones. For this reason, technological progress to reduce noise pollution could have a very positive effect on the air transportation industry.

Airplane exhausts contribute to emissions of a number of air pollutants that are monitored by the US government, including volatile organic compounds (VOC), oxides of nitrogen ( $NO_x$ ), carbon monoxide (CO) and particulate matter (PM). Airplane contributions to the aggregate emissions of these pollutants are small relative to emissions from highway vehicles, but they tend to be spatially concentrated at airports, most of which are in urban areas. Thus, the relatively low levels of pollutants do not fully express the potential

impacts on human health. State Implementation Plans (SIP) in non-attainment areas generally include airplane exhausts in emissions inventories. However, due in part to environmental standards on new equipment that have been imposed by US environmental legislation, emissions per landing and takeoff of most pollutants have decreased dramatically since the 1980s.

As one of the most energy intensive forms of personal and freight transportation, air transportation makes a major contribution to the emissions of  $CO_2$  and other greenhouse gases. According to the International Panel on Climate Change (1999), air transportation accounts for about 3.5% of total anthropogenic radiative forcing<sup>ii</sup>, which is about 13% of the total due to transportation. Furthermore, the share is expected to increase to about 5% by 2050 because of the rapid growth of air travel relative to other economic activities.

While the US does not have a formal policy for greenhouse gas reduction in place, it may have one in the future. The European Union, which has signed the Kyoto protocol, recently instituted a program by which  $CO_2$  emissions from airplanes will be capped at the 2004-2006 level and tradeable permits will be issued. This means that airlines must improve the fuel efficiency of their fleets, eschew any further growth in operations or purchase permits from other airlines that either curtail operations or improve efficiency at a rate that more than offsets their growth.

## **Part II: Challenges for the Future**

This second part of the paper takes a closer look at what I believe are the two most pressing challenges facing air transportation in the Northeast Corridor over the next two decades. The first is the problem of managing congestion in an environment of rapid growth in demand and severe constraint on infrastructure expansion. The second are the present and impending environmental constraints on air travel.

### **Addressing Congestion in the Northeast Corridor**

The figures in table 3 indicate that demand for air transportation services will continue to grow rapidly over the next twenty years. If sufficient capacity is not developed to accommodate this demand, congestion and resulting delays will grow as well. There are actually two types of congestion associated with air transportation: congestion in the air space and congestion at airports. While airspace congestion is just beginning to emerge as an important issue, airport congestion is already an established problem and I will focus on it here.

One can envision a number of mechanisms to address congestion at airports:

- *Physical expansion.* This can involve increasing the number of runways and the number of terminal facilities, or increasing the capacity of existing runways and terminals.
- *Shift to larger planes.* If there is a limit to the number of planes that can land over a given time interval, the only way to increase the number of enplanements is to increase the seating capacity of planes.
- *Reductions in separation.* More planes can be accommodated over a time interval if the safe interval of separation between planes can be increased. Improvements in air traffic control technology have already reduced separations in recent years and new technologies promise further reductions.
- *More rational assignment of existing capacity.* Institutional mechanisms such as congestion pricing and various approaches to slot management may increase the value of the air transportation service delivered per time interval, even if it does

not increase the number of planes. (There may be some overlap between this mechanism and the shift to larger planes.)

- *Shift of services to smaller airports.* To some extent this process has already begun with services provided by Southwest and other low-fare carriers.
- *Provision of comparable transportation services by alternative modes.* Specifically, the shift of some shorter air trips to high speed rail.

### *Physical Expansion*

Physical expansion, especially of runway capacity, may be the most obvious mechanism for addressing congestion, but it is also the most problematic from a social and political perspective. Most airports in the Northeast Corridor are in densely settled urban or suburban areas where there is significant resistance to the negative externalities associated with airports: especially noise pollution but also air pollution and the high level of vehicular traffic generated by airport customers.

The recent addition of a new runway to Logan International Airport in Boston is a case in point. Proposed as early as the 1970's, the new runway (the first addition in 40 years) came into service in November 2006 after lengthy court battles and a long FAA review. Furthermore, construction of the runway was only possible when the airport authority (Massport) agreed to limit its use to about one in three days when prevailing winds make use of an existing runway impossible, and to limit its use even on those days to small and medium sized planes. While this may be an extreme case, it illustrates that the process of runway expansion is slow, expensive and uncertain.

Other types of infrastructure improvements can have significant impacts on airport capacity. For example, construction of improved taxiways and holding areas that minimize the time it takes queuing plans to enter the runway or landing planes to exit it may increase the number of takeoffs and landings per hour. While such improvements yield smaller benefits than the construction of new runways, they may generate less public opposition.

Of course an alternative to infrastructure expansion at existing airports is the construction of new airports. This implies an even more difficult process of approval and public opposition and would require a political commitment that few elected officials would be willing to make.

### *Shift to Larger Planes*

Given the limited possibilities for expanding physical capacity, a number of other mechanisms for reducing congestion are based on trying to increase number of passengers that passes through existing facilities. One such mechanism is a shift to larger planes. If there is a fixed separation interval between planes using a runway, it is still possible to move more people through the runway by increasing the average number of passengers per plane<sup>iii</sup>. (A similar argument applies for freight.)

To a significant effect this has been accomplished through increased load factors in the post-deregulation era. But as average load factors move toward 1, increased passenger flow requires a shift to planes with larger seating capacities. The shift to hub-and-spoke networks has had this result to a limited extent, but current trends do not suggest that such a trend is in force.

Swan (2007) gives a number of reasons for the persistent popularity of smaller planes. First, large planes take longer to “turn” at the gate because of the large number of passengers to load and unload and the extra time needed for fueling and maintenance. Thus, a significant portion of the scale economy benefits (reduced costs per passenger mile) that airlines enjoy from larger planes is offset by higher idle times. Second, air travel markets place a reasonably high value on frequency – that is, passengers will pay more for flights with frequent service because they are more likely to come close to their desired departure and arrival times. Here again, some of the cost savings of large planes are offset, this time by higher fares on more frequent services that use smaller planes.

There is also the issue of airport noise, which is lower for small planes. The outcome of these factors has been that growth in the average size of plane has been flat to declining since about 1990 (Swan, 2007, Figure 3.)

Of course, one clear way to increase the average size of plane would be to eliminate small general aviation (GA) planes from airports with scheduled commercial flights. I'll return to this question below.

### *Reductions in Separations*

Air traffic control is an excellent example of how information technology may be applied to expand the capacity of physically limited infrastructure (Lakshmanan and Anderson, 2000.) In this sense, it can be viewed as the major precursor to the more recent concept of intelligent transportation systems (ITS.) Initially the use of radar in conjunction with radio communications made it possible to keep track of the locations of various planes and maintain safe separations as they approach airports, while at the same time ensuring that departing planes do not interfere with planes that are already in the air. This is combined with ever more sophisticated weather detection and forecasting systems to move a larger and ever larger number of planes simultaneously and to reduce safe separation intervals.

The progress in air traffic control technology is continuing via a gradual transformation from a radar based system to one that employs satellite based global positioning systems. The new technology, called ADS-B (Automatic Dependent Surveillance – Broadcast) will be implemented throughout the US over the period 2009-2013, although a complete transformation from radar systems will take longer because ADS-B requires equipment to be installed in all planes. The new technology promises ever shorter safe separations.

Air traffic control technology has had a huge impact. It largely explains why it has been possible for flight activity to grow so much more rapidly than physical infrastructure. Yet there must be diminishing returns at some point. Ultimately, separations will be limited by the length of time it takes for arriving and departing planes to clear the runway. A

study by MITRE Corporation (reported in Golaszewski, 2002) showed that an ambitious program of improved air traffic control and runway technology can mitigate but not eliminate expected growth in flight delays by 2015.

#### *More Rational Assignment of Existing Capacity*

Institutional rules to determine what flights can use airports at what times in the United States have been largely absent or *ad hoc*. Congestion pricing and slot management are two organizational policies that have been proposed as means to ensuring that scarce runway capacity is distributed efficiently. In a theoretical sense, “efficiency” here means that the benefit enjoyed by those flights that land are at least as large as the costs in terms of congestion that they impose on other flights.

Congestion pricing is frequently proposed by economists, but very seldom applied successfully in practice. The idea is that a landing fee should be charged that reflects not only the operations cost of the airport but also the congestion cost imposed on other flights (Levine, 1969). Since the congestion charge may be zero at off peak periods, airlines have an incentive to shift their scheduled flights away from the congested peaks. This is similar to the notion of congestion pricing of highways, where tolls are higher at peak hours, although there are significant differences between the road and airport cases (Nombela, de Rus and Betancor, 2004).

Implementation of congestion pricing implies a revision of landing fees, which even in the absence of a congestion charge should serve to discourage small commercial and GA flights. Landing fees in the US have traditionally been based on the weight of the airplane, which favors small and GA users. Since a small plane has a similar impact on congestion as a large one<sup>iv</sup>, a congestion pricing scheme starts with a flat landing charge to which a congestion charge is added, depending upon the time of day. Such a scheme not only encourages schedule shifts away from the peak, but more generally discourages small and GA users – which naturally increases the average size of aircraft.

According to Shank (2005), congestion pricing has been applied in only a very few cases and has for the most part been unsuccessful because those users who are disadvantaged have succeeded in bringing legal challenges and applying political pressure. For example, a 1988 attempt by Logan Airport in Boston to impose a hybrid fee structure with a flat fee and a small upward adjustment based on weight was challenged in court by GA interests who argued that it was discriminatory. The case was successful and Logan Airport had to return to its original weight-based fees.

In the 1960's, LaGuardia Airport in New York was more successful in imposing a congestion pricing scheme that specifically targeted GA users. According to Shank (2005), La Guardia was able to survive legal challenges because GA users had a dedicated alternative at Teterboro Airport, so they could not make a convincing case that they were being priced out of the New York market. In 1988, LaGuardia extended the congestion fees to cover regional air carriers as well as GA, but in 2000 an act of Congress mandated unlimited access for regional carriers. (The spike in congestion following this interference resulted in a slot management plan, discussed below.) As the experiences of Logan and LaGuardia indicate, congestion pricing schemes are likely to have a greater negative impact on some users than on others. Since airport authorities are public agencies, rather than private firms, disadvantaged users have a variety of legal and political mechanisms available to prevent implementation.

Slot management simply refers to a system whereby a fixed number of landings are permitted during each hour of the day and some set of rules is established to distribute those slots to users. From an economic perspective, an efficient mechanism would be a slot auction, but this is seldom the case in practice. In Europe, where many airports are slot managed, grandfathering is often the most important principle for slot assignment, a situation that may stifle competition and innovation. (See Madas and Zografos, 2006, for a discussion of alternative slot allocation strategies.)

La Guardia is one of the few US airports to use a slot management scheme (known as the FAA "High Density Rule.") Under this rule slots are capped at 75 per hour. Most are

grandfathered, while a certain number are made available by lottery. The two other High Density Traffic Airports (HDTA) are also located in the Northeast Corridor: JFK and Reagan National.

Slot management is an effective way to reduce delays at airports, but it does not really solve the congestion problem. We can define the congestion problem as existing because more people want to travel by air than the system of airport facilities can manage. Slot management does not address the imbalance; it simply caps the number of people who can fly. The benefits to air travelers from reduced delays due to slot management must be weighed against the cost incurred on travelers who are unable to fly because of the slot limit and the possible increase in fares due to supply constraint.

#### *Shift of Services to Small Airports*

With a number of the major airports in the Corridor under severe congestion constraint, increasing the number of scheduled flights from smaller airports that generally serve GA is an attractive alternative. To some extent, Southwest Airlines and other low-cost carriers have moved this process forward. For example, while Southwest offers no service from Logan, it offers service from Nashua, NH and Providence, RI that are advertised to the Boston market. It also offers service from Islip, Long Island (although it has some service to LaGuardia) and Baltimore-Washington International (although it has some service to both Reagan-National and Dulles.) In some cases, however, attempts by low cost airlines to offer services from suburban airports have been stymied by public opposition to an increased number of flights, as in the case of Hanscom Airport in Bedford, MA.

Besides the potential for public opposition, there are other limitations on the ability of smaller airports to absorb traffic from large, congested airports. For the most part, they are only useful for point-to-point service (which may include service to hubs) since the opportunities to make connections from such airports are limited. Also, many smaller airports do not have sufficiently long runways for the use of larger commercial jets.

Perhaps a more practical strategy than shifting large commercial planes to smaller airports is to shift GA traffic to those airports. As the comparison of the experiences of Logan and LaGuardia airports in imposing congestion pricing suggests, the availability of an alternative airport detracts from the legal arguments of GA interests for access to major airports. Another example is the State of Maryland, which operates BWI Airport. Because it also operates another airport (Glen Martin Field) specifically for GA traffic it is able to discourage GA from using BWI. The FAA defines a set of airports as “relievers” because of their ability to divert GA traffic away from larger airports nearby and congress has set aside a small proportion of airport improvement funds for them.

*Provision of Comparable Service by Alternative Mode*

The two alternative modes of intercity transportation in the Northeast Corridor are rail and highway. Given the high level of road congestion in the Corridor, diversion of trips to private automobile travel is hardly a desirable policy and intercity bus transportation is probably too slow to represent a direct substitute for air transportation. Thus high-speed rail service is the alternative with the greatest potential to serve as a viable substitute for air travel.

According to AMTRAK, 2005 ridership in the Northeast Corridor was about 9.5 million. This is a very substantial number, roughly equivalent to the number of enplanements at Baltimore-Washington International Airport and greater than enplanements at Reagan-National.

There are, however, a number of reasons to be skeptical about the potential for high-speed rail service to make an increasing impact on the air travel market. The first is the fact that AMTRAK continues to incur losses of about \$1 billion per year. It is likely that if fares were raised sufficiently to cover this shortfall, ridership would drop precipitously. Perhaps the best hope is for the operations in the Corridor to be split out from other national operations, as it probably has a higher potential for profitability in the dense corridor market. Even if AMTRAK can be restored to financial health without increasing fares, it is (like small airports) an alternative only for point-to-point travel, mostly within

the corridor. Nevertheless, increasing New York based high-speed rail by even 50% could have a very significant impact in reducing (or slowing the growth of) delays at LaGuardia and other Corridor airports.

### **Environmental Constraints on the Growth in Air Transportation in the Northeast Corridor**

We live in an era of heightened public sensitivity to the environmental impacts of all types of economic activities. Until recently, concern over the environmental impact air travel has been largely limited to noise pollution issues. Noise pollution impacts tend to be localized, affecting a small population severely. Opposition by groups representing this highly affected population have been effective in slowing and in some cases thwarting expansion of airport infrastructure and activities. Other impacts, including regional air pollution and climate change, affect a broader segment of the population and may therefore result in more widespread opposition to expanded air transportation in the future.

#### *Noise Pollution*

Noise pollution around airports has been an issue since the early days of commercial aviation. Federal policy with respect to noise pollution goes back to the 1960's and generally takes the approach of mandating successively stricter maximum noise standards for new airplanes (referred to as stage 1,2 and 3 airplanes) and requiring that all substandard planes be either retired or retrofitted by certain dates. So, for example, all airlines were required to bring their fleets up to stage 3 standards – either by retiring old plane or installing “hush kits” – by 1999. (Some contend that “hush kits” are ineffective and that all planes built under stage 2 standards should be retired, see Crowley, 2001.) As noted earlier, these standards have resulted in a significant reduction in the number of people exposed to airplane noise above 65 db. A new set of stage 4 standards was introduced were introduced for all new planes whose design is submitted to FAA after January 1, 2006.

More recently federal policy has been extended to actions either on the airport grounds or in the surrounding communities to help limit exposures. The FAA has determined that residential land use is not compatible with noise above an average of 65 db. Airports are encouraged to create maps of noise levels that define the most adversely effected areas. Funds from the Airport Improvement Program are provided for mitigations such as purchasing land in high noise impact areas, paying for the installation of soundproofing in severely effected homes and other buildings, building noise barriers around the airport and creating new taxiways and holding facilities that keep airplanes further away from local neighborhoods.

Despite these measures, public opposition to airport expansion has not waned – indicating an increased sensitivity to noise pollution over time. FAA has noted that complaints about airport noise have been registered at ever lower noise levels and at ever greater distances from airports (USDOT, 2007.) Thus, abatement policies to date do not seem to have eliminated, or even substantially weakened, noise pollution as a constraint on siting new airports and expanding existing airports. This constraint is especially binding in the Northeast Corridor, where the high population density leads to relatively large exposed populations around existing or proposed airport sites.

In the longer term, new airplane technologies are under development that may provide radical reductions in noise pollution. A collaborative research project of MIT and Cambridge University (UK) known as the Silent Aircraft Initiative (SAI) is attempting to develop a new class of passenger airplane with noise levels so low as to be “imperceptible outside the airport perimeter.” (<http://www.cambridge-mit.org/project/home/default.aspx?objid=1409>) The new aircraft would have a radically different shape that is more like the “flying wing” style stealth military planes than a conventional airliner. This means that runways, gates etc. would have to be reconfigured to serve it. Despite these problems, a broad coalition of firms in the aerospace industry -- including Boeing, Rolls Royce, several airlines and air freight companies – are collaborators in the SAI. While commercialization of this technology is 15-20 years off,

it could potentially be the key to unlocking capacity constraints on air travel in the Corridor and beyond.

### *Local and Regional Air Pollution*

As noted earlier, airplanes make a relatively small contribution to the main categories of local and regional air pollutants. In particular, airplanes account for around 1-1.5% of emissions of oxides of nitrogen ( $NO_x$ ), which is one of the precursor pollutants for ground level ozone, commonly known as smog. Despite the relatively small share, airplane emissions are coming under increasing scrutiny for a number of reasons. For one thing, they are highly concentrated. Emissions from cars and trucks are much larger in aggregate, but they are much more broadly spread out across the landscape. Since the effects of air pollution on human health depend on concentrations and exposed populations, rather than on aggregate emissions, concentrated emissions may do more damage than dispersed emissions. Also, as the fastest growing category of transportation emissions, airplane emissions are expected to make up a greater share of total emissions in the future.

A large proportion of top 50 airports are located in areas that fail to meet EPA's concentration standards. In some cases airplane emissions account for as much as 4% of the  $NO_x$  total, so airport activities become a substantial part of the State Implementation Plans (SIPs) that commit state governments to policy actions aimed at improving air quality. This means that if emissions are to rise at the airport due to growth in air traffic, offsetting reductions must be found elsewhere. Stricter ozone concentration standards were introduced this year (2007). It remains to be seen whether the new standards will have a significant impact on airport operations.

The US federal government has enforced some restrictions on airplane emissions for about 30 years, but did not have a specific standard for  $NO_x$  until 1997. In 2005, EPA instituted a new set of  $NO_x$  standards for new airplanes that are about 16% more strict than the 1997 standards (USEPA, 2005). (The new regulation adopts a set of standards that were defined by the United Nations International Civil Aviation Organization.)

Nevertheless, the new regulations have relatively little impact because the vast majority of airplanes either approved or in production for use in the US already meet them. Both the European Union and the US are currently pressing for much more stringent international standards, reducing  $NO_x$  emissions by 50-80% over the next ten to fifteen years. In anticipation of tighter standards, NASA has included development of low emissions engines in its Ultra-Efficient Engine Technology (UEET) program and Boeing has a research team working on low emissions airplane designs.

At least for the moment, regional air pollution provides much less constraint on air travel activities in the Northeast Corridor than does noise pollution. But it is at least possible that it will become a much more binding constraint over the next ten years or so.

### *Greenhouse Gases*

As noted earlier, aviation accounts for only about 3.5% of global emissions of  $CO_2$  and other greenhouse gases. Thus, it has received less public attention in debates about climate change than emissions from automobiles and electricity generation. But while its share is small, it is the fastest growing major source of emissions. Furthermore, there is no technological breakthrough on the horizon – jet engines will run on aviation kerosene and achieve efficiency improvements in the range of 1-1.5% per year for the foreseeable future (*Economist*, 2006). The simple arithmetic is that if passenger and freight aviation activities continue to grow at rates of 3-6% per year, fuel consumption (and thereby  $CO_2$  emissions) will grow at a rate of 1.5 – 5% per year. (To put this into perspective, a 3.5% growth rate implies that consumption will double in about 20 years.) Since most other categories of fuel demand are expected to grow more slowly, the share of aviation in greenhouse gas emissions will increase rapidly. Of course, constraints on the supply of infrastructure discussed elsewhere in this paper might prevent such rapid growth from extending far into the future.<sup>v</sup>

The rapid growth in greenhouse gas emissions has been a point of much greater contention in the European Union than in the United States. This is because the EU is committed to significant reductions in emissions under the Kyoto Protocol. A recent

study at the University of Manchester (Bows et al, 2005) plays up the crucial role of aviation in a policy to reduce aggregate emissions. The United Kingdom recently committed to a reduction of emissions of 60% from 1990 levels by the year 2050. The study estimated, using relatively conservative assumptions, that air travel would make up 40% or more of the *total* emissions allowable under the 60% reduction goal by 2050. Under assumptions that the authors considered more realistic the air travel share would be even higher. Their conclusion is that any realistic policy to achieve the greenhouse gas reduction goal must include a curtailing of air travel growth. It was in the context of this type of argument that the EU has instituted a cap and trade program to arrest growth in greenhouse gases from aviation.

There several possible implications for air transportation the Northeast Corridor and elsewhere. If the United States undertakes an aggressive policy of greenhouse gas mitigation in the near future, it is unlikely that air travel will be exempted. Even if no such policy is adopted, the increasing share of air transportation in emissions will eventually lead to greater public awareness of the role of aviation in climate change. This, in turn, will lead for greater calls to reduce air travel by environmental groups and perhaps broader public resistance to expanding infrastructure.

### **Concluding Comments**

Air transportation, both of passengers and of freight, plays a crucial role in the highly interconnected economy of the Northeast Corridor. As the economy grows, and resources shift into economic activities that are intensive users of air transportation services, demand will continue to grow. But constrains that are already evident such as the failure to expand airport infrastructure, as well as environmental constraints that will only become more pressing in the future, imply that the growth in supply will not keep up with the growth in demand (at least not at current prices). The likely result is increased delays, increased fares or some combination of the two.

Both technological and institutional changes are needed if this rather pessimistic picture is to change. Until now, technological advances in air traffic control have made it

possible to move a rapidly growing number of flights through a slow growing infrastructure. Continued advances of this type will be necessary in the future, but they cannot provide the whole solution. Among vehicle technologies on the horizon, the “silent” aircraft holds a special promise because it could significantly mitigate one of the main impediments to expanding infrastructure. This technology is at least 15 years from broad application and will require a lot of adjustments in airport infrastructure – broader runways, different gate configurations, etc. Also, it does not necessarily solve the other environmental problems: air pollution and greenhouse gases. But as a potential key to unlocking public resistance to infrastructure expansion it deserves special attention, especially from policy makers.

In the mean time, institutional reforms may help move more passengers and freight through the existing infrastructure. I emphasize “passengers and freight” as opposed to “landings and takeoffs” because it is the former that contribute to economic growth and development. There is no doubt that a market-based provision of aviation terminal services would allocate facilities to flights in a very different way than the current legislation-based system. Under the current system, landing fees are generally too low to provide any incentive for more efficient use of the infrastructure and there is little or no means of differentiating potential users according to their willingness to pay. This is not to suggest that privatization of airports is necessarily the answer. (In fact, privatized airports acting under strict price regulation might not be any better than the current system.) Rather, airports should be free to apply market principles in setting prices for their services. If slots are to be capped, then at least a large proportion of slots should be distributed by auction. (If nothing else, this would provide information on what price the market will bear.) Otherwise landing fees should be set high enough to exclude flights with low economic value. This does not necessarily mean the policy of providing adequate capacity for GA flights must be abandoned. Rather, facilities at reliever airports could be improved to better serve them. Ironically, the best way to reduce congestion at large commercial airports may be to spend money on small GA airports.

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<sup>i</sup> This study is based on 1995 data but probably reflects current circumstances fairly well.

<sup>ii</sup> Radiative forcing refers to the contribution via various gas emissions of a particular human activity to climatic change. Calculation of radiative forcing takes account of the fact that various greenhouse gases have different effects per unit emitted on the warming of the atmosphere via the greenhouse effect.

<sup>iii</sup> In reality it is not that simple, because larger planes require somewhat longer separation on landing and require a bit more time to take-off. But to the extent that the proportion time increase is smaller than the proportional increase in the number of seats, larger planes can increase passenger throughput.

<sup>iv</sup> On the one hand, small planes require less time to take off and require smaller separations among themselves, so one could argue that small planes have a smaller impact on congestion. On the other hand, when small and large planes are mixed, separations intervals must be increased to avoid the dangerous effect of wake turbulence from large planes on small planes landing behind them. (These issues are addressed in Wells and Young, 2004.) What is certain, however, is that small planes have a larger impact on congestion measured on a *per passenger* basis.

<sup>v</sup> This is the expectation of the Energy Information Agency, which projects the aviation share of energy consumption to remain stable out to 2030 because infrastructure constraints will slow growth in air transportation.