New York Airspace Effects on Operations

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Introduction

The northeast United States, and more particularly the New York area, has seen a huge growth in demand for air traffic services over the last 20 years. Airport authorities and airspace planners have accommodated this growth as far as possible. Together with the prevailing weather patterns in the area, however, this environment has created challenges for airspace managers (the Federal Aviation Administration [FAA]), as well as for airspace users (airlines, pilots, and dispatchers).

No single cause accounts for all of these challenges to the expedient flow of air traffic. Conceptually, flow problems can be cast in terms of a balance between air traffic demand and capacity. In this context, the most important factors might be as follows:

- Air carriers schedule flights at or above the maximum Visual Flight Rules (VFR) capacity of an airport during peak times.

- Airport runways and “transition” airspace have finite capacity, which is impacted by bad weather.

Our hypothesis is that the New York area represents a unique situation in the continental U.S. (CONUS) which has impacts on airline operations in terms of delays, predictability, and flexibility of operations in ways that affect profitability.

Our examination of this hypothesis relies largely on Enhanced Traffic Management System (ETMS) data, especially on a certain day—Friday, October 23, 1998. This day was special because VFR conditions prevailed throughout the CONUS. One may therefore assume that a complete, or nearly complete, set of scheduled flights actually flew that day, serving as a good case for the study of congestion effects.

This paper first examines a number of attributes that characterize the region, and then assesses some of the impacts on airline operations associated with these attributes. The MITRE Corporation’s Center for Advanced Aviation System Development studied the problems of New York Airspace as part of an Internal Research and Development effort. Data and analyses here are abstracted from this research (DeArmon, 2000).

Characterizing Attributes of the Area

Geographic Density of Airport Operations

The FAA counts operations for airports and for Terminal Radar Approach Controls (TRACONs). However, since TRACONs vary widely in size and shape, a consistent, comparable means of evaluating the geographic density of airport operations required a more flexible definition. For this purpose, we used a statistical technique called "cluster analysis," which describes groupings of similar entities. This technique was applied to observed arrivals and departures for October 23, 1998, grouping the nation's busiest 200 airports by geographic proximity, i.e., those within 100 nautical miles (nmi) of each other. We found the New York area has a greater density of airport operations than other areas of the U.S. (see Table 1).

Table 1. Airport Groupings for Threshold Distance of 100 nmi

Number of Arrivals and Departures	Cluster Members (leader is listed first, followed by other airports located within 100 nmi of the leader)
8263	PHL EWR LGA IAD DCA BWI JFK TEB HPN MDT ABE ISP SWF ACY MMU
4400	ORD MDW MKE MSN PWK RFD CGX MLI DPA
4004	LAX SAN SNA ONT BUR PSP SBA VNY BFL CRQ
2971	DFW DAL ADS
2956	CVG IND DAY ILN LEX FWA
2934	ATL BHM PDK FTY
2933	DTW GRR TOL YIP PTK SBN LAN AZO FNT MBS DET

These operations values are consistent with FAA's 1997 operations counts; the rank ordering of the busiest 20 or 30 airports agrees quite well. Obviously, the airspace for these regions, as a resource for providing air traffic services, is fixed in size. Comparing the first and third clusters, the Philadelphia/New York/Washington, D.C. region has more than twice the arrivals of the Los Angeles/San Diego region, but the airspace is the same size.

Comparing Sectorizations

Sectorization is the process whereby FAA airspace planners and operations specialists divide the airspace into appropriately sized and shaped volumes that facilitate safe, orderly air traffic flows and are appropriate work units for an air traffic controller or team. Airspace planners create sectors in "transition" airspace, say, 30–200 nmi around airports, to segregate flows into and out of terminal areas.

Using the Lee-Sallee shape measure (Clarke, 1990), we compared the shapes of transition airspace around eight airports: Atlanta (ATL), Cincinnati (CVG), Dallas/Ft. Worth (DFW), Detroit (DTW), Newark (EWR), Washington Dulles (IAD), Los Angeles (LAX), and Chicago (ORD). We evaluated the surrounding airspace at FL120, with a

50nmi radius, and the airspace at FL180 with a 100nmi radius. We found EWR sectors to be both narrower and shorter than those around other airports. This is one of the characteristics that make the New York airspace unique—it has many transition sectors with low or nil lateral maneuverability. Smaller sectors results in EWR having the highest number of sectors in its surrounding airspace, also, which implies more coordination and communication between controllers themselves and between pilots and controllers.

Traffic Flow Distribution in Transition Airspace

An effective way to observe the restrictive nature of the New York airspace is to study historical traffic flows, particularly in the transition region, where there are many departures and arrivals. The concentration of these flows, as described by their lateral and vertical spacing, can be compared with flows at other busy terminal areas to examine the characteristics of transition airspace. For this analysis, ETMS data was used to count aircraft crossings of a fixed-radius cylinder of airspace placed around an airport. The flights were characterized as departures, arrivals, or overflights, and their crossing points (aircraft entries and exits into this cylinder) were plotted as functions of azimuth (direction from the airport) and altitude for specified periods of time. In effect, the cylinder has been unrolled onto a rectangular surface. The EWR, ATL, ORD, DFW, and DEN terminal areas were examined in this way, by analyzing a 100 nmi radius cylinder placed around each airport.

At an airport with a four-corner arrival post pattern, arrivals are loosely clustered at four points of the compass, interspersed with similarly clustered departure streams. A significant portion of the operations consists of high-altitude overflights, with some low-altitude overflights attributable to general aviation traffic. Airspace between arrival posts is not very crowded. This allows fix-load balancing, whereby arrivals are moved from post to post to adjust demand for the various arrival posts. Such plots were generated for ATL, DEN, ORD, and DFW. ORD has a greater volume of traffic, including dual parallel arrivals to one arrival fix, but otherwise is similar to the others.

A similar analysis for the New York airspace reveals a much more congested flow pattern. Figure 1 shows flow data for a cylinder centered on EWR. As noted earlier, the operations count alone for New York guarantees a more congested airspace. However, since there are multiple airports involved, the flow pattern is also much more complex than the airports mentioned above.

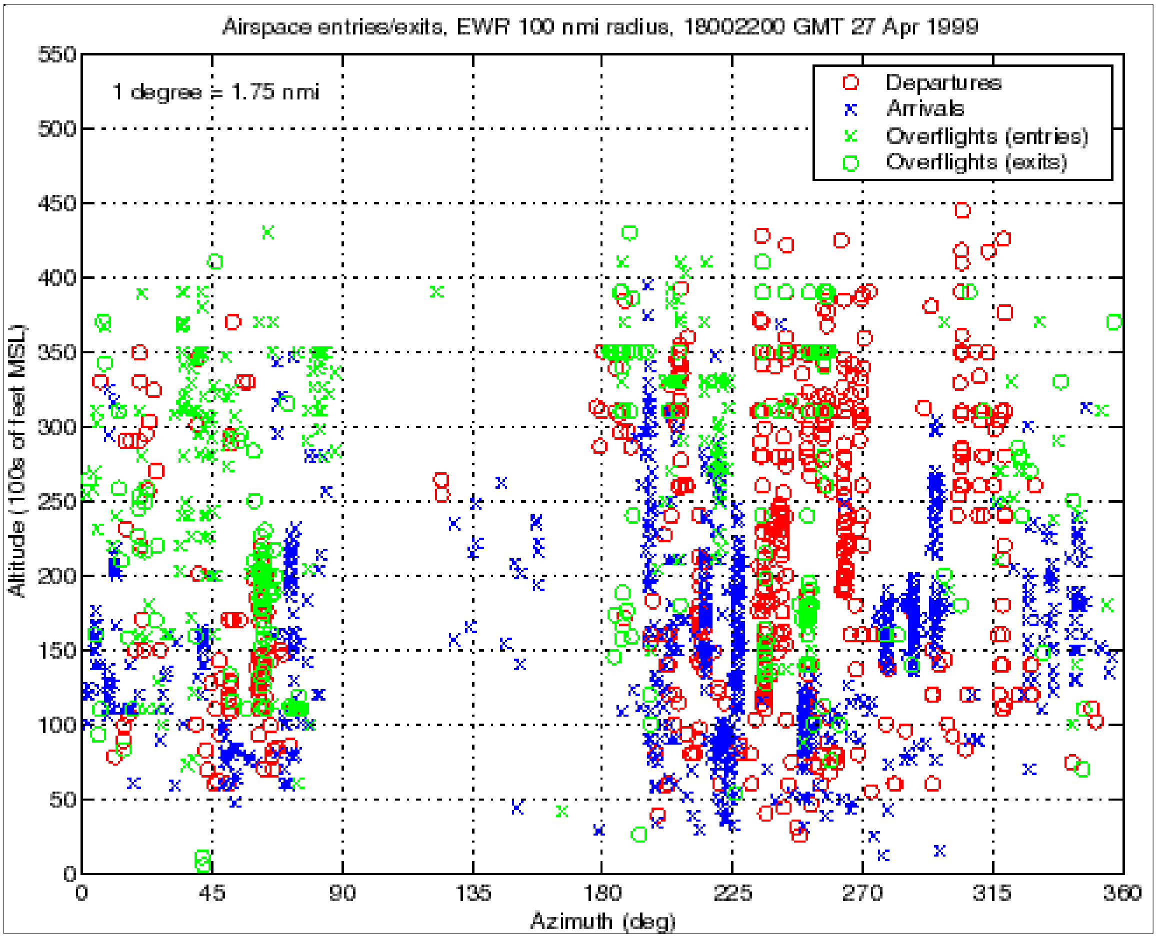

Figure 1. Entries and Exits of a 100 nmi Cylinder for a Busy 4-Hour Period at EWR

One salient feature of these flows is the virtually empty airspace quadrant from 90 to 180 degrees azimuth. This feature is due to the Atlantic offshore warning areas, which are closed to commercial air traffic except for a narrow corridor at 135 degrees (often used for flights to and from the Caribbean and South America). This airspace limitation, combined with the need to handle flows for several major airports at once, results in tight flow patterns with little lateral variation in path among flights. This lack of variation is clear for arrivals and is also visible in some of the departure flows. For example, between 180 and 225 degrees azimuth and below 25,000 feet, five arrival streams are visible.

The need for tight lateral and vertical spacing is evident when the arrival flows are broken out by airport (see Figure 2). The arrival flows between 180 and 225 degrees are divided among PHL (two streams), EWR, JFK, and LGA, and the only way to keep them safely separated is to restrict the lateral variability of the flows. Aircraft flying in the New York area therefore must keep strictly to their defined flight paths. This arrangement makes fix-load balancing difficult, since aircraft need to cross several flows to fly between arrival fixes. In fact, to switch between the western and southern arrival fixes to EWR, airlines need to replan flights hundreds of miles outside the EWR terminal airspace.

The proximity of these flows also leaves little room for holding near the airport. This means that when airport capacity is reduced because of weather, aircraft are often forced either to hold hundreds of miles from their destination or, for shorter flights, to hold on the ground.

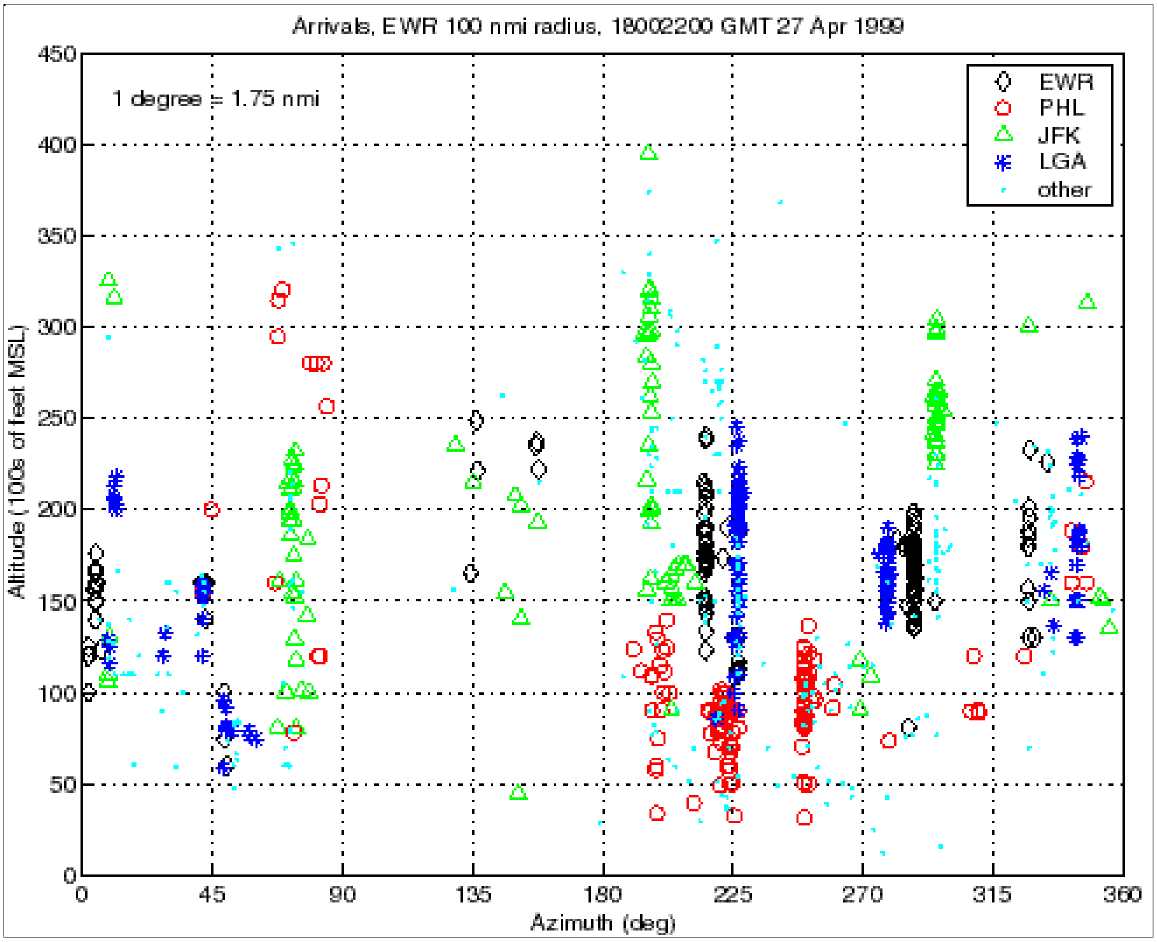

Figure 2. Same Conditions as in Figure 1, but with Only Arrivals, Marked by Destination

Departure and overflight flows are more laterally concentrated for EWR than for the other airports, following rigid routes through the New York transition airspace. This tightness of the overflight routes is not visible in any other airspace studied. This is because several of the "overflight" flows are actually arrival flows to other major airports outside of the New York airspace (BOS, PVD, BWI, DCA, and IAD). In comparison, the other airports studied do not overlap significantly with other major terminal areas and do not exhibit this traffic pattern.

The most significant impact of the complex flow patterns shown here is the severe limitation on lateral maneuverability for any flights passing through the New York transition airspace. While EWR may have the landing capacity to serve all the arriving flights, the inability to move flights from an overloaded arrival fix to a more lightly loaded fix results in holding. In turn, the limited holding capacity near the airport causes aircraft to begin holding farther and farther away from the TRACON, and it becomes difficult to restart the flow smoothly once the arrival fix load has been reduced to normal. As a corollary, ground delay programs and ground stops involving the New York airports are common, since closure of arrival or departure routes forced by convective weather results in insufficient free airspace with which to plan alternate flight paths.

Impacts on Airlines

Constrained Airspace and Weather

Delay is one of the major impacts on airlines of constrained NAS resources. There are several ways of accounting for delay. One characterization (Federal Aviation Administration, 1997) uses units of “flights delayed per thousands of operations.” A flight is declared delayed if its forward progress is impeded by 15 minutes or more in any one facility. Examining 1997 FAA data for the busiest 50 airports in the CONUS, the New York area is the worst of the top seven terminal areas in this category. There were 116 per 1000 New York area flights recorded as receiving delays, more than twice as many delayed flights as for the next worst area, San Francisco.

According to the FAA report, the above delay is caused mainly by weather. Weather has impacts on both airports and airspace. For New York, the transition airspace is so tightly allocated that weather tends to block flows altogether; departures must wait on the ground. At other facilities in the country with less tightly allocated airspace, some flexibility is possible; airspace may be resectorized either laterally or vertically so that arrival and departure flows are much less disrupted than in the New York area.

How much disruption occurs during an hour of en route weather? We compared New York area operations counts for one hour of our good weather day to an hour of a day with convective weather activity blocking departure flows over western Maryland, Pennsylvania, and West Virginia. On 23 April 1999, the bad-weather day, operations, especially departures, were greatly reduced as compared with 23 October 1998. (There were 123 departures during the 3pm local time hour on 23 October, compared to 56 departures during the same hour on 23 April.) This level of impact could be expected to affect airline operations for the remainder of the day because of the well-documented phenomenon of “propagation of effects” (DeArmon, 1993).

Airborne Holding

Another impact on airlines of constrained NAS resources is on the location of airborne holding. Airborne holding occurs on VFR as well as IFR days. Holding is a response to variations in demand at airports and/or fixes. These resources may be oversubscribed (i.e., demand exceeds capacity) even during VFR conditions. The situation may be due to ripple effects from events elsewhere in the NAS; it may also occur because airlines choose to schedule aircraft beyond an airport's capacity.

Holding is used to maximize utilization of capacity at an arrival airport by maintaining a queue of holding aircraft near the airport. The constant pressure of an arrival queue at the airport allows airlines to use arrival slots as soon as they become available. If there are no aircraft near the airport waiting to fill slots as soon as they open, arrival capacity is wasted.

The restrictive nature of the New York airspace can be seen in the location of airborne holding on VFR days for aircraft bound for the New York area. Figure 3 shows where all airborne holding occurred for aircraft bound to EWR, JFK, LGA, and PHL during the VFR days of April 1999. The location of airborne holding was determined by an analysis of the ETMS track data. As is evident in this figure, much of the airborne holding for EWR, LGA, and JFK arrivals takes place outside the New York Air Route Traffic Control Center (ARTCC) (ZNY). By contrast, at other high-demand airports, most airborne holding on VFR days is contained within the same ARTCC; an example is DFW (see Figure 4).

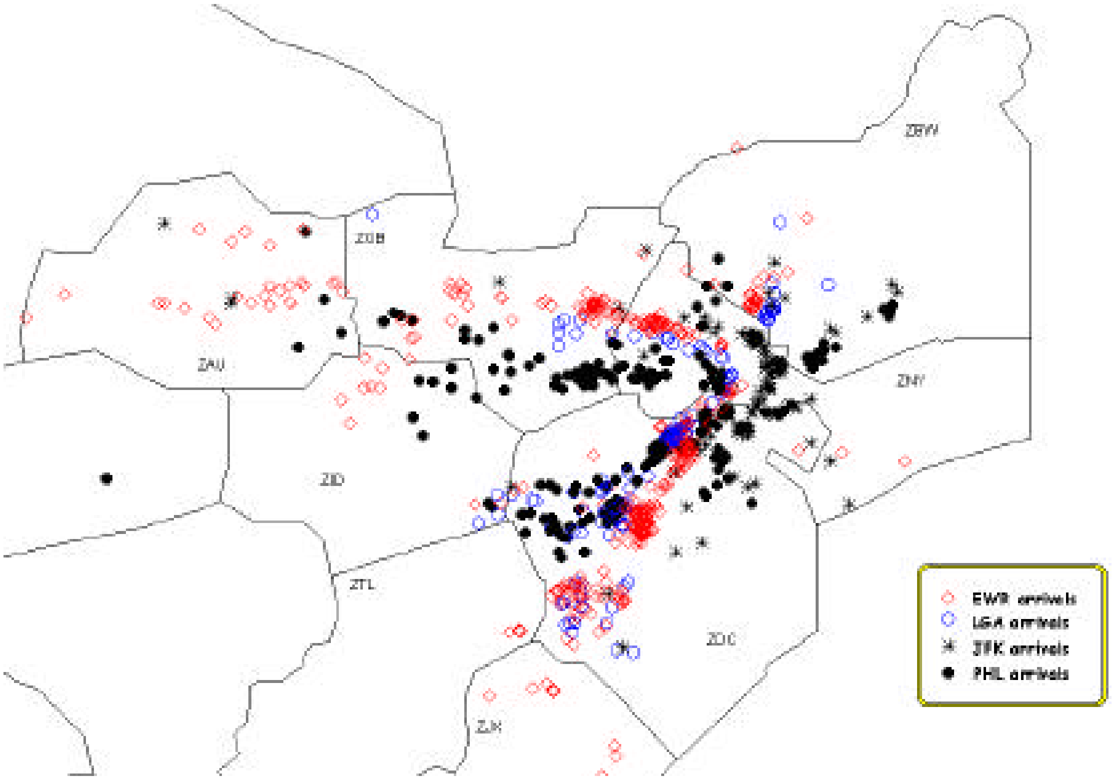

Figure 3. Holding Locations of Arrivals into EWR, LGA, JFK, and PHL During VFR Days, April 1999

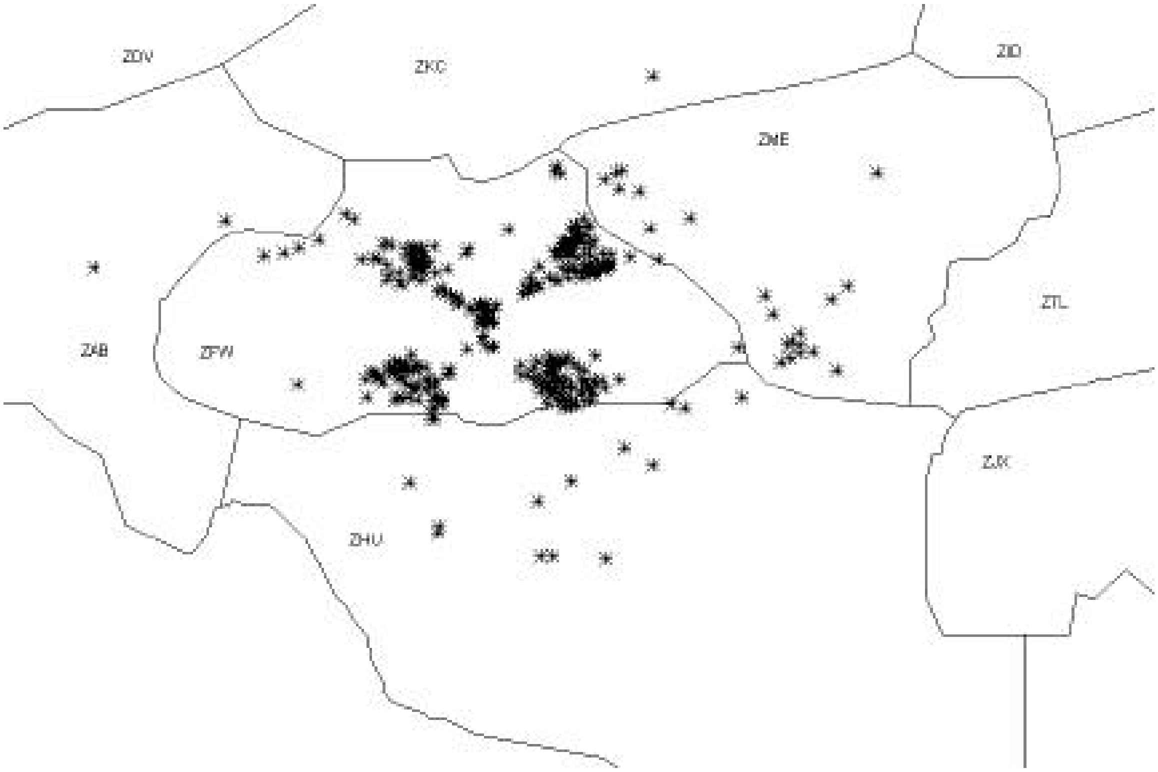

Figure 4. Holding Locations of Arrivals into DFW During VFR Days, April 1999

The lack of room for lateral maneuverability around the New York airports, as discussed earlier, means that arrivals to these airports experienced airborne holding far from the airport, whereas arrivals into DFW, where the surrounding transition airspace allows greater lateral maneuverability, may hold closer to the airport. Our studies show distinct clusters of airborne holding during the VFR days at ATL (approximately seven clusters) and DFW (approximately four clusters). Also, holding for New York-bound arrivals extends much farther out than is the case for other airport's arrivals. Most airborne holding happens well beyond 200 nmi for EWR (the median holding distance is 237 nmi). LGA's median holding distance is 167 nmi. The median holding distances for ATL and DFW are even smaller: 65 nmi and 112 nmi, respectively.

Under the current system constraints, air traffic bound for the New York area does not have the option of holding closer to the arrival airport, as do ATL and DFW traffic. When arriving aircraft can hold closer to the arrival airport, they do.

Because holding occurs farther from the destination airport in the New York area, it occurs in several different facilities. All of the first-tier ARTCCs of ZNY (Washington [ZDC], Cleveland [ZOB], and Boston [ZBW]) hold New York-bound aircraft. As a result, ZNY coordinates more with adjacent facilities, even during VFR conditions, than does, say, DFW. The workload of ZNY's first-tier ARTCCs, as well as some second-tier ARTCCs, is necessarily increased. In fact, over half of the airborne holding instances for traffic bound for EWR, LGA, and JFK occur in ZDC; only a little over a fifth of the total holding instances occur in ZNY on VFR days. By contrast, more than 85 percent of the holding instances for DFW-bound traffic occur within DFW's ARTCC (ZFW). This is due largely to the greater amount of lateral maneuverability available in DFW's transition airspace, allowing aircraft to hold closer to the airport. It is also due in part to the airport's central location within the ARTCC, and to the greater size of ZFW.

Impact of Failure to Grant User Preferences

We believe that because of the complex, congested airspace in the New York area, the FAA grants fewer airline user preferences, even though New York has an enormous demand for more flexibility. To illustrate the demand for free flight in New York, we compared the National Route Program (NRP) flights in six market areas: New York; Chicago; Dallas; Los Angeles; Washington, D.C.; and Atlanta. Beyond 200 nmi limits at either end of the flight, NRP flights no longer need fly only on published ATC preferred routes. Requests for NRP flights can therefore be considered as representing a desire for increased flexibility. We used ETMS v5.6 data for the weeks of May 18, 1997 and March 15, 1998 to determine the demand for NRP flights. For each market area, we compared the average daily NRP operations (arrivals to and departures from the market's airports) and the average daily total market traffic operations.

New York is clearly the leader in airport operations for all flights, with one-quarter of the traffic in the six markets. However, New York has a greater proportion of NRP flights (almost one-third of the total NRP flights within the six markets), a disproportional increase in demand for greater flexibility. Looking at all NRP flights throughout CONUS, the six areas examined accounted for about a third of all operations during that week. New York, with the heaviest NRP demand, accounts for almost a third of this total.

Despite its high demand for NRP flights, New York (as well as Chicago, Los Angeles, and Washington, D.C., the next top NRP areas) cannot take advantage of reductions in the NRP 200 nmi limits. The FAA (1998) has recognized the increasing need for more flexibility and has identified a set of departure procedures (DPs) and standard terminal arrival routes (STARs) that airlines can use in lieu of these limits. These DPs and STARs generally lie within the 200 nmi radius surrounding the airport. Of the six markets examined, only Dallas has both DPs and STARs; Atlanta has one STAR. The other markets, while having higher demand for flexibility, have neither a DP nor a STAR.

Those flights not using the NRP are required to fly along preferred routes if published. In this case also, the New York market is more constrained than the rest of the country. Although the FAA has been making an effort over the last two years to reduce the number of required preferred routes, the routes eliminated in 1998 were in the middle of the country and had no significant traffic. In 1999, routes have been eliminated on the West Coast as well as in the center of the country, but the only route near New York to be eliminated is that between Philadelphia and Los Angeles. Although flights to and from the New York area have a high demand for flexibility in route planning, they are constrained in the routes that can actually be chosen when filing flight plans.

We decided also to examine flight plan route amendments to see whether New York flights have any more flexibility in amending their intended routes. We chose to use the same day (October 23, 1998) for this analysis since, with good weather all across the country, it may be assumed that ATC did not initiate the route amendments that were issued. Rather, the amendments were most likely requested by the airline—either by the dispatcher prior to flight release or by the pilot once airborne.

We started with an analysis of the flight route amendments themselves. Using ETMS data received through the Aircraft Situation Display to Industry (ASDI), we compared the distribution of values for flights to the top 20 U.S. airports. We created a ratio comparing the total number of ETMS route amendment messages with the total number of ETMS arrival messages for each of the airports. These ratios are averages; they do not differentiate between flights with single numbers of messages and those with multiple numbers of messages, yet they do embody a clear interpretation of "route amendments per flight." For the top 20 U.S. airports, the mean proportion of flights per airport with amended routes was 66.6 percent; the median was 70.5 percent. We found the ratios for EWR, LGA, and nearby PHL were all below the mean, with ratios of 60 percent, 51 percent, and 32 percent respectively.

Our studies show the phenomenon of relatively low numbers of flight route amendments is not related to flight length or early filing. However, there was a correlation with the location of the destination airport, specifically, how far west the arrival airport is. Clearly, airlines flying to East Coast airports are granted fewer route change requests. Knowing this, airlines may be requesting fewer changes.

Summary

This paper has demonstrated that the New York area represents a unique situation in the NAS. A geographic concentration of runways creates an exceptionally high demand for transition airspace resources. FAA airspace planners and managers have responded by using fine-tuned sectorization to accommodate arrival and departure flows specific to the important airports EWR, JFK, LGA, and PHL. However, this very tight allocation of airspace has implications for day-to-day operations. Small changes in conditions result in major impacts on the airlines in such areas as airborne holding and ground stops for departure flights. The FAA vigorously pursues a free flight policy, accommodating users' substantial demand for services to the greatest degree possible. The New York area continues to be a challenge in this regard.

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Appendix: Airport Identifiers

ABE	Lehigh Valley International (PA)
ACY	Atlantic City International (NJ)
ADS	Addison (TX)
ATL	William B Hartsfield Atlanta International (GA)
AZO	Kalamazoo/Battle Creek International (MI)
BFL	Meadows Field (CA)
BHM	Birmingham International (AL)
BUR	Burbank Glendale Pasadena (CA)
BWI	Baltimore Washington International (MD)
CGX	Merrill C Meigs Field (IL)
CLE	Cleveland Hopkins International (OH)
CLT	Charlotte/Douglas International (NC)
CSG	Columbus Metropolitan (GA)
CVG	Cincinnati/Northern Kentucky Internationa (KY)
DAL	Dallas Love Field (TX)
DAY	James M Cox Dayton International (OH)
DCA	Ronald Reagan Washington National (DC)
DET	Detroit City (MI)
DFW	Dallas/Fort Worth International (TX)
DPA	Dupage (IL)
DTW	Detroit Metropolitan Wayne County (MI)
EWR	Newark International (NJ)
FNT	Bishop International (MI)
FTY	Fulton County Airport Brown Field (GA)
GRR	Kent County International (MI)
HPN	Westchester County (NY)
IAD	Washington Dulles International (VA)
ILN	Airborne Airpark (IL)
IND	Indianapolis International (IN)
ISP	Long Island MacArthur (NY)
JFK	John F Kennedy International (NY)
LAN	Capital City (MI)
LAX	Los Angeles International (CA)
LEX	Blue Grass (KY)
LGA	La Guardia (NY)
LUK	Cincinnati Municipal Airport Lunken Field (OH)
MBS	Tri City International (MI)
MDT	Harrisburg International (PA)
MDW	Chicago Midway (IL)
MKE	General Mitchell International (WI)
MLI	Quad City International (IL)
MMU	Morristown Municipal (NY)
MSN	Dane County Regional/Truax Field (WI)

OAK	Metropolitan Oakland International (CA)
ONT	Ontario International (CA)
ORD	Chicago O'Hare International (IL)
PDK	Dekalb Peachtree (GA)
PHL	Philadelphia International (PA)
PSP	Palm Springs Regional (CA)
PTK	Oakland County International (MI)
PVD	T. F. Green International (RI)
PWK	Palwaukee Municipal (IL)
RFD	Greater Rockford (IL)
SAN	San Diego International/Lindbergh Field (CA)
SBA	Santa Barbara Municipal (CA)
SBN	Michiana Regional Transportation Center (IN)
SDF	Louisville International/Standiford Field (KY)
SFO	San Francisco International (CA)
SJC	San Jose International (CA)
SNA	John Wayne Airport/Orange County (CA)
SWF	Stewart International (NY)
TEB	Teterboro (NJ)
TOL	Toledo Express (OH)
VNY	Van Nuys (CA)
YIP	Willow Run (MI)