

**RESPONSES TO AIRPORT DELAYS – A SYSTEM STUDY OF  
NEWARK INTERNATIONAL AIRPORT**

by

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B.Sc. Aeronautical Engineering  
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Submitted to the Department of Aeronautics and Astronautics and  
the Engineering Systems Division  
in Partial Fulfillment of the Requirements for the Degrees of

**MASTER OF SCIENCE IN AERONAUTICS AND ASTRONAUTICS**

and

**MASTER OF SCIENCE IN TECHNOLOGY AND POLICY**

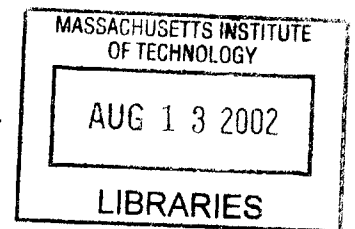
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**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

June 2002

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## **ABSTRACT**

Airport delays are a significant problem in the United States air transportation system. Between 1997 and 2000 the number of flights delayed increased by between 20 and 25% per year, despite only a 3 to 5% increase in enplanements per year. Newark International Airport (EWR), one of New York City's primary airports, is one of the airports in the United States most impacted by delays. Newark had the highest percentage of operations delayed in 1999, and was second only to LaGuardia Airport in 2000. Nearly 85% of delays at Newark are caused by adverse weather impacting the airport. Because of limited capacity and a very full schedule operated at the airport, when adverse weather impacts the airport departure operations are severely delayed. Despite this, unlike the national average, delays at Newark have not increased significantly since 1998. This indicates that the airlines, air traffic control (ATC), and the Port Authority of New York and New Jersey have successfully adapted.

On June 29, 2000, a research team from MIT visited Newark Airport to identify the key problems and assess the effectiveness of any adaptations made. Results of this study indicate that airspace capacity limitations downstream of the airport become a primary flow constraint at the airport, and that when these constraints occur they are the source of most surface delays.

Responses to the delays at Newark have been both tactical and strategic. Key tactical ATC responses examined include the application of restrictions; re-routing with the help of the National Playbook; the use of decision-aiding tools; improved inter-facility communication; and utilization of runway 11-29. Key strategic ATC responses examined include the formation of the Air Traffic Control System Command Center, and the New York airspace redesign. A number of tactical airline responses to delays were also examined, including cancellation of low priority flights and the transfer of the passengers to ground transportation; pre-sequencing of departures; and improved access to information. Key strategic responses examined include changes to the schedule operated at the airport, and particularly flattening out of the banks operated; a new fleet, which requires less maintenance and has greater dispatch reliability; and improved relations with the FAA and Port Authority of New York and New Jersey.

After examination of the problems at the 10 most delayed airports in the United States, the applicability of the key responses identified at Newark to these airports was also examined in detail. Those airports for which the most responses were identified to be applicable were Atlanta, San Francisco, Philadelphia and Dallas/Fort Worth. Those responses identified to be most applicable to other airports were the further extension of the National Playbook to other regions, the use of decision aiding tools, airspace redesign, pre-sequencing of departures, and a decrease in the number of operations at the airport. A policy analysis was completed for each of these responses.

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# ACKNOWLEDGEMENTS

I would like to thank my advisor Prof. John-Paul Clarke for his guidance and support throughout this project, and for his friendship and interest in my life. It has been a pleasure working with you and I could not have asked for a better advisor. I am truly glad that we met on the cricket field back in the summer of 1999. I would also like to thank the Departure Planner team and Global Airline Industries Program for their support and advice on the project. I would particularly like to thank Francis Carr for his assistance in developing the model of Newark Airport for use with the Sloan system studies, and Stephane Bratu for his help extracting ASQP data for me.

I would like to thank Barry Lawrence of the Port Authority of New York and New Jersey for the CATER data that proved to be so useful for my research; Tim Stull of Continental Airlines for organizing the trips to the Continental facilities at Newark Airport; Susan Baer for organizing the trip to the Port Authority of New York and New Jersey facilities at Newark Airport; and Leon Prusak of the FAA for organizing the trips to the Newark ATC Tower, and the New York TRACON and Center.

I would like to thank the MIT Global Airline Industries Program and MIT Sloan System Studies for funding my research, and the Sloan Foundation for funding these programs. I would also like to thank the University of the Witwatersrand and Chamber of Mines of South Africa for the overseas research scholarships that I received from them upon starting at MIT.

I would like to thank my friends at Park Street Church, the MIT Graduate Christian Fellowship, and in my Bible study, for their support and friendship during my stay in Boston. I truly appreciate your support and prayers regarding every aspect of my life. Thank you especially to Marcela, Yann, Megan, Thomas, Toni, Ken, and Michelle.

I would like to thank my office mates for their support and friendship during my stay at MIT. I will miss you all. Thank you Tom Gorin, Alex, Trin, Tom Reynolds, Hayley and Lixia.

I would also like to thank my parents for their support and advice in all things. You mean so much to me, and I have missed you so much. Thank you also to my twin brother Simon, without whom I could not have come through this experience. You have been the best friend I could possibly ever have, even when I was not that for you.

Finally, I would like to thank my Lord and Savior, Jesus Christ, for his work on the cross that allows me to stand before the Almighty God without fear of the judgment I deserve, and in so doing be able to be a vessel for His purposes on this earth. As J.S. Bach appended his compositions, **Soli Deo Gloria**. All Glory to God.



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# NOMENCLATURE

## ACRONYMS:

|        |   |
|--------|---|
| ABE    | Lehigh Valley International Airport, Allentown, Pennsylvania (Airport Code) |
| ACARS  | Aircraft Communication Addressing and Reporting System                      |
| APREQ  | APproval REQuest  |
| ARTCC  | Air Route Traffic Control Center  |
| ASQP   | Airline Service Quality Performance   |
| ATA    | Air Transport Association   |
| ATC    | Air Traffic Control   |
| ATCSCC | Air Traffic Control System Command Center                                   |
| ATCT   | Air Traffic Control Tower   |
| BWI    | Baltimore Washington International Airport (Airport Code)                   |
| CDM    | Collaborative Decision Making   |
| CLT    | Charlotte/Douglas International Airport (Airport Code)                      |
| CODAS  | Consolidated Operations and Delays Analysis System                          |
| CPR    | Continental Recovery Plan   |
| DCA    | Ronald Reagan Washington National Airport (Airport Code)                    |
| DFW    | Dallas/Fort Worth International Airport (Airport Code)                      |
| DOT    | Department Of Transport   |
| DSP    | Departure Spacing Program   |
| EA     | Environmental Assessment  |
| EDT    | Eastern Daylight Time   |
| EIS    | Environmental Impact Statement  |
| ETMS   | Enhanced Traffic Management System  |
| EWR    | Newark International Airport (Airport Code)                                 |
| FAA    | Federal Aviation Administration   |
| FDIO   | Flight Data Information Operation   |
| GDP    | Ground Delay Program  |
| GI     | General Information   |
| GMT    | Greenwich Mean Time (also called Zulu time)                                 |
| HVR    | Historically Validated Restriction  |
| IAD    | Washington Dulles International Airport (Airport Code)                      |
| IDS-4  | Information Display System-4  |
| IFR    | Instrument Flight Rules   |
| ITWS   | Integrated Terminal Weather System  |
| JFK    | John F Kennedy International Airport (Airport Code)                         |
| LAHSO  | Land and Hold Operations  |
| LGA    | LaGuardia Airport (Airport Code)  |
| McTMA  | Multi-Center Traffic Management Advisor                                     |
| MINIT  | MINutes In Trail  |

|        |   |
|--------|---|
| MIT    | Miles In Trail, or Massachusetts Institute of Technology (depending on context) |
| NAS    | National Airspace System  |
| NCDC   | National Climate Data Center  |
| NEPA   | National Environmental Policy Act   |
| NEXRAD | NEXt generation weather RADar   |
| NOAA   | National Oceanic and Atmospheric Administration                                 |
| NYDP   | New York Departure Pit Complex  |
| OAG    | Official Airline Guide  |
| O-D    | Origin-Destination  |
| OIS    | Operations Information System   |
| ORD    | Chicago O'Hare International Airport (Airport Code)                             |
| ORF    | Norfolk International Airport (Airport Code)                                    |
| PANYNJ | Port Authority of New York and New Jersey                                       |
| PHL    | Philadelphia International Airport (Airport Code)                               |
| SNA    | John Wayne-Orange Country Airport (Airport Code)                                |
| SNCF   | Société Nationale des Chemins de fer Français                                   |
| SWAP   | Severe Weather Avoidance Program  |
| TEB    | Teterboro Airport (Airport Code)  |
| TMA    | Traffic Management Advisor  |
| TMC    | Traffic Management Coordinator  |
| TRACON | Terminal Radar Approach CONtrol   |
| VFR    | Visual Flight Rules   |
| WSI    | Weather Services International Corp.  |

# CHAPTER 1: PROBLEM STATEMENT

## 1.1 INTRODUCTION

Because the demand for air travel continues to increase, whereas system capacity has become difficult to increase accordingly, airport delays have progressively become a significant problem in the U.S. air transportation system. Figure 1 shows the number of delays system wide from 1995 to 2000, alongside the number of domestic enplanements in the U.S. over the same period [1][2]. As the figure shows, enplanements have grown at a steady rate of between 3 and 5% each year since 1995, while the number of delays have increased at a rate of between 20 to 25% per year since 1997. The year 2000 shows a record high of 450,289 delays, and although enplanements and delays are likely to be lower in 2002 because of the consequences of the terrorist attacks of September 11, 2001, enplanements, and thus delays, are expected to return to previous levels quickly, leading to continued increases in delays.

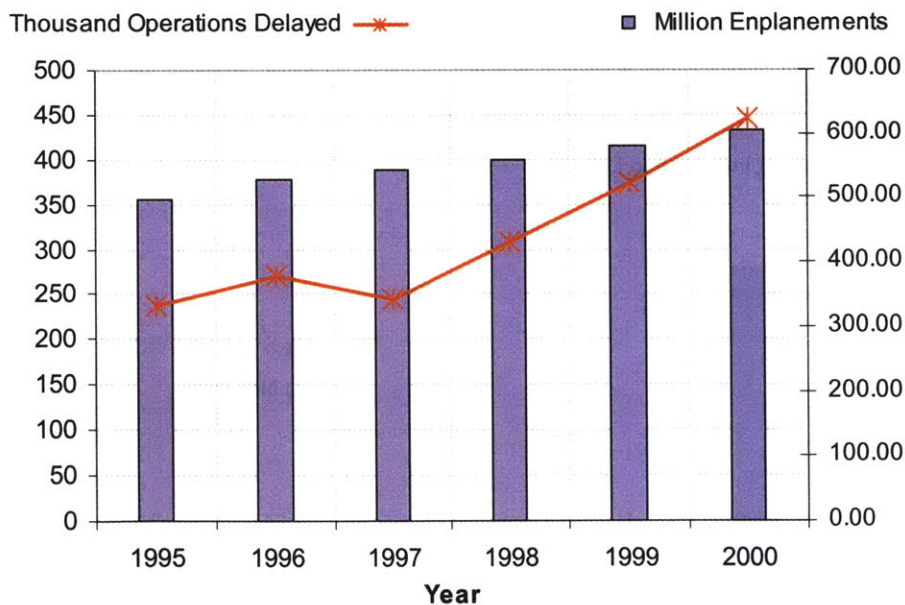


Figure 1. US domestic enplanements and number of delays system wide [1][2].

One of the most delayed airports in the United States is Newark International Airport (airport code EWR). Newark is one of the three primary airports in the New York Metropolitan area, the others being John F Kennedy International Airport (JFK) and LaGuardia Airport (LGA). In 1999 Newark had the highest percentage of delayed operations of all airports in the United States, at 7.9% [3]. In 2000 this

percentage increased to 8.1% of operations, putting it second only to LaGuardia in percentage of delayed operations [3]. The delays at LaGuardia were a result of the lifting of regulations at the airport according to the Air 21 legislation [4].

According to the Air Transportation Association, Newark airport also had the highest average air traffic control (ATC) departure delays of any airport in the country in both 1999 and 2000. In 1999 Newark operated with an average ATC departure delay of 19.5 minutes, followed by Washington Dulles (IAD) at 16 minutes. In 2000 Newark operated at an average ATC departure delay of 18.5 minutes, followed by LaGuardia at just over 15 minutes [5][6]. These numbers suggest that in comparison to other airports, ATC delays are a major contributor to delays at Newark airport.

The annual percentage increase in delays at Newark, since 1995, is presented in Figure 2, alongside that for NAS. The data was calculated from the Newark and system wide delay history [2]. It is clear that since 1997 delays have increased at a slower rate at Newark than system wide, compared to 1996 when the increase in delays was significantly higher than system wide. From 1999 to 2000 the increase in delays was only 1.6%, compared to the 19% increase system wide [2]. It thus appears that the Federal Aviation Administration (FAA), airlines and Port Authority of New York and New Jersey (PANYNJ) have been able to adapt their operations at Newark to reduce delays. This study thus examines the operations at Newark, and the responses to delays by ATC and the airlines, to identify the responses that were most effective in reducing delays.

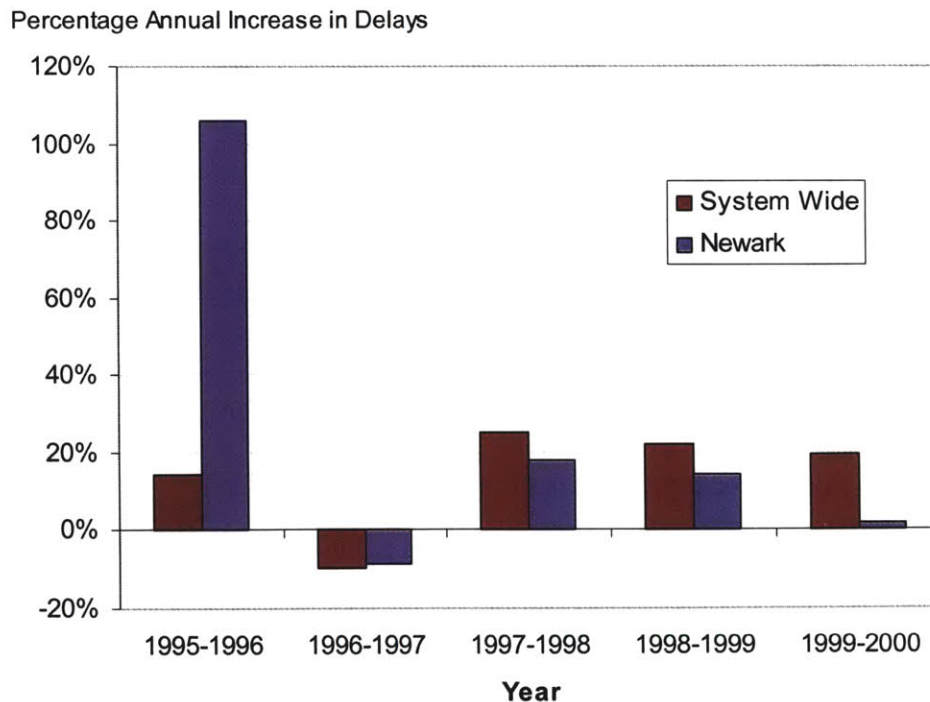


Figure 2. Percentage annual increase in delays at Newark airport, and system wide.

## 1.2 CAUSE OF DELAYS

Figure 3 shows the average distribution of reported arrival delays according to where the delay was accumulated, as recorded by the Air Transportation Association (ATA) member delay reporting program, from January to September 1999 [5]. The figure shows that the majority of delays are accumulated during taxi out (53%). This is because ground holding is used extensively in the United States, in which aircraft are delayed at their origin if the predicted demand at their destination is expected to exceed the predicted capacity. Thus the majority of the control of flights is performed before departure, and consequently the majority of the inefficiencies, and thus delays, manifest in departure operations.

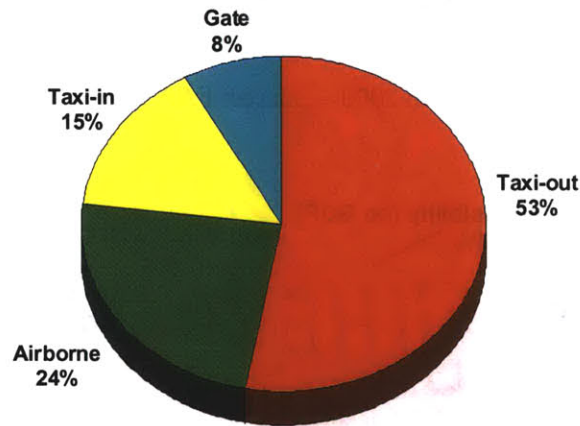


Figure 3. Distribution of delay time, ATA member delay reporting program, January- September 1999.

Figure 4 shows a pie chart of the breakdown of the causes of ATC delay in the National Airspace System (NAS), as identified by the FAA [6]. According to the chart 68.7% of ATC delays in the NAS were caused by weather in 2000. Weather has also been identified as a primary cause of delays at Newark airport. Figure 5 shows the breakdown of causes of delays at Newark, according to Allan, Gaddy and Evans, at Lincoln Laboratories [7]. This chart shows that a total of 84% of arrival delays at Newark are related to weather (68% to local weather, and 16% to weather elsewhere). Weather generally has a greater impact on departure operations than arrival operations, because of the use of ground holding in the United States. Local weather also affects departures to as great an extent as it affects arrivals. It may thus be inferred that weather is also the primary cause of departure delays at Newark.



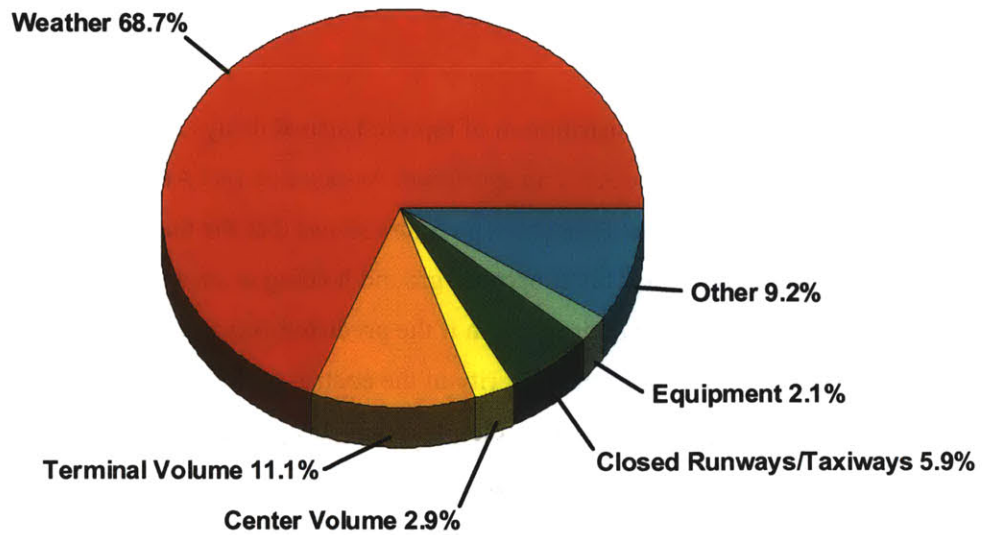


Figure 4. National causes of ATC delays in 2000 – Source: FAA [6].

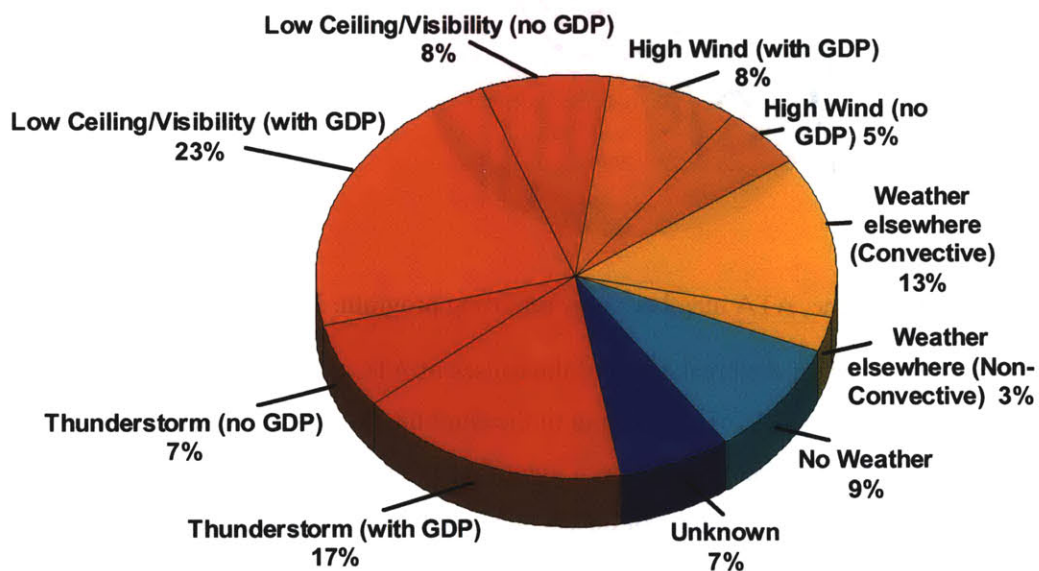


Figure 5. Cumulative delay impact at Newark (Sept. 1998 – Aug 1999) [7].

The chart in Figure 6 shows the number of delays at Newark and the total annual precipitation, from 1995 to 2000. The data for total annual precipitation at Newark airport was collected from the National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC) [8]. As the figure shows, the total precipitation at Newark is fairly consistent from 1995 to 2000 except for 1996 when precipitation was greater. The number of delays was also clearly greater in 1996, breaking away from the trend of the rest of the data, suggesting further that weather has a particularly significant impact on delays at the airport. The increase in delays after 1997 however appears to be driven by other factors than weather alone.



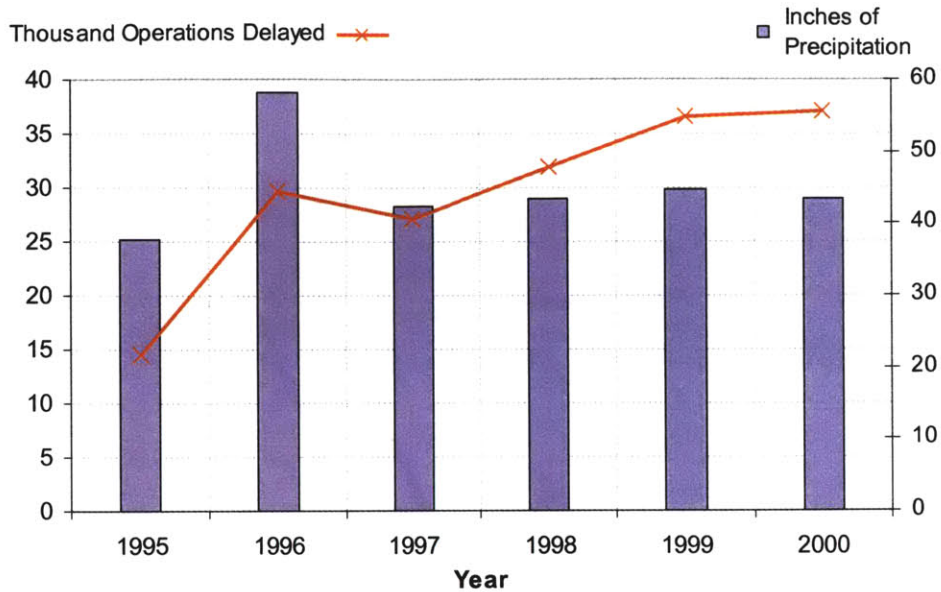


Figure 6. Number of yearly delays and inches of precipitation – Newark [2][8].

### 1.2.1 Cause of Weather Delays at Newark

Weather delays are caused by sensitivity of an airport to adverse weather, the frequency of adverse weather at the airport, the schedule operated by the airlines relative to the capacity of the airport, and airspace congestion in the terminal area.

The average reduction in airport capacity caused by adverse weather can be determined by comparing VFR (Visual Flight Rules) and IFR (Instrument Flight Rules) airport capacities. According to the FAA Airport Capacity Benchmark report [9], the reduction in capacity at Newark due to adverse weather is 24% of the average VFR capacity. This is only slightly higher than the average of the 31 busiest airports in the United States (21.43% of average VFR capacity). This sensitivity to adverse weather is related primarily to runway and gate limitations. Newark’s parallel runways are only 950 feet apart and thus too close together for independent IFR parallel approaches, and runway 11-29 is too short for many jet operations and thus has limited usage. The airport also has high gate utilization, forcing flights to pushback despite high departure delays, instead of holding at the gates. An airport diagram is shown in Figure 7.

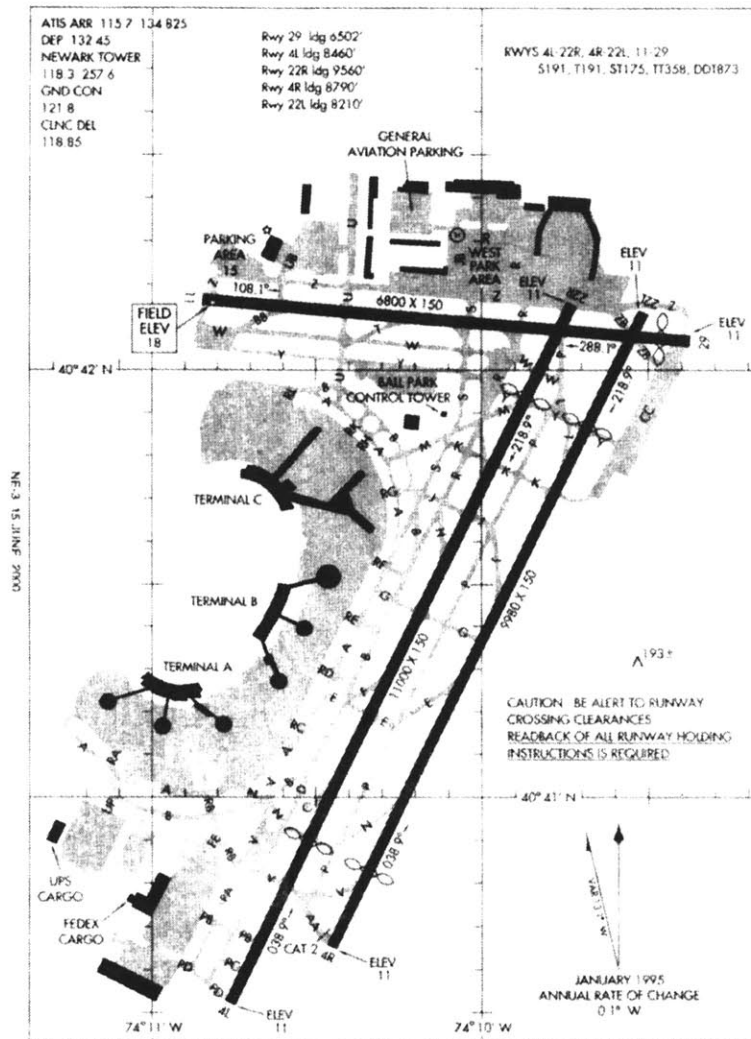
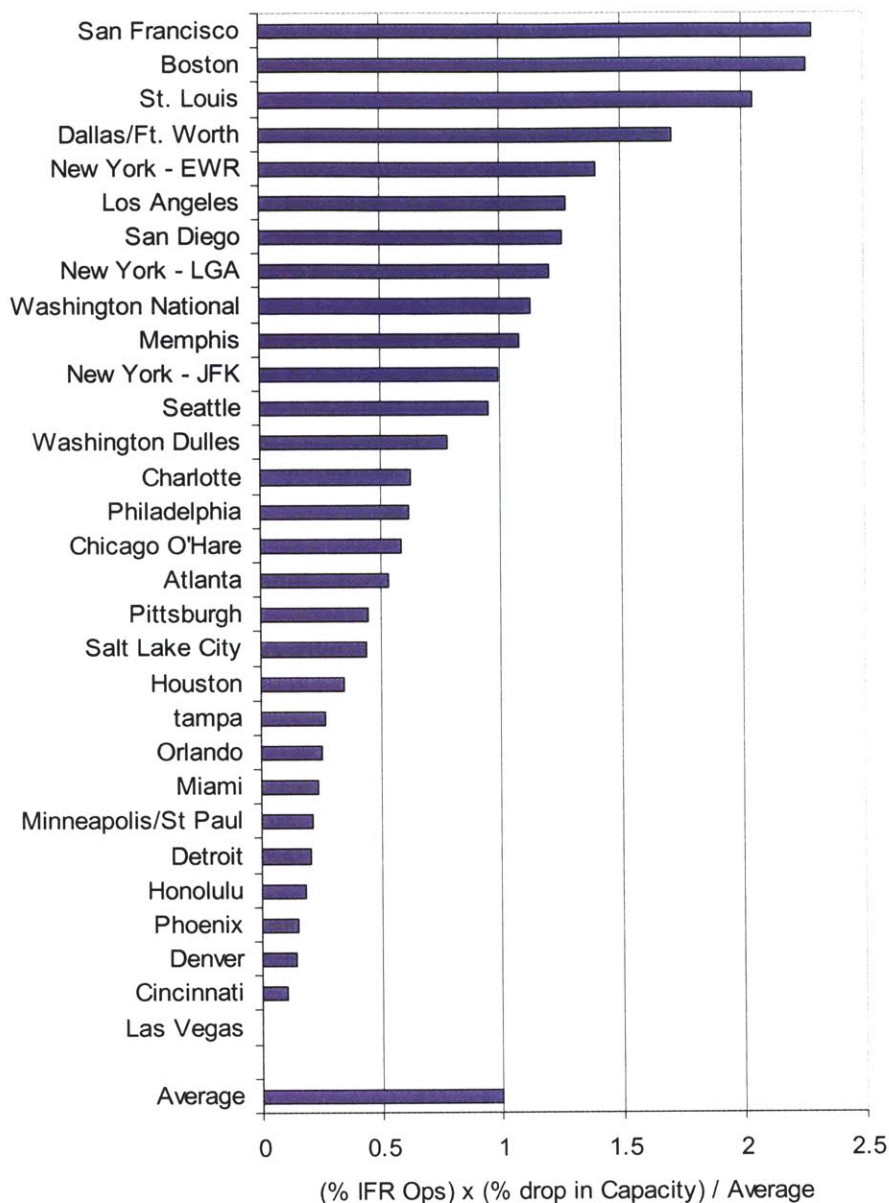


Figure 7. Airport diagram, Newark Intl (EWR), Newark, NJ [10].

The frequency of adverse weather can be determined by examining the percentage of IFR operations at Newark relative to other airports. According to the Airline Service Quality Performance (ASQP) data in June 2000, 20.5% of operations at Newark were IFR, which is again slightly higher than the average for the 31 busiest airports in the United States (16.3%).

The impact of adverse weather on the airport can be estimated by multiplying the percentage drop in capacity caused by adverse weather and the percentage IFR operations. Normalizing relative to the average for the 31 busiest airports in the United States Newark is 1.4 times as impacted by adverse weather as the average. This is significant as, according to this measure, the only other airports more severely impacted by weather are Dallas/Fort Worth (1.71), St. Louis (2.05), Boston (2.26) and San Francisco (2.29). Figure 8 shows the weather impact metric for the 31 busiest airports in the United States.



**Figure 8.** Impact of weather on the airport – product of percentage capacity drop and percentage frequency of weather on airports, normalized relative to the average, June 2000.

The impact of the weather delays on an airline’s schedule is also related to the schedule operated relative to the normal airport capacity and the bad weather capacity. The chart in Figure 9 shows the schedule at Newark in June 2001. It is clear that the airport is actually scheduled beyond even the normal VFR capacity in some cases and well beyond bad weather IFR capacity in most instances. At normal capacity however there are enough recovery periods to meet the schedule with relatively few delays. With the decrease in capacity caused by bad weather, however, it is clear that the schedule is more severely impacted, and that the recovery periods are far fewer, far smaller, and far shorter. Consequently delays are likely to propagate throughout the day.

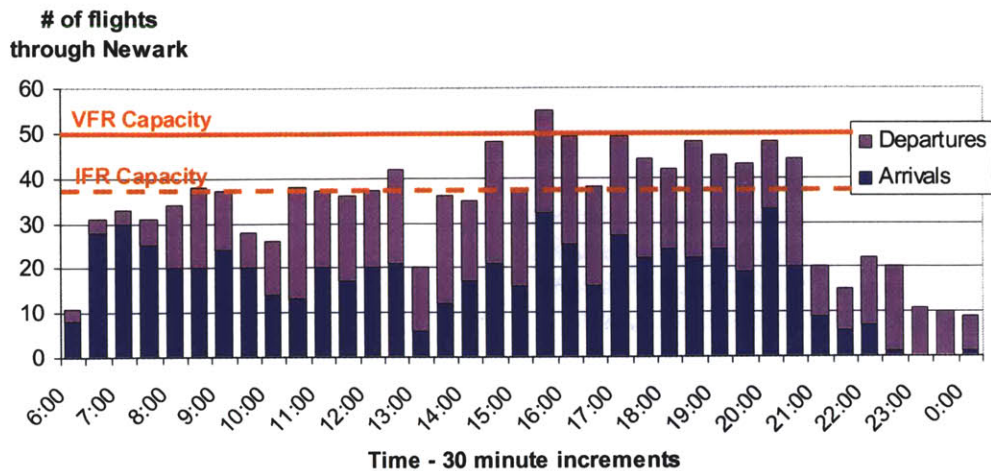


Figure 9. Average daily arrivals and departures per 30 minute interval - June 2001.

Airspace Congestion also contributes to delays at Newark airport. At most airports airspace congestion is related directly to the schedule operated at the airport, but at Newark, because it is one of four significant airports in the area (Newark, JFK, LaGuardia and Teterboro), this is not the case. Because of their close proximity to one another the arrival and departure paths to and from the airports overlap, meaning that operations must be coordinated and problems at any single airport impact operations at the other three airports as well. The airspace is designed accordingly with Newark operations particularly restricted to the east of the airport, to accommodate LaGuardia and JFK arrival and departure routes. The FAA has also identified New York airspace congestion as a primary concern as the two top chokepoints identified within the NAS [11] are the west and north departures from the New York Metroplex. These apply particularly to the west and north departures from Newark and LaGuardia.

## 1.3 SYSTEM OPERATION

### 1.3.1 Air Traffic Control Operations

The basic role of the ATC system in the United States is to prevent collisions between aircraft that fly in the system, and to organize and expedite the safe and orderly flow of air traffic whilst utilizing the airspace as efficiently as possible [12]. In the airspace around major airports, such as Newark, these goals are achieved through the use of the departure fixes, restrictions and re-routes.

#### Departure Fixes

A simplified map of the New York airspace layout is shown in Figure 10, showing the primary fixes used for departures from Newark. The primary departure fixes are identified below along with lists of destinations for which the fixes are commonly used.

- GAYEL and COATE, associated with jet-routes J95 and J36, are generally used for northwest bound traffic, such as that to Minneapolis/St. Paul (MSP), Seattle (SEA), and San Francisco (SFO) through GAYEL, and Chicago O'Hare (ORD) through COATE.
- ELIOT (associated with J60 and J80), PARKE (associated with J6), LANNA (associated with J48) and BIGGY (associated with J75) are generally used for traffic to the west, the southwest, and the south. ELIOT is generally used for traffic to the Midwest and the west coast, including Cleveland (CLE), Kansas City (MCI), Denver (DEN), Los Angeles (LAX), and Honolulu (HNL). PARKE is generally used for traffic to the southwest, Texas, and the South, including San Diego (SAN), Dallas/Fort Worth (DFW), Nashville (BNA), and Washington Dulles (IAD). LANNA is generally used for traffic to Texas, and the Deep South, including Houston (IAH), New Orleans (MSY), and Atlanta (ATL). BIGGY is generally used for traffic to the South, including Washington National (DCA), Baltimore (BWI), Charlotte (CLT), and Tampa (TPA).
- WHITE, associated with J209, is generally used for traffic to the South, to Florida, and to Central and South America, including Norfolk (ORF), Orlando (ORL), Fort Lauderdale (FLL), Miami (MIA), and Caracas Venezuela (CCS).
- GREKI and MERIT are generally used for traffic to the north, and to Europe, including Montreal (YUL) and Burlington, VT (BTV) through GREKI and Boston (BOS) and all of Europe through MERIT.



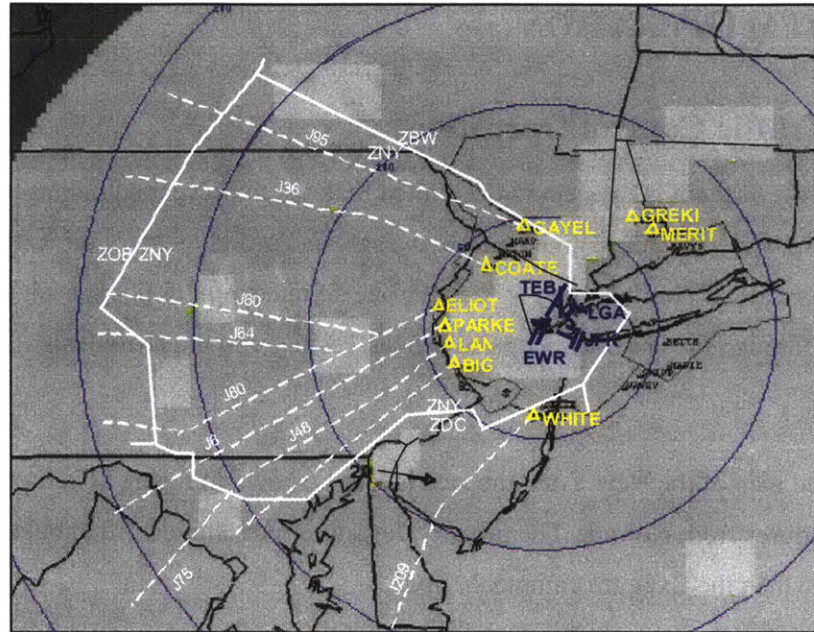


Figure 10. Primary departure fixes for Newark International Airport.

### Restrictions

Restrictions are applied to fixes and jet-routes in order to regulate traffic flow within the system. A number of types of restrictions exist. The most commonly used are as follows:

- Miles in Trail (MIT) and Minutes in Trail (MINIT) – Specific separation between aircraft in miles and minutes respectively.
- Approval Request (APREQ) – Aircraft must request approval to push back from gate. Approvals given on a case-by-case basis. Normally used for aircraft flying to airports with active delay programs.
- Fix closures – Complete closure of a fix, i.e. no traffic allowed through the fix. Effectively an extreme form of MIT/MINIT.
- Ground Delay programs (GDPs) at destination/arrival airports – Implemented to control air traffic volume to airports where the projected traffic demand is expected to exceed the airport's acceptance rate for a lengthy period. Normally initiated when the airport's acceptance rate is reduced, e.g. due to adverse weather. [13]

Small separation adjustments, such as the stretching of the minimum 3 MIT separation inside TRACON (Terminal Radar Approach CONTROL) airspace to the minimum 5 MIT en-route separation, can be accomplished in the TRACON airspace by vectoring the aircraft. Such vectoring does however

involve high controller workload, and thus when large separations adjustments are required, such as in most specified MIT or MINIT restrictions, the restrictions must be imposed at the runway.

Because a GDP restricts flow into the airport, it increases arrival delays, which are those statistics reported to the Department of Transport (DOT). Consequently airlines prefer to avoid GDPs at their hub airports. According to Continental management at Newark GDPs are, however, essential for efficient operation at Newark airport. When poor weather impacts the airport, restrictions are applied to departures regardless of whether a GDP is implemented. With no GDP, departures are delayed whilst arrivals continue to land according to schedule. There is thus normal flow into the airport but limited flow out of it, leading to surface congestion. The demand for gates means that flights must be pushed back to hold on the taxiways instead of at the gate. However, parking space is also limited, and taxiways quickly become congested. If a GDP is implemented, however, arrivals are also delayed, effectively delaying the whole schedule. Although the statistics are poor this avoids the surface congestion problems and allows for efficient airport operation, which reduces departure delays. GDPs, although not popular with the airline headquarters, are thus important for effective operation at Newark airport.

### Re-routes

It is clear that if a specific route has severe restrictions, or is closed, re-routing of flights is preferred. However, dynamic re-routing is difficult. This is because all facilities affected by the re-route must agree to the re-route a priori. This often involves a high number of facilities, requiring extensive inter-facility communication and cooperation. This takes time, and re-routes are thus often only approved after the weather has moved, and the re-route is no longer useful.

A set of preplanned re-routes for specific fix and jet-route closures was thus developed for the NAS, although currently focuses on the New York airspace. This is known as the National Playbook and was developed by the Severe Weather Group at the Air Traffic Control System Command Center (ATCSCC). The National Playbook was developed to give the ATCSCC, field facilities, and system users a common product for identification of re-route opportunities. The playbook contains the most common scenarios that occur each severe weather season. Each "play" includes the resource or flow impacted, facilities included, and specific routes for each facility involved. The playbook is available on the ATCSCC web site and is updated every 56 days [14]. The National Playbook does however have limitations, as it does not cover all possible fix and jet-route closure combinations. The plays must also often be used in conjunction with other strategies, as they are not adequate to solve the problem alone.

### **1.3.2 Airline Operations**

Newark airport has three terminals, Terminal A, B and C. Terminal A, which has 25 gates, is used for operations for most domestic airlines, including some Continental operations (6 gates). Most Continental flights operate from Terminal C, which has 42 gates, all of which are operated by Continental. Terminal B, which has 23 gates, is operated by the PANYNJ for international arrivals.

Continental operates a hub at the airport, and including Continental Express, operates approximately 55% of operations at Newark, making it the dominant airline. Continental operates an operations center and ramp tower, and since it operates all the gates at Terminal C, has been given control of the taxiways surrounding Terminal C. During adverse weather Continental is also given control of an extended ramp area according to a letter of agreement with the FAA. This includes a number of taxiways near runway 11-29, and sometimes, if it is not being used and congestion is high, runway 11-29 as well. According to the letter of agreement with the FAA during the extended ramp operations all other airlines on these taxiways take preference over Continental aircraft. A number of parking areas also exist. Using these and the Continental controlled taxiways Continental is able to perform pre-sequencing of its aircraft before they are transitioned to FAA control. The aircraft are pre-sequenced according to their departure fixes and because the FAA operates on a first come first serve basis, this allows Continental to reduce its departure delays.

Load planning and dispatch are performed at Continental headquarters in Houston. Other operations, such as gate management, maintenance, catering, and baggage handling are managed locally. Most of these functions are controlled or performed from within the Continental operations center.

### **1.3.3 System Dynamics in Adverse Weather – Site Visit, June 29, 2000**

In order to identify the causes of delays at Newark, a detailed study was performed of the weather, air traffic control and airline performance during a period when operations at Newark were severely restricted i.e. June 29, 2000. This day was severely impacted by summer thunderstorms, and in the middle of the summer, when demand for air travel was high. This day was also the Thursday before the “Fourth or July” weekend, so traffic through the airport was high in preparation for the long weekend. The site visit also coincided with the “worst summer ever” i.e. the worst summer of airport delays in history. A team from MIT observed operations and collected data at the New York TRACON, the Newark ATCT (Air Traffic Control Tower), and the Continental ramp tower at Newark.



## Weather and Restrictions

The national weather map in Figure 11 shows the national weather at 9:30:00 EDT (13:30:00 Zulu (GMT)). The key features that affected Newark were the front extending from the coast off Maine down to Mississippi, and the front over Lake Eerie. The front from Maine to Mississippi moved east and impacted Newark throughout the day, affecting primarily south and west departures. The front over Lake Eerie also moved east and impacted the airport through the afternoon and evening, affecting primarily northeast and west departures.

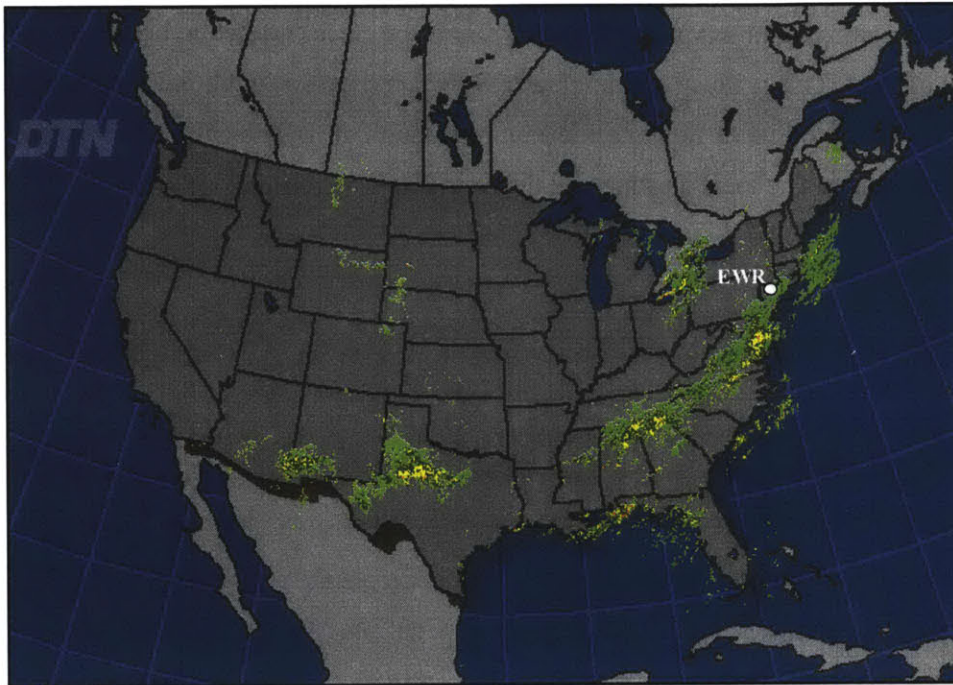


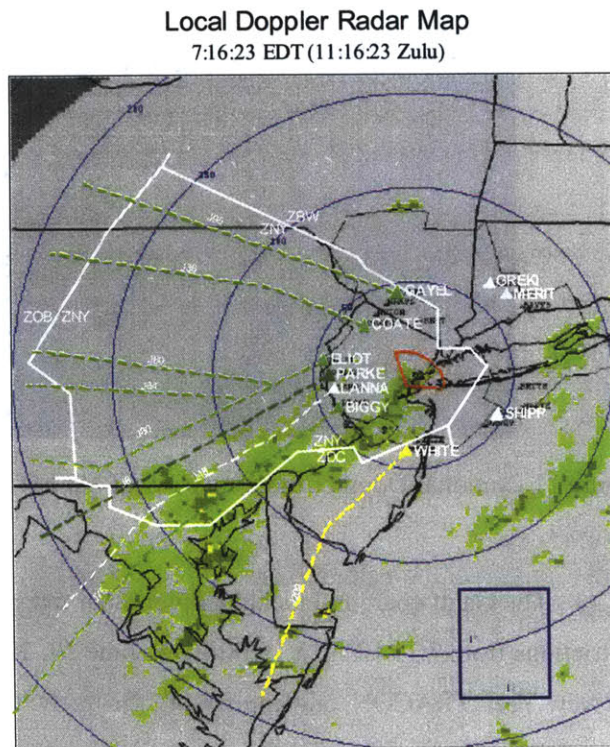
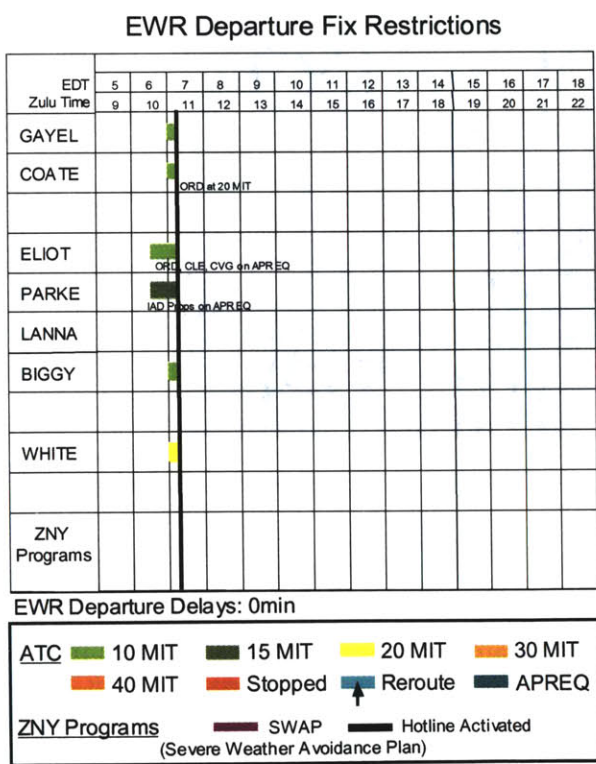
Figure 11. National Doppler radar map – 9:30:00 EDT (13:30:00 Zulu), Source: *Data Transmission Network*.

The Gantt chart and local Doppler radar maps in Figure 12 to Figure 18 show the departure restrictions from 7:15 EDT to 19:00 EDT, June 29, 2000. These are according to the logs collected from the New York TRACON, and apply to all the traffic through the specified fixes, not only the traffic from Newark. Superimposed on the Doppler radar maps are maps of New York ARTCC (Air Route Traffic Control Center), with the primary departure fixes and their associated jet-routes. The colors of the fixes and jet-routes correspond to the legend below the Gantt chart, as do the colors on the Gantt chart.

The initial restrictions applied are Historically Validated Restrictions (HVRs), which are based on historical data regarding aircraft volume and not the weather forecast. By 10:00 EDT the HVRs were lifted, except for that on BIGGY, which was closed briefly and then restricted to 40 MIT, because of

downstream weather. By 13:00 EDT the front from the northwest had begun to impact northwest departures, and 10 MIT restrictions were correspondingly applied to GAYEL and COATE. Because of downstream weather BIGGY and LANNA were restricted to 40 MIT and WHITE was closed. By this time the front to the south of the airport was moving off the coast of New Jersey. By 14:30 EDT, ELIOT was also restricted, to 20 MIT, because of the local weather from the northwest. At 16:00 EDT the local weather was impacting all north and west departure fixes, and COATE, all west fixes, and WHITE were all closed. All the west fixes were opened by 16:50 EDT, before being closed again by 18:15. BIGGY was then opened, and much of the westbound traffic re-routed through it.

The most significant observation from the study is the close correlation between the weather and the restrictions applied. This is illustrated in Figure 19, which shows a simplified representation of the restrictions in Figure 12 to Figure 18 alongside a representation of when local weather impacted the corresponding jet-routes. The local weather and the restrictions correlate closely.



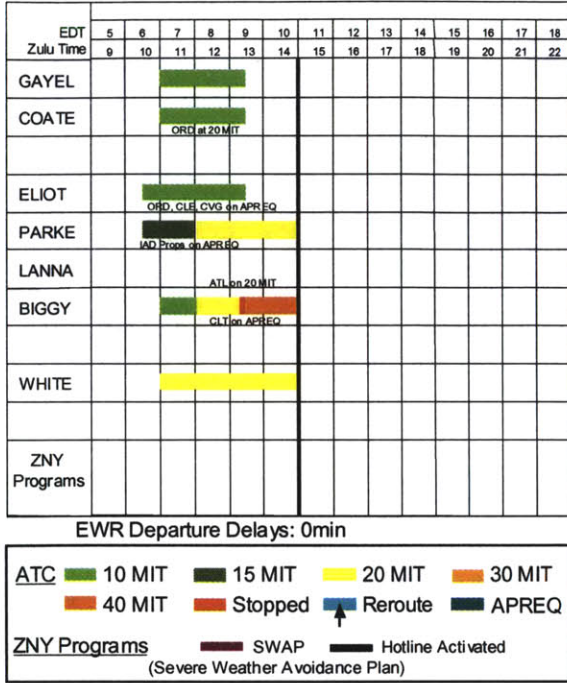
Source: Lincoln Laboratories ITWS

North-east fixes unrestricted throughout day

Figure 12. Restrictions and local Doppler radar map – 7:15 EDT (11:15 Zulu).

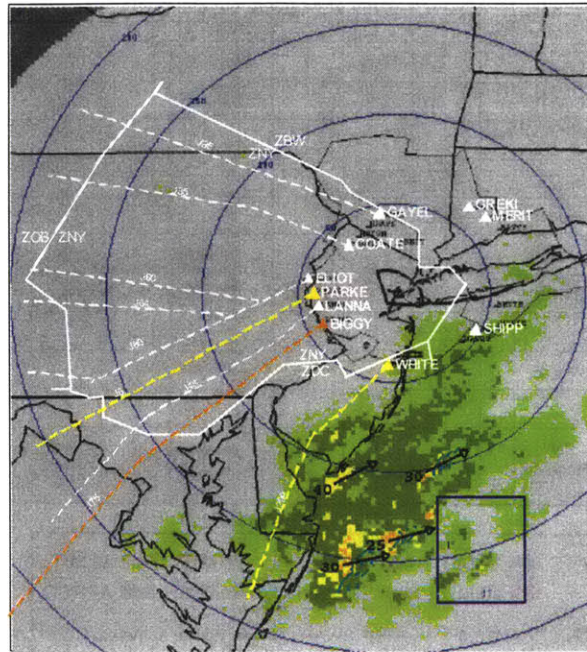


EWR Departure Fix Restrictions



North-east fixes unrestricted throughout day

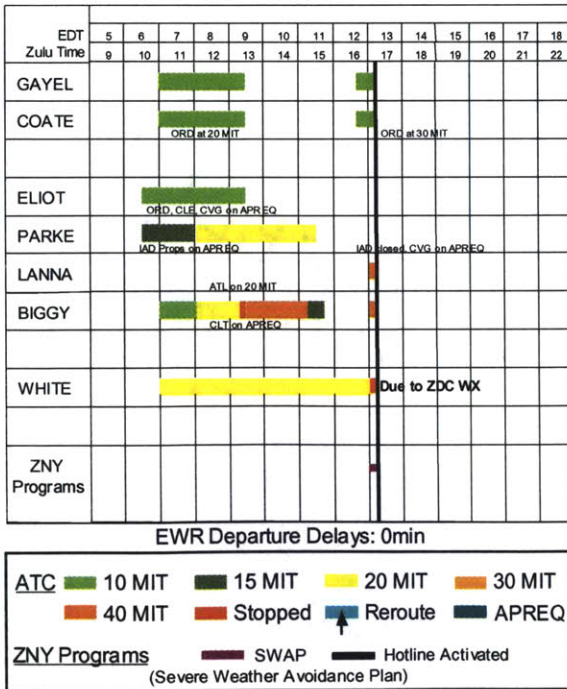
Local Doppler Radar Map  
10:58:34 EDT (14:58:34 Zulu)



Source: Lincoln Laboratories ITWS

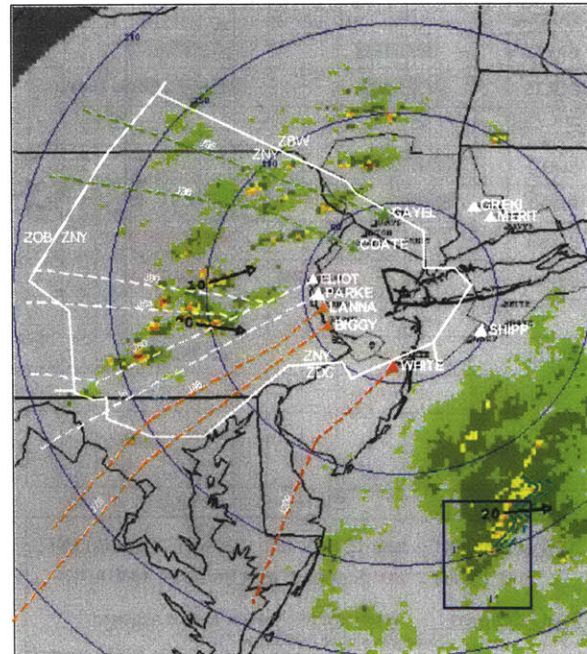
Figure 13. Restrictions and local Doppler radar map – 11:00 EDT (15:00 Zulu).

EWR Departure Fix Restrictions



North-east fixes unrestricted throughout day

Local Doppler Radar Map  
12:58:45 EDT (16:58:45 Zulu)



Source: Lincoln Laboratories ITWS

Figure 14. Restrictions and local Doppler radar map – 13:00 EDT (17:00 Zulu).



### EWR Departure Fix Restrictions

| EDT Zulu Time | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---------------|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| GAYEL         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| COATE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| ELIOT         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| PARKE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| LANNA         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| BIGGY         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| WHITE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| ZNY Programs  |   |   |   |   |   |    |    |    |    |    |    |    |    |    |

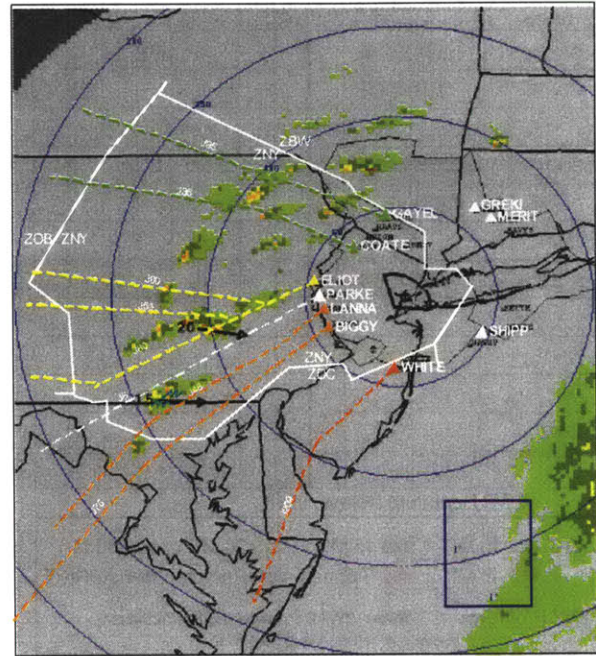
EWR Departure Delays: 15min

|              |        |                   |                                 |        |
|--------------|--------|-------------------|---------------------------------|--------|
| ATC          | 10 MIT | 15 MIT            | 20 MIT                          | 30 MIT |
|              | 40 MIT | Stopped           | Reroute                         | APREQ  |
| ZNY Programs | SWAP   | Hotline Activated | (Severe Weather Avoidance Plan) |        |

North-east fixes unrestricted throughout day

### Local Doppler Radar Map

14:58:36 EDT (18:58:36 Zulu)



Source: Lincoln Laboratories ITWS

Figure 15. Restrictions and local Doppler radar map – 15:00 EDT (19:00 Zulu).

### EWR Departure Fix Restrictions

| EDT Zulu Time | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---------------|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| GAYEL         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| COATE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| ELIOT         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| PARKE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| LANNA         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| BIGGY         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| WHITE         |   |   |   |   |   |    |    |    |    |    |    |    |    |    |
| ZNY Programs  |   |   |   |   |   |    |    |    |    |    |    |    |    |    |

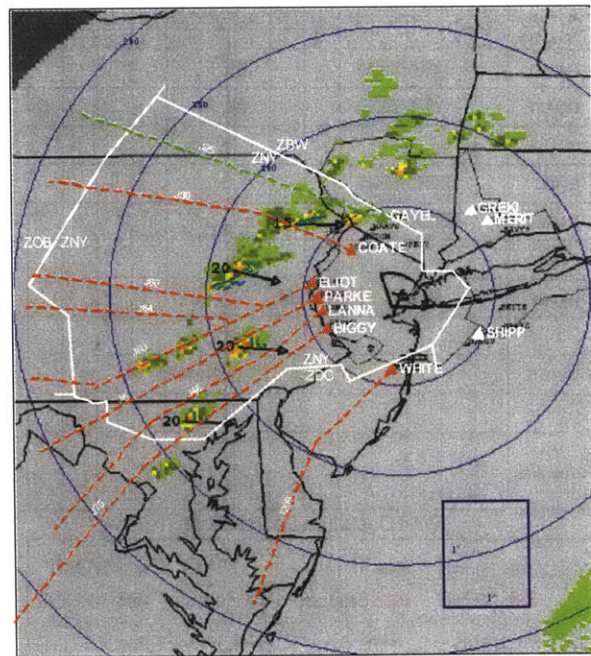
EWR Departure Delays: 45min

|              |        |                   |                                 |        |
|--------------|--------|-------------------|---------------------------------|--------|
| ATC          | 10 MIT | 15 MIT            | 20 MIT                          | 30 MIT |
|              | 40 MIT | Stopped           | Reroute                         | APREQ  |
| ZNY Programs | SWAP   | Hotline Activated | (Severe Weather Avoidance Plan) |        |

North-east fixes unrestricted throughout day

### Local Doppler Radar Map

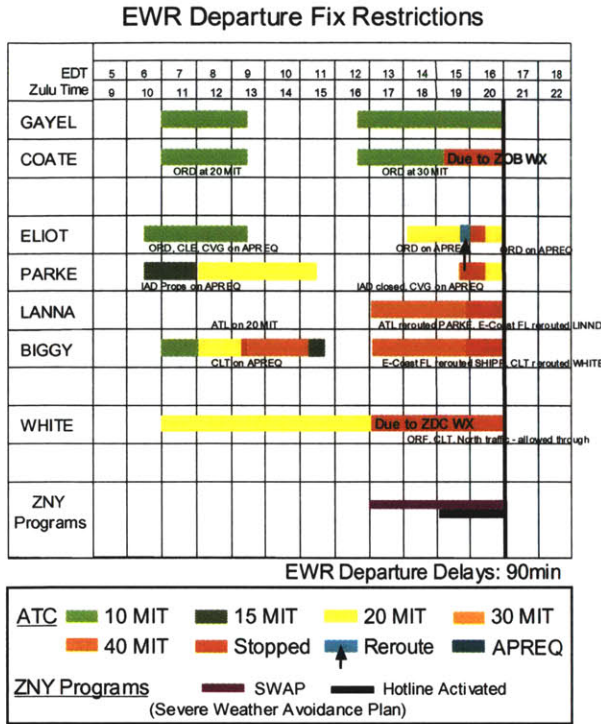
16:12:37 EDT (20:12:37 Zulu)



Source: Lincoln Laboratories ITWS

Figure 16. Restrictions and local Doppler radar map – 16:15 EDT (21:15 Zulu).

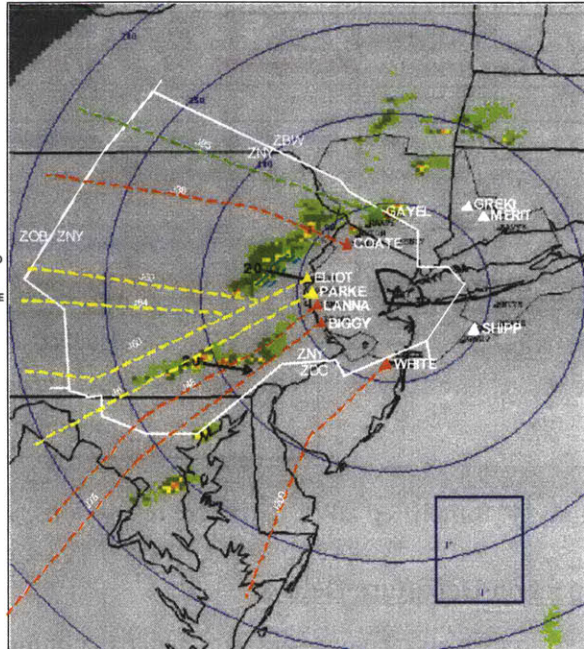




North-east fixes unrestricted throughout day

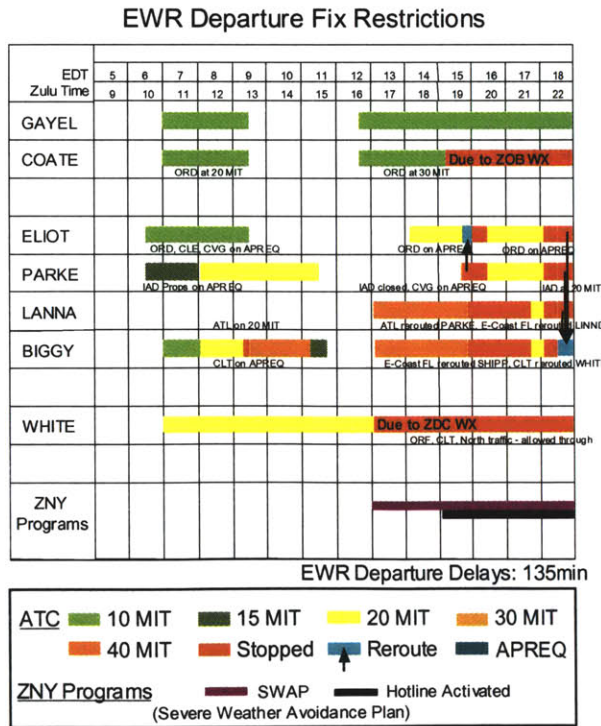
### Local Doppler Radar Map

17:02:36 EDT (21:02:36 Zulu)



Source: Lincoln Laboratories ITWS

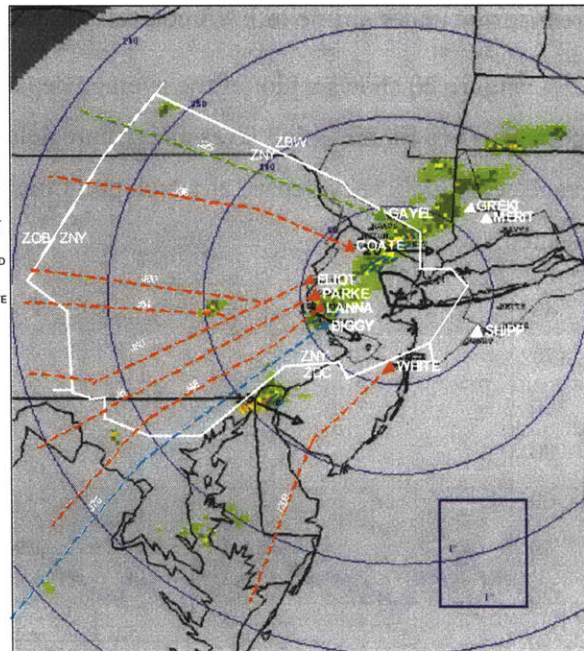
Figure 17. Restrictions and local Doppler radar map – 17:00 EDT (22:00 Zulu).



North-east fixes unrestricted throughout day

### Local Doppler Radar Map

19:04:27 EDT (23:04:27 Zulu)



Source: Lincoln Laboratories ITWS

Figure 18. Restrictions and local Doppler radar map – 19:00 EDT (23:00 Zulu).

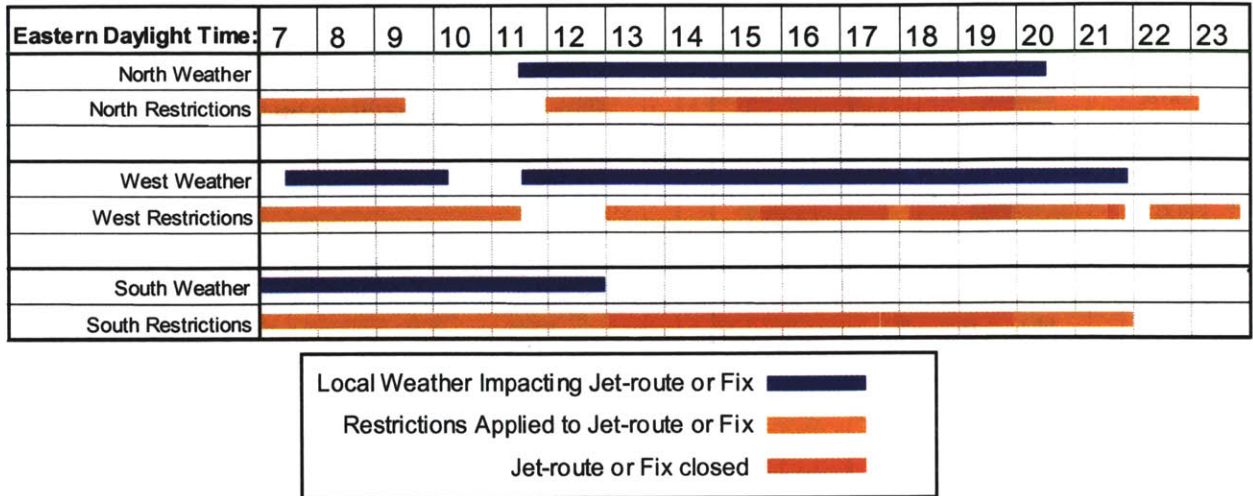


Figure 19. Simplified EWR departure restrictions and local weather - June 29, 2000.

### Impact on Departure Delays

Departure delays were calculated as follows:

$$\text{Departure Delay} = \text{Actual wheels off time} - (\text{Scheduled pushback time} + 12 \text{ min average taxi time})$$

The 12 minute average taxi time is as recommended by Continental Airlines. This delay definition is particularly useful because it includes both gate and taxi delays, regardless of whether they were incurred under airline or FAA control. They are thus the delays actually felt by passengers.

Figure 20 shows a plot of the average departure delay of aircraft waiting to depart from Newark airport. This is a running plot, so as aircraft are delayed they progressively add more time to the presented average delay, until they depart, at which point their delay no longer counts towards the average delay presented.

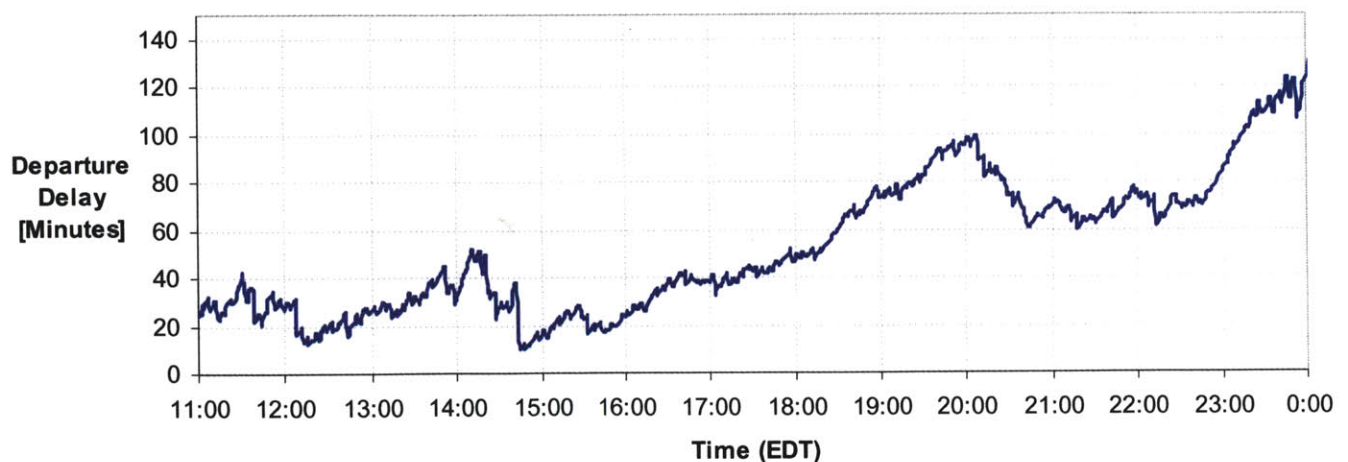
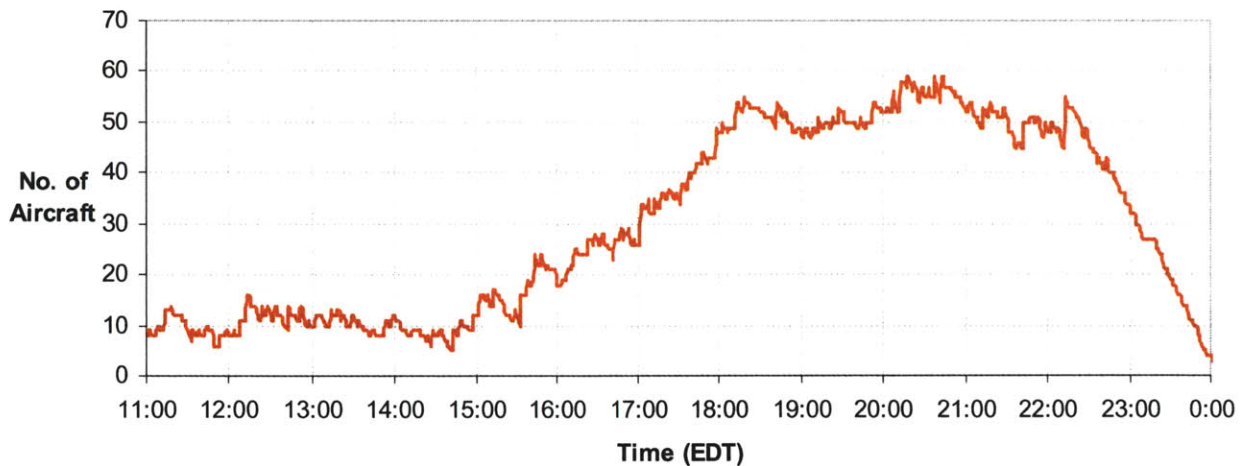


Figure 20. Running plot of average departure delay of aircraft waiting to depart from Newark Airport.



Examination of arrival delays into Newark on June 29, 2000 show particularly high arrival delays around 13:00 EDT, as a result of the implementation of the Severe Weather Avoidance Program (SWAP) which was active from 13:00 to 22:30 EDT. SWAP is an FAA delay program which blocks off large chunks of airspace in regions where thunderstorms are reported. This explains the correspondingly higher departure delays at 14:20 EDT. However, arrival delays were not unusually high after 14:30 EDT, suggesting that the increase in departure delays from 15:00 EDT were the result of other effects. The data presented in Figure 20 can be multiplied by a similar running count of the number of aircraft waiting to depart from the airport, shown in Figure 21. This yields a running plot of the total departure delay of aircraft waiting to depart from the airport. This is presented in Figure 22. Again, as aircraft are delayed they progressively add more time to the presented delay, until they depart, at which point their delay no longer counts towards the delay presented.



**Figure 21.** Running plot of number of aircraft waiting to depart from Newark Airport, June 29, 2000.

Figure 22 effectively shows a measure of the total frustration of passengers, as it accumulates the delays of all the aircraft waiting to depart. The plot is also progressive, and can thus be compared to the Gantt charts of restrictions presented in Figure 19. Thus the correlation between the delays and the restrictions can be examined. It is clear that delays start to climb precisely when there are fix closures in all three directions, just before 16:00 EDT. This particularly coincides with the fix closures to the west. It is then also clear that it is when the fix closures are lifted that the delays start to decrease again at 20:00. Again, at 21:30, when there are again fix closures to the west, delays climb again, until just before 22:00 when the west closures are lifted. The correlation between the fix closures and the delays is very clear.

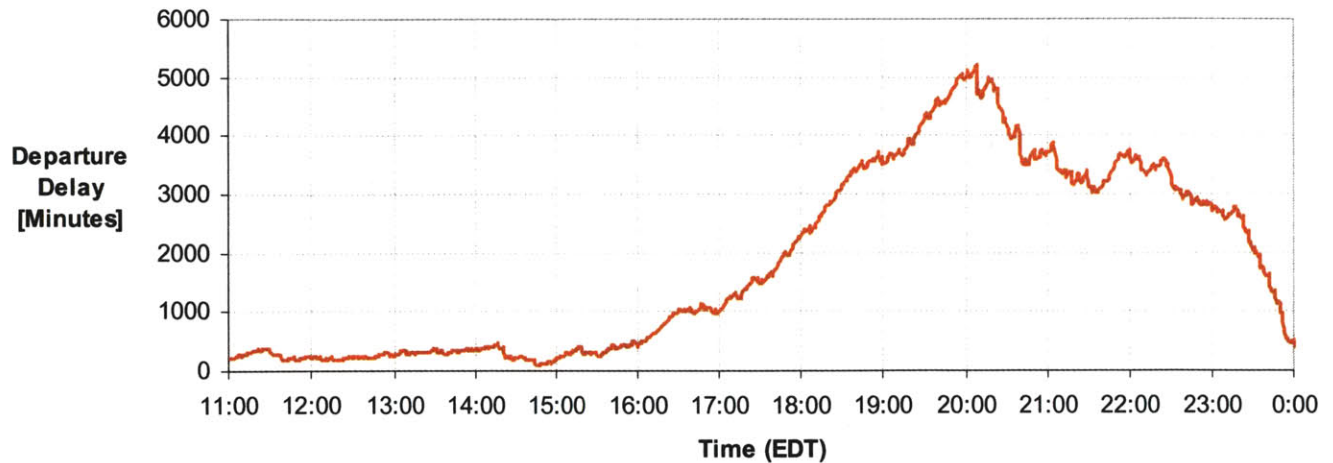


Figure 22. Running plot of total departure delay of aircraft waiting to depart from Newark Airport.

Comparison to a Day not impacted by Adverse Weather

In order to calibrate the degree to which it was the downstream constraints that caused the delays at the airport, data from a second day when there was no adverse weather impacting Newark, was processed for comparison with the data from June 29, 2000 (Figure 22). By examination of the FAA’s CODAS database (Consolidated Operations and Delay Analysis System), and of NEXRAD (NEXt generation weather RADar) national mosaic reflectivity images of the United States, Tuesday, August 22, 2000 was identified to have little weather impacting Newark. This day was also during the working week, ensuring a schedule density comparable to that of June 29, 2000. A national mosaic reflectivity image of the US for this day can be seen in Figure 23. There is clearly very little weather on the East Coast, and none near New York City. This was the case throughout the day.

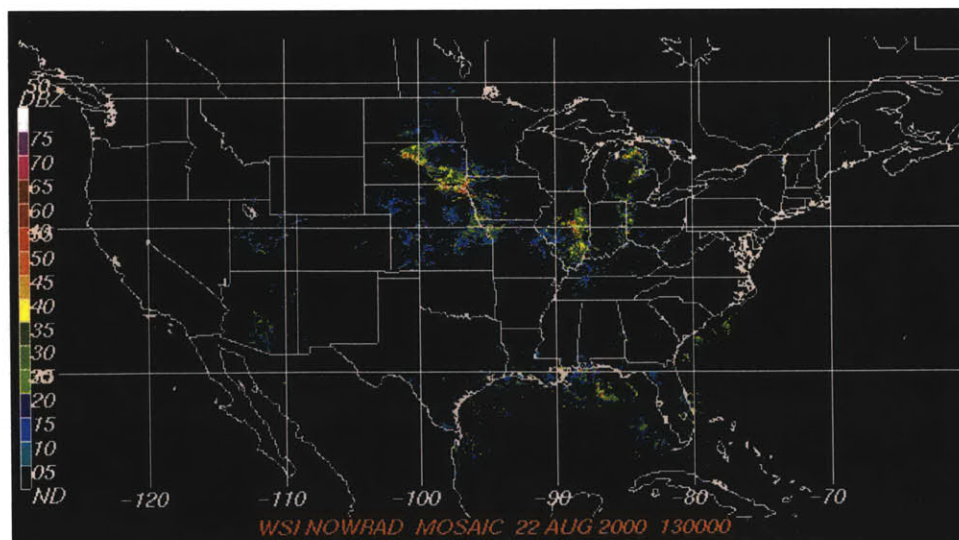
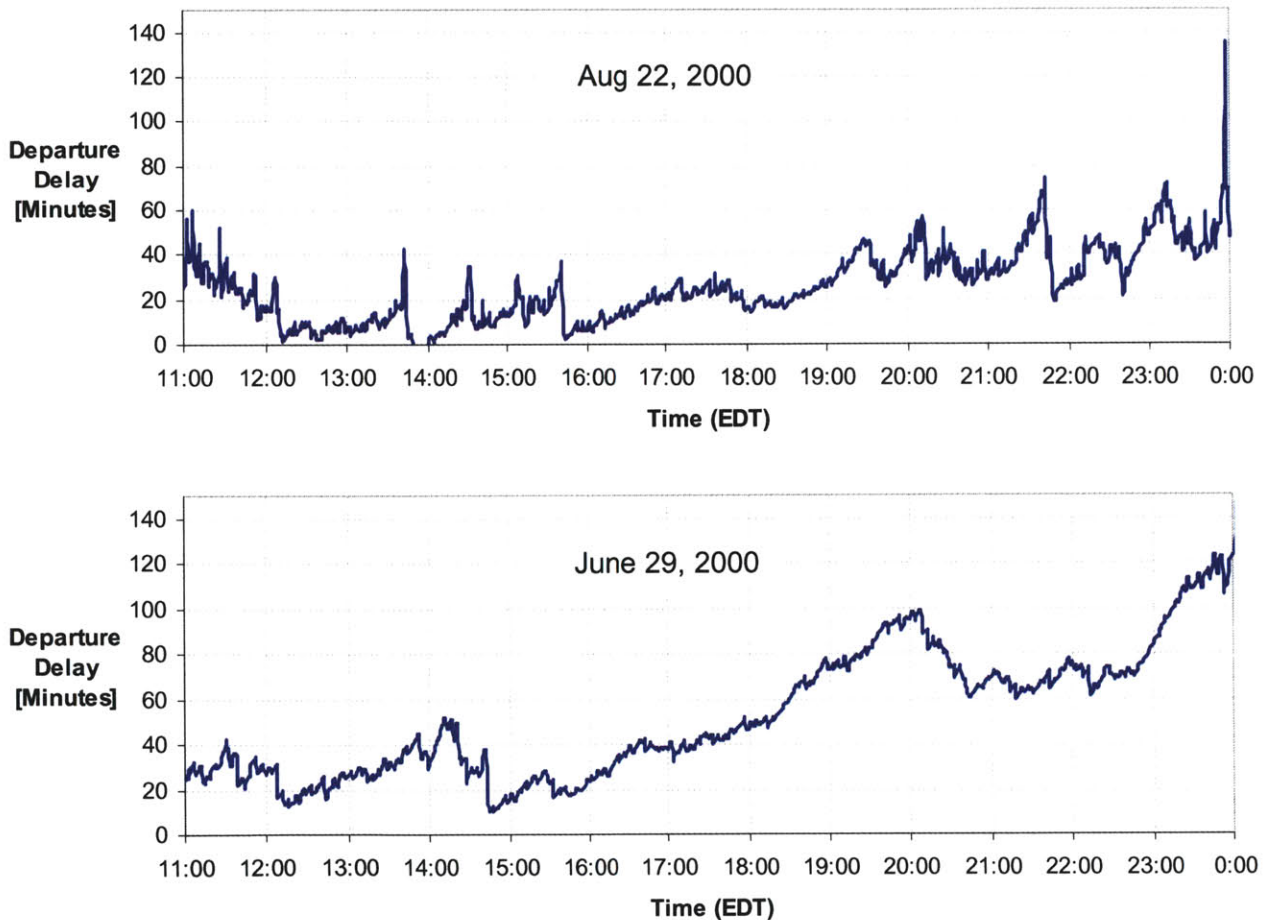


Figure 23. NEXRAD National Mosaic Reflectivity Images – August 22, 2000, 9:00:00 EDT (13:00:00 Zulu), Source: NEXRAD. [15]



Figure 24 shows a running plot of the average departure delay of aircraft waiting to depart from the airport on August 22, 2000, alongside that for June 29, 2000 (from Figure 20). Comparing these it is clear that average delays were significantly lower on August 22, than on June 29. The average delays on June 29, 2000, from 11:00 to 16:00 EDT are actually comparable to the average delays on August 22, 2000, from 18:00 to 23:00 EDT. This suggests that the average delays on June 29, 2000, before 16:00 EDT, were not more severe than normal. It was only when the front from the northwest closed the west and north fixes, with the south fixes already closed from the front to the south, that average delays increased significantly above that of normal conditions.



**Figure 24.** Running plots of average departure delay of aircraft waiting to depart from Newark Airport, August 22, 2000 (upper) and June 29, 2000 (lower).

Figure 25 shows a running plot of the total departure delay of aircraft waiting to depart from the airport on August 22, 2000, alongside that for June 29, 2000 (from Figure 22). Comparing these it is clear that delays on August 22, 2000 were significantly less than those of June 29, 2000. The difference between the two days is that the adverse weather of June 29, 2000 was not present on August 22, 2000,

suggesting that it is the downstream constraints identified on June 29, 2000, that caused the severe delays on that day.

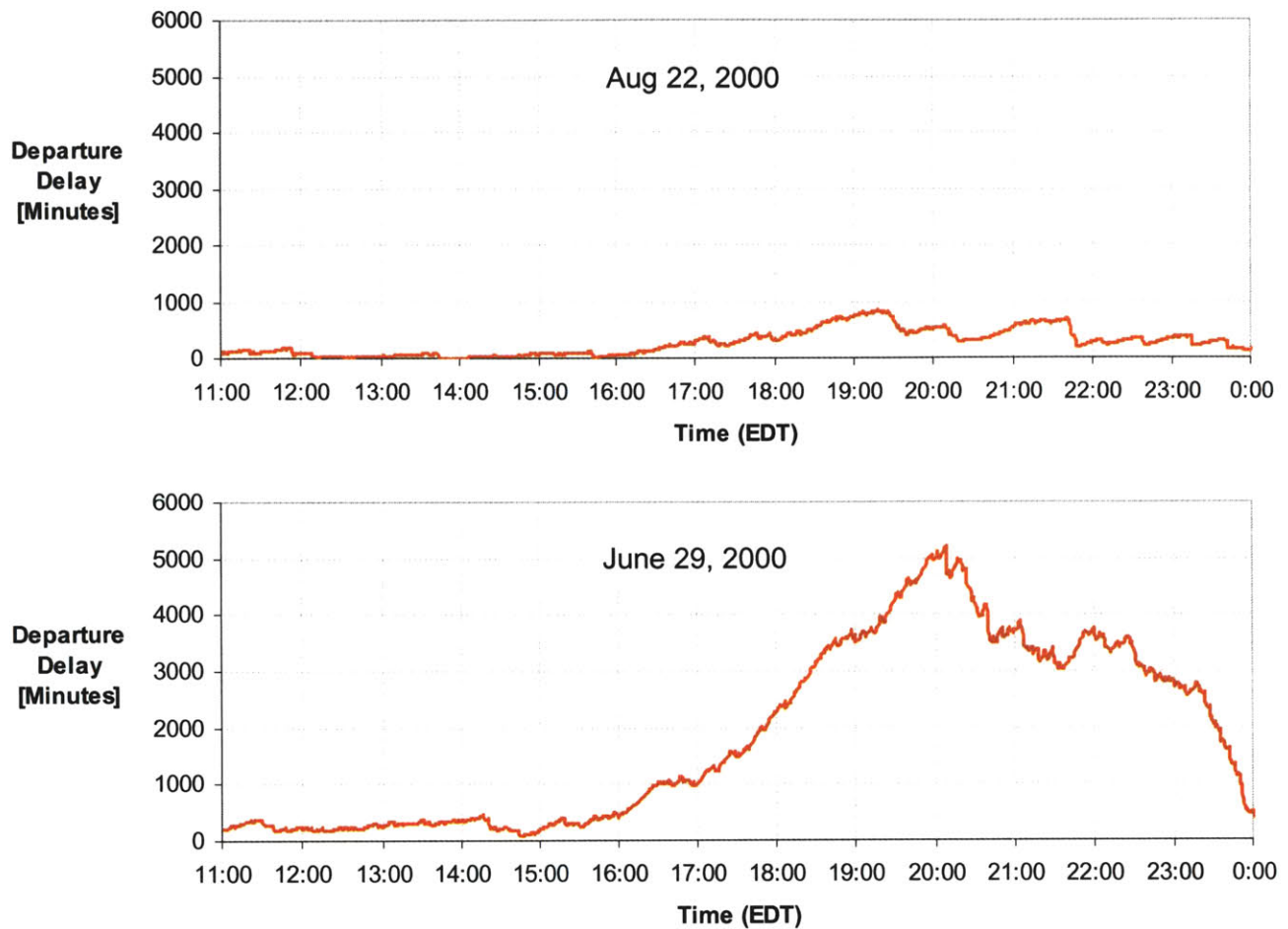


Figure 25. Running plot of total departure delay of aircraft waiting to depart from Newark Airport, August 22, 2000.

### 1.3.4 Key Conclusions

The key conclusion drawn from the site visit on June 29, 2000 is that downstream airspace capacity limitations were a primary flow constraint and the primary cause of surface delays. Weather was clearly the primary cause of the restrictions, seen by the correspondence between the local weather and the restrictions applied. The propagation of these external constraints to the airport surface was observed in the increase in departure delays coinciding closely with those periods when restrictions were most severe.

# **CHAPTER 2: ATC RESPONSE TO DELAYS**

## **2.1 INTRODUCTION TO ATC RESPONSE**

Pressure from both the public and from congress has forced the FAA to respond to the severe airport delays in the NAS. FAA Administrator Jane Garvey has spoken about ATC delays and capacity before congress a number of times, including a statement specifically dedicated to air traffic congestion in the New York Metroplex, on July 16, 2001 when testifying before the Committee on Transportation and Infrastructure, Subcommittee on Aviation [16]. Correspondingly, ATC has responded to the delays at Newark in a number of ways. These are discussed in detail in sections 2.2 and 2.3.

## **2.2 TACTICAL ATC RESPONSES**

Tactical responses are those responses performed on a day-to-day basis when delays develop at the airport, as opposed to strategic responses, which are performed once, to prevent the delays from developing at all. Tactical responses to airport delays, by ATC, include:

- The application of restrictions to fixes or jet-routes;
- Re-routing of aircraft, and the utilization of the National Playbook for formulation of re-routes;
- Utilization of decision aiding software such as the Departure Spacing Program (DSP) and the Integrated Terminal Weather System (ITWS), for improved ATC decision-making.

Furthermore, the following responses have been questioned as to their potential to reduce delays:

- Improved inter-facility communication;
- Increased utilization of runway 11/29.

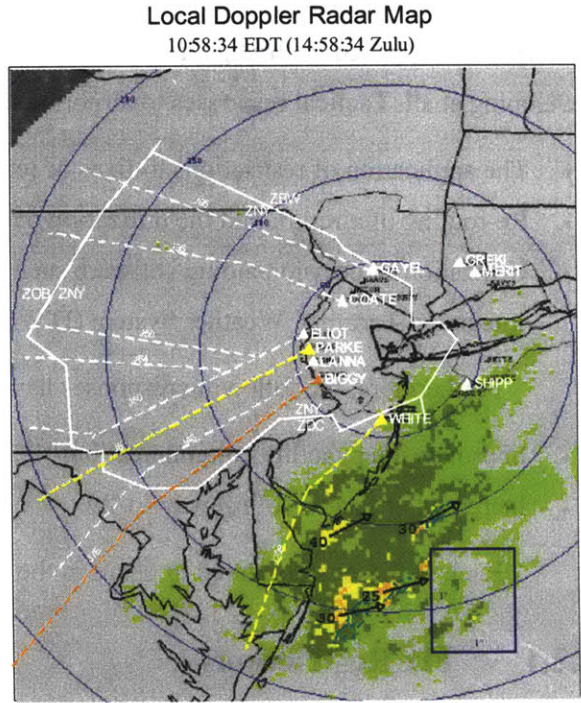
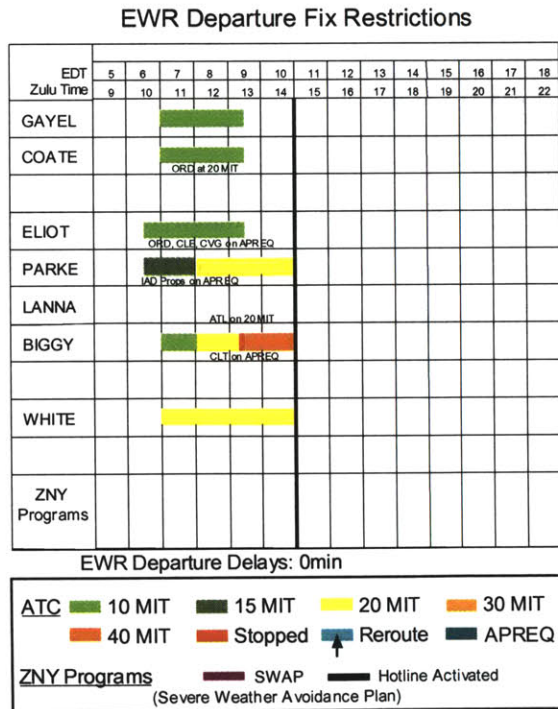
Each of these is discussed in detail in the sections following.

### **2.2.1 Fix Restrictions**

The application of restrictions to fixes and jet-routes is the primary ATC response to adverse weather. Limiting the number of aircraft using a specific fix or jet-route when that fix or jet-route is impacted by weather is essential to ensuring the safety of the NAS. These restrictions result in delays at

airports as demand exceeds capacity. Detailed observations were consequently made of the restrictions applied to the primary departure fixes for Newark airport, on June 29, 2000.

Figure 26 shows the Gantt chart and local Doppler radar map at 11:00 EDT. The Doppler radar map shows the weather moving east, off the coast. At this time it was no longer having a direct impact on the southern west fixes, but continued to impact WHITE in the south. WHITE was correspondingly restricted to 20 MIT. The HVRs were complete, leaving the north and northern west fixes unrestricted. A 20 MIT restriction had, however, been applied to PARKE and a 40 MIT restriction applied to BIGGY. According to the Gantt chart this fix was also closed briefly, at 9:20 EDT. However, it is clear that BIGGY was not impacted by local weather, so these restrictions must have been the result of capacity constraints further away from the airport. Figure 27 shows the national weather over the destination cities with preferred routings from Newark through BIGGY. These cities were clearly severely impacted by the front extending from off the coast of New England down to the Gulf of Mexico. It is thus downstream weather that is the cause of the restriction, and not local weather. This was also the case for PARKE and LANNA, although LANNA remained unrestricted because the volume of traffic through this fix was light.



Source: Lincoln Laboratories ITWS

North-east fixes unrestricted throughout day

Figure 26. Restrictions and local Doppler radar map – 11:00 EDT (15:00 Zulu).



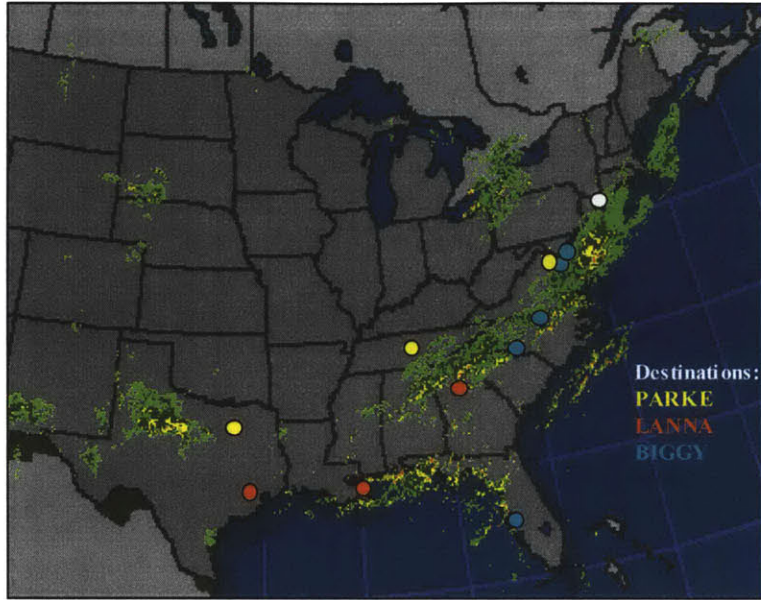
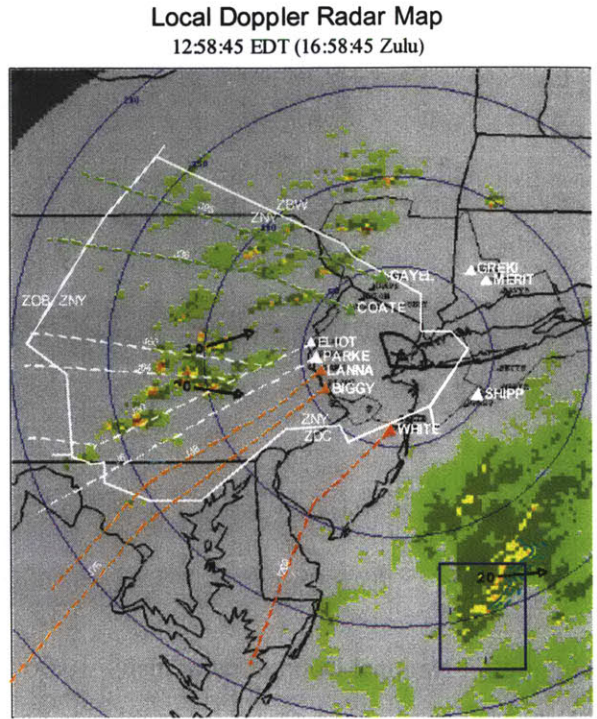
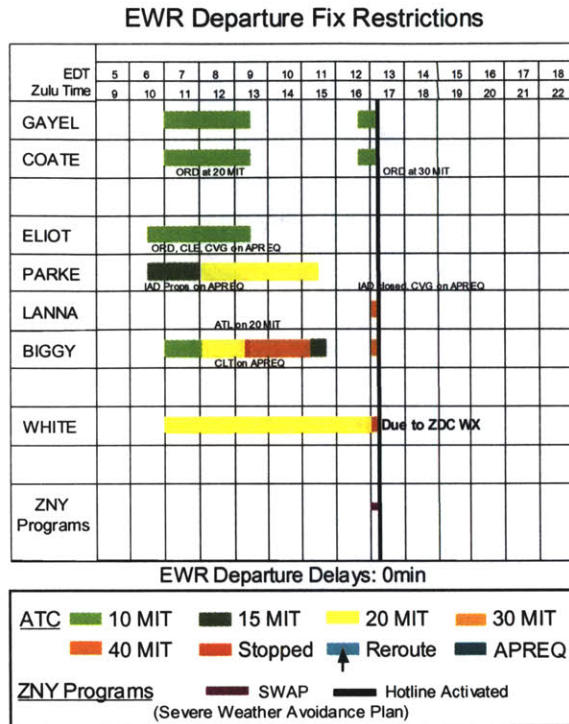


Figure 27. National Doppler radar map – 10:30:00 EDT (14:30:00 Zulu), Source: Data Transmission Network.

Figure 28 shows the Gantt chart and local Doppler radar map at 13:00 EDT. At this time the weather to the south of the airport had continued to move off the coast, now no longer impacting WHITE locally. However, the front originally over Lake Erie had started to impact the north and northern west fixes locally. The weather to the northwest of the airport, although somewhat sparse, was severe in places. Consequently GAYEL and COATE had been restricted to 10 MIT. ELIOT and PARKE, the two northern west fixes, were however unrestricted, despite local weather, and instead LANNA and BIGGY were restricted, to 40 MIT. WHITE was also closed at this time, despite no local weather. As can be seen in Figure 29 these restrictions were again caused by downstream weather severely impacting the majority of destination cities for flights from Newark with preferred routings through these fixes. ELIOT and PARKE, although impacted by local weather, were unrestricted because of light traffic (at 13:00 ELIOT was accepting 5 aircraft per hour, and PARKE, 0 aircraft per hour). This suggests that it is not only the weather that affects restrictions, but also the amount of traffic through the fixes. By 15:00 EDT the flow rate on ELIOT had increased to 25 aircraft per hour, whilst PARKE remained low at 2 aircraft per hour. Correspondingly ELIOT was restricted to 20 MIT by 15:00 EDT, whilst PARKE remained unrestricted.



North-east fixes unrestricted throughout day

Source: Lincoln Laboratories ITWS

Figure 28. Restrictions and local Doppler radar map – 13:00 EDT (17:00 Zulu).

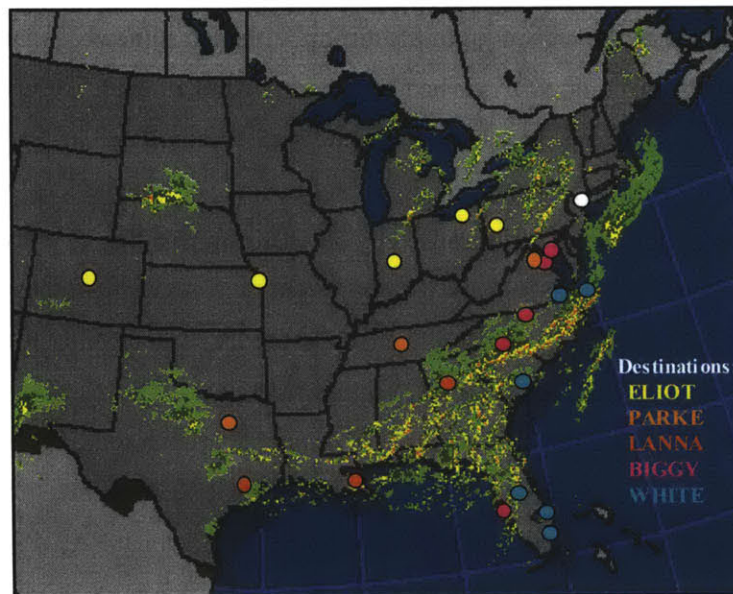


Figure 29. National Doppler radar map – 12:30:00 EDT (16:30:00 Zulu), Source: Data Transmission Network.



The severe weather avoidance plan (SWAP), also went active at 13:00 EDT. This was because of the severe restrictions to the west, and the closure of WHITE, the primary southbound fix. At 15:00 EDT the hotline, a direct and continuous telephone communication between all the facilities in the area, was activated.

It is clear from the above discussion that it is not simply local weather that affects restrictions, but rather a coupling of local weather, downstream weather, and traffic demand. Each of these factors should thus be addressed in the development of tools designed to aid decision making in the implementation of restrictions.

### ATC Tower Response to Restrictions

The FAA ATCT reacts to restrictions by changing pushback times. This response was examined by analyzing the departure rates from Newark airport, on June 29, 2000. Figure 30 shows the schedule as filed by the airlines, with the changes made by the controllers in the ATCT overlaid in green and red. Both departure rates were calculated using data transcribed from the flight strips collected on the site visit to Newark on June 29, 2000. The rates apply to wheels off time, and not pushback time, assuming a nominal taxi-time at Newark of 12 minutes (as used by Continental). The schedule filed by the airlines includes all changes to the Official Airline Guide (OAG) schedule implemented by the airlines. Cancellations are not included in either departure rate.

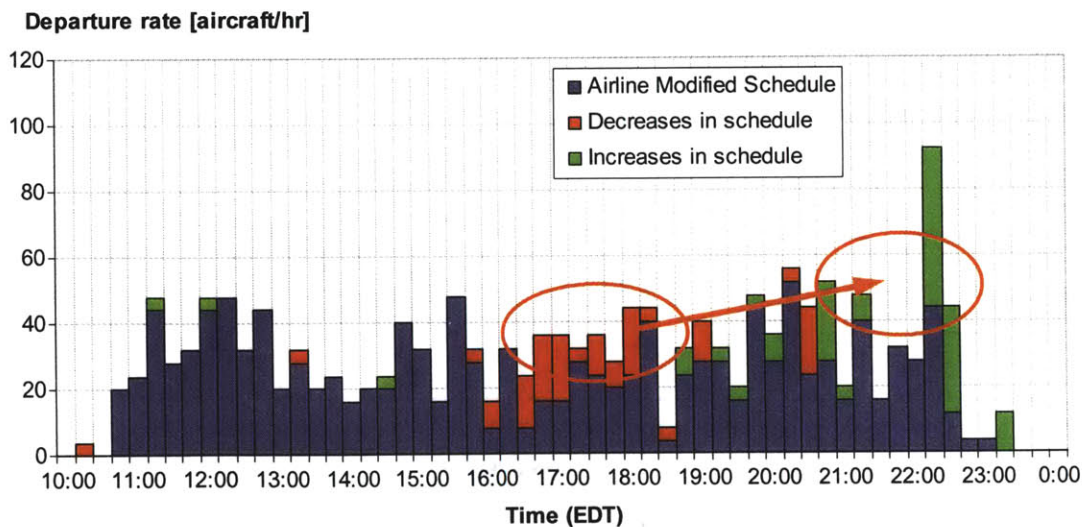


Figure 30. Airline filed and ATC departures rates, June 29, 2000.

There are few changes by ATC until 16:00 EDT, when there is a significant decrease in the ATC modified rate, until 18:45 EDT. There is then a significant increase in the ATC modified rate from 20:30 to 22:45 EDT. These periods are indicated by the red ovals in the figure. Comparing this to Figure 31,

which shows simplified departure restrictions, as in Figure 19, it is clear that the decrease in departure rate coincides closely with that period when the fixes were closed.

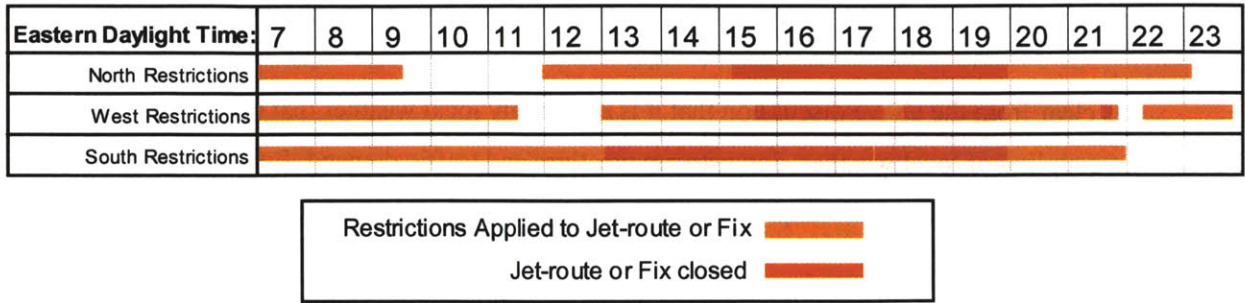


Figure 31. Simplified EWR departure restrictions - June 29, 2000.

The effects of the departure queue operations, after the aircraft have been pushed back, can be examined by comparing the ATC modified departure rate and the actual departure rate from Newark airport, on June 29, 2000. This is presented in Figure 32. The ATC scheduled departure rate is that after modification by both the airlines and ATC. Again both departure rates were calculated using data transcribed from the collected flight strips; the rates apply to wheels off time; and cancellations are not included.

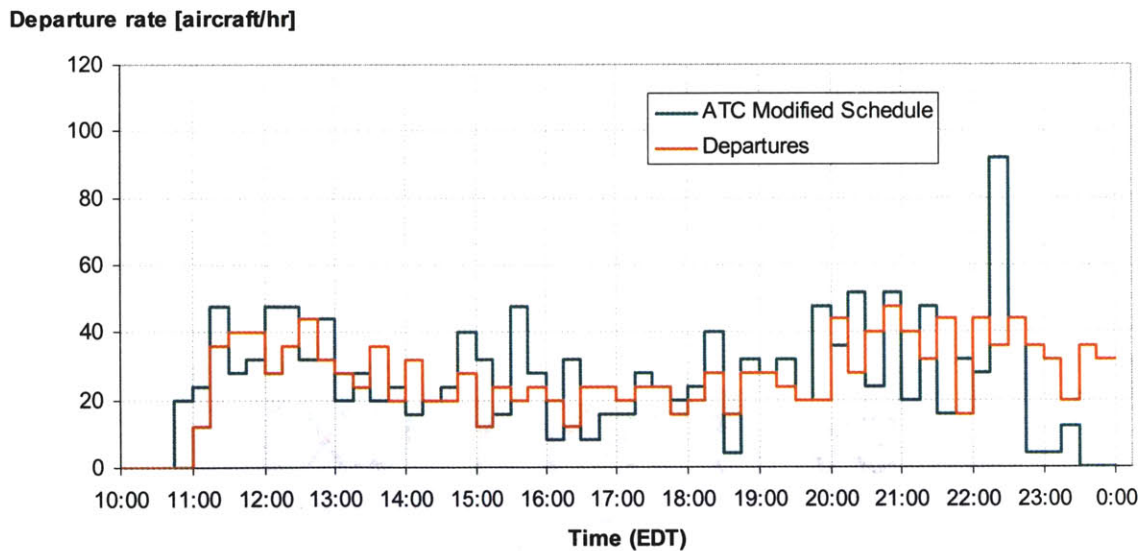


Figure 32. Scheduled and actual departure rates, June 29, 2000.

These two departure rates do not initially appear to coincide very closely. However, ignoring the fluctuations below a period of about 30 minutes, the longer-term shape of the plots does coincide closely throughout the day. The poor correspondence at the shorter period is because manpower issues do not allow FAA controllers to modify the departure rates often enough to make them more accurate than



observed. The airlines and controllers also tend to schedule flights on the hour or half hour, whilst the actual departure rate is directly affected by the dynamics of the fix restrictions and departure queue.

The longer-term shape of the ATC scheduled rate is affected by the banking structure used by the airlines, and the rescheduling performed by the airlines and the FAA. The close correlation of the longer-term ATC scheduled and actual departure rates suggests that the FAA and airline rescheduling was successful in the longer term. However, because of manpower constraints, short-term restriction changes, and the requirement for airlines to file final flight plans 45 minutes before scheduled pushback, the ability of airlines and ATC to respond quicker is limited. This would however improve efficiency and reduce delays.

Clearly the ATC scheduled rate is lowest from 16:00 through to 20:00 EDT. This is because of the modifications by ATC seen in Figure 30. The actual departure rate is a direct function of the restrictions, and particularly the longer term restrictions such as the lengthy fix closures to the west and south. The longer term shape of the actual departure rate, like the scheduled departure rate, coincides closely with the restrictions in Figure 31, as expected. The shorter term fluctuations do however mean that improvements can be made and efficiency improved. Decision aiding tools designed specifically to improve short-term response in the ATCT may improve efficiency and thus allow more aircraft to depart per hour, leading to a reduction in delays.

## Conclusions

Restrictions are implemented by ATC, according to a coupling of local weather, downstream weather, and traffic demand. The airport ATCTs then respond to these restrictions by rescheduling departures in the longer-term, and by releasing aircraft to each fix at a rate consistent with the restrictions on each fix in the short-term. Development of decision aiding tools to improve both the implementation of the restrictions and the ATCT response to them would increase efficiency and reduce delays.

### **2.2.2 Re-routes**

Re-routing aircraft from their original flight plan onto a new less restricted route is a preferred method for dealing with severe fix or jet-route restrictions. The reason for this is that re-routes around sections of the flight path that are severely restricted can reduce delays on routes that would otherwise be severely delayed. Figure 33 illustrates two routes, with two components each – a fix or jet-route local to the origin airport, and a downstream fix or jet-route. If the two routes were separate a local or downstream constraint would stop the flow on that route. However, if re-routes between routes were allowed, shown by the dashed lines, the local weather on one route would not impact the flow to the destinations on that route, as aircraft could be re-routed onto the other route locally, and returned to their

original route after the local constraint. Similarly if one route had local constraints and the other had downstream constraints, flow on the route with downstream constraints could be lightly restricted, and traffic from the route with local constraints re-routed onto it, before being re-routed back, after the local constraints. If correctly planned, this could leave the level of traffic on the fix with downstream constraints low enough to meet the restrictions required downstream.

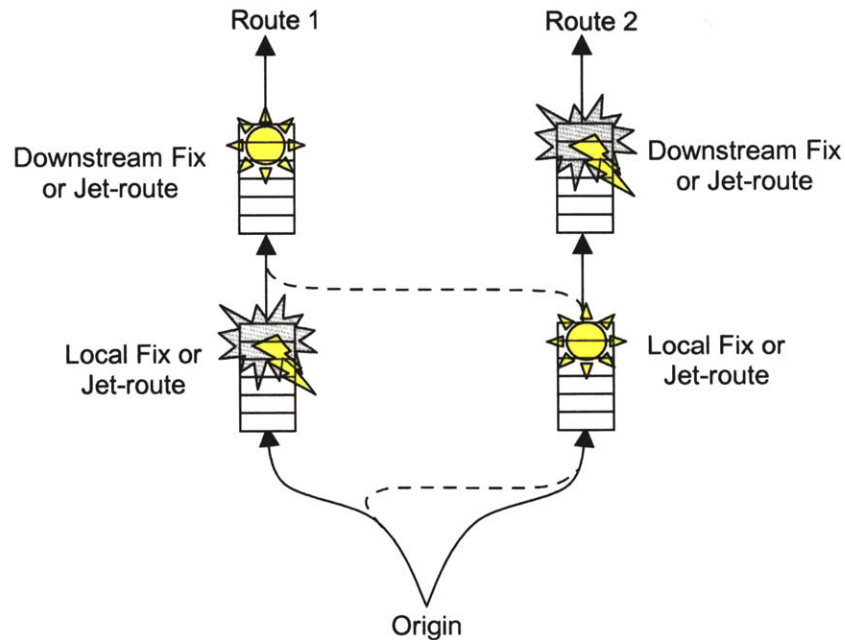


Figure 33. Advantages of re-routing.

Despite its benefits, re-routing is difficult to implement, as all facilities affected need to agree on the re-route, which is coordinated through the ATCSCC. This may often involve a number of facilities with conflicting interests. Because of these difficulties the National Playbook was developed, which provides pre-determined re-route suggestions for specific fix and jet-route closures. On November 15, 16 and 17, 2000, the Newark ATCT, Port Authority of New York and New Jersey, New York TRACON, and New York ARTCC, were visited and controllers interviewed. According to these interviews the National Playbook is well respected and the re-routes implemented are generally taken directly from the Playbook. During the June 29, 2000 site visit to Newark Airport, however, controllers did not use the Playbook extensively. This was because plays did not exist for the weather scenarios that impacted the airport that day. The Playbook can only be used for the specific weather scenarios in the book. A detailed examination of those re-routes implemented follows.

Figure 28, which shows the restrictions and local Doppler radar map for 13:00 EDT, clearly shows a gap between the two fronts, through which WHITE and J209 pass. This gap grows as the day progresses. It appears initially that this gap could allow traffic to fly west by departing through WHITE

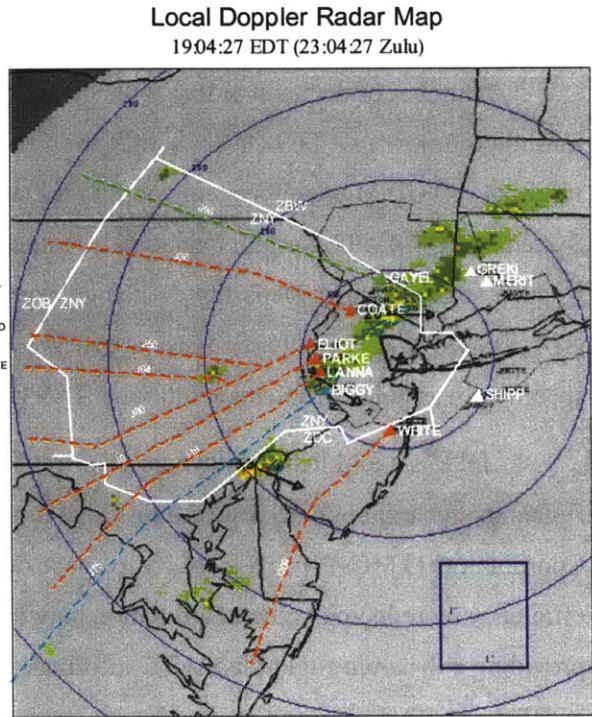
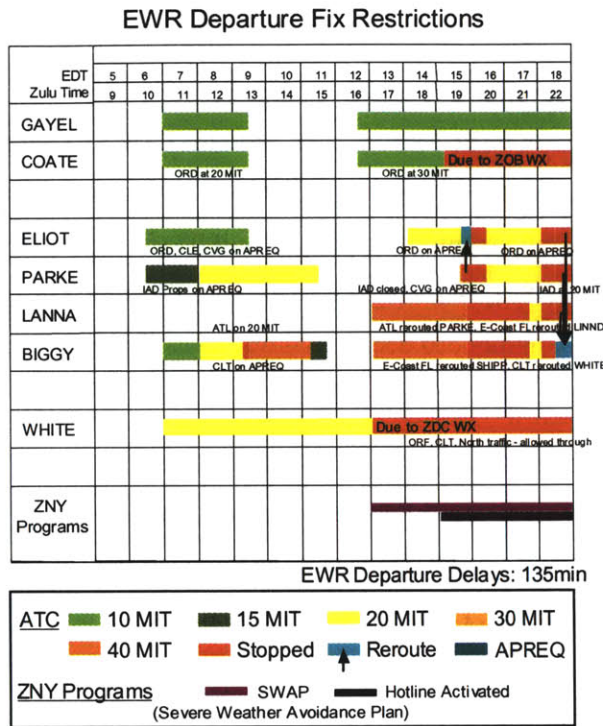
and flying west around the south of the front coming through from the north west. However, this would require that the aircraft change their flight plans from flying from New York Center to Cleveland Center, to flying from New York Center to Washington Center, and then to Cleveland Center from the south. Because this re-route crosses center boundaries it would have required extensive coordination between the three Centers, through the ATCSCC. New York arrivals from the south also pass through this corridor, and Washington arrivals and departures use the airspace just south of the front from the northwest. The flights would be interacting with traffic to and from Washington Dulles (IAD), Washington National (DCA), Baltimore (BWI) and Philadelphia (PHL). With improved inter-facility coordination however, this gap in the weather may have been able to be utilized, allowing much traffic out to the west.

Figure 34 shows the Gantt chart and local Doppler radar map at 16:15 EDT. The weather from the northwest continued to move towards New York City, and can be seen to impact the north and west departure fixes. Because of the local weather COATE and all the west fixes were closed. These were the departure fixes with the highest traffic. WHITE remained closed because of downstream weather, although some re-routes were allowed through the gap between the two fronts to Norfolk (ORF) and Charlotte (CLT). The traffic to these destinations was however light in comparison to that scheduled through the west fixes, and the original flight plans also took the flights through the same ARTCCs.

One of the plays in the National Playbook, called NO-WESTGATES/RBV\_1 is designed for use when all west departure fixes are closed. This play, however, re-routes aircraft through COATE and WHITE, both of which were closed on June 29 when the west fixes were closed. This re-route was thus unavailable. The only open fixes were those to the northeast. There is a play in the National Playbook called TOP-THE-WX\_1, which is a special request routing for “topping the weather”, where west departures fly through MERIT, to the northeast, in order to cut back to the north of the weather. However, when the west fixes were closed on June 29, there was heavy traffic flying to Europe so these fixes were also unavailable.







Source: Lincoln Laboratories ITWS

North-east fixes unrestricted throughout day

Figure 35. Restrictions and local Doppler radar map – 19:00 EDT (23:00 Zulu).

## Conclusions

The National Playbook can only be utilized for weather situations for which plays are developed, and can thus only be utilized for a severe weather situation if a play is developed for that scenario. It is thus essential that plays continue to be developed and the Playbook updated. Even the Playbook re-routes can however be rendered un-usable by constraints on the destination fixes.

It is not clear to what degree inter-facility coordination would have had to be improved to have allowed the re-route through the gap between the fronts, from 3pm to 5pm on June 29. It does appear however that re-route opportunities would be greatly improved by more efficient inter-facility coordination.

### **2.2.3 Decision-Aiding Tools**

A number of decision aiding tools have been developed to improve communication and information flow in ATC. These include the Enhanced Traffic Management System (ETMS), General Information (GI) Message System and Flight Data Information Operation (FDIO), Information Display System-4 (IDS-4), the System Command Center Operations Information System (OIS) Website, Doppler weather radar displays, Departure Spacing Program (DSP), and Integrated Terminal Weather System (ITWS). DSP and ITWS particularly are two recently introduced decision-aiding tools designed specifically as delay problems within the NAS have become a primary focus of the FAA.

DSP is a tool that uses dynamic air traffic information from specially adapted airports to schedule flights through common departure fixes. This tool provides controllers and Traffic Management Coordinators (TMCs) with the ability to space departing aircraft. However, the tool also improves efficiency by reducing voice coordination between the ATCT, the TRACON and ARTCCs, and providing a dynamic flight plan, ATC information, and reports. DSP also provides departure controllers and TMCs with the aircraft ground lineup status for aircraft departing from each airport runway in the system [17]. In April, 2000 DSP was installed at Newark, LaGuardia, JFK, and Philadelphia ATCTs; New York and Philadelphia TRACONs; and New York ARTCC.

According to interviews carried out on November 17, 2000, DSP is a great benefit to the New York Departure Pit (NYDP) Complex at the New York ARTCC, which issues departure clearances to each departing aircraft. This is because DSP is able to check flight plans automatically according to preferential departure routings, and thus enables NYDP controllers to issue clearances electronically, doing away with flight strips in the NYDP. The tool was also described as useful for ensuring the efficient utilization of open fixes and for coordination of aircraft departure times for better system efficiency. However, it does not provide any assistance in optimizing routes or assignment of re-routes. In contrast to its use at the ARTCC, according to interviews on November 16, 2000 DSP is not used extensively at the New York TRACON. The tool was described as powerful but requiring more airports to be truly useful to the TRACON.

ITWS is a system that is designed to provide safety and planning tools to all terminal aviation system users, by providing improved weather information. The system was developed initially by MIT Lincoln Laboratories, and further by Raytheon and TRW. It is designed to characterize current terminal weather situations and forecast 30 minutes into the future, presenting the data on a Doppler radar map. ITWS includes wind shear and microburst predictions, storm cell and lightning information, terminal area winds aloft, runway winds, and short-term ceiling and visibility predictions. The ITWS demonstration

system was introduced in New York in the fall of 1998, and its capability extended to include 30 minute predictions of convective storms in the summer of 1999. The system is currently operational at Newark, Teterboro, LaGuardia and JFK ATCTs; the New York TRACON; New York, Boston and Washington ARTCCs; and the ARTCSCC in Herndon, VA. American, Continental, Delta, Federal Express, Northwest, Southwest, United, UPS and US Airways also either have access to the situation display or Internet access to ITWS.

According to interviews on the June 29, 2000 site visit, a visit to the Newark ATCT, New York TRACON and New York ARTCC on November 15-17, 2000, and a visit to Continental at Newark June 14 and 15, 2001, ITWS has been well received and is used routinely. However, as ITWS only characterizes the terminal area, controllers expressed a desire to also see ITWS applied further a field than the Terminal Area. National weather maps from the Internet are thus generally used in conjunction with ITWS. Despite this, according to a study by Lincoln Laboratories [7] ITWS provides an annual delay reduction of over 49,000 hours, which has a monetary value of over \$150,000,000 per year. The study also shows that delays could be further reduced if ITWS were extended to provide prediction of thunderstorm decay, and the onset and ending of capacity limiting events such as low ceiling or high surface winds.

### Conclusions

Both DSP and ITWS appear to have been successful in improving decision aiding within ATC operations. Both can however be further developed, including the inclusion of more airports in the DSP system, and the extension of ITWS to include weather further a field. It is also recommended that the integration of both tools with other decision aiding tools be considered, so as to maximize their effectiveness and benefit to the system.

### **2.2.4 Communication**

Another way in which delays can be reduced is by increasing the efficiency of strategic communication and coordination within the air traffic control system. Strategic communication and coordination has been recognized as a critical area in which system efficiency can be improved, leading to the development of the Collaborative Decision Making (CDM) initiative, developed to improve communication between ATC facilities and the airlines. The initial prototype operation was implemented in January 1998, at Newark and San Francisco, and it was expanded to all airports in September 1998. This initiative has led to traffic management tools that aim to increase information sharing between parties whilst reducing the requirements for coordination. The traffic management tools developed through this initiative have been effective at improving communication between ATC and the airlines, but

according to Davison and Hansman [18] the effectiveness of the CDM initiatives can be further enhanced by their application to the ATC system internally, particularly to inter-facility communications. Davison and Hansman identify a number of emergent themes, including an ambiguous organizational structure, information flow issues, awkward and unorganized communications and coordination, and organizational cultural issues. A number of recommendations are made including further centralization of authority to the ATCSCC; proceduralization of the communication of new or revised restrictions; proceduralization of commonly used re-routes; and restructuring teleconferences and hotlines.

### **2.2.5 Utilization of Runway 11-29**

Runway 11-29 is the third runway at Newark airport, after the parallel runways. This runway has limited utilization and more use would definitely add capacity. However there are significant limitations to the runway's use. Firstly, there are complications resulting from operations on the runway interacting with arrivals and departures to and from the other airports in the area, particularly LaGuardia and Teterboro airports. Secondly, there are also limitations on the types of aircraft able to depart on the runway, because of its length. The runway is only 6,800 ft long. Assuming sea level performance, standard conditions, maximum take off weight, and a dry runway surface, the only aircraft operated by Continental able to depart from the runway are the Boeing 737-700, the Embraer ERJ135, the Embraer EMB120 and the Aerospatiale ATR 42-320. This means that many of the aircraft operated at the airport cannot use the runway, and must instead operate from the parallel runways. Continental airlines are also converting from using turboprop aircraft such as the ATR 42-320, to using regional jets, such as the ERJ135 and ERJ145 (which cannot depart from runway 11-29). The result is further reduced utilization of runway 11-29, and increased use of the already congested parallel runways.

Operations are also limited by interactions with the two parallel runways at Newark, introduced with the extension of the parallel runways to cross runway 11-29. Simultaneous operations of runway 11-29 and runway 22R have subsequently been restricted [19]. Arrivals on the runway are also affected by the requirement to use LAHSO (Land and Hold Operations) in order to hold short of runway 4L-22R. At the time of the runway extension pilot unions contended that the FAA had not done enough to ensure that LAHSO was safe and had recommended that their members refuse to use the procedure. Consequently LAHSO had received bad press and added to the reduced utilization of the runway 11-29.

It is recommended that steps be taken to improve coordination with Teterboro and LaGuardia, so as to allow increased utilization of the runway. Particularly, the New York airspace redesign should also take this factor into account.



## **2.3 STRATEGIC ATC RESPONSES**

Strategic responses are those responses that are acted upon once, to prevent delays from developing at all, and change the way the system operates, as opposed to a tactical response, which is performed on a day-to-day basis when delays develop. The consequences of a strategic response are seen on a day-to-day basis.

Strategic responses by ATC include the development of the Air Traffic Control System Command Center (ATCSCC) in Herndon, VA, and the redesign of the New York airspace.

### **2.3.1 Air Traffic Control System Command Center**

The role of the Air Traffic Control System Command Center (ATCSCC) is to manage the flow of approximately 50,000 aircraft operations per day within the continental United States. The facility strives to balance air traffic demand with system capacity and safety, and has been operational since 1994. The formation of the ATCSCC, and the CDM initiative, which began in 1998, lead to a change in the organizational structure of the ATC system. The primary change was from a decentralized structure to a more centralized structure, with authority centralized to the ATCSCC. As identified by Davison and Hansman [18], the ATC system has aspects of a centralized hierarchical structure at the national level, in that the ATCSCC's responsibility is to maintain efficiency throughout the other ATC facilities. However, each ATC facility ultimately still functions autonomously, without being under the authority of the ATCSCC, revealing a more decentralized structure at the local level. This creates ambiguity in the organizational structure, which affects coordination at the local level. [18]. As identified by Davison and Hansman [18], further centralization of authority to the ATCSCC would reduce the ambiguity of the organizational structure. However it would also relinquish flexibility at the local level.

### **2.3.2 New York Airspace Redesign**

The New York airspace redesign is part of the FAA's National Airspace System Operational Evolution Plan, which calls for changes in how aircraft operate to better match available capacity to meet demand. The Operational Evolution Plan intends to identify solutions to increase terminal throughput; to reduce en-route congestion by increasing flexibility; to keep terminal throughput closer to visual levels in all weather conditions; and to increase flexibility to cope with en route severe weather [20]. The objective to increase terminal throughput includes redesigns of a number of terminal areas in the United States, including that of New York and Philadelphia.

The New York airspace redesign is still in its development stages. However, according to Chairman of the House Subcommittee on Aviation Rep. John Mica, speaking after a congressional hearing looking at ways to alleviate congestion at New York City airports on July 16, 2001, the FAA's airspace redesign program is a top priority to cut down on delays, particularly at LaGuardia. According to FAA Administrator Jane Garvey, who spoke at the same hearing, the redesign will not be completed until late 2005 or early 2006. [21]

### Purpose

The purpose of the New York airspace redesign is to identify ways to increase the efficiency of air traffic flows into and out of the metropolitan area, including Philadelphia, whilst still maintaining or improving the level of safety and air traffic services that are currently in place. This is necessary to respond to the increased demand for air travel, which requires increased system reliability, and thus a reduction in delays. Some of the direct results of the redesign will be reduced delays at major airports, reduced pilot and controller workload, enhanced safety, and reduced adverse environmental impacts such as noise and air emissions. [22]

### Redesign Process

According to the National Environmental Policy Act (NEPA) of 1969, all federal agencies are required to determine the impacts of any major action on the environment, prior to the implementation of the project. In compliance with the act all federal agencies and organizations in the United States must complete an Environmental Impact Statement (EIS) or Environmental Assessment (EA) to determine the environmental impact of the projects under consideration.

In the development of the EIS the FAA carried out pre-scoping workshops with the public at 31 different locations around New York, New Jersey, and Philadelphia. The purpose of these workshops were to increase the partnership with selected officials and the public in the very early stages of the redesign, expand the design options based on the public input, increase understanding of critical public issues that will need to be addressed in the redesign, improve public understanding of the project and its goals, and to develop a more comprehensive project.

After the pre-scoping workshops the FAA used the input in the formal airspace redesign process. This involved development of basic concepts, computer modeling, and eventually the development of alternatives for evaluation. Four alternatives were developed, and are presented in more detail below. In the draft EIS, the FAA describes the baseline environmental conditions and also analyzes environmental impacts of this baseline associated with each of the alternatives considered. However in the final EIS the

FAA are to select a preferred alternative and describe any mitigation efforts that would reduce the impacts associated with the alternative chosen. [22]

### Concepts

The airspace redesign is particularly complicated in the New York/New Jersey/Philadelphia region because of the proximity of the four commercial service airports, which leads to an airspace that is very complicated with respect to ingress and egress routes, and is also highly congested.

The redesign is to incorporate a number of strategies already developed to reduce congestion and environmental effects. These include:

- Increasing the altitude of flights, keeping them higher for longer. This would include both higher altitude arrivals and faster climb to altitude for departures.
- Where possible aircraft are to be either dispersed or concentrated over highways, industrial areas, and other less noise sensitive areas. This is to reduce the noise influences on the community.
- Make use of advanced navigation tools to enable the above strategies and to reduce conversations between the pilot and controller.
- Reduce flying time.

Four alternative concepts were proposed for the redesign, as follows. These are described according to an interview in January 2001 with Mike Sammartino, Manager, Airspace Branch, Eastern Region Air Traffic Division, FAA.

1. Modify the current system, without redesigning it from the ground up.
2. White paper approach – complete redesign, keeping only the runways.
3. A hybrid between the white paper approach and the current system
4. Use of the ocean for the majority of departures.

The alternative of modification of the current system would incorporate the strategies identified above, but little more. Particularly this alternative would involve use of the improvements in airplane design, including higher altitude arrivals and faster climb to altitude for departures. This alternative would also make extensive use of flight paths over waterways.

The white paper concept is a complete redesign of the system from the ground up, leaving only the runways. The new system structure would be likely to be similar to the four corner concepts at Chicago O'Hare (ORD), Atlanta (ATL), Denver (DEN), and Dallas/Fort Worth (DFW). This structure uses the four corner points for arrivals, with departures flowing out between the corners. Unlike the current structure in New York and Philadelphia, which treats each airport separately, the new structure

would treat the entire region as a single airport, until defined points within the airspace at which point the aircraft would be separated to their respective airports. Particularly in the case of arrivals, the new structure would treat the entire region as a single airport until a point 20 miles from New York, at which point the aircraft would be split up to its respective destination airports. This means that if one arrival route were particularly busy aircraft could simply be offloaded onto other arrival routes, regardless of their destination airport. The current system does not allow for this, as arrivals are restricted to the routes for their respective airports. The interaction within the 20 mile radius of New York is likely to be complicated and will need careful development.

The hybrid approach is a combination of the above two alternatives, where some of the current structures would be utilized, but there would still be extensive redesign.

The final approach is to send departures specifically out over the ocean, from all the region's airports. This alternative is fairly simple in terms of its design, but is complicated politically. It is strongly supported by some communities of New Jersey, as it would mean that there would be far fewer flights over these cities. It is not however as popular with some other communities.

### Conclusions and Recommendations

As stated by Chairman of the House Subcommittee on Aviation Rep. John Mica the New York airspace redesign, as part of the FAA's National Airspace System Operational Evolution Plan, is to be the top priority to cut down on delays [21] in the New York area. It is likely to be the most significant change to the air traffic control system structure, and is also thought to be the most likely to achieve significant reductions in delays. This is however very dependent on the solution chosen, and the ability of the redesign process to avoid bureaucratic inertia, such as would occur by attempting to completely satisfy all of the stakeholders, many of whom have contradicting interests.

### **2.3.3 Other Strategic Solutions**

Newark is constrained by the limited number of runways it operates. The addition of a new runway, however, is not a feasible solution at this time. Any new runway would need to be built alongside the parallel runways, but sufficiently far from them as to allow for simultaneous operations. This would however require the new runway to be built where Interstate I-95 is currently located, and it is not considered feasible to move this interstate because of the presence of the Newark harbor to its east. Newark is thus not likely to develop a new runway in the foreseeable future.

Demand management has also been proposed as a solution to reduce congestion at the airport. Currently Newark operates slot control at Terminal B only. According to interviews with Susan Baer,

General Manager at Newark International and Teterboro Airports for the Port Authority of New York and New Jersey, on November 15, 2000, further slot control is being considered, as is peak hour pricing. No further steps have yet been taken in this regard, however.

## **2.4 CONCLUSIONS AND POLICY IMPLICATIONS**

In 2000 Newark airport had the highest ATC delays in the country, and was second only to LaGuardia in percentage of operations delayed. The cause of delays at Newark was primarily weather, with 84% of arrival delays related in some way to weather. The weather's impact on the airport is related to the sensitivity of the airport to adverse weather and the frequency of adverse weather. Newark also operates a very full, flat schedule, with few recovery periods, and is highly congested, Newark being one of four primary airports in the New York Metroplex. According to a site visit to the airport on June 29, 2000, the primary flow constraint, which leads to the high surface delays at the airport, is downstream airspace capacity limitations.

ATC Responses to the delays at Newark have been both tactical and strategic. Tactical responses include application of restrictions and reroutes, and the use of decisions aiding tools. Other suggested responses include improved inter-facility communication and increased utilization of runway 11-29. Strategic responses to delays in the system include the formation of the ATCSCC, and a redesign of the NAS. A number of conclusions related to these responses were identified, as described below.

Restrictions are implemented not only because of local weather, but are also affected by downstream weather and traffic levels through the departure fixes. It is recommended that ATC decisions aiding tools be developed that account for all of these factors. Integration with current systems such as ITWS and DSP is also essential. It is also essential for decision aiding tools to be developed to improve particularly the short-term efficiency of ATCT departure operations.

Dynamic re-routing is difficult because of the need for all the facilities to be in agreement for a re-route to be approved. With improved inter-facility communication re-routing could thus be utilized to a greater extent, and thus delays reduced. It is thus recommended that steps be taken particularly to improve inter-facility communication, which may include the further development of decision aiding and communication tools. The National Playbook, developed to suggest re-routes and improve their utilization, although useful, needs to be further developed to include more plays. These would address combinations of fix closures not addressed in the current edition of the playbook.

Two decision-aiding tools, DSP and ITWS, have recently been implemented at Newark and its associated ATC facilities. DSP is a great benefit to the NYDP at the New York ARTCC and is useful for ensuring efficient use of fixes, but was not used much by the New York TRACON as it did not include

enough airports to be truly useful. It is thus recommended that DSP be further developed to include more airports. ITWS has been well received and is used routinely. According to a study by Lincoln Laboratories [7] it is responsible for an annual delay reduction of over 49,000 hours. However controllers expressed a desire to see the system applied further a field as well as within the Terminal Area. It is thus recommended that the system be extended to include weather further a field. It is also recommended that the integration of both DSP and ITWS with other decision aiding tools be considered in detail.

Because of the competitive nature of the industry in which decisions aiding tools are developed it may be necessary for some government intervention to allow efficient integration of the decision aiding tools developed. It is essential that the tools developed integrate well as simply increasing the number of tools available to controllers is likely to overload them and increase their tasks instead of decreasing them. Instead the systems developed needs to be highly integrated, operating together with a minimum of interfaces to controllers. This may require certain information about system design to be made available to other contractors, when this information would normally be withheld for competitive reasons.

According to the study by Davison and Hansman on communication and coordination issues in the NAS [18] the organizational structure is ambiguous. The formation of the ATCSCC has led to a centralized control structure, with authority centralized to the ATCSCC. However, each ATC facility ultimately still functions autonomously, revealing a more decentralized structure at the local level. As identified by Davison and Hansman, further centralization of authority to the ATCSCC would reduce the ambiguity of the organizational structure. A number of other themes are visible, such as information flow issues, awkward and unorganized communications and coordination, and organizational cultural issues.

Increased utilization of runway 11-29 would add capacity, but it is significantly limited by operational interaction issues with particularly Teterboro and LaGuardia; its length, with many aircraft types not able to operate on the runway; and operational issues related to crossing the parallel runways. It is particularly recommended that efforts be taken within the system to improve coordination with Teterboro and LaGuardia to allow increased utilization of the runway. However, this should also be addressed in detail in the re-design of the New York airspace. This may require the introduction of new FAA procedures between the three airports.

The New York airspace redesign, part of the FAA's National Airspace System Operational Evolution Plan, is a top priority to alleviate congestion at the New York airports. It is thus thought to be the response to delays likely to have the greatest impact on reducing delays in the New York Metroplex, and at Newark airport. The careful development of the New York airspace redesign is thus essential.

# **CHAPTER 3: AIRLINE RESPONSE TO DELAYS**

## **3.1 INTRODUCTION TO AIRLINE RESPONSE**

The airline response to delays is of key importance because it is the airlines that suffer the consequences of the passenger's dissatisfaction when flights are delayed or cancelled. They must consequently not only take measures to reduce delays but also take measures to accommodate passengers and make the delays that occur as painless as possible. This is particularly true at Newark where the delays are primarily caused by adverse weather, which is out of the control of the airline.

Both the tactical and strategic airline responses to delays at Newark are discussed in detail in the following sections. Because Continental Airlines is the dominant operator at the airport the discussion focuses on responses by Continental.

## **3.2 TACTICAL AIRLINE RESPONSES**

Tactical responses by the airlines include:

- Adjustment of scheduled departure time.
- Prioritized cancellations.
- Advanced ground control, including pre-sequencing for the departure queue.
- Extended accommodation of passengers.
- Improved access to information, for better prediction and understanding of delays.

### **3.2.1 Adjustment of Scheduled Departure Time**

Apart from simply allowing a delayed departure to wait at the gate or in the departure queue, an airline can modify its departure time, re-file its flight plan, or cancel the flight. Changing the scheduled departure time is the simplest and most common response. A flight plan is generally re-filed only if changes are made to the route by which the aircraft is to reach its destination, which is generally considered to be the responsibility of the FAA, and not the airline. Cancellations are generally avoided because it is so disrupting to passengers.

Airline modification of a flight's departure time and re-filing of its flight plan must be done a minimum of 45 minutes before the original scheduled departure time. Modification of the departure time

can best be examined by comparing the departure rate as predicted by the OAG schedule with the departure rate after modifications by the airlines, i.e. before it is modified again by ATC.

Observations from Site Visit, June 29, 2000

Detailed observations were made of the departure rate from the airport on June 29, 2000, at Newark airport. Figure 36 shows the scheduled departure rate from the airport according to the OAG, with the changes made when the flight plans were filed by the airlines shown in green and red. These departure rates were calculated from the data transcribed from the flight strips collected on the site visit, and apply to wheels off time, and not pushback time. This schedule is the final schedule filed in the flight plans, whereas the OAG schedule is published at the beginning of every month. The schedule is still to be modified by ATC before take off. Cancelled flights are not included in either departure rate, so all the differences between the two rates must be accounted to re-scheduling by the airlines.

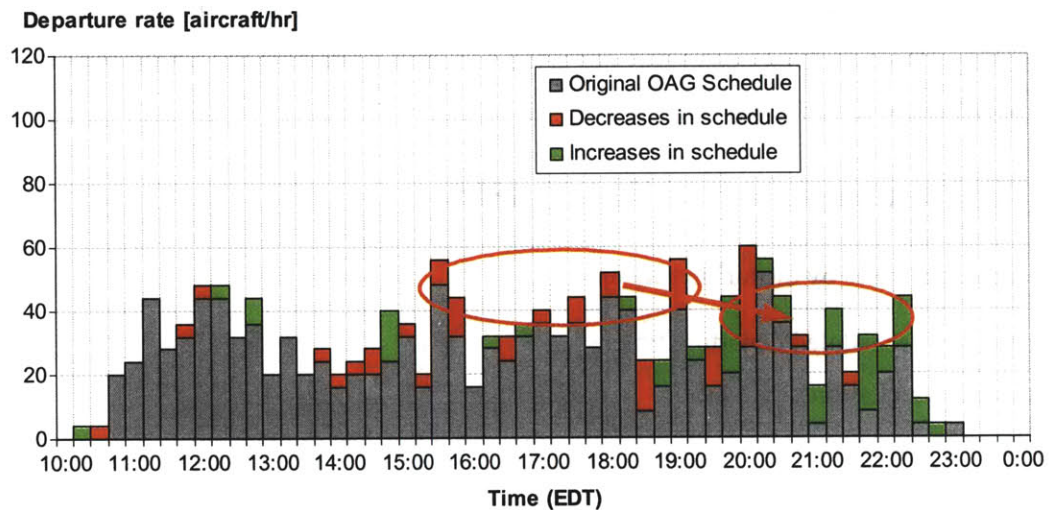


Figure 36. Airline OAG and filed departure rates, June 29, 2000.

There are clearly few changes to the original OAG departure rate, suggesting that the airlines do little rescheduling, even when restrictions and delays are severe. The most significant change is a consistent slight decrease in the departure rate from 15:00 to 19:30, and a corresponding increase from 19:30 to 22:30. This is shown in Figure 36 by the red ovals. Comparing this to Figure 37, which shows simplified departure restrictions, it is clear that the decrease in departure rate coincides with that period when the fixes were closed.



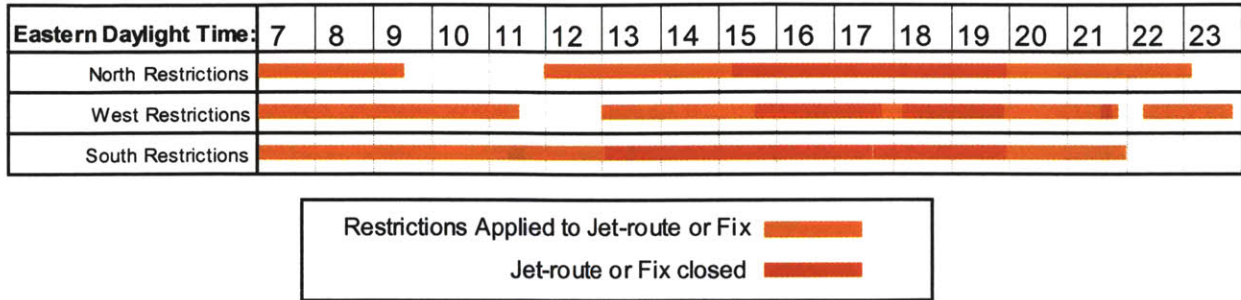


Figure 37. Simplified EWR departure restrictions - June 29, 2000.

Conclusions

The very limited airline re-scheduling observed is related to the requirement for the new flight plan to be submitted 45 minutes in advance of the specified pushback time, thus limiting its tactical usefulness. It is thus recommended that this limit be re-evaluated and reduced to the extent possible. As with re-routing, a desire not to infringe on the responsibility of the FAA is also thought to limit this type of response. It is thus recommended that guidelines be laid down clarifying the role of ATC and the airlines for re-scheduling and re-routing. This information would also be useful in the development of a decision-aiding tool that aids the airlines in re-scheduling and re-routing before the 45 minute cutoff time.

**3.2.2 Prioritized Cancellations**

If a flight is to be delayed another response is to cancel the flight. This is however a drastic measure, and is traditionally a choice of last resort. However, when severe delays are expected, advance cancellation of low priority flights can significantly reduce delays of higher priority flights. According to interviews with Continental Airlines at Newark on June 14, 2001, higher priority flights include international flights, transcontinental flights, flights to hubs, and high load factor flights. Low priority flights are generally shorter haul spoke flights.

Observations from Site Visit, June 29, 2000

Continental Airlines, including Continental Express, canceled a number of aircraft on June 29, 2000 because of the high delays and severe departure restrictions from Newark. The number of cancelled aircraft per 15 minute interval is presented in Figure 38. It is clear that the greatest number of cancellations were for aircraft scheduled to depart between the times 15:00 to 19:00. This coincides with that period when restrictions and fix closures were most severe, evident in Figure 37.

# Cancelled A/C  
(per 15 min interval)

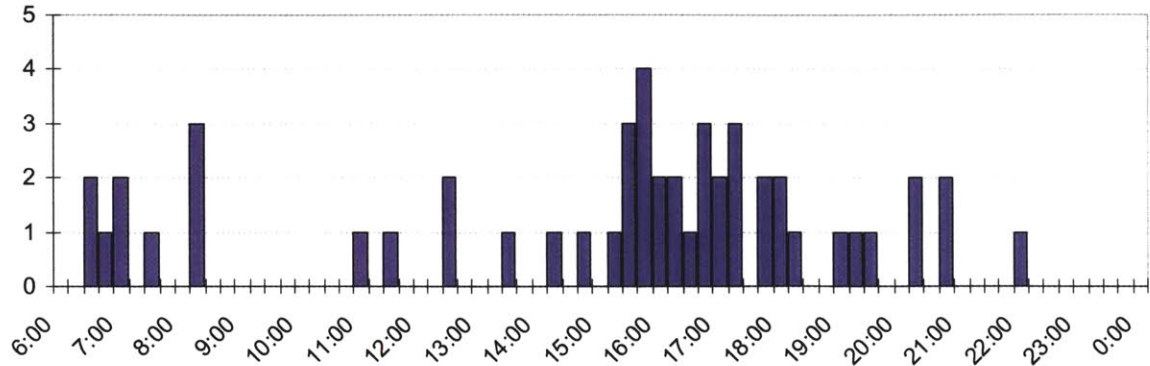


Figure 38. Number of aircraft cancelled by Continental Airlines, including Continental Express, June 29, 2000.

In order to examine the strategy behind the cancellations the number of cancelled flights was plotted against origin-destination (O-D) flight distances, which is presented in Figure 39. It is clear from the chart that the majority of cancellations are the shorter haul flights, with progressively fewer cancellations as the flight distance increases. According to interviews with at Newark on June 14, 2001 Continental started to apply this strategy on May 10, 2000, when passengers displaced from a cancelled short haul flight were sent to their destination by train. This is practical if the travel time by rail is of the same order of magnitude as the flight time would have been if the flight were delayed instead of being cancelled, so short haul passengers are not severely impacted. As a result of the success of this operation Continental has entered into an agreement with Amtrak allowing passengers from cancelled short haul flights to be sent to their destination by rail. Continental has also been operating buses with Continental flight numbers to Lehigh Valley International Airport in Allentown, Pennsylvania (ABE) since 1997. It is impractical however to use trains or buses to replace cancelled longer haul flights. Thus, Continental Express flights are often cancelled in favor of longer haul Continental Airlines flights. Continental is continuing to work with Amtrak to make this operation smoother.

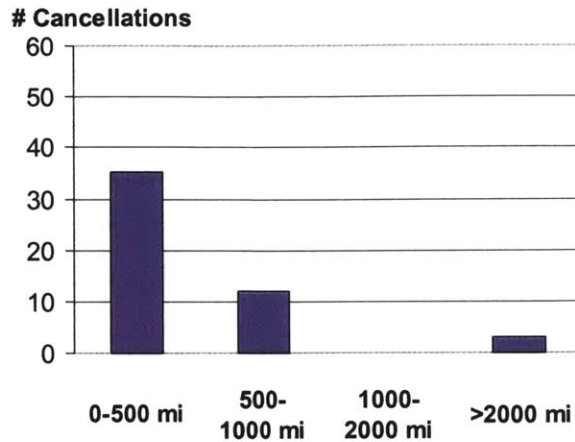


Figure 39. Number of Continental cancellations by origin-destination distance.

### Conclusions

The response to the severe restrictions and delays at the airport on June 29, 2000 by canceling flights was clearly far greater than by re-scheduling, as described in section 3.2.1. Specifically it was observed that Continental uses a type of “pawn strategy” where short haul, low priority flights are sacrificed to reduce delays for longer haul, higher priority flights. This strategy is supported by cooperative agreements with Amtrak reducing the impact of the cancellation as the passengers still get to their destination, by rail or road. The strategy reduces congestion, making it attractive to all stakeholders.

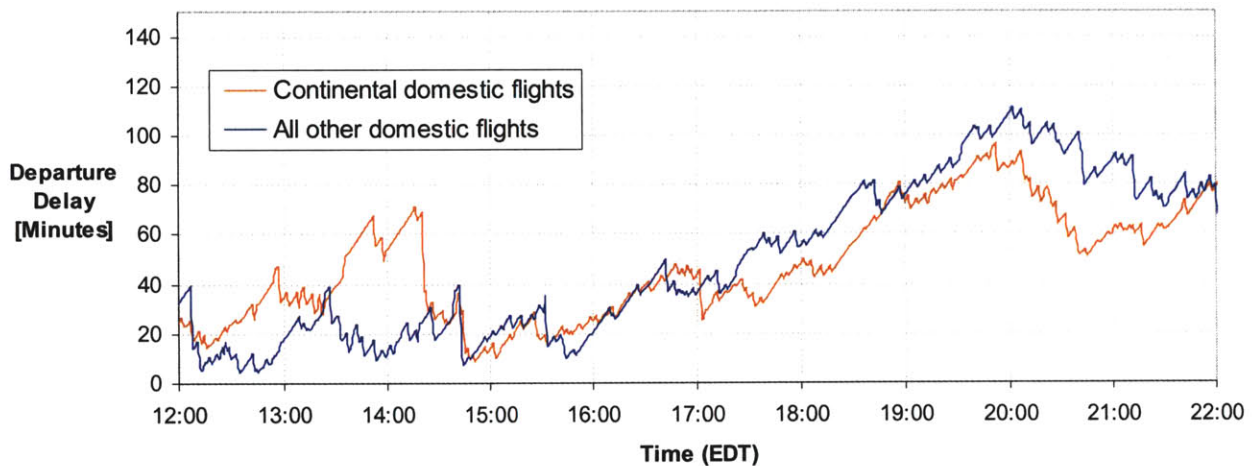
### 3.2.3 Advanced Ground Control

Continental Airlines controls much of the ramp area near terminal C, and during the extended ramp operations Continental is given control of more taxiways. This allows the Continental ramp tower to manipulate the sequence of its Continental departures in such a way as to help ATC, and thus reduce delays. This is termed pre-sequencing or staging. Aircraft are sequenced according to which departure fix they are scheduled to take off through, and according to the departure restrictions in place. Thus aircraft scheduled to depart through the same departure fix are spaced in the departure sequence such that they are available to the FAA precisely when they require aircraft for that particular fix. If a fix is closed the aircraft scheduled to depart through that fix can be pulled out of the sequence and sent to a parking area to await either a re-route or the opening of the fix.

One of the consequences of pre-sequencing by Continental is that when the FAA requires an aircraft to a particular fix, it is inevitably a flight that Continental has pre-sequenced that is available first. This improves the efficiency of the departure process for those flights that are pre-sequenced, but, it is argued, reduces the efficiency of the departure process for those flights not pre-sequenced. This is the argument of operators on the airport’s south ramp.



The benefit of pre-sequencing can be examined by comparing the delays of Continental flights and those of other domestic carriers. International flights are ignored as they are given priority by the FAA, and are thus unaffected by pre-sequencing. These delays, for the site visit on June 29, 2000, are presented in Figure 40. This figure shows a running plot of the average departure delays of aircraft waiting to depart from Newark. There is clearly an initial peak in Continental delays from 13:30 to 14:30. Through examination of a running plot of the average arrival delays of Continental aircraft at Newark, the cause of this peak is identified as high arrival delays from 12:30 to 14:30, thought to be induced by the pending implementation of the Severe Weather Avoidance Program (SWAP), which was implemented at 13:00. These high arrival delays were restricted to Continental aircraft only because the other airlines had no flights at this time. The steady climb in average departure delays from 15:00 is not however thought to be because of arrival delays, as the arrival delays at this time were not high. This period instead coincides directly with the most severe fix closures, seen in Figure 31, suggesting that they were a direct result of external constraints. From 17:30 through to 22:00 Continental delays are consistently lower than those of the other domestic carriers. This coincides with the most severe fix restrictions, shown in Figure 31, which is when the Continental pre-sequencing is likely to have its greatest benefits.



**Figure 40.** Running plot of average departure delay of flights waiting to depart from EWR.

### Conclusions and Recommendations

The pre-sequencing employed by Continental does appear to reduce Continental delays when the airport is impacted by adverse weather, but is also suspected to increase the delays of those flights not pre-sequenced. It is thus recommended that the operators on the south ramp cooperate to also pre-sequence flights. This would require the development of a ramp tower for the south ramp, which would need to be coordinated with all the operators on the south ramp. An agreement for a new extended ramp area may also have to be developed with the FAA, and the south ramp tower would then have to coordinate with the Continental ramp tower to further optimize the FAA departure operations.

### **3.2.4 Extended Accommodations of Passengers**

Because of the increase in number and severity of delays in the NAS passenger frustration and aggressive behavior has increased. Since Newark has particularly severe and frequent delays, Continental Airlines has sought to reduce passenger frustration in a number of ways, including:

- Giving higher priority to arrivals, to reduce taxi-in delays. This means however that departures are pushed earlier than they otherwise would, to free up gates for incoming arrivals. Thus although arrival delays are reduced, departures must be pushed back even when they are to be severely delayed in the departure queue. In many instances, it would be better for passengers to remain at the gate.
- Developing the Continental Passenger Recovery (CPR) plan, which sets up procedures for deplaning when arrivals do not have access to a gate. Deplaning is done at the UPS facility on the south ramp, if the arrival lands on runway 22L, and at the Continental de-icing tent if it lands on runway 4R. Passengers are then bused to the terminal. This means that if arrivals are delayed, and it is impossible for a gate to be made available, passengers can still deplane.
- Updating passengers every 15 minutes on the flight status and likely delay length, during gate delays. This keeps passengers informed, and gives them the opportunity to decide against flying if they desire to.
- Introducing plasma screens in the terminals, showing convective weather maps, which allows passengers to see the weather that is causing their delays.
- On location galley and lavatory servicing, watering of animals, and crew changing for severely delayed aircraft holding in parking areas.

Continental is clearly taking a number of steps to minimize the discomfort of delays. This is a very visible gesture to passengers that the airline recognizes that there is a problem with delays and that it is working to solve it.

### **3.2.5 Information Availability**

The Continental ramp tower is equipped with a number of tools to enable it to respond to delays quickly. These include:

- The Integrated Terminal Weather System (ITWS).
- Weather Services International (WSI) weather forecasting.
- Access to ATCT radio frequencies.
- Hotline to the FAA ATCT.
- Access to the Aircraft Communication Addressing and Reporting System (ACARS).



The Continental operations center also has access to information, including:

- Updates on all active ground delay programs.
- Continental managers at Newark are able to listen into the daily strategic planning teleconference between the region's ATC facilities.
- Continental managers are also able to listen into the FAA's full time hotline between the region's ATC facilities operational during heavy system congestion.

The information available to Continental, and specifically in its ramp tower and through the strategic planning teleconference and the hotline during heavy system congestion, have provided Continental with a better understanding of the restrictions impacting the airport, and have thus enabled it to respond to them more efficiently, such as through pre-sequencing of its departures. It is however recommended that the Continental evaluate and then adjust its operational structure to ensure full utilization of the information from these tools.

### **3.3 STRATEGIC RESPONSES TO DELAYS**

Strategic responses by the airlines at Newark airport include:

- Decrease in operations.
- Changes to the Continental fleet.
- Changes to the schedule operated at Newark.
- Changes to Continental's ground operations.
- Improvement of Continental's relationship with the FAA and PANYNJ.
- Development of a relationship between Continental Airlines and Amtrak.
- New Continental facilities at the airport.

#### **3.3.1 Decrease in Operations**

Because Newark airport is not slot controlled, airlines are free to operate as many flights from the airport as desired. Because of "the problem of the commons" however competition leads to over utilization of the airport, and more flights are scheduled than can be efficiently accommodated by the airport. This leads to delays. When an airline dominates an airport however, cooperation to reduce the total number of operations, and thus delays, is easier. Because Continental operates 55% of flights at Newark, the system wide growth in operations has been avoided at Newark, and operations have in fact been reduced. It is clear in Figure 41, which shows total operations at Newark, according to the FAA OPSNET database, that there is a small but steady reduction in operations from 1997 to 2000.

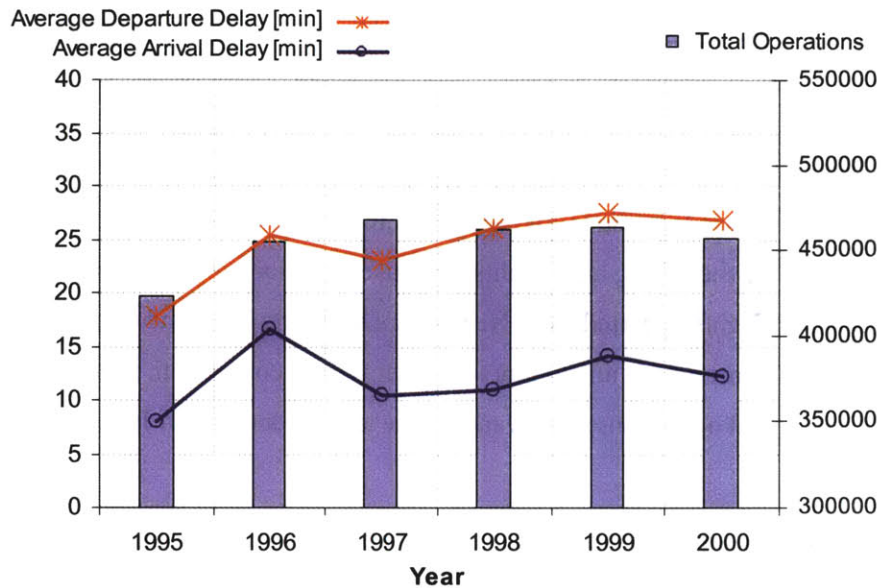


Figure 41. Total Operations at Newark, alongside average arrival and departure delays.

Average arrival and departure delays, plotted alongside the total operations in Figure 41, can be seen to have leveled out since this time, after the peak in delays in 1996 caused by particularly poor weather that year. The response by the airlines to reduce operations has clearly been effective at reducing delays, suggesting that at an airport such as Newark, where a single airline is dominant to a relatively small extent, cooperation is possible without regulation.

### 3.3.2 Continental Fleet Changes

Continental has made a number of changes to its fleet, and because of its hub operations and corresponding dominance at Newark, these changes have had an effect on the airport. The most significant fleet changes made by Continental include:

1. Renewal of the Continental fleet.
2. An increase in the average aircraft size operated through Newark.
3. A conversion from turboprops to regional jets.

#### Renewal of Continental Fleet

The current fleet operated by Continental is very new. 50% of its aircraft operating from Newark on June 28, 2000 were manufactured after 1995, and 88% after 1985. The age of a fleet has a significant effect on maintenance costs, as newer aircraft are more reliable and require less maintenance to keep them airworthy; and on dispatch reliability, which directly impacts the number of mechanical delays. The replacement of older aircraft with new aircraft is however expensive. The decision to re-equip the airline with new aircraft was however described by Louis Farinaccio, Assistant Director of Operations for

Continental Airlines, at Newark, on June 14 and 15, 2001, to be one of the most important strategic changes made.

### Increased Average Aircraft Size

Because of Newark's location in the Northeast, it is well positioned as a gateway to Europe, and is used by Continental for these long haul flights. Because of its location on the east coast, a number of Continental's domestic flights operated from Newark are also long haul, and this has allowed Continental to increase the size of its aircraft, in an attempt to further reduce congestion. Figure 42 shows the average capacity of the Continental operations at Newark for the last Wednesday in June for all years from 1995 to 2001.

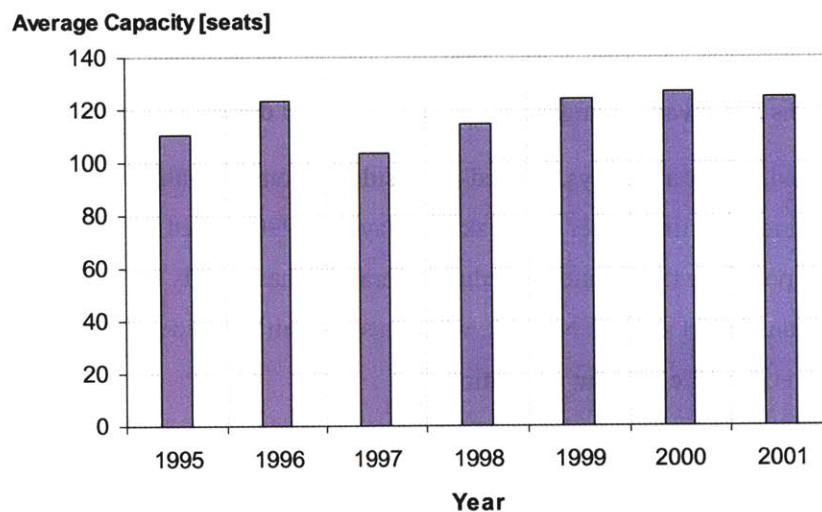


Figure 42. Average capacity of Continental operations at Newark, excluding Turboprops and Regional Jets, last Wednesday in June, 1995 to 2001.

The average capacity decreases in 1997 because the McDonnell Douglas DC-10s operated by Continental were retired that year. The average capacity can then be seen to steadily increase from 154 passengers to an average of over 160 passengers in 2000. Because of the increase in aircraft size fewer flights are offered between specific origin destinations pairs, and it is this reduction that reduces congestion. Passengers do generally however prefer higher frequency because of the reduced connection times and because flights are more likely to be at convenient times. This is not however such a problem with international flights because passengers expect longer connection times and less frequency.

## Conversion from Turboprops to Regional Jets

Turboprops have higher cabin noise than jets, fly significantly slower, and operate at a lower altitude, and thus experience more turbulence. Jets are also perceived by the flying public to be better. In the case of very short haul flights turboprops still appear to have superior economics, but the stage length at which this is no longer the case continues to drop. The result is that there has been a strong trend in the airline industry to convert from turboprops to regional jets. Continental is no exception. Figure 43 shows the percentage of Continental operations at Newark by turboprops and regional jets, for the last Wednesday in June for all years from 1995 to 2001.

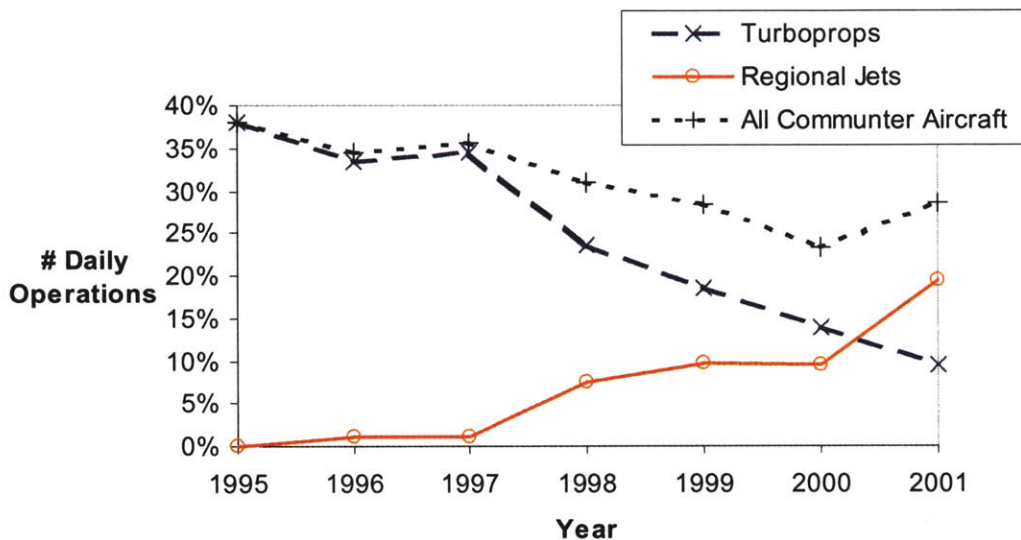


Figure 43. Percentage of Continental operations by Turboprops and Regional Jets at Newark, last Wednesday in June, 1995 to 2001.

Since 1997 there has been a clear decrease in the percentage of turboprops operated, and an increase in the percentage of regional jets operated, suggesting that Continental has been actively replacing turboprops with regional jets since 1997. The percentage of commuter aircraft operated clearly decreases from 1997 to 2000, suggesting a move away from this type of aircraft. However, in 2001 the percentage of commuter operations increases again, significantly, through a large increase in the percentage of regional jets operated. This corresponds to the general industry trend towards more commuter aircraft used on the increased frequency spoke flights from airline hubs. The reason for this is the continually improving range and economics of regional jets.

Although regional jets are attractive to the airlines, because of the performance characteristics of the aircraft their operation at Newark does lead to decreases in the efficiency of certain ATC operations.



These include:

- An increase in the use of the primary parallel runways, and a corresponding decrease in the usage of runway 11-29, because regional jets require more runway for take-off than turboprops.
- Increased arrival and departure separation requirements, which translates into a reduction in airport and airspace capacity.
- Reduced use of LAHSO.
- More departure delays resulting from regional jets competing for high altitude routes out of the New York Metropolitan area.

### 3.3.3 Schedule Changes

One of the most significant airline responses to delays at Newark has been adjustment of their schedules. The most significant changes have been those made by Continental, since 1997, including a change to its banking structure.

#### Schedule De-banking

A traditional airline schedule is designed around banks, which are periods when a high number of flights arrive or depart. These are separated by periods when few flights arrive or depart. Flights are grouped in banks to avoid long layover times for connecting passengers. The system works well when the daily volume of flights through the airport is not close to the airport capacity, as it can be run near capacity during the banks, and well below capacity between banks. Airlines are also able to recover from any delays that occur during a bank by utilizing the excess capacity between the banks. Such a schedule however is ineffective at airports where the banks exceed airport capacity during adverse weather to such an extent that delays cannot be recovered. This was the case at Newark in 1996. Continental airlines thus reduced the degree to which its schedule was banked, as can be seen by comparing the schedule in 1996 and 2001 in Figure 44 and Figure 45. The VFR and IFR capacities are also shown in these figures.

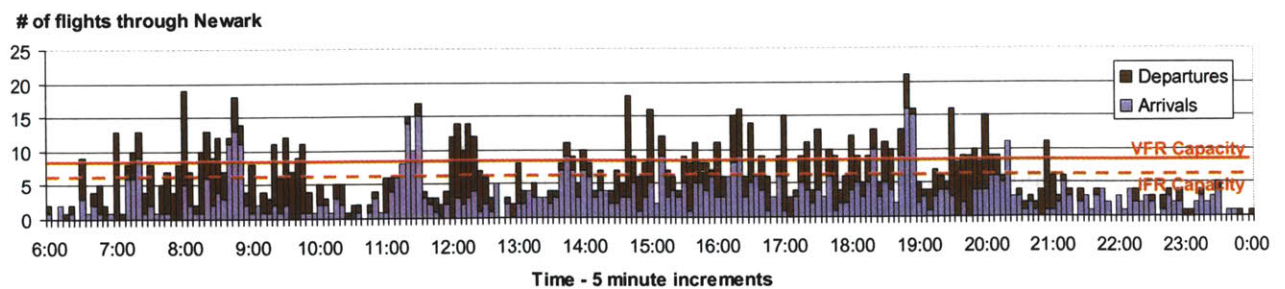


Figure 44. Airport schedule of all airlines operating at Newark, June 26, 1996.



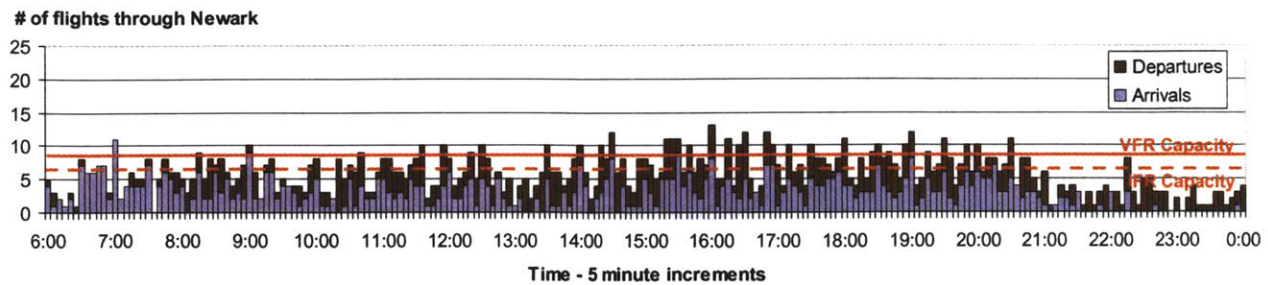


Figure 45. Airport schedule of all airlines operating at Newark, June 27, 2001.

In order to measure the degree to which an airport has a banked structure to its schedule, a metric was developed by Prof. John-Paul Clarke (MIT department of Aeronautics and Astronautics). The basis for the metric is the average number of connecting flights for each arrival throughout the day, per five minute interval, plotted against the time since the arrivals. The plot in Figure 46 shows this for Continental flights on June 26, 1996. The shape of the plot relates directly to the banking structure. A banked structure would show a large number of flights relatively soon after each arrival, decreasing quickly as the time since arrival increases. An un-banked schedule would show a flat plot, with little change in the average number of connecting flights as the time since the arrival increases. Because the drop off in connections is approximately linear, a straight line can be fitted through the data points after the first peak. A more highly banked schedule has a steeper gradient. A metric for the degree to which the schedule is banked can then be defined as the inverse of the magnitude of the gradient of this straight line. This metric represents the number of minutes required for the number of connections to reduce by 1 flight. Thus:

$$Metric_{Banking\ structure} = \frac{1}{|m|}$$

where  $m$  is the gradient of the straight line fitted to the data.

The plots in Figure 46 to Figure 48 show the average number of connecting flights for Continental Airlines, at Newark, for every five minute period plotted against the time since each arrival. A straight line is fitted through a consistent portion of the data, the equation of which is also presented, from which the desired metric for banking structure can be calculated.

The schedule shown in Figure 46, for June 1996, is a highly banked structure, peaking 45 minutes after the arrivals. A second bank is also clear, peaking 3 hours 20 minutes after the arrivals. The period between the banks, which averages a low 1.5 connections per arrival, is 1 hour 35 minutes. This provides a long recovery period between banks. The straight-line curve fit yields a metric of 23.6 minutes per connection.

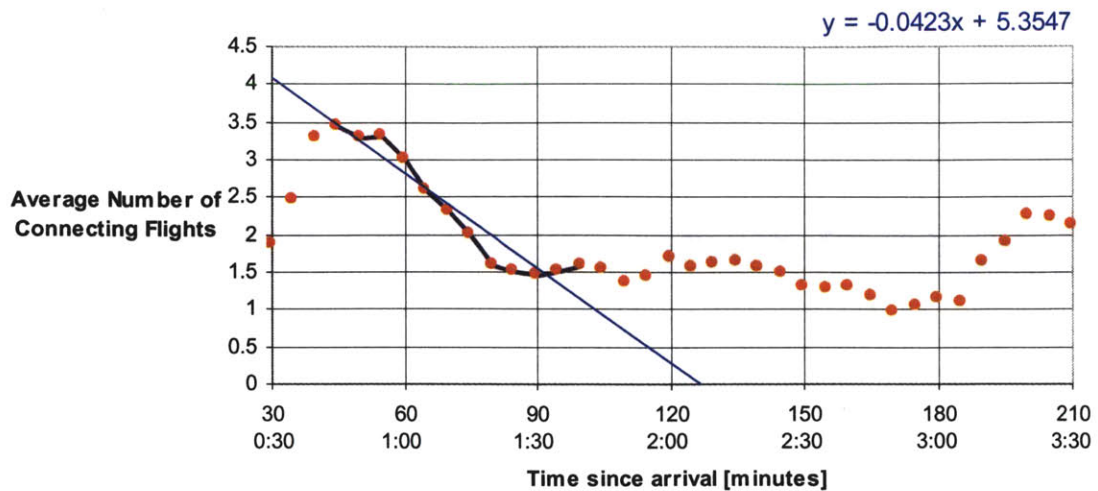


Figure 46. Banking Structure, Continental Airlines at Newark, Wednesday June 26, 1996.

As Figure 47 shows, there is a clear change in the banking structure in 1997. The first bank is no longer clear, nor does there appear to be a second bank. Significantly the straight-line curve fit yields a metric of 52.4 minutes per connection, which is significantly higher than that for 1996. The schedule is clearly flatter and less banked than in the previous year. This is one of the changes instituted after Gordon Bethune became CEO of Continental.

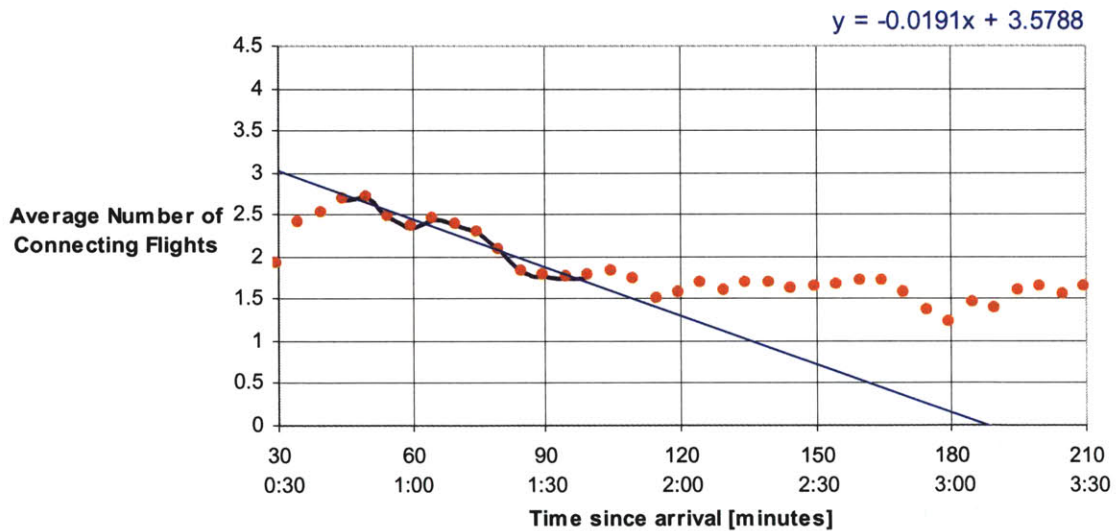


Figure 47. Banking Structure, Continental Airlines at Newark, Wednesday June 25, 1997.

The flattening of the banking structure at Newark continued after 1997, with 1998 yielding a metric of 72.5 minutes per connection, 1999 a metric of 164 minutes per connection, and 2000 a metric of 213 minutes per connection. Figure 48 shows the structure in 2001, with a metric of 222 minutes per connection. The schedule is clearly very flat, with no banks visible.

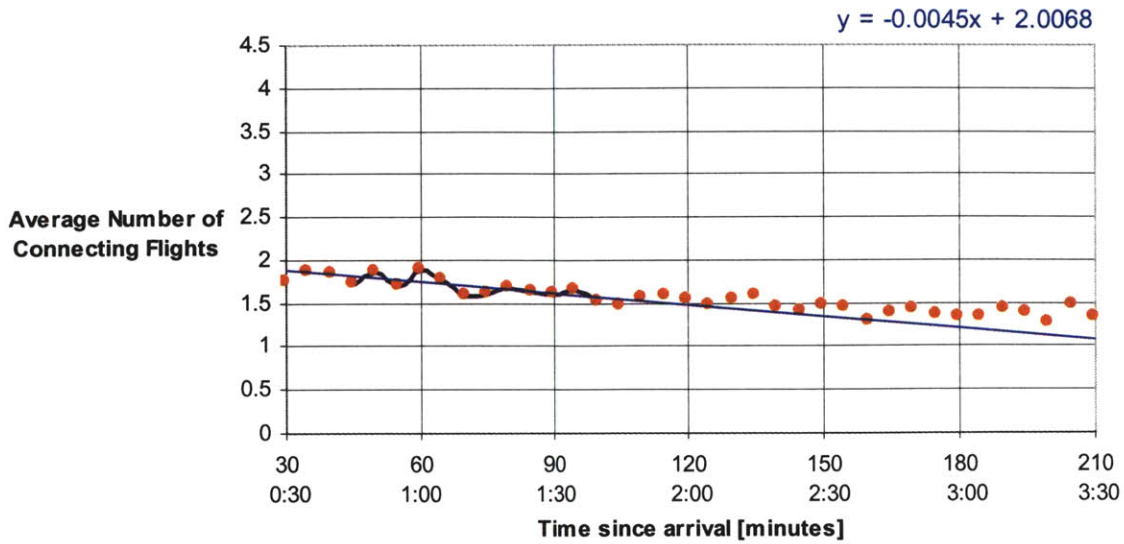


Figure 48. Banking Structure, Continental Airlines at Newark, Wednesday June 27, 2001.

There is a clear change from a highly banked schedule in 1996, to a considerably flatter schedule in 2001. It is also however important to consider other aspects of the schedule operated, such as the number and size of recovery periods. Although this affects the plots presented it is clearer to consider the whole schedule separately. Figure 49 and Figure 50 show the Continental schedules operated at Newark in 1996 and 2001, from 6am to midnight.

Figure 49 shows the schedule in 1996. Arrival and departure banks are clear in the morning, and there are some significant recovery periods. In the afternoon, however, the banking structure is less obvious, although the banks can still be identified. Recovery periods are shorter. Operations only appear to start in earnest at 7:00. The busiest period is in the afternoon and evening, extending from 13:00 to 20:30. Departures appear to effectively end at 21:30, and arrivals at 20:30, although arrivals continue after this time at a low rate, until 23:30.

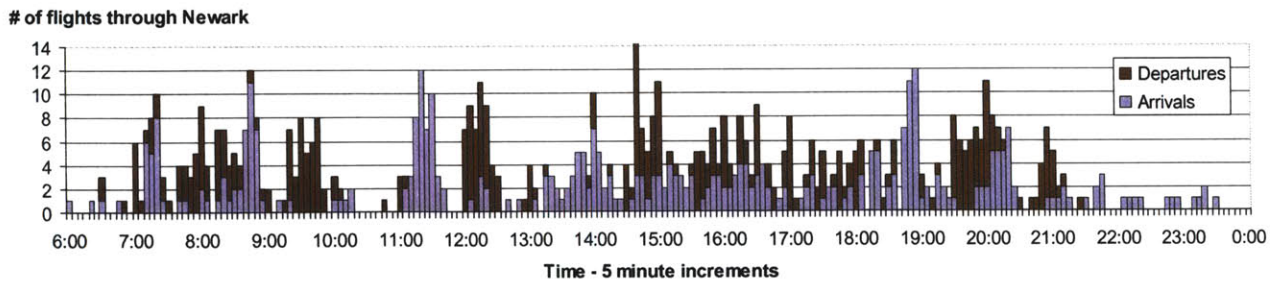


Figure 49. Combined Continental schedule operated at Newark, June 26, 1996.

Figure 50 shows the schedule in 2001. This appears to be very much flatter than that in 1996. No banks are visible and the number of flights remains approximately constant throughout the day. Recovery periods are however still present, although they are few and short. Departures clearly start earlier, before



6:30, although the first arrivals continue to be scheduled after 7:00. The busiest period of the day, although difficult to identify, again appears to be during the afternoon, from 14:00 to 21:00. Departures now end at past 22:00, and arrivals continue to midnight. Continental appears to have thus extended its schedule to utilize the early morning and late evening to a greater extent. Although it is not shown in the data, the first arrivals are at 4:15 in the morning, and the last arrival at 2:30 the next morning. This change was part of Continental's Project Total, in 2001. Other changes were also made in the project, including a change from a weekly schedule to a day-by-day schedule.

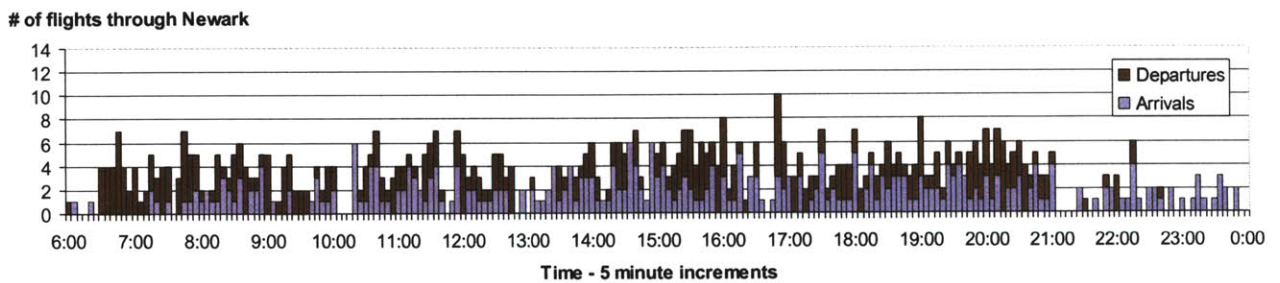


Figure 50. Continental schedule operated at Newark, June 27, 2001.

Considering a complete schedule, including other operators, suggests that most operators have extended their schedules as Continental has done. However, most have not de-banked their schedules to the extent that Continental has.

### Conclusions and Recommendations

Considering the average yearly delays in Figure 41, it is clear that there is a decrease in both arrival and departure delays from 1996 to 1997. Although this decrease is likely to be primarily related to weather, the changes made by Continental, and particularly the change in banking structure, appear to have had an impact on reducing delays. The increase in delays is also slow from 1997 to 2000, which coincides with the continued reduction in the degree of banking within the Continental Newark schedule, and the extension of the schedule into the early morning and late afternoon, suggesting again that the changes made had a positive effect on delays.

Although the flattening of Continental's schedule has reduced the number and duration of recovery periods at Newark, recovery periods have not been removed completely. Some degree of delay recovery is thus still possible during the day. With suitably sized recovery periods, a flat schedule can have lower delays than an equivalent banked schedule, as is demonstrated in this case. However it is recommended that the schedule be modified to optimize the magnitude and duration of the recovery periods, to minimize the accumulation of delays.

### **3.3.4 Ground Operations**

Continental Airlines has also made a number of changes to its ground operations in order to improve the efficiency of operations at the airport, including the introduction of supertugs, for movement of aircraft, and a number of changes to its specialized summer and winter operations.

Supertugs, developed by Douglas, of Birmingham, UK, are specially designed aircraft tugs that are able to perform more complicated maneuvers, are more powerful, and travel faster than traditional tugs. This allows them to operate on taxiways and thus reduces fuel burn. Instead of pulling the aircraft by its nose wheel, supertugs lift the aircraft by the nose wheel, carrying the forward weight of the aircraft. The aircraft is then moved in this lifted position, which is more stable than the traditional tow bar attachment.

Supertugs were introduced at Newark in September 1998. Apart from the improved performance of the tugs, they are simpler to manage and cheaper to operate. This is because of reduced labor requirements, and a separate Continental department dedicated to supertug operation and maintenance. In June 2000, Continental had 8 supertugs at Newark, some of which were operated up to 20 hours per day.

A number of changes were also made to the specialized winter and summer operations. This includes the use of the supertugs and development of the Continental Passenger Recovery (CPR) plan already mentioned in section 3.2.4. A number of changes in de-icing operations were also implemented, including the introduction of new de-icing trucks and the building of a de-icing hanger on the north ramp.

### **3.3.5 Developing of Relationships**

Continental has also further developed its relationship with the FAA and PANYNJ, and has starting to develop a relationship with Amtrak.

#### FAA and PANYNJ

Because the primary constraint at Newark is downstream airspace constraints propagating back to the airport, it is essential for the airlines at the airport not only to improve their operations, but also to improve their relationship with the FAA and PANYNJ.

In recent years Continental Airlines has increased its communications with the FAA and PANYNJ significantly. The FAA ATCT has extensive communication with the Continental ramp tower, particularly when Continental pre-sequence aircraft for the departure queue. Similarly Continental and the FAA cooperate when weather is impacting the airport, via Continental's extended ramp area operations. The conditions of operation are detailed in a letter of agreement between Continental and the FAA.



There is also an ATC desk at the Continental headquarters in Houston, which is dedicated to interacting with the ATCSCC.

The relationship between Continental and FAA was observed on the June 29, 2000, site visit to the airport, when a Continental Airlines flight to John Wayne-Orange County Airport (SNA) was in danger of missing the curfew in place to minimize community noise in Orange County. After discussions between the FAA and Continental the flight was allowed to skip to the front of the departure queue, whilst another Continental aircraft near the front of the queue was required to drop to the back.

### Amtrak

With the increasing congestion at airports, but continuing growth in travel, any conversion from air transport to ground transport would relieve the airspace system of some traffic. Such a conversion is however only feasible for short haul flights, where travel time on the ground is still practical, and of the same order of magnitude of a delayed short haul flight.

Since 1997 Continental Airlines has operated buses between Newark airport and Lehigh Valley International Airport in Allentown, Pennsylvania (ABE); and since May 2000 Continental has started to cancel short haul flights when weather impacts the airport, and transfer the passengers to trains. This reduces delays of higher priority flights.

Because Continental Airlines considers rail transport to be a key component in its future operations from Newark, it has started to develop a relationship with Amtrak. This includes an agreement regarding the transfer of passengers from cancelled flights to Amtrak, and may in the future include a code sharing agreement between the companies, allowing passengers to be scheduled on trains instead of aircraft. Continental envisions a number of short haul destinations, including Hartford and Philadelphia, served only by trains, which would reduce airspace congestion at Newark. This multi-modal approach has already been successful in Europe. For example Air France has a code sharing agreement with French railway company SNCF (Société Nationale des Chemins de fer Français), in which passengers travel from Paris to Brussels by rail, and not air. Air France also serve other destinations by rail.

Continental is in discussion with Amtrak to better accommodate passengers traveling to the airport from Manhattan, by rail. The Newark monorail system has been extended to a new Northeast Corridor train station, making the airport more accessible to passengers coming to the airport by rail. This strategy has also been successful in Europe.

### **3.3.6 New Facilities**

Continental Airlines has also responded to the delays at Newark by further developing its facilities at the airport. The most significant development is of a third concourse in Terminal C, located west of the current Concourse 2. It includes 15 new gates and a new international arrivals facility, which will mean that Continental international arrivals will no longer have to use Terminal B, which currently has the only international arrivals facility at the airport.

Continental is also in the process developing a new cargo facility, a new operations ramp tower, and a number of new hangers. Continental is clearly building a number of new facilities at the airport, and investing a considerable amount of money into its operation there.

## **3.4 CONCLUSIONS AND POLICY IMPLICATIONS**

In 2000 Newark airport had the highest ATC delays in the country, and was second only to LaGuardia in percentage of operations delayed. The cause of delays at Newark was primarily weather, with 84% of arrival delays related in some way to weather. The weather's impact on the airport is related to the sensitivity of the airport to adverse weather and the frequency of adverse weather. Newark also operates a very full, flat schedule, with few recovery periods, and is highly congested, Newark being one of four primary airports in the New York Metroplex. According to a site visit to the airport on June 29, 2000, the primary flow constraint, which leads to the high surface delays at the airport, is downstream airspace capacity limitations.

Airline responses to the delays at Newark are extensive, and include both tactical level responses and strategic level responses.

The key tactical responses to delays are currently the cancellation of low priority flights, and the transfer of the passengers to ground transportation; pre-sequencing of departures by Continental; and improved access to information, which is essential to the success of the other responses. The key strategic responses include changes to the schedule operated at the airport, and particularly flattening out of the banks operated; new aircraft which require less maintenance and have greater dispatch reliability; and improved relations with the FAA and PANYNJ. The development of the relationship with Amtrak and a move to a multi-modal transport system is also seen to be of key importance.

At Newark, Continental Airlines has demonstrated that delays can be reduced through a market response, without further increased regulation. The responses have been extensive and successful, and are thought to be the primary source behind the almost constant level of delays since 1997, despite increases

elsewhere. Regulatory intervention in certain areas may however further reduce delays. This includes pre-sequencing of all departures at the airport, and the operation of regional jets.

Currently Continental alone is pre-sequencing aircraft for the departure queue. Delays would be further reduced if all aircraft at the airport were pre-sequenced. This would require building and operating a ramp tower on the south ramp. This may be complicated because the south ramp is not dominated by any single airline. Since it is likely to benefit all operators, it is likely to receive support, even from Continental, which does operate from terminal A. The PANYNJ may however need to take the lead on the development, because the airlines may need outside coordination to cooperate productively.

Because regional jets are particularly profitable to the airlines that operate them, and because their impact on reducing the efficiency of the airport impacts all airlines at the airport together and not just the regional jet operators, game theory predicts that airlines will continue to convert from turboprops to regional jets. Even Continental, which is dominant at Newark airport, has replaced its turboprops with regional jets, suggesting that its benefits outweigh the costs. It may thus be necessary for the PANYNJ to introduce incentives or penalties. Particularly, incentives could be offered for operating aircraft that are capable of using runway 11-29, for aircraft that have reduced separation requirements, and for aircraft that do not require high altitude slots.

# **CHAPTER 4: EXTENSION TO OTHER AIRPORTS**

## **4.1 INTRODUCTION**

Because ATC and the airlines at Newark airport have responded to delays in a number of ways, growth in delays at the airport has been reduced from nearly 20% in 1997 to close to zero in 2000. This is in contrast to the continuing growth in delays system wide of between 20 and 25%, detailed in Figure 2 in Chapter 1. The lessons learned at Newark may be applicable to other airports, and applied appropriately may thus reduce delays system wide as well. It is thus essential to examine the applicability of the responses to delays at Newark to other airports in the system.

The key conclusion drawn from a site visit to Newark Airport and the New York TRACON on June 29, 2000 was that downstream airspace capacity limitations were a primary flow constraint and the primary cause of surface delays. Downstream constraints however impact all airports, to varying degrees, as downstream constraints are a function of the system operation as well as individual airports operation. Thus, responses at Newark airport that address downstream constraints should be applicable to all airports, to varying degrees. The degree to which these responses may reduce delays is dependent on the degree to which downstream constraints cause delays at each specific airport. Many airports also experience delays caused by local constraints, which are those constraints not related to downstream operations. Some of the responses to local constraints at Newark can also be applied to those airports with similar local constraints.

The cause of delays was thus examined for the 10 most delayed airports in the United States in 2000. This is presented in the sections below, after identification of the stakeholders, and a summary of the key responses to delays at Newark. The corresponding applicability of the responses to each airport is presented alongside the causes of delays at each airport.

## **4.2 STAKEHOLDERS**

The key stakeholders in the problem of airport delays are the airlines operating at the airports; the FAA, which controls the airspace system; and the airport authority, which operates the airport. In the case of Newark the operator is the Port Authority of New York and New Jersey. Through the airlines, the traveling public is also a stakeholder, and is the most directly impacted by airport delays. By extension, since the economy of the United States is supported by air travel, all the people in the United States are also stakeholders, indirectly.

The primary motivation of the airlines is to make money. It is thus essential for them to keep people flying, as this is their primary source of revenue. As delays discourage people from flying, so the airlines lose revenue, whilst maintaining similar costs. This is the primary reason that the airlines try to reduce airport delays. However, a complex interrelationship exists where competition from other airlines at the same airport, and in the same markets, encourages an increase in the frequency of operations at the airport. This generally leads to greater delays.

The basic role of the ATC system in the United States is firstly to prevent collisions between aircraft that fly in the system, and secondly to organize and expedite the safe and orderly flow of air traffic whilst utilizing the airspace as efficiently as possible [12]. These interests do however sometimes lead to opposing requirements. For example, concerning aircraft separation standards, improved flow efficiency would result from decreased separation standards, whilst improved safety would result from increasing separation standards. In these cases safety must be satisfied first.

The interest of the airport authority is also a balance between safe and orderly flow of air traffic utilizing the airport, and recovering revenue from the airport operations, which includes airside fees, landside fees, and terminal revenue through sales.

## **4.3 RESPONSES TO DELAYS**

Responses to airport delays are either market driven, or regulatory. Because the airline industry has been deregulated since 1978, airline responses to delays are mostly market driven. However, because ATC in the United States continues to be governed by the DOT, through the FAA, ATC responses are through regulation.

Many of the responses to date have been market driven. This is because business economics requires the airlines to react to delays. This forces the airlines to overcome the bureaucracy behind decision-making faster than is required of government agencies, which are not driven by the same business economics. The majority of these market driven responses have however been small and have



resulted in only small delay reductions. These responses have been limited because the nature of the system is such that market driven responses are only viable at airports that are dominated by a single airline. The industry is highly competitive, and because most airports are unrestricted, they are unlimited resources to all airlines that choose to operate there. This means that if any carrier reduces its operations, other carriers will increase their operations to take advantage of the newly available capacity. Many attempts to reduce delays individually are thus ineffective and uncompetitive. Any attempt to reduce competition on routes, specifically by merging airlines, has also generally been opposed by government anti-trust action. Market driven responses thus appear to be limited in their ability to reduce delays, unless anti-trust laws within the airline industry are relaxed.

Regulatory responses to delays have been limited to date, although some significant responses are under development. This includes a redesign of the airspace and demand management strategies, including peak hour pricing. These may take time to be implemented, but are likely to be the most effective at reducing delays.

The responses to delays identified at Newark are summarized below.

### **4.3.1 Key Responses to Delays at Newark**

#### ATC Responses

ATC responses to the delays at Newark have been both tactical and strategic. The standard tactical response, which is utilized throughout the NAS, is the application of restrictions and reroutes. Restrictions are implemented not only because of local weather, but also because of downstream weather and traffic demand through the departure fixes.

Dynamic re-routing is difficult throughout the NAS because all the impacted facilities must be in agreement before a re-route is approved. Dynamic re-routing is however particularly difficult in regions of high airspace congestion, because the facilities involved have less flexibility. The development of a set of preplanned reroutes for specific fix and jet-route closures would thus be most effective at reducing delays in these regions of high airspace congestion. The National Playbook is such a document, but currently focuses predominantly on operations in New York.

Decisions aiding tools, such as DSP and ITWS, have recently been implemented at Newark and its associated ATC facilities. DSP is used predominantly for communication, and would thus be most useful at facilities that suffer from high airspace congestion and require streamlined communication. ITWS however helps decision-making regarding application of restrictions, and would thus be useful for implementation at any facilities that are highly impacted by weather. The general implementation of

decision adding tools is likely to see most benefits from facilities with high airspace congestion, because it would reduce controller workload, and improve the efficiency of operations.

Improved inter-facility communication and further centralization of authority to the ATCSCC would reduce the ambiguity of the organizational structure and correspondingly reduce delays at Newark. This would improve operations throughout the NAS, but like further development of the National Playbook, would be most effective at reducing delays in those regions with high airspace congestion.

Increased utilization of runway 11-29 through the New York airspace redesign would also reduce delays at Newark. This is a local response, and a similar response could be applied to other airports with underutilized runways. The reasons for a runways under-utilization are however highly local.

Strategic responses to delays in the system include the formation of the ATCSCC, which is a system wide response, and the redesign of the New York airspace. The New York airspace redesign, part of the FAA's National Airspace System Operational Evolution Plan, is a top priority to alleviate congestion at the New York airports. Other similar programs within the National Airspace System Operational Evolution Plan focus on other regions with high airspace congestion. These responses are likely to have the greatest impact on reducing delays system wide.

### Airline Responses

Airline responses to the delays at Newark have also been both tactical and strategic. A key tactical airline response to delays at Newark is the cancellation of low priority flights to reduce delays on higher priority flights. Passengers from the cancelled flights are sent to their destinations by other modes of transportation. This response is likely to be effective only at airports that suffer from particularly high delays; at which a single airline is dominant; and from which short haul flights are served efficiently by other modes of transportation.

Continental Airlines also pre-sequences departures in order to reduce delays at Newark. Because other airlines are not able to pre-sequence their departures, Continental delays are reduced in comparison to the other carriers. Without regulation, this response can only be applied by airlines with airport dominance, and control of extensive ramp area. However, if the airport or FAA regulated pre-sequencing, this response could reduce delays at any airport that has appropriate taxiway configurations to allow it.

Continental has also responded to delays by taking steps to improve information availability to passengers and to ramp controllers. Although improved information availability to passengers does not reduce delays, it does allow the delays to be better understood and thus more readily accepted. This response would be effective at any airport suffering from severe delays. Improved information availability to the Continental ramp tower includes operation of the ITWS and WSI weather information

systems in the ramp tower, and a direct hotline with the FAA ATCT, which allows improved tactical response to delays. This is essential to the success of all other responses, and is applicable to any airport in which the airlines play a significant role in ramp and taxi operations.

A key strategic response to delays at Newark is a reduction in the growth of operations at the airport. This response is likely to limit the growth of delays significantly, but at airports without a single highly dominant airline is only really possible through regulation, because demand, and thus competition, will continue to grow. This response is more important at airports that are limited in their potential to increase in capacity because of environmental or community constraints, such as at Newark.

Continental also operates a very new fleet, which reduces maintenance delays and improves dispatch reliability. Continental has also increased the size of the aircraft operating from Newark, increasing capacity without increasing operations. Introduction of a new fleet can be implemented by any airline, but requires high capital investment. An increase in the average size of the aircraft operated from an airport, however, affects the entire system operated by the airline. Continental operates Newark as an international hub, which gains from an increase in the average aircraft size. This response must therefore be matched to the airline's operations at the airport.

Changes to the schedule operated by Continental, particularly the flattening out of the banks operated at the airport, is significant and reduces delays resulting from the banks operating well beyond capacity. Average connecting times for passengers are however increased. Because Continental is using Newark as an international hub this is not a problem. This response is thus only likely to reduce delays at airports that operate banks well beyond capacity, and are not able to recover the delays between banks. The response is also only really acceptable at international hubs, because of the increased connecting times. Continental has however also extended the schedule earlier into the morning and later in the night. This response is applicable to any airport, although is dependent on time zones and the number of transcontinental and transatlantic flights operated, and is limited at airports with noise curfews.

Continental has also improved ground operations including the operation of super-tugs and new de-icing equipment. Super-tugs particularly improve taxi operations, and could be utilized effectively at any airport by airlines requiring extensive taxi operations.

Finally Continental continues to develop its relationship with the FAA and PANYNJ. Such improved relations would be beneficial to any airport, but particularly those with confined taxi operations. Continental has also started to develop a relationship with Amtrak, and is moving towards development of a multi-modal transportation system. Development of the relationship with Amtrak and a move to a multi-modal transport system is seen to be of key importance for the future. A move towards a

multi-modal transportation system is again only likely to be effective at airports from which short haul flights are served efficiently by other modes of transportation

The specific applicability of the above responses to the 10 most delayed airports in the United States is presented in section 4.4 below.

#### 4.4 EXTENSION TO OTHER AIRPORTS

The 10 airports with the highest number of delays in 2000 were as follows:

1. LaGuardia (61,120 delays)
2. Chicago O'Hare (57,545 delays)
3. Newark (37,132 delays)
4. Atlanta (28,229 delays)
5. San Francisco (24,478 delays)
6. Boston (24,120 delays)
7. Philadelphia (21,521 delays)
8. Dallas/Ft. Worth (20,638 delays)
9. Los Angeles (17,141 delays)
10. Phoenix (14,024 delays)

The significance of the delays at these airports is dependent on the number of operations at the airports. The chart in Figure 51 shows the percentage of operations delayed in 2000. The average is that of the 31 busiest airports in the United States. Clearly all have a higher percentage of operations delayed than the average.

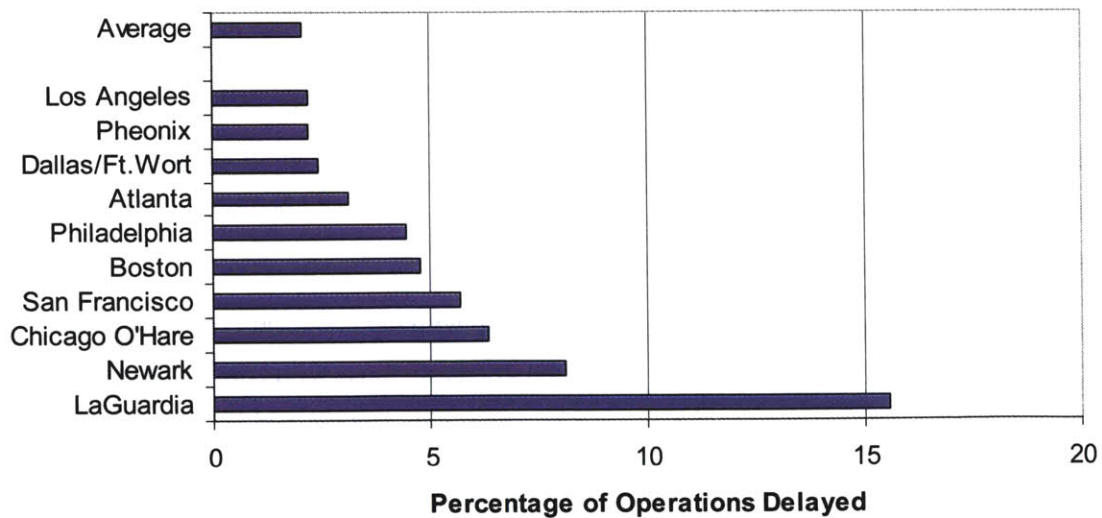


Figure 51. Percentage of operations delayed for 15 most delayed airports in the US, 2000 [3]

The increase in delays over the year preceding 2000 is presented in Figure 52. The increases in the percentage of flights delayed at Chicago O’Hare, San Francisco, Dallas/Ft. Worth, Philadelphia, Boston, Los Angeles and LaGuardia are all greater than 15%, which is a significant increase over a single year. The increases at Newark and Phoenix are significantly lower, below 5%. At Atlanta the percentage of flights delayed has decreased.

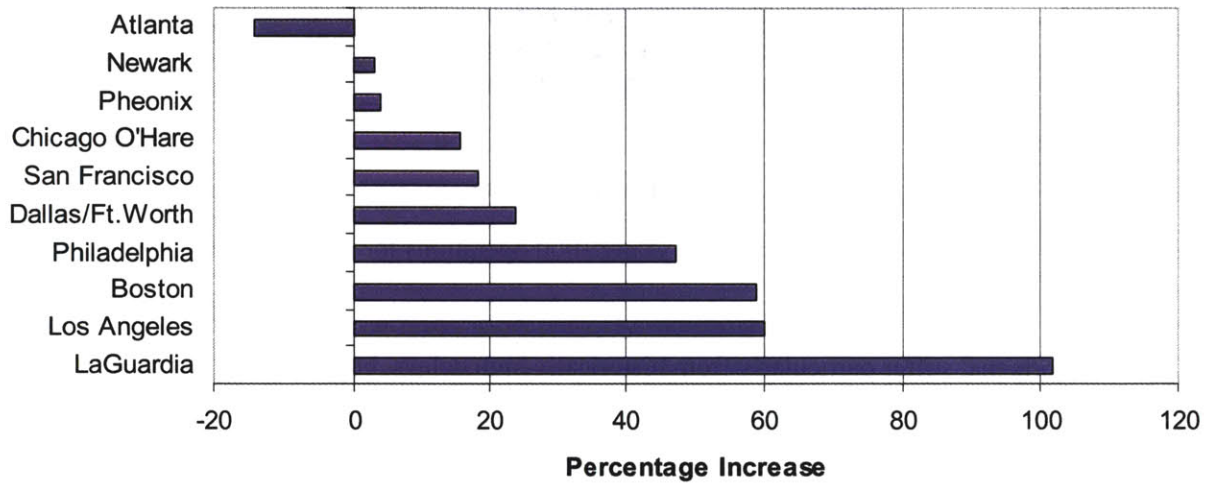
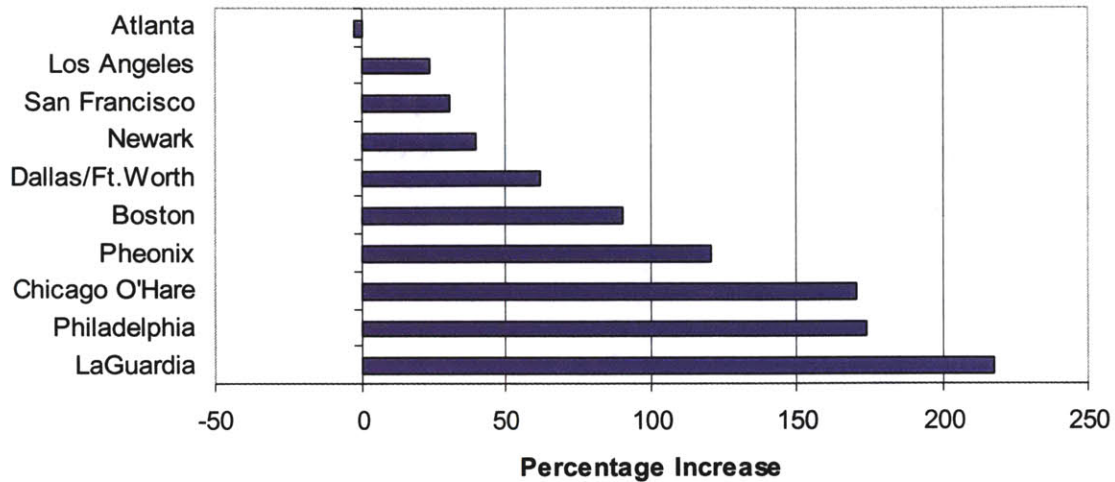


Figure 52. Percentage increase in number of delays per 1000 operations for the 15 most delayed airports in the US, 1999 to 2000.

The increases in delays from 1997 to 2000 are presented in Figure 53. This chart shows the trend in delays at the airports over the last 4 years, and thus provides a better indication of the long-term increases in delays at the airports. Atlanta shows a decrease in operations, whilst all the other airports show increases in percentage delays greater than 20%. The greatest increases are for Chicago O’Hare, Philadelphia and LaGuardia, which are all above 150%. Phoenix had an increase greater than 100%.





**Figure 53.** Percentage increase in number of delays per 1000 operations for the 15 most delayed airports in the US, 1997 to 2000.

The airports that suffer particularly from historically high delays, but have not increased significantly in the four years preceding 2001 are Newark and San Francisco. Airports that had significant increases in delays in the 4 years preceding 2001, but little in 2000 were Chicago O'Hare and Phoenix. Delays at LaGuardia, Philadelphia, and Boston also increased significantly in the 4 years preceding 2001, but continued to show high increases in delays in 2000 as well. Los Angeles however showed only recent high increases in delays, in 2000, and not in the 4 years prior to this. Atlanta showed decreases over the 4 years prior to 2001, and in 2000 specifically.

### Causes of Delays

Weather is the source of 68.7% of arrivals delays, system wide [6]. The cause of weather delays, however, is related to the decrease in capacity at an airport resulting from adverse weather, the frequency of adverse weather at the airport, the schedule operated at the airport, and local airspace congestion.

Figure 54 shows the average capacity drop resulting from adverse weather, at the 10 most delayed airports in the United States. The chart plots the difference between average VFR and IFR capacities, according to the FAA Airport Capacity Benchmark report [9]. The average is that of the 31 busiest airports in the country. Figure 55 then shows the frequency of adverse weather at the airports, showing percentage of IFR operations at the same airports, during June 2000. Again the average is that of the 31 busiest airports in the country. It is important to consider both the capacity reduction and the frequency of the weather. Phoenix for example has the highest reduction in capacity induced by adverse weather, but the lowest frequency of that adverse weather.

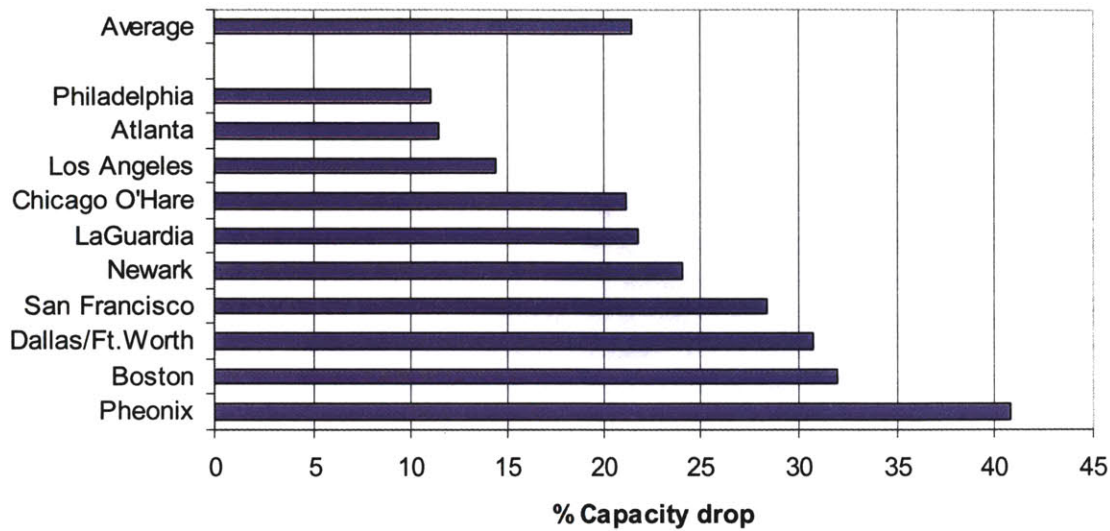


Figure 54. Average airport capacity drop, in percentage, caused by adverse weather.

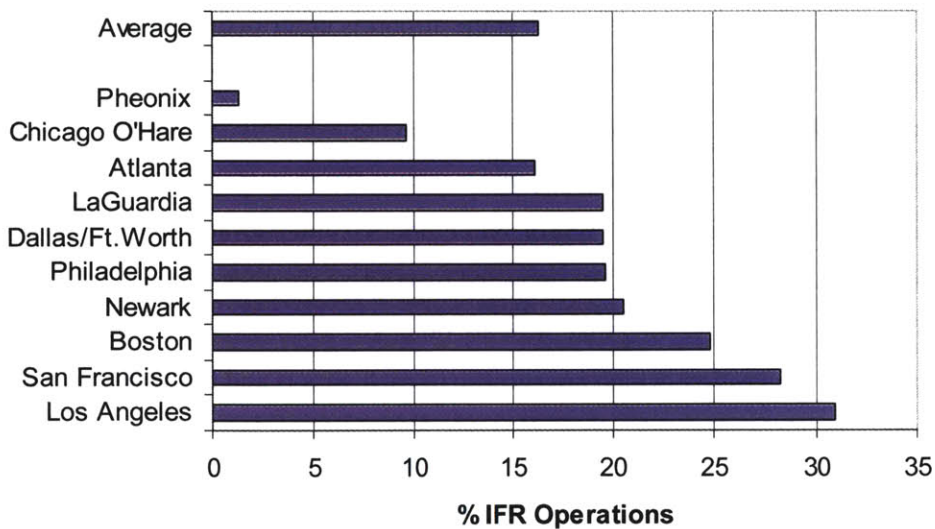


Figure 55. Percentage of IFR operations, June 2000.

Multiplying the results of the two charts in Figure 54 and Figure 55, and then dividing by the average of the 31 busiest airports in the country, yields a metric to describe the impact of adverse weather on the airports, which is shown in Figure 56. As can be seen the most impacted airports are San Francisco, Boston, and Dallas/Ft. Worth, which are all greater than 150% of the average. LaGuardia, Los Angeles and Newark are also more impacted than the average. Phoenix, Atlanta, Chicago O'Hare, and Philadelphia are all impacted to a lesser degree than the average.

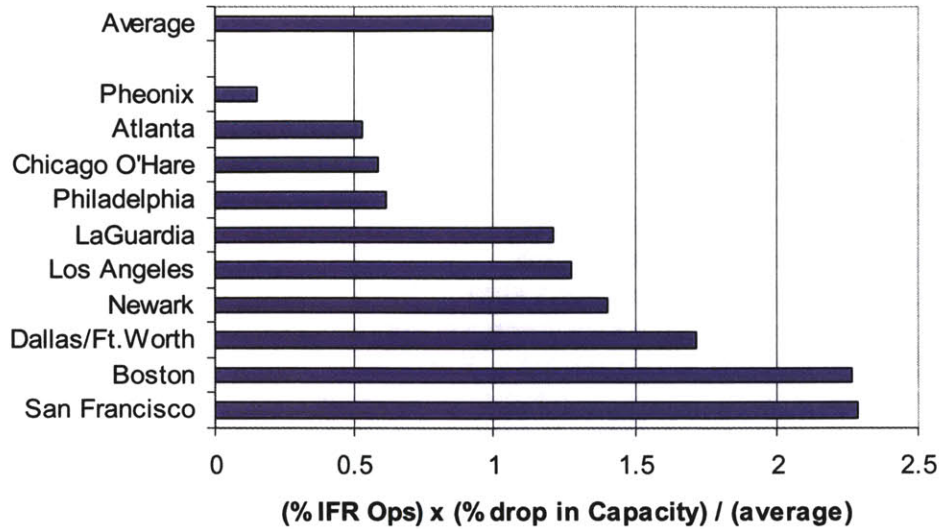


Figure 56. Impact of weather on the airport – product of percentage capacity drop and percentage frequency of weather on airports, normalized relative to the average, June 2000.

The impact of the schedule on the operations at the airport is described in the chart in Figure 57, which shows the percentage of operations above VFR capacity, in August 2000, according to the Air Transport Association [6]. Data for Phoenix and LaGuardia was not available. Although Chicago O'Hare and Atlanta have a high percentage of operations beyond capacity, the impact of adverse weather on the airport is not as significant. Boston, Dallas/Ft. Worth, San Francisco and Newark on the other hand have few operations beyond capacity, but are the most impacted by adverse weather. These airports are also some of the most delayed airports suggesting that there are other key factors affecting delays. These include airspace and surface congestion, which are specific to each airport and to the banking structure operated at the airports.

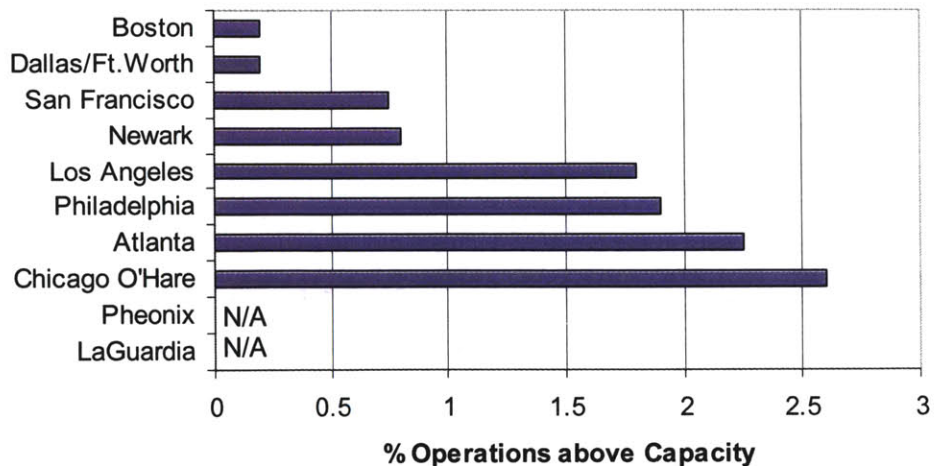


Figure 57. Percentage of Operations above VFR Capacity, August 2000.



Figure 58 shows an indication of the congestion problems at airports around the United States. This chart was developed by MITRE/CAASD [23] through observations at the airports, and shows which airports suffer from airspace congestion, surface congestion, or both. As can be seen in the figure, the New York and Washington areas show particular problems with both airspace and surface congestion, as do some other regions. Figure 59 shows average ATC departure delays in 2000, compared to that of the average airport, as reported by the ATA [6]. The data for Dallas/Ft. Worth, Los Angeles and Phoenix was unavailable. As the figure shows, average departure delays are highest at LaGuardia, Newark and Philadelphia, all of which are in the New York Metroplex. ATC departure delays relate to both airspace and surface congestion.

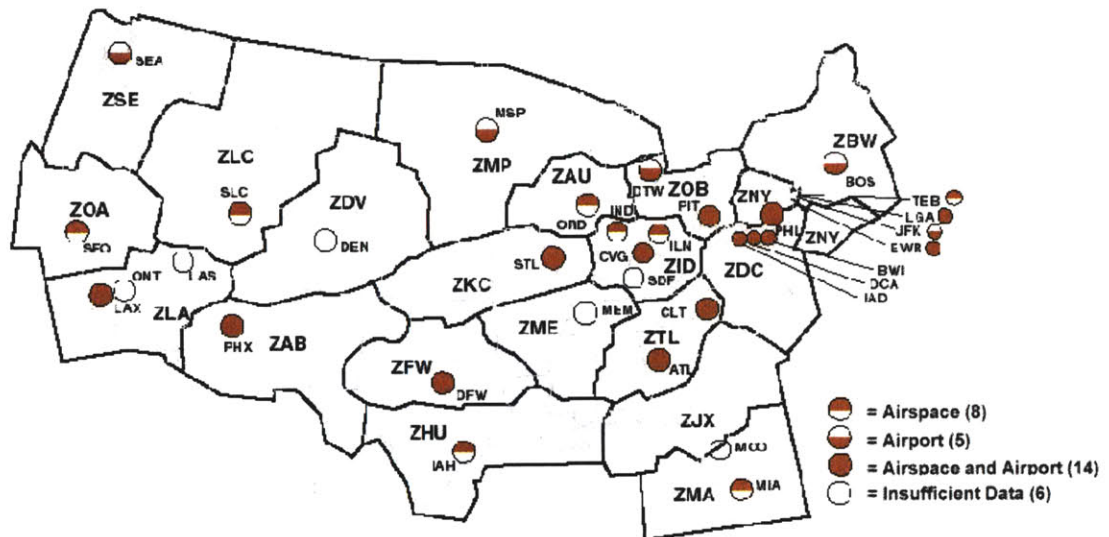


Figure 58. Airspace and surface congestion in the United States [23].

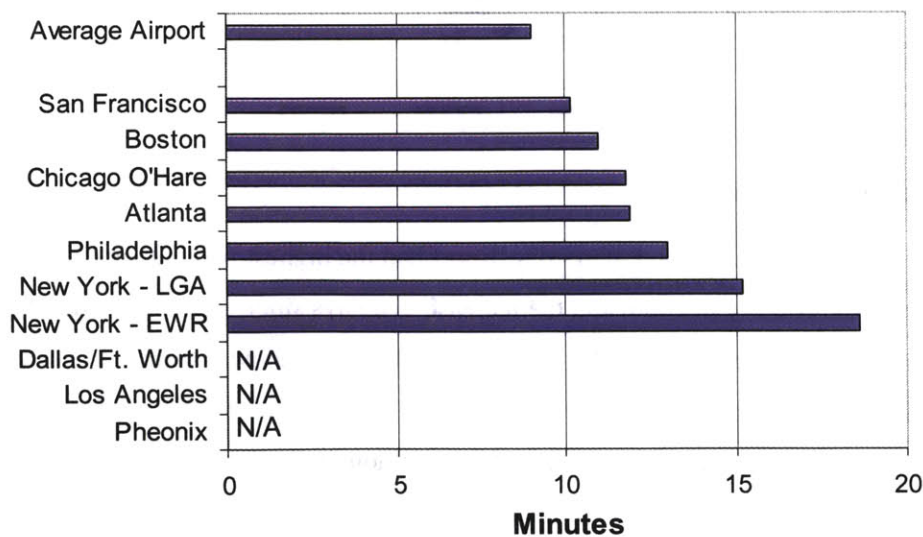


Figure 59. Average ATC departure delays, 2000 [6].

Specific consideration of the nature of the delays at each airport and of the responses identified at Newark airport, enable recommendations to be made for extension of the lessons learned at Newark to other airports. Such discussions follow in section 4.4.1 below.

#### 4.4.1 Application to Specific Airports

Below is a discussion of the causes of delays and the most appropriate responses to delays at the 10 most delayed airports in the United States. An airport map is presented with each airport, with the blue runways representing possible future runway developments at the airport. The arrow on each figure points to North, and a scale is included with each figure.

##### New York LaGuardia (LGA)

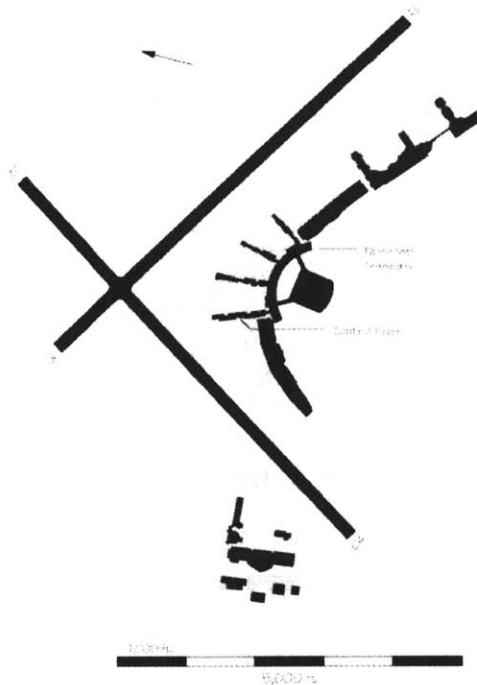


Figure 60. Airport diagram of LaGuardia airport (LGA) [24].

As presented earlier in section 4.4, LaGuardia airport had the highest percentage of operations delayed of any airport in the country in 2000, and the increase in delays since 1999, and since 1997, were also the highest of any airport in the country. The increase in delays in 1999 was primarily because of the lifting of slot restrictions on regional jet flights to small markets as mandated by the Air 21 legislation [4]. In response a number of new operations were introduced without any corresponding increase in capacity, resulting in severe delays. This legislation has since been reintroduced, in a different form, so delays are not likely to increase as much in 2001.



The weather impact metric, shown in Figure 56, is just above average for LaGuardia, suggesting that although weather is a factor, there are also other factors that are causing the delays at the airport. According to the study by MITRE CAASD shown in Figure 58 [23] both airspace and surface congestion are primary causes of delays at LaGuardia. ATC departure delays at LaGuardia were also very high in 2000, as shown in Figure 59, suggesting that many of the delays at the airport are related to air traffic control.

The schedule operated at LaGuardia is shown in Figure 61, with the VFR and IFR capacities superimposed. As can be seen although the majority of the demand is below capacity, demand peaks beyond even VFR capacity every half hour. Recovery periods, especially during IFR conditions, are also small. The banking structure, shown in Figure 62, is fairly flat, except for the effect of the high number of flights scheduled on the hour and half hour. A banking metric, which measures the average time for the number of connections available to reduce by one, is 256 minutes (4 hours 16 minutes) per connection. This is high, indicating a fairly un-banked schedule. This is not surprising given the O-D nature of traffic in and out of LaGuardia.

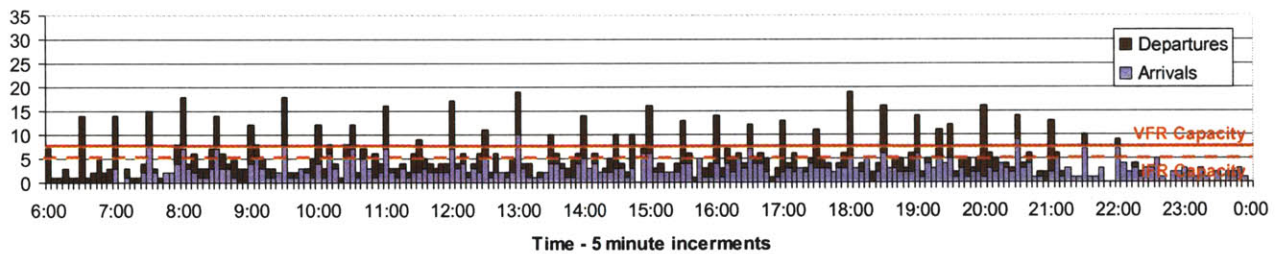


Figure 61. Schedule operated at LaGuardia, June 28, 2000.

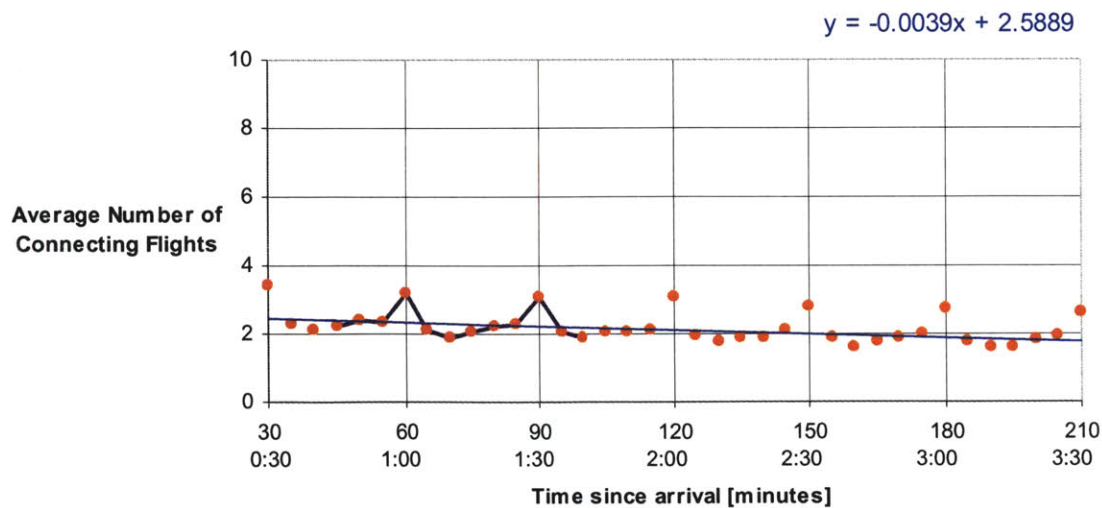


Figure 62. Banking structure operated at LaGuardia, June 82, 2000.

US Airways operates the most flights at LaGuardia with 41% of the scheduled operations at the airport. American Airlines is second with 17.2%. Thus although the airport is not dominated by any one airline, US Airways does have the most operations by a significant margin.

### *Recommended Responses*

Because LaGuardia suffers from high delays and the schedule is very full, a reduction in the number of operations is recommended. Because a single carrier does not dominate, however, regulatory action is likely to be required to accomplish this. Regulatory responses such as peak hour pricing or other forms of demand management are recommended. With high ATC delays, improvement of ATC operations, through implementation of decision aiding tools, is also suggested, although in many cases it has already been applied. Like Newark the greatest benefit is likely to come from the New York airspace redesign.

Because of the lack of a single dominant carrier cancellation of low priority flights, to decrease delays on high priority flights, is likely to be difficult. It would however be likely to reduce delays. Similarly pre-sequencing departures according to fixes and fix restrictions would also be likely to reduce delays, but may require regulation because of the lack of a dominant carrier. A move to a multi-modal transportation system may also reduce delays, and is particularly applicable to LaGuardia because of the airports location in a large city in the North East, near to a number of other large cities. LaGuardia is also a domestic airport and is thus likely to operate a high number of short haul flights.

## Chicago O'Hare (ORD)

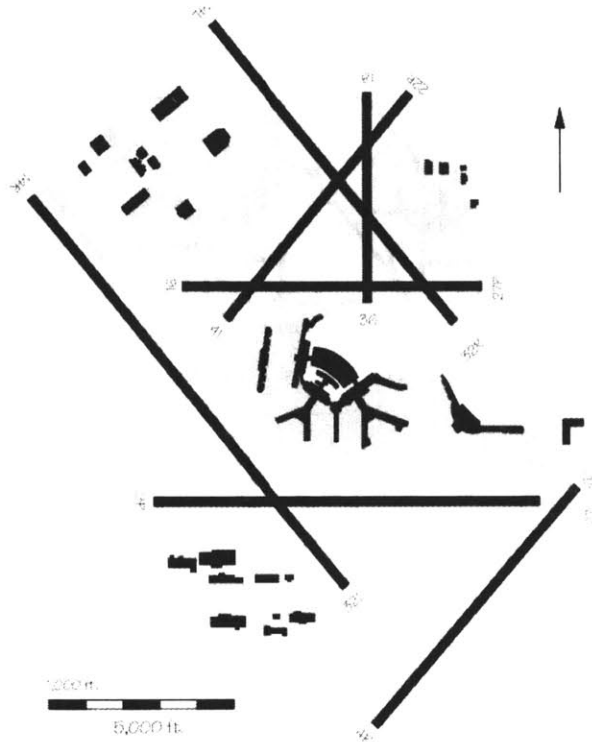


Figure 63. Airport diagram of Chicago O'Hare International Airport (ORD) [24].

As presented earlier in section 4.4, in 2000 Chicago O'Hare had a high percentage of operations delayed in comparison to the average. Also, whilst the increase in delays since 1999 was fairly small, the increase since 1997 was particularly high. The growth in delays at Chicago O'Hare has thus been reduced over the last year, suggesting that positive steps have been taken to reduce delays at the airport.

The weather impact metric for Chicago O'Hare, shown in Figure 56, is below the average, suggesting that delays at the airport are primarily caused by other factors. According to the study by MITRE CAASD shown in Figure 58 [23] airspace congestion is a primary cause of delays at Chicago O'Hare. This is supported by the fact that the average ATC departure delay, shown in Figure 59, was also higher than that of the average airport, in 2000, suggesting that many of the delays at the airport are related to air traffic control.

The schedule operated at Chicago O'Hare is shown in Figure 64, with the VFR and IFR capacities superimposed. As can be seen, although the majority of the demand is below capacity, there are a number of times at which demand is above even VFR capacity, and many cases where demand is above IFR capacity. As presented in Figure 57 Chicago O'Hare has a high number of operations above capacity. Chicago is slot controlled, however, so the number of operations is limited by regulation.

Recovery periods are also small. The banking structure, shown in Figure 65, is fairly flat, but does show a small degree of oscillation. This indicates some banking, which is supported by the banking metric, which is relatively low at 26.8 minutes per connection.

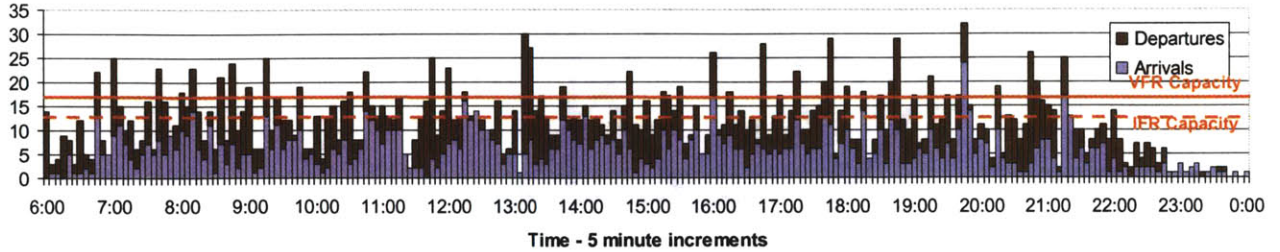


Figure 64. Schedule operated at Chicago O'Hare, June 28, 2000.

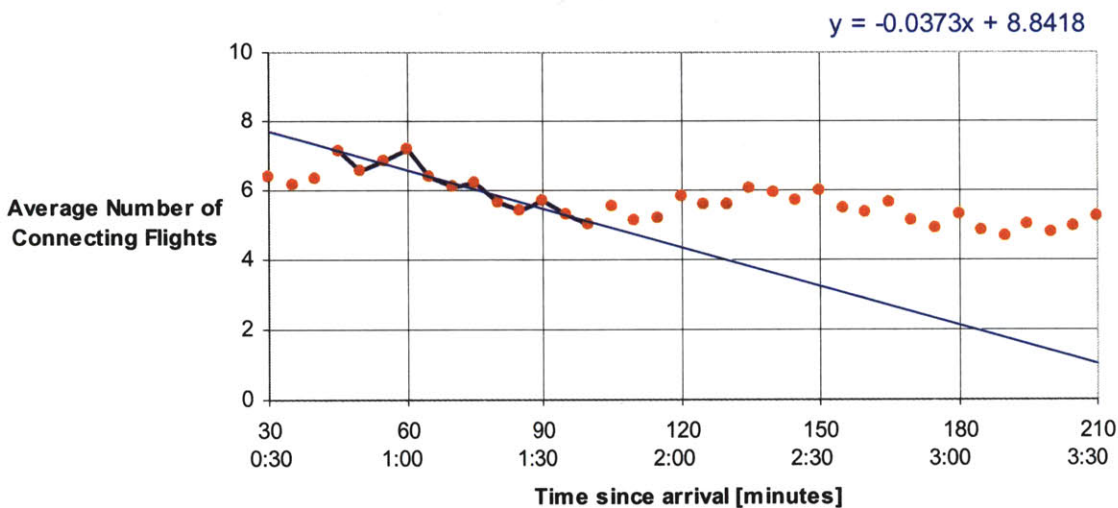


Figure 65. Banking structure operated at Chicago O'Hare, June 82, 2000.

United Airline operates the most flights at Chicago O'Hare with 49.5% of scheduled operations. American Airlines is second with 34.3%. Thus no single carrier dominates the airport, even though both United and American have a high percentage of operations.

*Recommended Responses*

As ATC is a significant cause of delays at the airport extension of the National Playbook to also focus on Chicago may increase the utilizations of re-routes, and thus reduce delays. Similarly increased use of decision aiding tools may reduce controller workload and improve the efficiency of ATC operations, and thus reduce delays. Because a single carrier does not dominate the airport, pre-sequencing of departures is likely to be difficult to coordinate, short of regulation. Because of the high airspace congestion, however, pre-sequencing of departures may reduce delays very successfully. The introduction of regulation to implement pre-sequencing of departures may be easier at Chicago O'Hare

than at other airports, as the airport is already regulated with slot control. A decrease in operations may also reduce delays. This would require reduction of the number of slots available, which is likely to be difficult because of the politics associated with slot control.

### Atlanta (ATL)

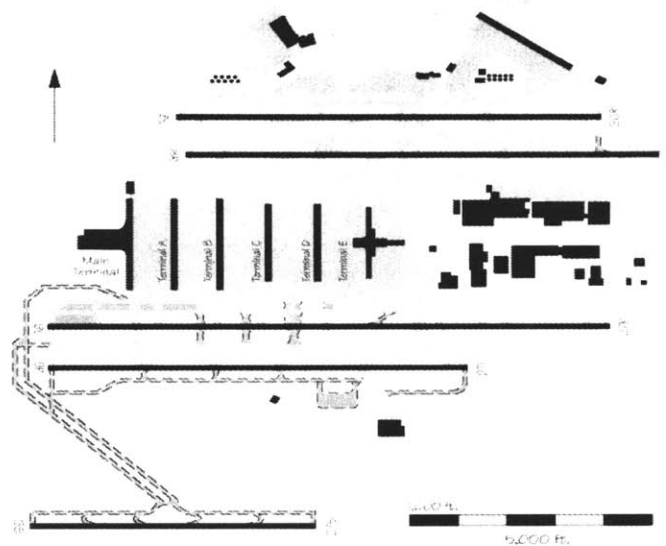


Figure 66. Airport diagram of the William B. Hartsfield Atlanta International Airport (ATL) [24].

As presented earlier in section 4.4, delays at Atlanta airport in 2000 were above average. However, the airport had shown a significant decrease in delays since 1999, and a small decrease since 1997. This suggests that changes have been made at Atlanta since 1997 that have been very successful.

According to Figure 56 the weather impact metric at Atlanta is below average, suggesting that other factors cause the majority of the delays at the airport. Specifically, according to the study by MITRE CAASD shown in Figure 58 [23], both airspace and surface congestion are primary causes of these delays. The average ATC departure delays, as shown Figure 59, was also higher than that of the average airport in 2000, suggesting that some amount of the airspace and surface congestion is related to ATC.

The schedule operated at Atlanta is shown in Figure 67, with the VFR and IFR capacities superimposed. As can be seen, although the majority of the demand is below capacity, the departure banks extend above both VFR and IFR capacity in many instances. According to Figure 57 a high number of operations at Atlanta in August 2000 were above capacity, suggesting that the schedule is one of the primary causes of delays at the airport. There are still a number of recovery periods present, although many are not long. The banking structure, shown in Figure 68, oscillates significantly,



suggesting a highly banked schedule. This is also supported by the banking metric of only 14.0 minutes per connection.

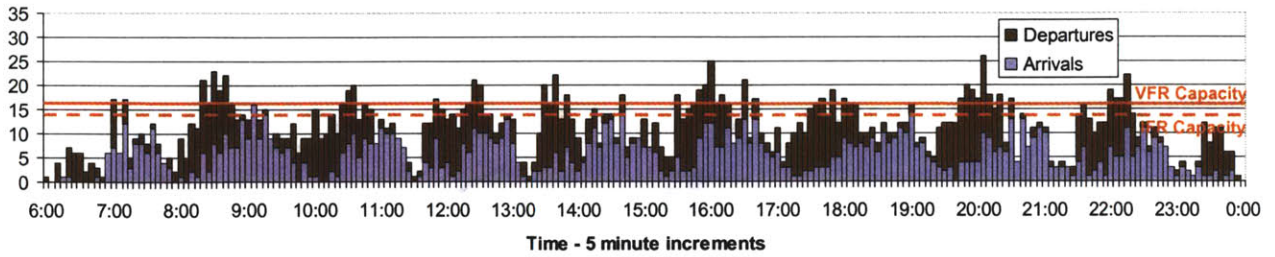


Figure 67. Schedule operated at Atlanta, June 28, 2000.

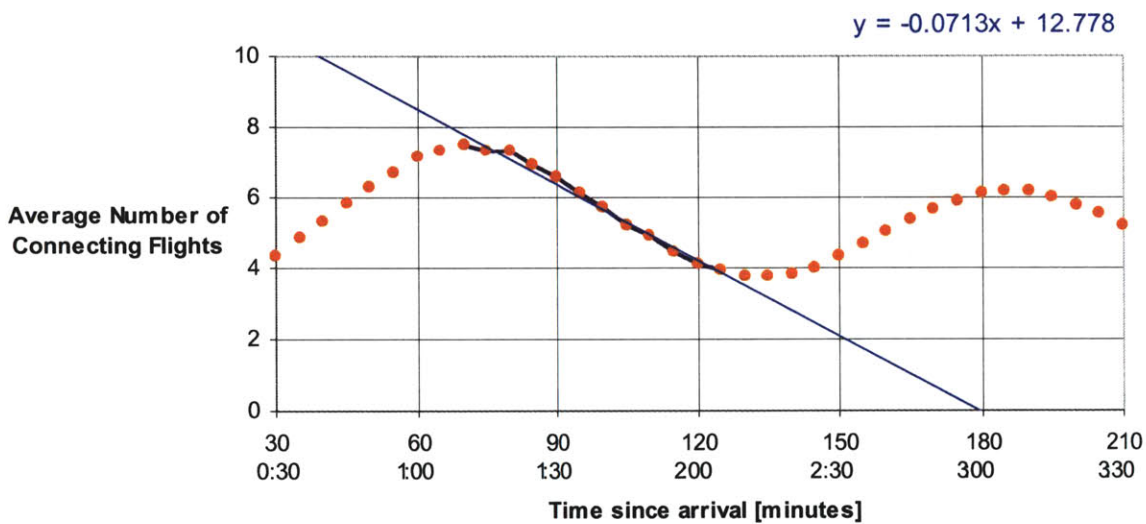


Figure 68. Banking structure operated at Atlanta, June 82, 2000.

Delta Airline is the dominant carrier by a significant margin, operating 65.6% of scheduled operations at the airport, with Airtran second, operating 9.2% of operations. No other carrier operates more than 4% of operations. Thus Atlanta is heavily dominated by a single airline, Delta.

*Recommended Responses*

Because the airport is impacted by ATC related delays, the extension of the National Playbook to also focus on Atlanta may reduce delays by providing pre-planned re-routes. However, weather is not as significant a problem at Atlanta as at Newark. The National Playbook is thus likely to be less effective at reducing delays than at Newark. Increased usage of decision aiding tools by ATC, such as the Dynamic Spacing Program (DSP), is also likely to reduce delays by streamlining communication and enabling ATC to handle the airspace congestion in the region more efficiently.

Delta Airlines may be able to reduce delays at the airport by pre-sequencing departures according to departure fixes and fix restrictions. This may also require improved coordination with the FAA, to improve the operation of the pre-sequencing, but because Delta dominates the airport, pre-sequencing may be possible without further regulation. Cancellation of low priority flights in order to reduce the delays of higher priority flights may also reduce delays, but there are fewer destinations close enough to replace with ground transportation to make this response as successful as at Newark. A decrease in operations is likely to reduce delays as it appears that the schedule operated is a significant cause of the delays. Again, because Delta dominates the airport this may be possible without regulation. Similarly, de-banking may reduce delays, although since the schedule has few recovery periods already this response may not reduce delays significantly. Delta also does not use Atlanta primarily as an international hub, but as both its primary domestic hub, and an international hub. This response may thus be unattractive to passengers because of the increased connection times.

San Francisco (SFO)



Figure 69. Airport diagram of San Francisco International Airport (SFO) [24].

As presented in section 4.4, delays at SFO in 2000 were high, whilst the increases in delays since 1999 and 1997 were relatively low. This suggests that SFO has reacted to the increase in delays, and like Newark, has managed to reduce the growth in delays.

According to Figure 56 the weather impact metric is the highest of the airports in the country, and well above the average. This suggests that weather is a very significant cause of delays at the airport. According to the study by MITRE CAASD shown in Figure 58 [23] airspace congestion is also a significant cause of delays at SFO. This is likely because of its location in the San Francisco Bay area, the ATC system for which is complicated by a number of other large airports including Oakland and San Jose. In 2000, however, SFO had an average ATC departure delay only just above that of the average airport, as shown in Figure 59.

The schedule operated at SFO is shown in Figure 70, with the VFR and IFR capacities superimposed. As can be seen, although the majority of the demand is below capacity, there is some demand above IFR capacity, and even some above VFR capacity. As seen in Figure 57, however, SFO has a fairly low number of operations above capacity. Under IFR conditions, however, recovery periods are very small. The banking structure, shown in Figure 71, is extremely flat, and the banking metric is 238 hours per connection. This is the highest of any airport considered, indicating the flattest banking structure of the airports considered.

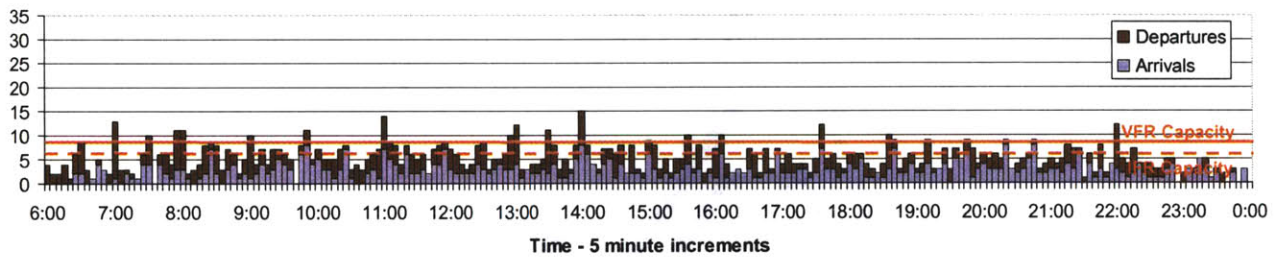


Figure 70. Schedule operated at SFO, June 28, 2000.

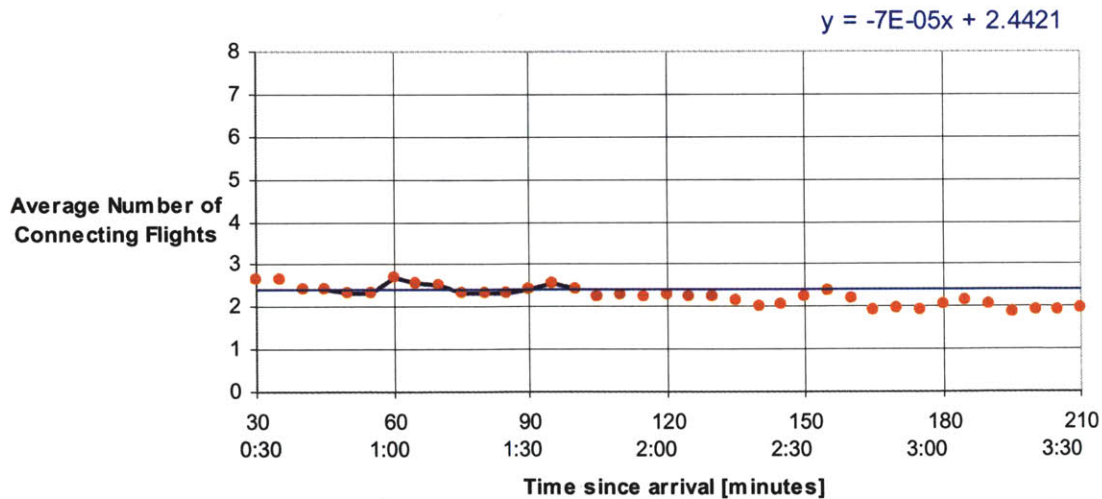


Figure 71. Banking structure operated at SFO, June 82, 2000.

United Airlines is the dominant carrier by a significant margin, operating 62.9% of scheduled operations at the airport. No other carrier operates more than 8% of operations. Thus SFO is heavily dominated by a single airline, United.

### *Recommended Responses*

Because weather is significant problem at SFO it is likely that extension of the National Playbook to focus on the Bay area would reduce delays at the airport, providing pre-planned re-routes that would be faster to implement in adverse weather conditions than standard re-routes. Similarly the implementation of decision aiding tools such as ITWS would improve ATC operations by improving decision making regarding application of restrictions. DSP is also likely to be successful at SFO because the airport suffers from airspace congestion problems, and is located near other large airports. Finally regarding regulatory responses, a redesign of the airspace, as is underway in New York is likely to improve operations and thus reduce delays, although probably not to the extent of New York.

A reduction in the number of operations at the airport may reduce delays as demand often exceeds even VFR capacity. Because the airport is dominated by a single carrier, this may also be possible with little regulatory action. Pre-sequencing of departures is also likely to reduce delays at the airport, because weather and airspace congestion are a problem, although because average ATC delays are not particularly high, this response is not likely to be as successful at SFO as at Newark. Because the airport is dominated by a single carrier, it is likely that no further regulation will be required to introduce pre-sequencing. Cancellation of short haul flights in preference for higher priority flights is also likely to reduce delays, and because the airport is located near some other cities, transferring the displaced passengers onto rail may be possible. It is not however likely to be as convenient as in the North East. Similarly a general move to multi-modal transport may have a degree of success in the region. Finally United may also be able to increase the average size of the aircraft operating at the airport, as the airport can be used as an international hub to the Pacific Rim.

## Boston (BOS)

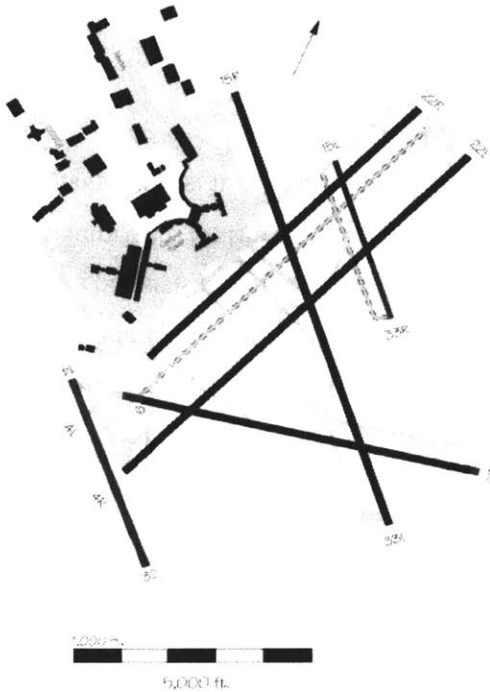


Figure 72. Airport diagram of General Edward Lawrence Logan International Airport, Boston (BOS) [24].

As seen earlier in section 4.4, the percentage of operations delayed at Boston Logan in 2000 was particularly high, as was the increase in delays since 1999. The increase in delays since 1997 was also high, although not to the same extent. This suggests that delays will continue to rise and that responses to this increase have not been successful as yet.

The weather impact metric, presented in Figure 56, is very well above the average, and the second highest of the airports considered, suggesting that weather is a particularly significant cause of delays at the airport. According to the study by MITRE CAASD shown in Figure 58 [23] surface congestion is also a primary cause of delays at Boston Logan. Despite this the average ATC departure delay at Boston Logan in 2000 was above that of the average airport, as shown in Figure 59. Part of the reason for this is that the ramp at Boston Logan is also controlled by ATC, and thus surface congestion is affected by ATC departure delays to a greater extent.

The schedule operated at Boston Logan is shown in Figure 73, with the VFR and IFR capacities superimposed. As can be seen, although the majority of the demand is below capacity, there is some demand above even VFR capacity. According to Figure 57 there are few operations above capacity. Particularly during IFR conditions, however, there are few recovery periods. The banking structure,



shown in Figure 74, is very flat. The banking metric is consequently high, at 323 minutes (3 hours 23 minutes) per connection.

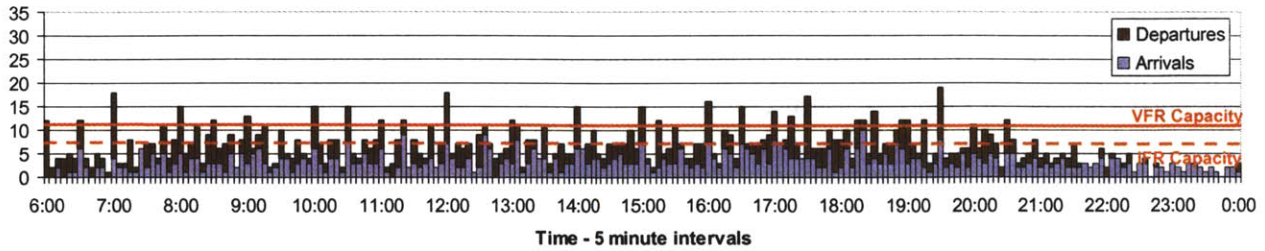


Figure 73. Schedule operated at Boston Logan, June 28, 2000.

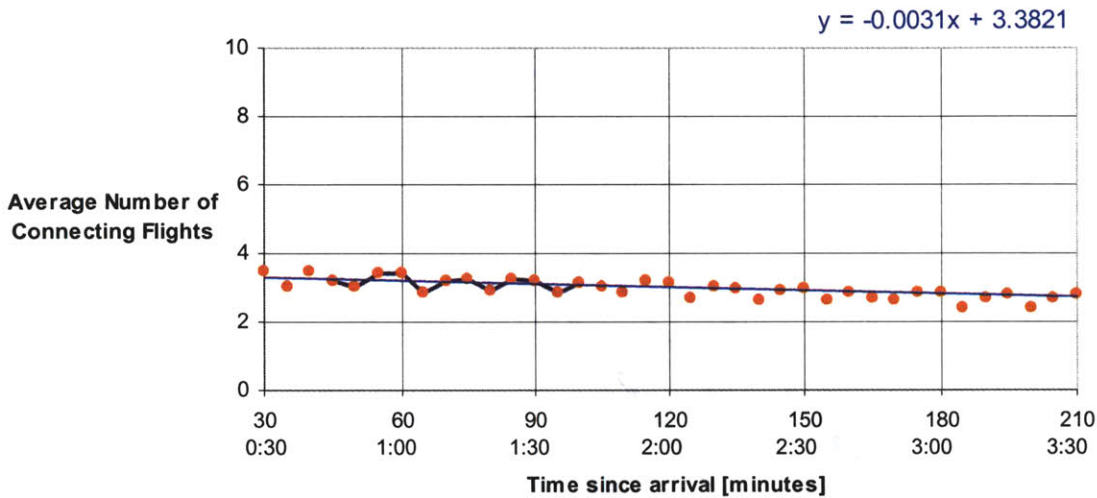


Figure 74. Banking structure operated at Boston Logan, June 82, 2000.

US Airways operates the highest number of flights at the airport, at 30.7% of scheduled operations; American Airlines operates the second highest number, at 21.6%; and United Airlines operates the third highest, at 10.9%. Thus Boston Logan is not dominated by any single airline.

#### Recommended Responses

Because weather is a cause of delays at the airport the extension of the National Playbook to also focus on Boston is likely to improve the efficiency of re-routing, and may thus reduce delays. Similarly the introduction of decision aiding tools such as ITWS may improve ATC operations, which appears to be a significant cause of delays at the airport. Unfortunately because the entire ramp is controlled by the FAA, pre-sequencing of departures by the airlines is not possible. However, a decrease in the number of operations at the airport would be possible through regulation, and may reduce delays. Because no single carrier is dominant, the number of operations is unlikely to be reduced without regulation.

Because the airport is not dominated by a single carrier, airline responses are limited. However, if any airline converts to operating primarily international flights at the airport, average aircraft size may increase, which may reduce delays if fewer aircraft are then operated. Given the airports location in the North East a general conversion to multi-modal transport may also be successful, and reduce delays by reducing the number of flights to nearby cities.

### Philadelphia (PHL)

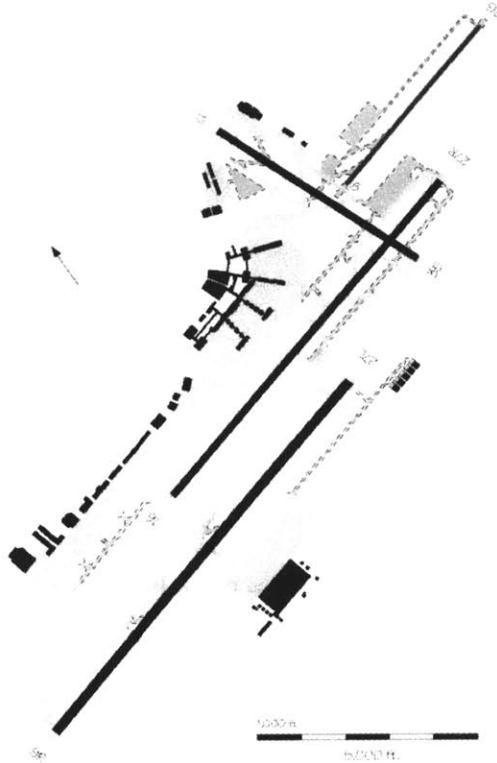


Figure 75. Airport diagram of Philadelphia International Airport (PHL) [24].

Earlier in section 4.4 it was presented that the percentage of operations delayed at Philadelphia in 2000 was fairly high, as was the increase in delays since 1999. The increase in delays since 1997, however, was very large. This suggests that the responses to delays at this airport have not been successful at reducing the increase in delays.

The weather impact metric calculated for Philadelphia is below average, as shown in Figure 56, suggesting that weather is not a particularly significant problem at the airport. According to the study by MITRE CAASD shown in Figure 58 [23], however, both airspace and surface congestion are primary causes of delays at Philadelphia. The airspace problems correspond to the airports location between the very busy airspaces of both New York and Washington DC. As shown in Figure 59, in 2000 the average ATC departure delay at the airport was high in comparison to that of the average airport.

The schedule operated at Philadelphia is shown in Figure 76, with the VFR and IFR capacities superimposed. As can be seen although the majority of demand is below both VFR and IFR capacity, there are many occasions when demand exceeds capacity for brief periods. Because of these periods Philadelphia has a fairly high percentage of operations above capacity, as shown in Figure 57. In most cases however there are large recovery periods even during IFR conditions. The banking structure, shown in Figure 77, shows some oscillation, and yields a banking metric of 27 minutes per connection, indicating that the schedule is banked, although not strongly.

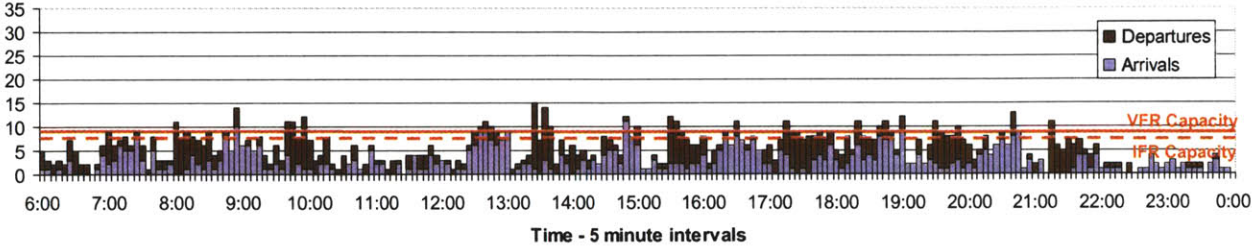


Figure 76. Schedule operated at Philadelphia, June 28, 2000.

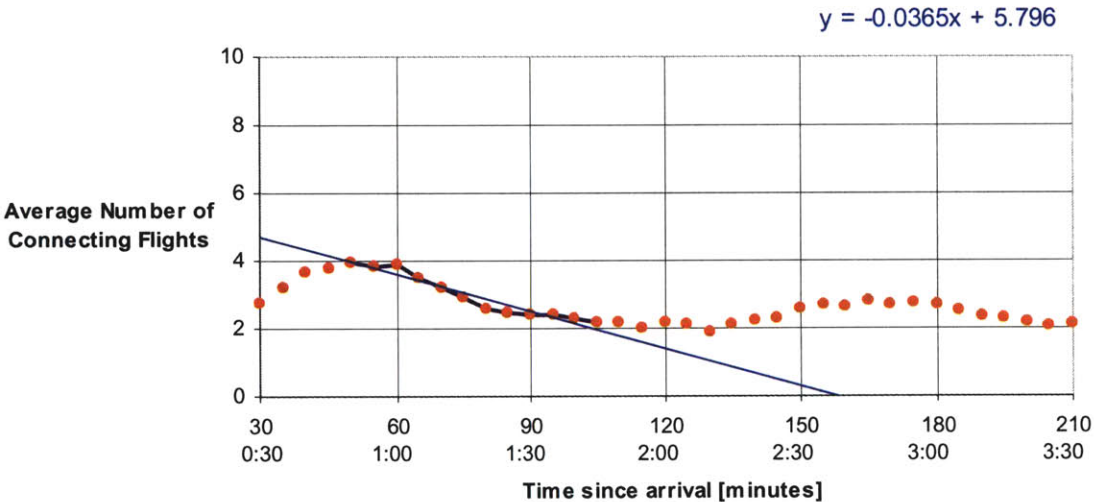


Figure 77. Banking structure operated at Philadelphia, June 82, 2000.

US Airways dominates the airport, operating a large 70.2% of scheduled operations. No other airline operates more than 6% of the flights at the airport. Thus Philadelphia is highly dominated by a single airline.

### *Recommended Responses*

Extension of the National Playbook to also focus on Philadelphia is likely to improve re-routing from the airport, and reduce delays, with the airport suffering from airspace congestion. Similarly, the application of decision aiding tools such as DSP is likely to improve operations, by streamlining communications and improving the efficiency of ATC operations. This is likely to be particularly beneficial at Philadelphia as it is situated right between New York ARTCC and Washington ARTCC. Related to this, NASA Ames is currently working on a development of the Traffic Management Advisor (TMA), a decision support tool for ARTCCs. The new tool, called Multi-Center TMA (McTMA), is to aid coordination between more than one center, and is specifically being designed for application at Philadelphia [25]. The redesign of the New York airspace is likely to improve operations at Philadelphia significantly, as the re-design is to include Philadelphia as well as the New York airports.

Because Philadelphia is also dominated by a single carrier, and suffers from many of the same problems that Newark suffers from, many of the airlines responses at Newark may be applicable to Philadelphia. Cancellation of short haul flights to reduce delays on higher priority flights is likely to reduce delays, and because of the airports location, transferal of displaced passengers onto ground transportation is likely to be successful. Similarly a general conversion to multi-modal transportation is likely to be successful. Pre-sequencing of departures according to departure fixes and restrictions is also likely to reduce delays, as the airport does have high delays related to ATC. This may also be possible without regulation because there is a single dominant carrier. Also, if US Airways begins to operate the airport particularly as an international hub, it may be able to de-bank to a certain degree and thus reduce delays during banks. This is particularly likely to be possible given the large recovery periods currently in the schedule.

## Dallas/Fort Worth (DFW)

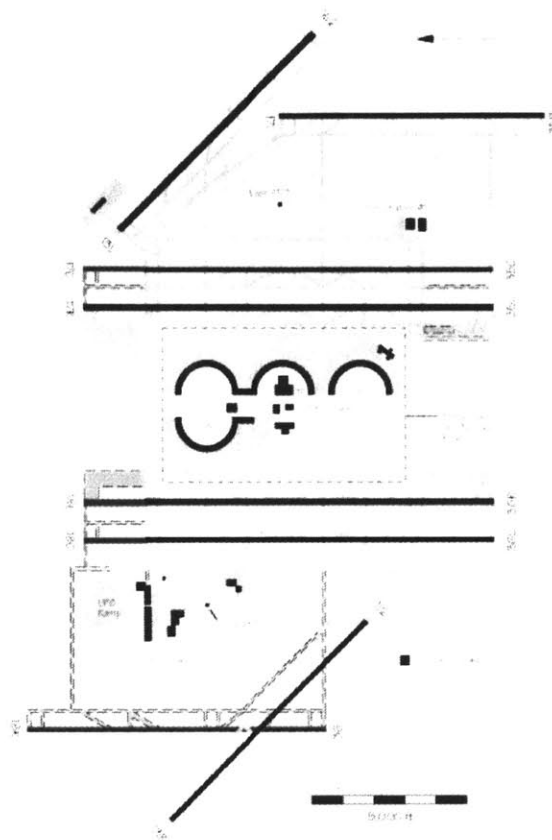


Figure 78. Airport diagram of Dallas/Fort Worth International Airport (DFW) [24].

The percentage of operations delayed at DFW in 2000 was just above the average. This was also the case for the increase in delays since 1997. However, the increase in delays since 1999 was larger. This suggests that responses had been successful until 1999, but have become less successful more recently.

As shown in Figure 56 the weather impact metric at DFW is well above the average, suggesting that weather is a significant cause of delay at the airport. The majority of this adverse weather is in the form of thunderstorms. According to the study by MITRE CAASD shown in Figure 58 [23] both airspace and surface congestion are also significant causes of delays at DFW.

The schedule operated at DFW is shown in Figure 79, with the VFR and IFR capacities superimposed. As can be seen the majority of demand is below VFR capacity, but during the banks the demand exceeds IFR capacity by a significant margin. According to Figure 57 a very low number of operations are above capacity though. Large recovery periods also remain even under IFR conditions. The banking structure, shown in Figure 80, shows very significant oscillations, and yields a banking



metric of 6 minutes per connection. This is the lowest of all airports considered and indicates that the schedule is very highly banked.

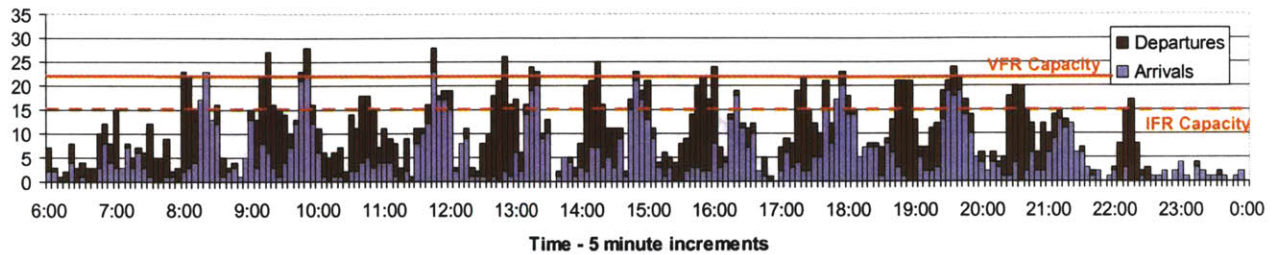


Figure 79. Schedule operated at DFW, June 28, 2000.

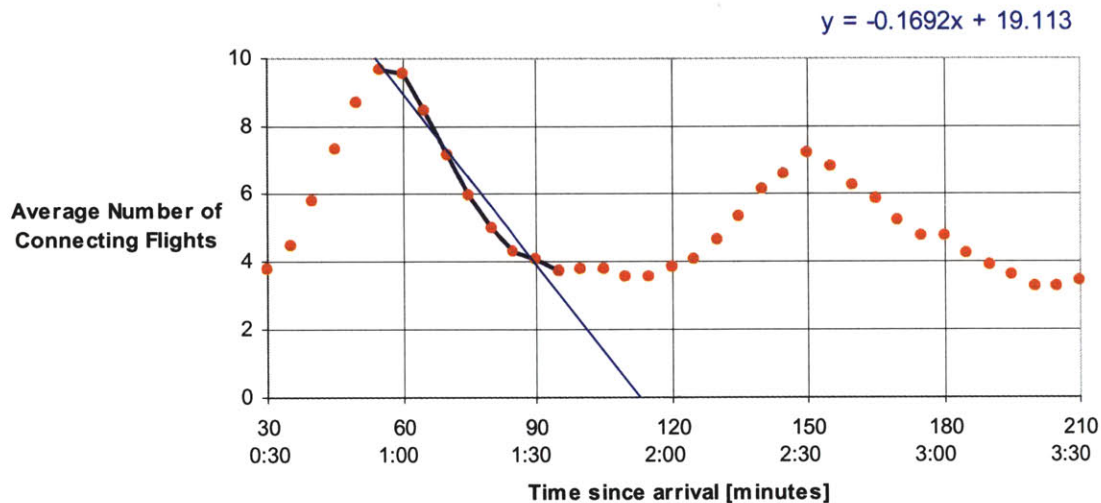


Figure 80. Banking structure operated at DFW, June 82, 2000.

American Airlines dominates the airport, operating 71.9% of scheduled operations. No other airline operates more than 12% of the flights at the airport. Thus DFW is heavily dominated by a single airline, American.

#### Recommended Responses

Because DFW is impacted by weather, the extension of the National Playbook to also focus on Dallas/Fort Worth is again likely to reduce delays by providing more efficient re-routing capabilities to ATC. Similarly the introduction of decision aiding tools such as ITWS may also reduce delays by improving the efficiency of ATC operations.

Again, because the airport is dominated by a single carrier, many of the responses by Continental at Newark may be applicable to American at DFW. Cancellation of short haul flights in order to reduce delays on the higher priority flights may be impractical because rail service in the South West is not well developed, and cities are too far apart for practical service by bus. Because the airport suffers from

weather, airspace and surface issues, pre-sequencing of departures according to departure fix and restrictions may reduce delays at DFW. Also, some degree of de-banking may reduce delays during IFR conditions, although because the airport is not an international hub, this may be less attractive to passengers, because of the increased connection times.

### Los Angeles (LAX)

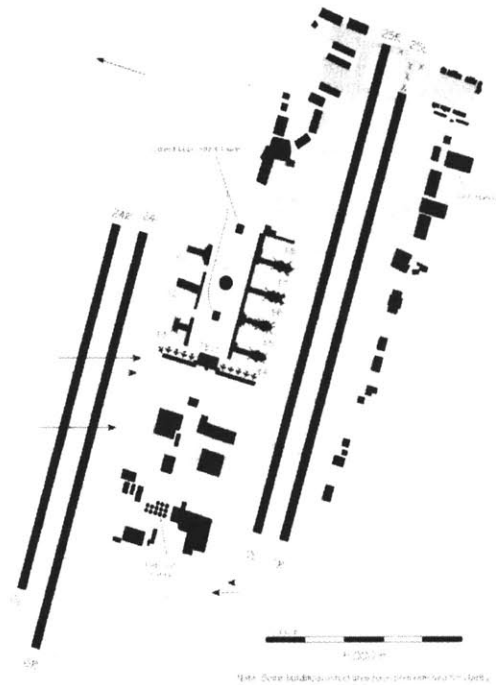


Figure 81. Airport diagram of Los Angeles International Airport (LAX) [24].

As presented earlier in section 4.4, the percentage of operations at LAX that were delayed in 2000 was only just above the average. In contrast, the increase in delays since 1999 was significant, whilst that since 1997 was small. Thus the increase in delays is particularly recent.

The weather impact metric at LAX is above the average, as shown in Figure 56, and suggests that weather does cause delays at the airport, although there are likely to be other significant causes as well. According to the study by MITRE CAASD shown in Figure 58 [23] both airspace and surface congestion are primary causes of delays at LAX. The airspace congestion corresponds to the airports location near a number of other significant airports such as John Wayne/Orange County Airport, Burbank-Glendale-Pasadena Airport, Ontario International Airport, and Long Beach/Daugherty Field airport. LAX also only uses one primary departure fix.

The schedule operated at LAX is shown in Figure 82, with the VFR and IFR capacities superimposed. As can be seen there is much demand above both the VFR capacity and the IFR capacity.

According to Figure 57 the percentage of operations above VFR capacity is correspondingly relatively high. Recovery periods are also small, suggesting that the schedule may be a cause of delays. The banking structure, shown in Figure 83, is very flat, and consequently yields a banking metric of a high 149 minutes (2 hours 29 minutes) per connection.

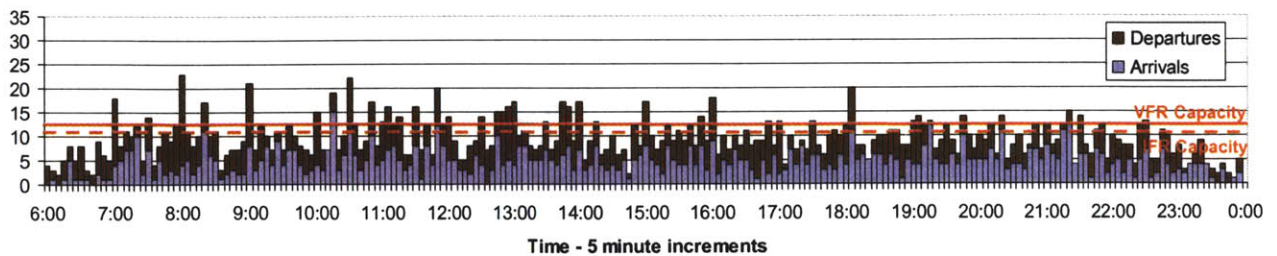


Figure 82. Schedule operated at LAX, June 28, 2000.

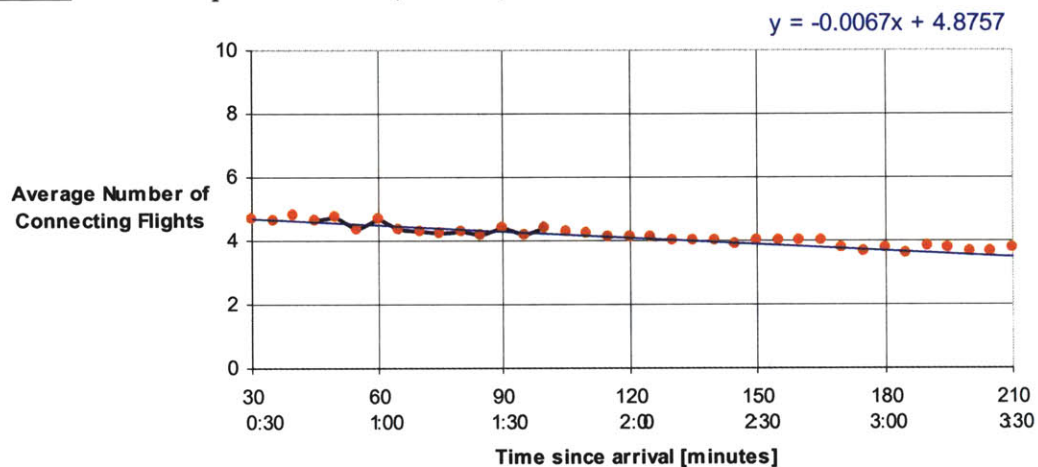


Figure 83. Banking structure operated at LAX, June 28, 2000.

United Airlines dominates the airport, operating 36.2% of scheduled operations. The second and third largest operators are American Airlines at 15.2, and Southwest Airlines at 13.7. LAX is thus dominated by United, but not to a significant degree.

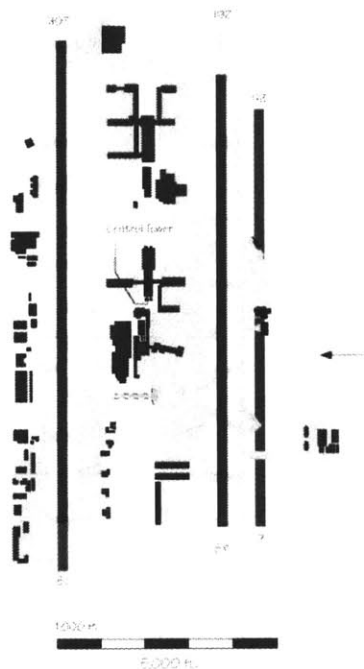
### *Recommended Responses*

As at many of the other airports considered, because airspace congestion and weather are problems at the airport, the extension of the National Playbook to also focus on Los Angeles would improve re-routing operations, and may thus reduce delays. Similarly the introduction of decision aiding tools such as DSP and ITWS may improve the efficiency of ATC operations, and thus reduce delays. Pre-sequencing of departures according to departure fixes and restrictions may also reduce delays, but because the airport is not dominated by a single carrier, its introduction may require regulation. Similarly a decrease in the number of operations at the airport would require regulatory action, and may particularly reduce the number of delays at the airport significantly because the schedule operated

currently is very full. Finally, because of the location of the airport close to a number of other significant airports, a redesign of the airspace may reduce delays.

The responses by the airlines are likely to be more limited at LAX than at Newark because no single carrier is dominant. However, a move to a multi-modal transportation system would be possible, as there are some short haul destinations within range of LAX for practical service with ground transportation. Cancellation of short haul flights to reduce delays on higher priority flights is however unlikely to reduce delays by a significant degree unless most carriers responded in this way. Similarly, a move to the use of larger aircraft, and thus a reduction in frequency of operations, is only likely to be effective in reducing delays if most carriers respond in this manner. The use of larger aircraft would be feasible as LAX is operated as an international hub to the Pacific Rim.

### Phoenix (PHX)



**Figure 84.** Airport diagram of Phoenix Sky Harbor International Airport (PHX) [24].

The percentage of operations at Phoenix in 2000 that were delayed is just above average. Closer inspection of the data reveals that whilst the increase in delays since 1999 was small, the increase in delays since 1997 was large. It thus appears that there have been successful responses to the delays at Phoenix recently.

The weather impact metric calculated for Phoenix, presented in Figure 56, is very well below the average, and the lowest of the airports considered. This suggests that weather is not a significant cause of



delays at the airport. According to the study by MITRE CAASD shown in Figure 58 [23], however, both airspace and surface congestion are primary causes of delays at Phoenix.

The schedule operated at Phoenix is shown in Figure 85, with the VFR and IFR capacities superimposed. As can be seen much of the demand is above the IFR capacity, and some above the VFR capacity as well. Recovery periods are large during VFR conditions but very small during IFR conditions. The banking structure, shown in Figure 84, shows clear oscillations, and yields a banking metric of 20 minutes per connection, which is relatively low. This indicates there that the schedule is banked.

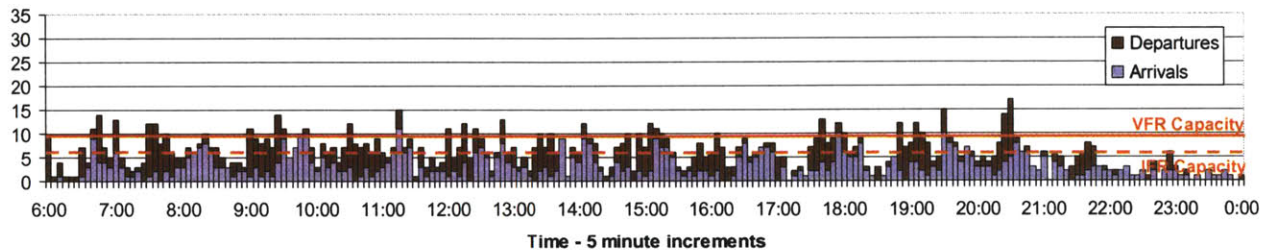


Figure 85. Schedule operated at Phoenix airport, June 28, 2000.

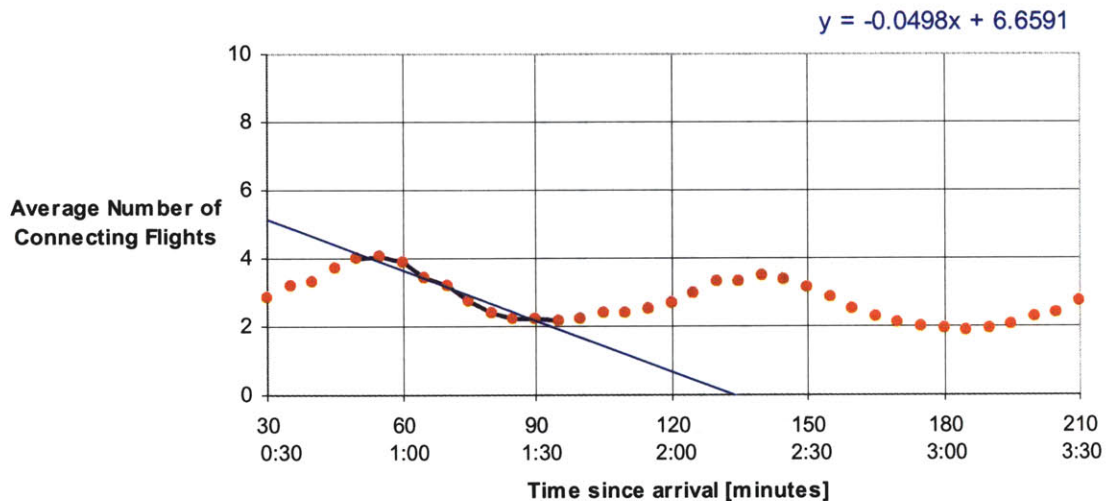


Figure 86. Banking structure operated at Phoenix, June 82, 2000.

Southwest Airlines operates the highest number flights at the airport, with 36.4% of operations, with America West Airlines very close behind with 35.2% of operations. No other carriers operate more than 8%. Thus Phoenix is not dominated by a single airline, but instead by two.

### Recommended Responses

Because airspace congestion is a problem at the airport, the implementation of decision aiding tools such as DSP may improve the efficiency of ATC operations, and thus reduce delays. Similarly pre-sequencing of departures according to departure fixes and restrictions may also reduce delays. However



because the airport is not dominated by a single airline, regulation may be required to implement pre-sequencing. Similarly a decrease in the number of operations may reduce delays, but would also require regulatory action.

#### **4.4.2 Conclusions**

As the analysis in section 4.4.1 has shown, a number of the responses identified at Newark are applicable to other airports in the United States. The responses appear to be particularly applicable to Atlanta airport, San Francisco airport, Philadelphia airport, and Dallas/Fort Worth airport. It is also important, however, to consider the policy implications of the responses identified, to ensure that these responses will be effective and to identify challenges in their implementation.

### **4.5 POLICY FORMULATION AND IMPLEMENTATION**

A number of responses to delays identified in the study of Newark airport are applicable to most if not all airports. These responses include the improvement of inter-facility communication within the ATC system. Any improvement in ATC operations would reduce delays system-wide, and inter-facility communication within the system is in need of improvement, as identified by Davison and Hansman [18]. Similar improvement in the cooperation and coordination between the operators at the airport, including the FAA, the airport authority, and the airlines, is likely to improve efficiency and thus reduce delays at any airport. Relating to strategic airline responses, extension of the schedule further into the early morning and late evening would reduce demand at other times, and thus reduce delays. This response is however limited at some airports because of curfews. Also, upgrading an airline's fleet by retiring older aircraft and purchasing new aircraft would reduce mechanical failures, improving dispatch reliability and reducing gate delays. Similarly an upgrade of ground equipment, such as the introduction of supertugs, would increase the efficiency of ground operations, and would thus reduce surface congestion.

The applicability of some other responses identified in the study of Newark airport could not be ascertained, because of a lack of information about the airports and ATC facilities considered. These responses include changes in the application of restrictions in the TRACON, increased utilization of any underutilized runways, and increased information availability to the airport ramp tower, or other specific facility.

A number of other responses to delays at Newark were identified to be applicable to the airports considered in section 4.4.1. With respect to ATC responses these include the extension of the National Playbook to also focus on other airports, the increased use of decision aiding tools such as DSP and ITWS, and redesign of the airspace. With respect to airline responses, which in many cases would have to

be encouraged by regulation, these include pre-sequencing of departures, and a decrease in the number of operations at the airport. A policy analysis is thus presented for each of these responses, in order to determine their likely acceptance and effectiveness. In each case the pros and cons are detailed for ATC, the airport authority, and the airlines operating at the airport. Particularly a reduction in delays is a consistent pro, although it is beneficial to different stakeholders for different reasons. Thus, the benefits to each stakeholder of reducing delays are detailed in Table 1.

Table 1. Pros and cons of reductions in delays

| Stakeholder               | Reduction in Delays   |      |
|---------------------------|---|------|
|                           | Pros  | Cons |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>• Reduced airspace congestion</li> <li>• Efficient use of the airspace</li> <li>• Improved flow of traffic</li> <li>• Improved safety</li> </ul>     | None |
| Airport Authority         | <ul style="list-style-type: none"> <li>• Reduced surface congestion</li> <li>• Improved safety</li> </ul>   | None |
| Airline                   | <ul style="list-style-type: none"> <li>• Fewer passenger complaints</li> <li>• Improved image with customers</li> <li>• Better on-time performance</li> <li>• Reduced fuel costs</li> </ul> | None |

National Playbook Extension

This policy involves extension of the National Playbook to also focus on other ATC facilities and airports, with pre-determined re-route suggestions for a number of the most likely fix and jet-route closures. The outcome of such a tool would be increased utilization of re-routes, and thus improved traffic flow during adverse weather conditions, and during other disruptions.

The books extension would have to be developed by the FAA, and particularly the FAA facilities involved, although they would need to coordinate closely with the ATCSCC. Funding would also likely come from the FAA. Pros and cons of the policy for each of the primary stakeholders are presented in Table 2.

Table 2. Pros and cons of extension of the National Playbook

| Stakeholder               | National Playbook Extension  |   |
|---------------------------|--|---|
|                           | Pros   | Cons  |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>• Improved re-routing</li> <li>• Reduced delays</li> <li>• Reduced communication with ATCSCC</li> <li>• National Playbook already developed</li> <li>• Relatively easy development</li> <li>• Relatively low development costs</li> </ul> | <ul style="list-style-type: none"> <li>• Cost</li> <li>• More re-routing</li> </ul> |
| Airport Authority         | <ul style="list-style-type: none"> <li>• Reduced delays</li> <li>• No cost</li> </ul>  |   |
| Airline                   | <ul style="list-style-type: none"> <li>• Reduced delays</li> <li>• No cost</li> </ul>  |   |

Clearly the airport authority and the airlines are likely to support the policy. The FAA is only likely to support the policy for the facilities with highest delays, and not for every facility where the tool is likely to be useful. This is because the resources and funding required are likely to be scarce, and their use requires clear justification. The primary focus of the DOT has also shifted away from congestion and onto security, since the events of September 11, 2001. There are however calls from many sectors suggesting that congestion will soon be a primary concern again.

Decision Aiding Tools

This policy involves the implementation of currently developed decision aiding tools at more airports around the country; the further development of these tools; and the development of other decision aiding tools that preferably interface with those already developed. The outcome would be reduced controller workload and improved efficiency of ATC operations in many respects. This would particularly include improved utilization of restricted fixes and jet-routes, better estimation of weather impact on the airspace and thus less severe restrictions, and streamlined communications. This would in turn increase capacity during adverse weather conditions, and thus reduce delays.

The extended implementation of the current decision aiding tools to other facilities would be directed by the FAA, which operates the facilities. Similarly the development of the current tools, and of new tools, would ultimately have to be supported, and funded, by the FAA, as the tools would ultimately be used in the FAA facilities. However the majority of development of the tools would come from private firms and NASA. Coordination between the developers and the FAA would thus be critical. Pros and cons of the policy for each of the primary stakeholders are presented in Table 3. This does not include the contractors, which would be in support of the policy because of the revenue that it would generate.

Table 3. Pros and cons of further development of decision aiding tools

| Stakeholder               | Decisions Aiding Tools  |  |
|---------------------------|---|--|
|                           | Pros  | Cons   |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>• Improved operational efficiency</li> <li>• Reduced delays</li> <li>• Reduced controller workload</li> <li>• DSP and ITWS already developed</li> <li>• Relatively easy development</li> <li>• Relatively low development costs</li> </ul> | <ul style="list-style-type: none"> <li>• Cost</li> <li>• Training required, with learning curve</li> <li>• Resistance to change from controllers expected</li> </ul> |
| Airport Authority         | <ul style="list-style-type: none"> <li>• Reduced delays</li> <li>• No cost</li> </ul>   |  |
| Airline                   | <ul style="list-style-type: none"> <li>• Reduced delays</li> <li>• No cost</li> </ul>   |  |

Clearly the airport authority and airlines are likely to support the policy. Any extended use of the currently developed tools is also likely to be supported by the FAA as the tools have already been developed, and tested, and thus implementation at other facilities would not add much cost. Further development of these tools is likely to yield benefits for little added cost, because the basic tools have already been developed. The development of new tools may however see some resistance from the FAA, unless the need for the tools is clear. Because the current focus of the DOT is on security, if the new tools improved security, as well as reducing congestion, support for their development would be improved significantly.

### Airspace Redesign

This policy involves a redesign of the airspace directly impacting the airport in question. The outcome would be a new airspace design that would improve traffic flows within the airspace. In a number of cases, because the airspace operated currently is unequipped for the volume of traffic operated within it, such a redesign may increase the capacity of the airspace significantly and improve the efficiency of its operation. This would reduce airport delays at airports within the airspace and at other airports served from the airspace.

The program would likely be funded by the FAA and DOT, because of its magnitude and impact on the transportation system. Pros and cons of the policy for each of the primary stakeholders are presented in Table 4. Again, this does not included any contractors, which would be in support of the policy because of the revenue that it would generate.



Table 4. Pros and cons of airspace redesign

| Stakeholder               | Airspace Redesign  |   |
|---------------------------|--|---|
|                           | Pros   | Cons  |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>Improved system operational efficiency</li> <li>Reduced delays</li> </ul> | <ul style="list-style-type: none"> <li>High cost</li> <li>Extensive retraining required, and long learning curve</li> <li>Resistance to change from controllers expected</li> <li>Long term solution</li> </ul> |
| Airport Authority         | <ul style="list-style-type: none"> <li>Reduced delays</li> <li>No cost</li> </ul>                                |   |
| Airline                   | <ul style="list-style-type: none"> <li>Reduced delays</li> </ul>   | <ul style="list-style-type: none"> <li>Modified procedures</li> <li>Pilot re-training with learning curve</li> <li>Uncertain costs</li> </ul>   |

Clearly the airport authority is likely to support the policy, but it is not clear in the cases of the FAA or the airlines. An airspace redesign is likely to be very expensive, depending on the specific airspace being redesigned. It is thus likely that the FAA and DOT will only support redesign of those airspaces in most need. The complete redesign of the system, which is also currently under consideration, is likely to occur in stages, enabling the FAA to learn by experience as well as spread the cost over many years. Primarily because the cost of the redesign to the airlines is unclear, airline support of the policy is also unclear.

Pre-sequencing Departures

Pre-sequencing of departures would improve departure operations on the ground, and thus reduce ATC departure delays. The implementation of this policy would however depend on whether the airport was dominated by a single carrier or not. If a single carrier dominated the airport, that carrier would most likely be able to pre-sequence departures at the transfer from ramp control to FAA ground control. This may require an agreement with the FAA to formalize procedures, and would be enhanced if the carrier had control of any extended ramp area, such as is the case at Newark. Pre-sequencing would allow the carrier be supply aircraft to the FAA in the most convenient order for the given fix restrictions in place, unlike those of the other carriers that would not be pre-sequenced. This would mean that during restricted operations the dominant carrier’s aircraft would generally be selected first. The dominant carrier would thus benefit specifically, whilst the other carriers may actually incur higher delays. Because the action is market driven, and would not require regulation, however, the action is not analyzed further.

Cooperation between non-dominant carriers is likely to be difficult, because of competition. Thus, if no carrier dominates the airport, the FAA or airport authority would have to implement the



policy by introducing regulation. Regulation requiring the airlines to simply coordinate their departures to be pre-sequenced is unlikely to yield suitable results. On the other hand, a transfer of ramp control from the airlines to the FAA ground control would require unreasonable resources of the FAA. The most likely regulatory action would then be to transfer ramp control to the airport authority, as is the case at airports such as Washington Dulles. The pros and cons of this regulatory action, for each of the primary stakeholders, are presented in Table 5.

Table 5. Pros and cons of pre-sequencing under airport authority control

| Stakeholder               | Pre-sequencing, under airport authority control   |   |
|---------------------------|---|---|
|                           | Pros  | Cons  |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>• Pre-sequenced aircraft</li> <li>• Efficient departure operations</li> <li>• Reduced delays</li> <li>• No cost</li> </ul> |   |
| Airport Authority         | <ul style="list-style-type: none"> <li>• Better utilization of the airport</li> <li>• Opportunity to raise airport fees</li> <li>• Reduced delays</li> </ul>      | <ul style="list-style-type: none"> <li>• High cost</li> <li>• Possible Tower construction required</li> </ul> |
| Airline                   | <ul style="list-style-type: none"> <li>• Reduced delays</li> <li>• Reduced ramp operating costs</li> </ul>  | <ul style="list-style-type: none"> <li>• Less control of flights</li> <li>• Increased airport fees</li> </ul> |

Clearly the FAA is likely to support the policy. If the policy were carefully developed all airlines would benefit with reduced delays, but the increased airport fees likely may still make the policy unattractive to the airlines. The attractiveness of the policy to the airport authority, which would implement the policy, is also unclear. This is because of the high cost of the policy, but increased revenue and improved airport utilization likely.

### Decrease in Number of Operations

Decreasing the number of operations at the airport would reduce demand, and would thus reduce delays. If the flights removed from the schedule were at periods when demand was above capacity, delays would be reduced directly. If the flights removed were not at periods when demand exceeded capacity, the size of recovery periods would be increased, and the propagations of delays reduced.

Again, the implementation of this policy would depend on whether the airport was dominated by a single carrier or not. If the airport were dominated by single carrier this carrier may be able to reduce the number of flights that it operates at the airport. However, because of the competitive nature of the industry this would be difficult as competitors would be likely to increase the number of their operations correspondingly, to improve their market share. Only if the dominant carrier had such a high percentage of operations that a reduction in its operations would not see a reaction from any competitors at the airport would such a reduction make sense. Thus, a reduction in the number of operations at an airport

may often require regulation. This regulation is generally implemented by the airport authority and takes the shape of demand management, such as slot control or peak hour pricing. The policy’s implementation is generally funded by the airport authority, but in most cases also generates revenue as well. The pros and cons of this regulatory action, for each of the primary stakeholders, are presented in Table 6.

Table 6. Pros and cons of regulation to decrease the number of operations at the airport

| Stakeholder               | Decrease the Number of Operations at the Airport  |  |
|---------------------------|---|--|
|                           | Pros  | Cons   |
| Air Traffic Control (FAA) | <ul style="list-style-type: none"> <li>• Reduced demand</li> <li>• Reduced delays</li> </ul>  |  |
| Airport Authority         | <ul style="list-style-type: none"> <li>• More efficient operations</li> <li>• Reduced delays</li> <li>• Revenue from demand management</li> </ul> | <ul style="list-style-type: none"> <li>• Administrations costs</li> <li>• Reduced revenue from landings</li> </ul>     |
| Airline                   |   | <ul style="list-style-type: none"> <li>• Reduced operations</li> <li>• Increased costs of demand management</li> </ul> |

Clearly demand management would likely be attractive to the FAA, but not to the airlines, because of the reduction in revenue and increase in costs that it would induce. The attractiveness of the policy to the airport authority is unclear, because of the increased costs, but also increased revenues. Such regulation may also discourage competition, which is an outcome generally avoided by government.

### 4.6 CONCLUSIONS

Of the policies analyzed the extension of the National Playbook to also focus on other airports, further development of decision aiding tools, and redesign of the most inadequate airspaces all appear likely to see sufficient support for the policies to be implemented to some extent at least. However, it is unclear that introducing regulation for pre-sequencing departures, or for decreasing the number of operations at the airport, will receive support from the necessary stakeholders, which in both cases is the airport authority. The politics is likely to be complicated, particularly as there is resistance within the government to increase the amount of regulation in the air transportation industry. Since September 11, security has also been the primary focus of the government, and not congestion. However, if congestion becomes a problem again as soon as suggested from many sectors, the government will have no choice but to implement regulations to reduce delays.



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