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Airport Capacity Profiles

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16. Abstract

FAA has updated the airport capacity profiles as part of its ongoing effort to assess the capacity characteristics of the nation's busiest airports. The capacity profiles replace the Airport Capacity Benchmark Report, first published in 2001 and revised in 2004. This 2014 update is necessitated by changes in aviation trends, new runways that have been added to the National Airspace System (NAS), and improved modeling techniques. The capacity profiles serve as a basis for the Future Airport Capacity Task 3 (FACT3), an in-depth evaluation of airport capacity needs.

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original report

Introduction: Purpose and Definition

The Federal Aviation Administration (FAA) developed the airport capacity profiles, which have also been called benchmarks, to provide a high-level assessment of airport runway capacity now and in the future. The airport capacity profiles are a useful tool for communicating essential capacity information on the airport system.[1]

This report defines capacity as the hourly throughput that an airport's runways are able to sustain during periods of high demand, represented as the range between the ATC Facility Reported Rate and a model-estimated rate. Because capacity changes in response to weather and operational conditions, a capacity rate range was developed for each of three weather conditions--visual, marginal, and instrument. For each, the runway configuration with the highest sustainable throughput has been selected. Note that runway capacity is estimated independently of constraints in the en route or terminal airspace and parts of the airport beyond the runways.

The airport capacity profiles in this report are a relatively simple expression of the complex quantity that is airport capacity. They serve primarily as a reference point on the potential throughput rate (number of aircraft takeoffs or landings) at selected U.S. airports during a specific time. They can be used to identify and assess specific characteristics of airports, for instance to determine which airports are most severely affected by inclement weather.

The airport capacity profiles also provide context for strategic infrastructure discussions by providing a succinct estimate of the current and future state of capacity at the nation's major airports. The capacity profiles serve as a basis for the Future Airport Capacity Task 3 (FACT3), an in-depth evaluation of airport capacity needs. FACT3, which is expected to be published later in 2014, will estimate future delay and congestion levels at airports. The airport capacity profiles are also used to support ongoing NextGen Systems Analysis evaluations.

While the capacity profiles provide estimates of existing and future airport capacity, they are not sufficient to take the place of the more detailed analyses that are needed for environmental and cost/benefit evaluations.

Updating the Airport Capacity Profiles

The FAA has updated the airport capacity profiles as part of its ongoing effort to assess the capacity characteristics of the nation's busiest airports. The capacity profiles replace the Airport Capacity Benchmark Report, first published in 2001 and revised in 2004. This 2014 update is necessitated by changes in aviation trends, new runways that have been added to the National Airspace System (NAS), and improved modeling techniques.

This report includes airport capacity profiles for the 30 Core airports. The 2004 Benchmark Report provided capacities for the 35 airports that were a part of the FAA's Operational Evolution Partnership (OEP). However the FAA recently shifted its focus to the Core Airports to reflect current trends in system use. Core airports are identified as having significant levels of

[1] The term 'benchmark' is not used to describe airport capacity in this report, given the emphasis on defining capacity as a range rather than a point value. Moreover, the capacity data shows the sustainable throughput that can be achieved during specified conditions and is not meant for comparative purposes as a performance metric.

passengers or itinerant operations. Specifically, airports with 1% or more of total enplanements (defined as large hubs) or airports with 0.75% or more of total non-military itinerant operations are identified as Core airports. These airports have a significant impact on the overall performance of the NAS. Currently, 30 airports in the NAS meet the criteria to be designated as a Core airport.

Three additional airports (Long Beach, Oakland, and Orange County) are also included in Appendix A. While these airports do not meet the criteria to be identified as a Core airport, they were identified by FACT2 as likely to be capacity constrained in the future. As a result, these airports were analyzed in this report. FACT3 will refresh the identification of airports that are likely to be capacity constrained in the future.

The 2014 Airport Capacity Profiles, like past benchmark reports, evaluates the impact of future improvements on airport capacity. The future improvements in this report fall into three main categories: (1) runway improvements, (2) flight procedure improvements, and (3) air traffic control (ATC) technology improvements. New runways or runway extensions were included in this update if an environmental Record of Decision (ROD) has been issued by the FAA for the project. ATC technology or procedural improvements identified in this update are primarily aligned with the FAA's NextGen Implementation Plan (NGIP).[2] The NGIP concentrates on the mid-term planning horizon through the end of the decade. Therefore, this report assumes all these enhancements will be in place by 2020.

The 2014 update also includes the implementation of new technologies, procedures, and runways that were identified in past benchmark reports and have since been implemented. For example, since the last benchmark report was published in 2004, 12 new or extended runways have been commissioned at the Core airports, significantly improving overall system capacity. However, some airports remain capacity constrained.

The 2014 Airport Capacity Profiles should not necessarily be compared to the previous benchmark reports to identify progress. A new capacity modeling tool, revised configuration selection criteria, updated fleet mix information, and refinements to the methodology have produced more meaningful and consistent capacity rates. As a result, comparisons to the previous reports may be misleading.

Going forward, the FAA plans to keep the capacity profiles current. Rather than publishing an entire revision to the document, updates to specific airport capacity profiles will be posted to the public FAA website when new versions are available. The FAA anticipates developing revised capacity profiles when airport changes are identified – for example, new runway development, new ATC procedures that affect capacity, or updated ATC Facility Reported Rates. With ongoing periodic updates, the FAA expects that the airport capacity profiles will be kept current with none being older than about five years. Further updates, as well as errata, will be posted to the FAA's website at <www.faa.gov/airports/planning_capacity>.

[2] NextGen Implementation Plan (NGIP) is available at www.faa.gov/nextgen

Methodology

The methodology used for this report is meant to provide airport capacity results that are consistent and comparable across all the airports, while also capturing the individual characteristics of an airport. The capacity profiles have been developed through a series of interactions with ATC personnel, airport staff, analysis of operational data, and the consistent application of basic assumptions and parameters when modeling different airports.

The airport capacity profiles are a simplified expression of airport capacity, which is inherently a complex and dynamic quantity. As a result, airport capacity is presented as a range of two values for each weather condition. One value, the Facility Reported Rate, is developed by air traffic control (ATC) personnel at the facilities managing traffic for an airport (e.g., the control tower and approach control).[3] Also known as the "called rate," the Facility Reported Rate is used by ATC in traffic flow and metering initiatives. The other value defining the range is a capacity estimated by simulating the airport's operations, using standard assumptions about separation requirements and aircraft performance. For the 2014 report, MITRE's *runway*Simulator model was used to estimate the capacity value because it offers significant improvements over the analytical tool that was used for previous benchmark reports.

Basic Assumptions and Parameters

Basic assumptions and parameters form the foundation of the airport capacity profiles. They include:

- The parameters defining the three specific weather scenarios assessed for each airport
- The criteria for choosing which configuration to assess for each weather scenario
- The use of *runway*Simulator to estimate capacity at each airport, including the application of standard modeling parameters for runway occupancy, aircraft performance, and aircraft spacing
- The basic ATC rules (as defined by FAA Order 7110.65) which are applied to airport operations based on runway geometry, aircraft wake class, and weather conditions

This information was then supplemented by operational data that was analyzed to derive inputs, such as an airport's fleet mix. In addition, Aviation System Performance Metric (ASPM) data were analyzed and the Operational Information System for the Air Traffic Control System Command Center (ATCSCC) was consulted. This provided preliminary capacity rates and configurations, which were then confirmed or adjusted by ATC facility personnel.

Operational ATC personnel at each airport were engaged at several points in the process to inform the analysis and verify that an airport's operations were being accurately represented. Initially ATC personnel were asked to fill out a questionnaire about their airports operations. Current operations were then modeled, and ATC personnel were asked to review the draft results. Most of this interaction was facilitated by the ATCSCC. Future improvements were then modeled. Then, the airport operator and ATC personnel were asked for feedback on the modeled results.

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[3] Traffic demand plays a critical role in the called rates reported by the air traffic facility. Called rates are strongly affected by how busy the airport is and how aggressively the ATC management team sets target rates.

Weather Assumptions

Because capacity changes in response to weather and operational conditions, a capacity rate range was developed for each of three weather conditions--visual, marginal, and instrument. The three weather conditions are defined as follows:

- **Visual**: Ceiling and visibility allow for visual approaches, which are specific to each airport.
- **Marginal**: Ceiling and visibility are below visual approach minima, but better than instrument conditions
- **Instrument**: Ceiling less than 1,000 feet or visibility less than 3 statute miles.[4] Instrument Flight Rules (IFR) apply and radar separation between aircraft is required.

Weather conditions at or above the visual minima allows ATC to use visual operating configurations at an airport; however, the use of visual capacity rates is not always possible. Sometimes, ATC must operate more conservatively, using marginal rates even during visual weather conditions. This can be due to changing and variable weather that may go below visual criteria for short periods, or complex airspace. As a result, the actual usage of operating configurations can vary from estimates derived exclusively from weather data.

The frequency of occurrence of these weather conditions at each airport was determined for this analysis using data from the FAA ASPM database. The weather data in ASPM is provided by the National Oceanic and Atmospheric Administration. The time period sampled was from October 2008 to September 2010.[5] Only data between 7am and 11pm local time at each airport were used to avoid periods of low activity. Based on the ceiling and visibility data, and the visual approach minima for each airport, ASPM estimates whether visual or instrument approaches were conducted at the airport.

Runway Configuration Assumptions

For each of the three weather conditions, a specific operational runway configuration that is used during periods of high demand was selected to be profiled in this report.

Over the years, the FAA has developed a better understanding of how the airport capacity profiles are used in both Agency and stakeholder planning studies. With that in mind, a subtle but important change has been used in this report. In the two previous reports, the most commonly used runway configuration in each weather condition was profiled. The most common configuration is frequently, but not always, the one that has the highest capacity.[6] To

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[4] Atlanta has a fourth weather condition, Low Instrument. This weather condition has a ceiling of less than 500 feet or visibility less than 1 statute mile.

[5] Weather data for this study was only sampled for a 24-month period, in order to be consistent with the operational data in ASPM. However, many airports will use 10 to 30 years of weather data in evaluating long-term capacity needs, wind coverage, and configuration usage.

[6] Some airports are not able to operate in their highest capacity configuration as often as desired due to airspace constraints or wind. Others may not have enough demand to require the highest capacity, and therefore choose to operate in a less complex configuration.

provide more consistent results, this analysis selected the runway configuration that provides the highest sustainable throughput during periods of strong demand.[7]

For example, the highest capacity configuration at New York's LaGuardia Airport (LGA) in Visual weather (arriving Runway 22 and departing Runway 13) is not necessarily the most common configuration for this weather condition, due to unfavorable winds. However, using the highest capacity configuration provides more consistent capacity results over time, because the most common configuration at an airport is often a response to air traffic schedules that can ebb and flow.

To maximize capacity, ATC will operate some airports such as New York John F. Kennedy International or Washington Dulles International in either an arrival or departure priority mode, as opposed to a single balanced operation between arrivals and departures.

Modeling Operations in Runway Simulator

Once the weather conditions and runway configurations at an airport have been identified, an airport's operations are modeled in *runway*Simulator. This model simulates arriving and departing traffic at an airport, the decisions made about runway assignment and sequencing, and the flight operations themselves. A randomized traffic sample is generated that keeps pressure on the airport. The traffic sample reflects an airport's mix of aircraft types, which differ in their performance parameters. FAA Order 7110.65 separation standards are codified as rules that govern pairs of flight operations and these are modified to represent common pilot and controller behaviors. The runway configuration is set and exceptions noted to prohibit use of specified runways by certain aircraft types or to set aside runways for exclusive use by, say, general aviation traffic. A heuristic algorithm assigns runways and sequences traffic to balance efficiency and delay while respecting separation requirements and runway eligibilities.

When used to estimate capacity, *runway*Simulator generates traffic so that there is constant demand on the runway system. It does this for various arrival-departure mixes and, for each, simulates steady-state operations for several hundred hours. The average throughput achieved is recorded for each arrival-departure mix, and used to create the airport's capacity "curve" (a Pareto frontier; see Figure 3 on page 16). A variety of measurements and visualizations are made available to the analyst to verify and validate the simulation.

For this report, *runway*Simulator was used to estimate runway capacity with current and future operations. However, *runway*Simulator does not evaluate most non-runway constraints at the airport nor limitations elsewhere in the NAS. Such constraints may include:

- Taxiway and gate congestion, slot controls, construction activity
- Terminal airspace structure
- Traffic flow restrictions caused by en route miles-in-trail restrictions, weather, or congestion problems at other airports
- Seasonal limitations due to high temperatures that restrict aircraft climb rates

[7] Using the most common configuration can create the illusion of substantial increases or reductions in capacity as ATC changes how it operates an airport in response to demand.

Accordingly, the model-estimated capacity rate reflects only what is modeled and may not represent other limitations such as airspace structure, surface congestion, and weather patterns. The additional modeling that is being done for FACT3 will include airspace and surface components in the estimates of future delay and congestion levels.

At Newark Liberty International Airport (EWR), for example, the average actual throughput rates are less than the model-estimated rate, which represents operations in good weather in the most favorable runway configuration. However, airspace constraints and wind conditions frequently require the use of other configurations with less capacity. The actual throughput rates may also be affected by traffic flow control measures, such as mile-in-trail restrictions caused by en route weather.

The capacity rate ranges are based on and meant to be reflective of routine operations at the airports. Occasionally, the capacity rates may be exceeded under favorable conditions. Conversely, lower rates would be expected under adverse conditions, such very low ceiling and visibility, convective weather in the vicinity of the airport, or if demand is substantially less than capacity.

Current Operational Assumptions

Many of the improvements assumed for the previous capacity benchmark studies have now come to fruition. For this report, these improvements have been included as part of the current operations.

Note: Recent changes (2013) to converging operations at airports, in response to National Transportation Safety Board (NTSB) Recommendation A-13-024, are not yet included in the airport capacity profiles in this report. When amended operating procedures become available in 2014 following necessary safety reviews, the profiles of applicable Core airports will be updated and posted to the FAA website as described on page 4.

New runways or extensions have been constructed at 12 of the Core airports since 2003, as shown in **Figure 1**.[8] Runway improvements typically offer greater benefits than do technology or procedural improvements. The overall capacity impact of a new runway depends on its location relative to the airport's other runways and any restrictions on its operations. For instance, new parallel runways that are spaced at least 3,600 feet apart[9], will have the greatest impact on capacity for arrivals (2,500 feet apart for departures).[10]

8 The 2004 Benchmark Report included the new runways at DEN, MIA, IAH, and MCO that opened in 2003; however, these runways were not included in that report's baseline.

9 N-JO-7110.625, effective August 19, 2013, allows simultaneous close parallel approaches to runways spaced by a minimum of 3,600 feet or more without high update radar (e.g., PRM).

10 Under the NextGen program, FAA is pursuing reductions to runway separations for closely spaced parallel runways. In the near-term, FAA is evaluating what can be done with existing technology. Follow-on work will look at advanced technologies.

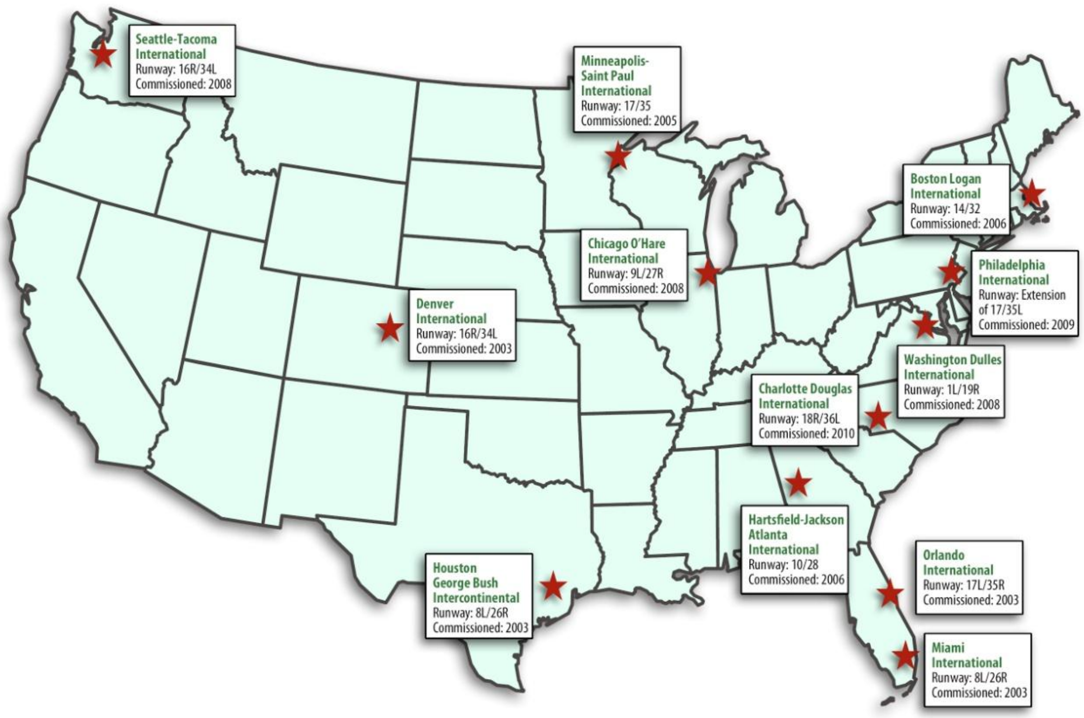

Figure 1. New Runways at the Core Airports

Traffic Management Advisor (TMA) provides traffic flow managers with a metering plan that organizes traffic in en route airspace to increase the utilization of the airport's arrival capacity. The plan is implemented by displaying specific aircraft schedule and delay information to en route controllers. When the controllers deliver the aircraft to the terminal area airspace boundary at the TMA scheduled times, the orderly flow of arrival traffic results in more efficient operations.

Reduced separation standards for parallel runways spaced less than 2,500 feet, have been authorized at select airports by FAA Order 7110.308. These revised standards allow parallel dependent instrument approaches to be conducted with 1.5-nautical mile (NM) diagonal spacing between certain pairs of aircraft. This procedure is only applicable to authorized runway pairs. As of October 2012, the procedure is authorized at Boston Logan (BOS), Cleveland Hopkins (CLE), Newark Liberty (EWR), Memphis (MEM), Philadelphia (PHL), Seattle-Tacoma (SEA), San Francisco (SFO), and St. Louis (STL) International Airports. However, not all of these airports are actively using the procedure. Implementation depends on the completion of required controller training and technology, as well as sufficient demand.

Simultaneous Offset Instrument Approaches (SOIA) refers to instrument approaches to a set of parallel runways less than 3,000 feet apart, utilizing a straight-in precision approach to one and an offset instrument approach with a transition to a visual landing for the other. With SOIA, the approach course separation meets parallel approach criteria even though the runway separation does not. Currently, this procedure is only in use at San Francisco International. At other airports with closely spaced parallel runways, the dependent staggered approaches authorized under FAA Order 7110.308 can provide a capability that is similar to SOIA.

Precision Runway Monitor (PRM) is a high update radar system that allows simultaneous instrument approaches to parallel runways as close as 3,000 feet apart. PRM is currently deployed and in use at Atlanta (ATL) and SFO International Airports.

Capacity Rates for Current Operations at the Core Airports

Table 1 shows the capacity rates for current operations at the Core Airports, presented as a range between the hourly rates reported by ATC (called rates) and the hourly rates estimated using the capacity model (model-estimated rates).

Using the same rates shown in Table 1, **Figure 2** plots the range or rates that are possible with different weather conditions. The airports are ordered by the Visual rates, from highest to lowest. Airport capacity generally decreases during inclement weather conditions, which may include poor ceiling and visibility (requiring different ATC procedures), unfavorable winds (so the best runway configuration cannot be used), or heavy precipitation. The extent of the reduction in capacity rates during operations in instrument conditions (as compared to visual conditions) varies widely across the 30 airports. These differences are due to different runway configurations and operational procedures in adverse weather at each airport.

In order to mitigate congestion, the FAA has put in place Orders limiting operations at Newark Liberty International (EWR), John F. Kennedy International (JFK), and LaGuardia (LGA) airports. While a capacity rate range is the hourly throughput that an airport is able to sustain during periods of high demand, the operational limits put in place under the Orders involve a trade-off between airport throughput and a tolerable level of delay. The Government Accountability Office (GAO) recommended, and FAA agrees, that operational limits for EWR, JFK, and LGA should be established under realistic weather and operating scenarios, not optimal conditions. This can result in less throughput under good weather conditions but helps prevent excessive delays during adverse weather periods. See Appendix B for additional information.

Table 1. Capacity Rate Ranges for Current Operations at the Core Airports

Airport Identifier and Name		Aircraft Operations (Arrivals and Departures) per Hour		
		Visual	Marginal	Instrument
ATL	Hartsfield-Jackson Atlanta International	216-226 (AP) 219-222 (DP)	201-208 (AP) 206 (DP)	175-190 (AP) 183-186 (DP) 168-169 (LIMC - AP) 168-179 (LIMC - DP)
BOS	Boston Logan International	116-125	109-112	84-86
BWI	Baltimore-Washington Thurgood Marshall International	68-80	64-80	62-64
CLT	Charlotte/Douglas International	176-182	161-162	138-147
DCA	Ronald Reagan Washington National	69-72	69-72	54-64
DEN	Denver International	262-266 (AP) 266-298 (DP)	224-279	224-243
DFW	Dallas/Fort Worth International	226-264	194-245	170
DTW	Detroit Metropolitan Wayne County	178-184	163-164	136
EWR	Newark Liberty International	94-99 (AP) 94-100 (DP)	76-84	68-70
FLL	Fort Lauderdale-Hollywood International	74-82	66-72	56-66
HNL	Honolulu International	117-120	91-105	60-77
IAD	Washington Dulles International	150-159 (AP) 156-164 (DP)	112-120 (AP) 136-145 (DP)	108-111 (AP) 125-132 (DP)
IAH	Houston George Bush Intercontinental	172-199	152-180	144-151
JFK	New York John F. Kennedy International	84-87 (AP) 90-93 (DP)	85-86	74-84
LAS	Las Vegas McCarran International	122-128	106-111	78-83
LAX	Los Angeles International	167-176	147-153	133-143
LGA	New York LaGuardia	80-86	76-77	74-76
MCO	Orlando International	160-171	148-161	144
MDW	Chicago Midway International	64-84	64-74	52-70
MEM	Memphis International	144-160	133-150	111-134
MIA	Miami International	132-150	132-148	100-104
MSP	Minneapolis-Saint Paul International	156-167	142-151	114-141
ORD	Chicago O'Hare International	214-225	194-200	168-178
PHL	Philadelphia International	120-126	94-96	84-88
PHX	Phoenix Sky Harbor International	138-145	108-109	96-101
SAN	San Diego International	48-57	48-52	48
SEA	Seattle-Tacoma International	100-112	86-100	76-78
SFO	San Francisco International	100-110	90-93	70-72
SLC	Salt Lake City International	148-150	138-140	114-120
TPA	Tampa International	113-115	95-115	90-95

AP = Arrival Priority Configuration   DP = Departure Priority Configuration   LIMC = Low Instrument

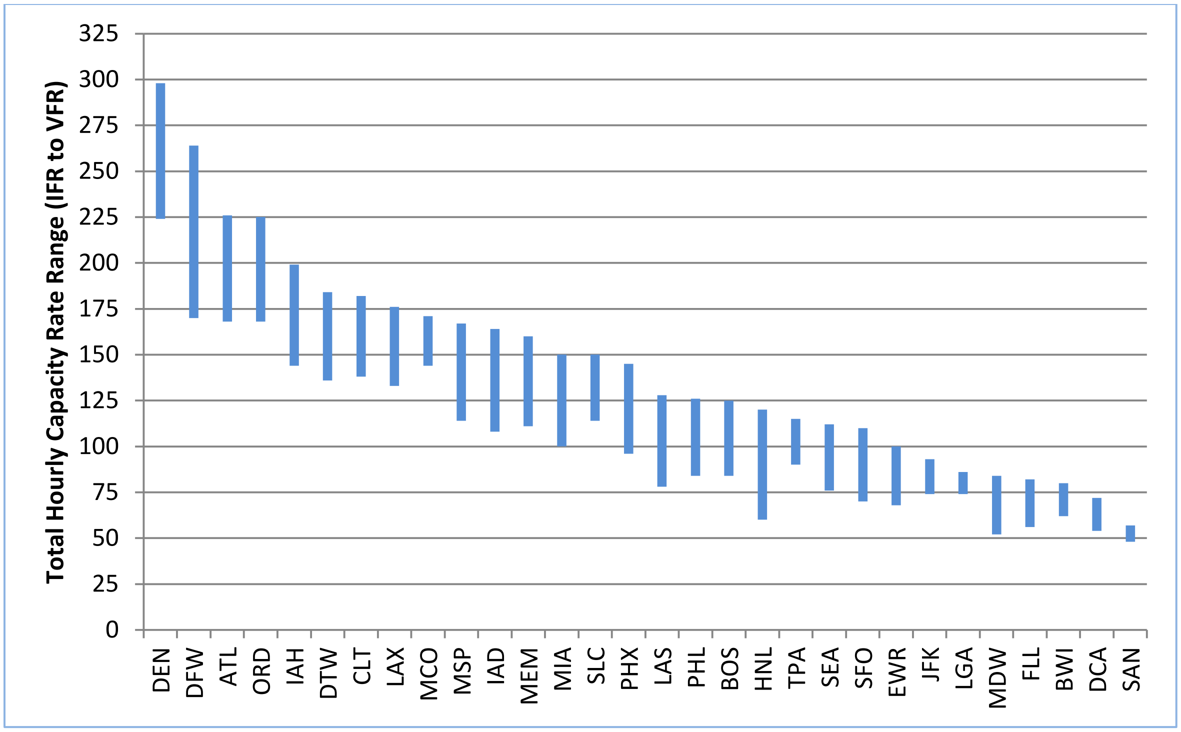

Figure 2. Range of Capacity Rates for Current Operations at the Core Airports

Future Improvements Assumptions

The NGIP describes many improvements to the NAS that will be tested, developed, and/or implemented in the NAS through about 2020. Future capacity rates were estimated for 2020 assuming that the technology and procedural improvements will be implemented at all eligible airports and will provide the expected benefits.

The set of future improvements modeled for this report were current as of January 2011. As FAA plans for NextGen implementation continue to evolve, updates to the future improvements assumptions will be incorporated into revised airport capacity profiles. The FACT3 modeling also includes refined assumptions for future improvements. The revised profiles will be posted to the FAA website as described on page 4.

Future capacity rates were also estimated separately to show the effect of future runways and extensions. The capacities associated with new or extended runways assume that the airspace design, technology, and ATC procedures needed for full operational performance of the new runway have been completed.

The future capacity rate estimates do not substitute for detailed benefit analyses that are used to evaluate proposed infrastructure and capital investment programs. The list of Future Improvements and their expected effects on capacity at each airport does not imply FAA commitment to, or approval of, any item on the list.

A brief description of each future improvement, as assumed in this report, is provided below:

Improved Parallel Runway Operations procedures recover lost capacity in poor weather through reduced separation standards and increased applications of dependent and independent operations.

- *Visual Paired Approaches* can be conducted at additional airports for aircraft on approach to closely-spaced runways if aircraft will maintain visual separation, allowing them to execute parallel approaches. Airspace will have to be redesigned to accommodate this procedure. (Visual Conditions)
- *Triple or Dual Simultaneous Independent Instrument Approaches* can be conducted if allowed by current runway spacing. However these approaches are not typically implemented until required by traffic levels or weather patterns, due to the additional staffing and equipment involved. (Marginal and Instrument Conditions)

Wake Turbulence Mitigation for Arrivals (WTMA) increases the use of reduced separation standards for closely-spaced parallel runways. Two separate procedures for WTMA are being developed; one or both may be used at a specific airport.

- *WTMA-System (WTMA-S)* will employ a wind forecasting algorithm to allow reduced separation between closely-spaced parallel arrivals under specific wind conditions. Many of the airports which have been authorized in FAA Order 7110.308 will also be eligible for WTMA-S. In some cases a precision approach capability will be required to support a second arrival stream. (Marginal and Instrument Conditions)
- *WTMA-Procedural (WTMA-P)* will enable reduced diagonal separation between closely-spaced parallel arrivals for all categories of lead aircraft, expanding the 7110.308 procedure to Heavy and Boeing 757 aircraft. In some cases a precision approach capability will be required to support a second arrival stream. (Marginal and Instrument Conditions)

Wake Turbulence Mitigation for Departures (WTMD) will eliminate the need for wake vortex separation behind a Boeing 757 or Heavy aircraft departing on the adjacent runway when specific wind conditions exist that reduce the vortex hazard. This procedure will allow airports to maintain airport departure throughput during favorable wind conditions. (Visual and Marginal Conditions)

Improved Runway Delivery Accuracy: The combined effects of several new capabilities, including Automatic Dependent Surveillance-Broadcast (ADS-B) Out, Cockpit Display of Traffic Information (CDTI), and Time Based Metering (TBM) in the terminal area, will improve the ability of controllers by 2020 to deliver aircraft to the runway with the desired separation from the preceding aircraft. This will reduce the average spacing between arrivals and boost arrival capacity. (All weather conditions)

Same Runway Departure Fanning will allow reduced separation between successive departures due to the availability of new RNAV procedures which provide divergent headings with more precise guidance and control for departing aircraft. (All weather conditions).

Estimated Capacity Rates for Future (2020) Operations at the Core Airports

Three Core airports have major runway capacity projects scheduled to open within the end-of-decade time horizon of this study: Chicago O'Hare International, Fort Lauderdale-Hollywood International, and Philadelphia International. While runway extensions are planned at other Core airports, only two runway extensions have been explicitly modeled as hourly throughput enhancements. The extension of Runway 9R/27L at Fort Lauderdale-Hollywood International and Runway 8/26 at Philadelphia International will increase airport capacity, because the increased length will make the runways available for use by a wider range of aircraft.

A smaller increase in the future capacity rate occurs where there are operational constraints on a runway. For example, the extended Runway 8/26 at Philadelphia International will remain unidirectional due to obstacle clearance restrictions (aircraft can only arrive from the east and depart to the east because the terminal is located off the west end of the runway).

Other airports may be considering new runway construction within the end-of-decade time horizon of this study. However, the study does not include future runway construction prior to issuance of a ROD. Other future new runways, such as the fourth parallel runway at Philadelphia International, are outside the time horizon for this report.

Table 2 shows the percentage increase in the estimated capacity rates at the Core Airports when all future improvements are considered, including: new runways, runway extensions, and ATC technology and procedural improvements. The specific types of future improvements modeled for each airport are also indicated in Table 2. The improvements shown in the table are only meant to be a representative list, and may not necessarily apply in all weather conditions.

For the specific improvements modeled in each weather condition, refer to the individual airport profiles. For those airports operating close to capacity, technology and procedural changes can have a significant impact in improving the airport’s performance. The greatest capacity benefit is generally derived from adding a new runway.

Table 2. Estimated Capacity Rates for Future (2020) Operations at the Core Airports

Airport Identifier	Percentage Capacity Improvements Over Today			Future Improvements					
	Visual	Marginal	Instrument	New Runway or Extension	Improved Parallel Runways Operations	WTMA	Improved Runway Delivery Accuracy	Fanned Departures	WTMD
ATL	8% (AP) 8% (DP)	7% (AP) 8% (DP)	6% (AP) 5% (DP)				✓	✓	
BOS	2%	4%	17%			✓	✓		✓
BWI	1%	3%	3%				✓		
CLT	12%	11%	9%				✓	✓	
DCA	1%	1%	2%				✓		
DEN	9% (AP) 13% (DP)	11%	13%				✓	✓	
DFW	6%	5%	4%				✓		
DTW	4%	9%	14%		✓		✓		
EWR	12% (AP) 11% (DP)	37%	6%		✓	✓	✓		✓
FLL*	59%	53%	77%	✓	✓		✓		
HNL	-	-	-						
IAD	4% (AP) 2% (DP)	27% (AP) 1% (DP)	24% (AP) 2% (DP)		✓		✓		
IAH	16%	13%	3%				✓	✓	✓
JFK	5% (AP) 4% (DP)	6%	9%				✓		
LAS	5%	5%	7%			✓	✓		
LAX	4%	3%	4%				✓		
LGA	3%	6%	8%				✓		
MCO	4%	2%	1%		✓				
MDW	-	-	-						
MEM	6%	1%	4%				✓		✓
MIA	1%	2%	6%		✓		✓		
MSP	3%	1%	1%				✓		
ORD*	14% (AP) 34% (DP)	27%	34%	✓			✓		
PHL*	6%	33%	9%	✓			✓		✓
PHX	-	19%	13%		✓				

Airport Identifier	Percentage Capacity Improvements Over Today			Future Improvements					
	Visual	Marginal	Instrument	New Runway or Extension	Improved Parallel Runways Operations	WTMA	Improved Runway Delivery Accuracy	Fanned Departures	WTMD
SAN	2%	2%	0%				✓		
SEA	5%	8%	4%				✓		✓
SFO	4%	3%	3%			✓	✓		✓
SLC	3%	4%	4%				✓		
TPA	-	6%	8%		✓				

AP = Arrival Priority
DP = Departure Priority
* Capacity estimates include benefit of all future improvements, including new or extended runway(s) as well as technology and procedural improvements

Differences from Previous Benchmarks

A significant difference between this report and the 2001 and 2004 editions is the capacity model used to produce the current and future capacity estimates. As noted in the methodology section, a new more sophisticated airport capacity model, *runway*Simulator, was used to estimate capacity for this updated report.

The need for a more advanced airport capacity model arose from the realization that airports have outgrown the capability of the FAA’s Airfield Capacity Model (ACM), in both size and complexity. ACM was used for both the 2001 and 2004 editions of the benchmark study. ACM is a computer program that analytically calculates the maximum average throughput of a runway system. It was originally developed in 1970s and was enhanced over the years to keep up with changes in computing technology. However the core functionality of the ACM has remained largely the same since it was created four decades ago. The ACM has several limitations that could not be addressed by incremental upgrades. To overcome these limitations, analysts had to perform additional calculations or combine multiple runway capacity results into a single airport capacity value.

As a new model, *runway*Simulator addresses many of these limitations. Up to 10 runways can be modeled, with an unlimited array of runway orientations. Thus, analysts no longer need to combine individual runway results because the entire airport can now be modeled in one capacity simulation. In addition, complex runway geometry, specialized ATC rules, and runway aircraft restrictions can be directly simulated in the model. This results in a more holistic approach to the estimation of airport capacity.

In addition to the new capacity model, comprehensive, up-to-date operational information was available from ASPM and the ATCSCC. Operational information was then supplemented by data obtained from local ATC facilities. Collectively, the data supported a change in the airport configuration selection criteria (as discussed previously) so that the runway configuration that provides the highest sustainable throughput during periods of strong demand was selected, rather than the most commonly used configuration. As a result, in some cases, the runway configurations profiled differ from those in the previous editions of the benchmarks.

Finally, recent operational data have been used in this study. Updated fleet mix data were obtained from FAA data sources; detailed fleet mix information by airport and a description of how it was derived can be found in Appendix D. Several other data sets were used to give context to airport capacity data (such as weather data, scheduled operations, and actual traffic) have also been updated for this report. The current ATC Facility Reported Rates are also used.

While the methodology used in this report is similar to that used for the previous editions, the updated results should nonetheless not be compared to previous reports. The model used to estimate capacity is different and improved, and recent data is reflective of the current operating environment.

Core Airport Capacity Profiles

The following sections present the capacity profiles for each of the Core Airports. The airports are presented in alphabetical order by the three-letter airport code, as in the prior tables and figures.

Each airport profile describes the runway configurations that were analyzed for each weather scenario, the ATC procedures used, and the effect of future improvements at the airport. If a new runway has been approved at the airport (i.e., a ROD has been issued), the effect of the runway is discussed separately.

Airport capacity rate range is represented by both ATC Facility Reported Rates (i.e., called rates) and model estimates using the *runway*Simulator model. The airport capacity, expressed as a rate range, is the hourly throughput that an airport's runways are able to sustain during periods of high demand. Because traffic demand has peaks during an hour (i.e., demand is not uniformly distributed throughout an hour), an airport operating at its capacity curve would experience significant levels of delay.

Capacity results for each weather condition are shown graphically (see **Figure 3** for an example). Modeled runway capacity is represented as a frontier (the solid black line) rather than as a single point to show the tradeoff between arrival and departure operations. Typically, the number of arrivals per hour will decrease as the number of departures increases, for at least a section of the capacity curve, since arrivals and departures often share runways (e.g., SAN). In certain cases (e.g., some ATL configurations in visual weather conditions), arrivals are independent of departures because they operate on separate runways, so there is no tradeoff. Airports generally operate with a mix of arrivals and departures, and would rarely operate at the extreme ends of the curve (i.e., all departure or all arrivals) for any length of time.

The capacity graphs show the model-estimated number of arrivals and departures per hour as well as the arrival and departure rate reported by the ATC facility. If the estimated or Facility Reported rate is, for example, 60 arrivals per hour and 30 departures per hour, it would be abbreviated as (60, 30).[11] The capacity rates are expressed as a range between the ATC Facility Reported Rate (**the red circle**) and a corresponding point on the model-estimated capacity curve (**the black square**).

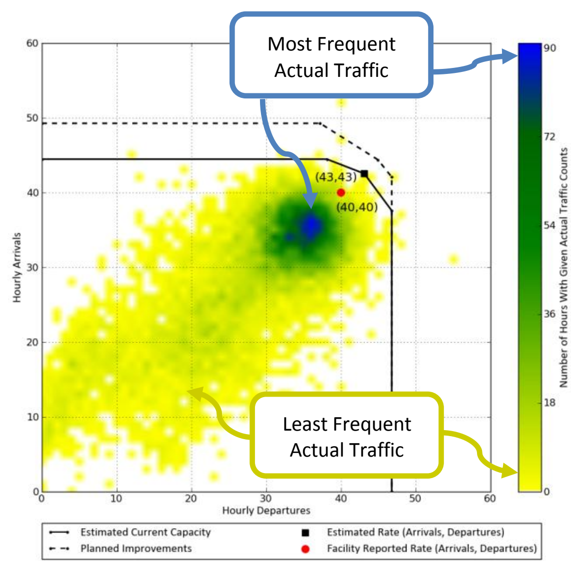

Figure 3. Sample Capacity Results

An average annual fleet mix is used to estimate the modeled capacity rates. Using an average can mask

[11] Arrivals are listed first in accordance with historical precedent and the convention used to express runway configurations.

the capacity variation seen in actual hourly operations. For airports that experience periods of strong demand by long-haul or heavy aircraft, actual throughput during those periods may be lower than the capacity rate range, due to the additional spacing required to accommodate these aircraft. However, on average this effect will be offset by other hours where a more homogenous fleet mix leads to higher throughput.

Actual traffic data is also shown on the capacity charts. These data represent actual operations at each airport from October 2008 through September 2010, between the hours of 7am and 11pm local time as reported in the FAA's ASPM database. Each combination of arrivals and departures may have occurred multiple times during this period. A color scale is used to depict how frequently these combinations occur with blue representing the most frequent combinations and yellow the least frequent.

ASPM data were used to determine the runway configuration and weather condition information. As discussed previously, the selected configuration was initially determined using ASPM data, where possible, but was confirmed through discussion with the ATC facility.

An airport layout diagram is included for each airport to better understand the various runway configurations that were analyzed. Future runway construction is also shown in these layouts. These diagrams were adapted from the airport diagrams found in the FAA Terminal Procedures Publications (available online at *aeronav.faa.gov*), and include some supplemental labeling of buildings and terminals.[12]

[12] Most of the airport diagrams were effective from 16-December-2010 to 13-January-2011 unless an airport requested that an updated version be used.

Core Airport Profiles

City	Airport	Airport Code
Atlanta	Hartsfield-Jackson Atlanta International	ATL
Boston	Boston-Logan International	BOS
Baltimore	Baltimore/Washington Thurgood Marshall Intl.	BWI
Charlotte	Charlotte/Douglas International	CLT
Washington, DC	Ronald Reagan Washington National	DCA
Denver	Denver International	DEN
Dallas-Fort Worth	Dallas/Fort Worth International	DFW
Detroit	Detroit Metropolitan Wayne County	DTW
Newark	Newark Liberty International	EWR
Fort Lauderdale-Hollywood	Fort Lauderdale-Hollywood International	FLL
Honolulu	Honolulu International	HNL
Washington, DC	Washington Dulles International	IAD
Houston	Houston George Bush Intercontinental	IAH
New York	New York John F. Kennedy International	JFK
Las Vegas	Las Vegas McCarran International	LAS
Los Angeles	Los Angeles International	LAX
New York	New York LaGuardia	LGA
Orlando	Orlando International	MCO
Chicago	Chicago Midway International	MDW
Memphis	Memphis International	MEM
Miami	Miami International	MIA
Minneapolis-St Paul	Minneapolis-Saint Paul International	MSP
Chicago	Chicago O'Hare International	ORD
Philadelphia	Philadelphia International	PHL
Phoenix	Phoenix Sky Harbor International	PHX
San Diego	San Diego International	SAN
Seattle-Tacoma	Seattle-Tacoma International	SEA
San Francisco	San Francisco International	SFO
Salt Lake City	Salt Lake City International	SLC
Tampa	Tampa International	TPA

Appendix A – Additional FACT2 Airport Capacity Profiles

City	Airport	Airport Code
Long Beach	Long Beach-Daugherty Field	LGB
Oakland	Metropolitan Oakland International	OAK
Orange County	John Wayne-Orange County	SNA

Appendix B – Relationship of the Capacity Rates to New York Area Airport Orders Limiting Operations

The capacity estimates in this report are based on information provided by ATC, including facility reported arrival and departure rates for several profiled weather conditions. The operational limits put in place under the Orders limiting operations for EWR, JFK, and LGA involve a trade-off between airport throughput and a tolerable level of delay under all weather conditions.

The Government Accountability Office (GAO) recommended, and FAA agrees, that operational limits for EWR, JFK, and LGA should be established under realistic weather and operating scenarios, not visual conditions. This can result in reduced throughput during good weather conditions but helps prevent excessive delays during adverse weather periods. The following paragraphs provide information specific to EWR, JFK, and LGA.

<u>EWR</u>: When developing the schedule limits for EWR, modeling showed an average adjusted capacity of 83 total operations per hour with high sustained delays throughout the day. Additionally, the FAA modeled the proposed 2008 schedules and projected an even higher level of congestion and delays from those proposed schedules with EWR already one of the most delay-prone airports in the NAS. The FAA established a goal of no increase in delays at EWR while permitting additional operations to the extent practicable. The current Order's limit of 81 scheduled operations per hour reflected that goal of no increase in delays and permitted a margin for unscheduled operations. Although the FAA accepted some flights above the hourly limits, it reserved the authority to retire returned slots exceeding the limits and to work with airlines to de-peak their schedules.

<u>JFK</u>: When developing the schedule limits for JFK, modeling showed that the average adjusted capacity was steadily increasing over time. Additionally, a procedural change in early 2007 allowed departures on Runway 31L beginning at Taxiway KK, thereby providing increased runway capacity and reduced departure delays. The FAA conducted discussions with airlines to seek voluntary agreement to retime flights at JFK from the busiest hours to less congested times when they could be accommodated with lower delay impact. The FAA's goal was to reduce the peak evening departure delays from the summer 2007 average of about 80 minutes. The limit of 81 scheduled operations per hour in the JFK Order reflected the goal of reducing peak evening departure delays, allowed some additional operations during non-peak times, and permitted a margin for unscheduled operations. As a result, modeled peak departure delays decreased to about 50 minutes or by 30 minutes per flight when compared to summer 2007. As part of the schedule discussions for JFK, the FAA accepted some flights that exceeded the scheduling limits but reserved the authority to retire returned slots exceeding the limits and to work with airlines to continue to further depeak their schedules.

<u>LGA</u>: FAA established a limit of 75 operations per hour in December 2000 to reduce delays associated with new flights operating under AIR-21 slot exemptions. Further modeling showed that a reduction in the scheduled limit from 75 to 71 operations per hour could generate a 41% decrease in average delays. Subsequently, the FAA reduced the hourly scheduled limit from 75 to 71 in the current Order to provide an opportunity for delay reduction at LGA from voluntary returns or slots failing to meet the minimum usage rules. The FAA did not withdraw operating authority to achieve the lower limit, but reserved the authority to retire returned slots exceeding the limit. Up to 3 unscheduled operations per hour are permitted by the Order.

Appendix C – Relationship of the Airport Capacity Profiles to FACT3

The airport capacity profiles serve as a basis for the Future Airport Capacity Task 3 (FACT3), an in-depth evaluation of airport capacity needs. FACT3, which is expected to be published in early 2014, will estimate future delay and congestion levels at airports. Table C-1 provides additional information on the distinctions between the Airport Capacity Profiles in this report and FACT3.

Table C-1: Comparison of Airport Capacity Profiles and FACT3

Comparison	Airport Capacity Profiles	FACT3
Objective	Report on the hourly throughput that an airport's runways are able to sustain during periods of high demand	Identify airports that are likely to be capacity-constrained in 2020 and 2030
Factors considered that affect capacity	Runways, technology, procedures	…adds airspace, surface movements, gates
Delay	Not evaluated	Future delay estimates are estimated, for the purpose of applying criteria to identify airports as capacity-constrained
Annualization	Not annualized; the profiles show sustainable hourly throughput during the highest capacity configuration during visual, marginal, and instrument conditions	Annualized demand and delay based on 16 sample days (demand and weather), as well as Annual Service Volumes (ASVs)
Future Operations	Provides model estimate of capacity in 2020 with future improvements that were current as of January 2011	Use refined future improvement assumptions to model estimates of capacity and delay in 2020 and 2030

Appendix D – Fleet Mix

Tables D-1 and D-2 show the fleet mix that was used for the individual airport capacity estimation. The fleet mix for each airport is grouped by wake category, which is what governs many ATC spacing requirements at an airport. Aircraft counts by airport for FY2009 were obtained from the Enhanced Traffic Management System Counts (ETMSC). The aircraft type designators (per FAA JO Order 7340.1) were used to identify the weight class, which is then converted to a wake category.

The wake categories, which are primarily based on weight, are defined as follows:

- Heavy – Maximum Gross Takeoff Weight (MGTOW) at least 300,000 pounds.
- Boeing 757 (B757) – The Boeing 757 series aircraft (757-200 and 757-300) are classified as Large, but they have special separation rules, and are treated like Heavy aircraft when they are the lead aircraft in a pair.
- Large – More than 41,000 pounds MGTOW but less than 300,000 pounds. For airports with environmental or noise restrictions, or limited runway length, Large aircraft were further categorized by engine type.
- Small – MGTOW of 41,000 pounds or less. The Small aircraft category was further broken down using same runway separation (SRS) categories at airports with a significant number of general aviation operations.[13]

The Airbus 380 (A380), which has an even greater wake vortex separation requirement than Heavy aircraft, operates at a few major airports in the U.S. However it comprises less than 1% of the annual fleet mix at these airports, and thus was not included as a separate wake category. There was little indication that A380s would have a substantial domestic presence in the future, since there were no A380s on order by any domestic airlines at the time the fleet mix analysis was performed.

ETMSC data is primarily derived from IFR flight plans filed by pilots and other automated data sources. Thus it rarely includes data for flights flying under Visual Flight Rules (VFR), as these flights are not required to file a flight plan. However, some airports in this report have a significant number of VFR operations. The difference between total operations from the FAA's Operations Network (OPSNET) and total operations from ETMSC was used as an estimate of VFR operations at each airport in FY2009. If the OPSNET total was more than 2% greater than the ETMSC total, a separate fleet mix was calculated for good weather operations (Visual conditions). Helicopter operations were filtered out of the fleet mix when data were available.

Table D-1 presents the fleet mix data for airports whose fleet mix does not change with the weather (i.e., these airports do not have substantial numbers of VFR operations). Table D-2 lists airports whose fleet mix was assumed to change with the weather. For these airports, the percentage of Small aircraft increases in Visual conditions, as VFR operations were assumed to be a part of the Small wake class.

[13] As defined by FAA Order JO 7110.65 paragraph 3-9-6.

Table D-1: Airports with the Same Fleet Mix in All Weather Conditions

	Annual Fleet Mix by Wake Class (Percentage)			
Airport	**Heavy**	**B757**	**Large**	**Small**
ATL	6.1	12.3	80.0	1.6
CLT	1.2	2.9	90.7	5.2
DCA	0.0	2.6	96.7	0.7
DEN	2.6	6.9	81.2	9.3
DFW	4.6	6.5	87.0	1.9
DTW	2.7	5.3	90.3	1.7
EWR	11.0	11.1	75.8	2.1
IAD	10.1	3.8	74.3	11.8
IAH	3.8	3.4	90.4	2.4
JFK	26.2	9.7	63.0	1.1
LAX	16.7	11.5	61.5	10.3
LGA	0.1	6.2	92.5	1.2
MCO	4.0	12.3	77.5	6.2
MEM	27.3	1.7	65.2	5.8
MIA	19.8	21.2	49.9	9.1
MSP	2.2	7.7	85.8	4.3
ORD	7.9	6.5	84.9	0.7
SEA	5.1	8.0	83.1	3.8
SFO	13.4	11.0	59.9	15.7

Table D-2: Airports with Different Fleet Mixes in Visual Weather Conditions

	Annual Fleet Mix by Wake Class (Percentage)				
Airport	Weather	Heavy	B757	Large	Small
BOS	Visual	4.8	9.4	69.7	16.1
	Marginal/Instrument	5.0	9.7	72.4	12.9
BWI	Visual	2.0	3.7	83.1	11.2
	Marginal/Instrument	2.0	3.8	84.9	9.3
FLL	Visual	1.4	5.6	66.2	26.8
	Marginal/Instrument	1.5	6.0	70.6	21.9
HNL	Visual	15.7	3.5	43.8	37.0
	Marginal/Instrument	21.8	4.9	60.8	12.5
LAS	Visual	1.8	6.0	78.7	13.6
	Marginal/Instrument	1.9	6.3	82.8	9.0
LGB	Visual	0.5	0.0	11.7	87.8
	Marginal/Instrument	3.0	0.1	64.6	32.3
MDW	Visual	0.0	0.2	82.3	17.5
	Marginal/Instrument	0.0	0.2	85.6	14.2
OAK	Visual	6.4	0.2	49.7	43.7
	Marginal/Instrument	9.0	0.3	69.6	21.1
PHL	Visual	4.7	5.1	84.4	5.8
	Marginal/Instrument	4.8	5.3	86.5	3.4
PHX	Visual	1.9	3.2	83.9	11.0
	Marginal/Instrument	2.0	3.3	86.2	8.5
SAN	Visual	2.8	6.9	77.1	13.2
	Marginal/Instrument	2.9	7.1	79.2	10.8
SLC	Visual	2.3	5.0	65.6	27.1
	Marginal/Instrument	2.6	5.6	74.4	17.4
SNA	Visual	0.2	2.5	33.9	63.4
	Marginal/Instrument	0.4	5.1	69.2	25.3
TPA	Visual	1.6	6.3	69.6	22.5
	Marginal/Instrument	1.7	6.6	73.6	18.1

Appendix E – Glossary of Acronyms

AAR	Airport Arrival Rate
ACM	Airfield Capacity Model
ADR	Airport Departure Rate
ADS-B	Automatic Dependent Surveillance - Broadcast
ASPM	Aviation System Performance Metric
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
CDTI	Cockpit Display of Traffic Information
CSPR	Closely-Spaced Parallel Runway
ETMSC	Enhanced Traffic Management System Counts
FAA	Federal Aviation Administration
FACT	Future Airport Capacity Task
FRR	Facility Reported Rate or "called rate"
IFR	Instrument Flight Rules
MGTOW	Maximum Gross Takeoff Weight
NAS	National Airspace System
NGIP	NextGen Implementation Plan
NM	Nautical Mile/s
NTSB	National Transportation Safety Board
OEP	Operational Evolution Plan
OPSNET	Operations Network
PRM	Precision Runway Monitor
ROD	Record of Decision
SID	Standard Instrument Departure
SOIA	Simultaneous Offset Instrument Approaches
SRS	Same Runway Separation
TBM	Time Based Metering
TMA	Traffic Management Advisor
VFR	Visual Flight Rules
WTMA	Wake Turbulence Mitigation for Arrivals
WTMA-P	WTMA-Procedural
WTMA-S	WTMA-System
WTMD	Wake Turbulence Mitigation for Departures