# Defining and Measuring Aircraft Delay and Airport Capacity Thresholds

**DETAILS**

65 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-28380-9 | DOI 10.17226/22428

**AUTHORS**

TransSolutions; Futterman Consulting; Harris Miller Miller & Hanson, Inc.; and Jasenka Rakas

AIRPORT COOPERATIVE RESEARCH PROGRAM

## ACRP REPORT 104

# Defining and Measuring Aircraft Delay and Airport Capacity Thresholds

**TransSolutions**
Fort Worth, TX

**Futterman Consulting**
St. Petersburg, FL

**Harris Miller Miller & Hanson, Inc.**
Herndon, VA

**Jasenka Rakas**
Berkeley, CA

*Subscriber Categories*
Aviation • Planning and Forecasting

Research sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2014
www.TRB.org

## AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

## ACRP REPORT 104

Project 03-20
ISSN 1935-9802
ISBN 978-0-309-28380-9
Library of Congress Control Number 2014930049

### COPYRIGHT INFORMATION

### NOTICE

The project that is the subject of this report was a part of the Airport Cooperative Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the Airport Cooperative Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

*Published reports of the*

**AIRPORT COOPERATIVE RESEARCH PROGRAM**

*are available from:*

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

*and can be ordered through the Internet at*

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

# THE NATIONAL ACADEMIES

*Advisers to the Nation on Science, Engineering, and Medicine*

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. C. D. Mote, Jr., is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. C. D. Mote, Jr., are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

**www.national-academies.org**

# COOPERATIVE RESEARCH PROGRAMS

## CRP STAFF FOR ACRP REPORT 104

**Christopher W. Jenks,** *Director, Cooperative Research Programs*
**Crawford F. Jencks,** *Deputy Director, Cooperative Research Programs*
**Michael R. Salamone,** *ACRP Manager*
**Joseph D. Navarrete,** *Senior Program Officer*
**Terri Baker,** *Senior Program Assistant*
**Eileen P. Delaney,** *Director of Publications*
**Hilary Freer,** *Senior Editor*

## ACRP PROJECT 03-20 PANEL
### Field of Policy and Planning

**David C. Smith,** *Port of Seattle, Seattle-Tacoma International Airport, Seattle, WA* (Chair)
**Gregory H. Albjerg,** *HNTB Corporation, Minneapolis, MN*
**Tina M. Anderson,** *University of North Dakota, Grand Forks, ND*
**Michael S. Hines,** *Metropolitan Washington Airports Authority, Dulles, VA*
**Gwenn Larson,** *Delta Connection, Minneapolis, MN*
**Matthew H. Lee,** *Landrum & Brown, Cincinnati, OH*
**Esther Hernandez,** *FAA Liaison*
**Steve Urlass,** *FAA Liaison*
**Heather M. Krause,** *US Government Accountability Office Liaison*
**Chris Oswald,** *Airports Council International–North America Liaison*
**Richard A. Cunard,** *TRB Liaison*

# FOREWORD

By Joseph D. Navarrete
Staff Officer
Transportation Research Board

*ACRP Report 104: Defining and Measuring Aircraft Delay and Airport Capacity Thresholds* provides airports and their stakeholders with guidance for understanding, selecting, calculating, and reporting measures of delay and capacity. The report describes common metrics, identifies data sources, recommends the most appropriate metrics based on user needs, and suggests ways to improve metrics.

---

Airports and their stakeholders, including airlines, passengers, and the FAA, use different definitions of delay, based on their unique needs. These different definitions may lead to misunderstandings among stakeholders and uncertainty as to how the measures are calculated and used in various situations. As airports often quantify capacity and delay to determine whether a planned capacity improvement is cost-justified, it is important that the most appropriate measures be used and effectively communicated. Nevertheless, practitioners may not have the knowledge and training needed to select the appropriate measures, gather the frequently large amounts of data required to derive the measures, and perform the often complex calculations needed to estimate delay and capacity. Research was needed to offer that guidance.

This research, led by TransSolutions under ACRP Project 03-20, began with a review and evaluation of existing delay and capacity definitions, data, metrics, and tools. The researchers next undertook an extensive interview effort that included the FAA, airport management, airlines, consumers, attorneys, aviation industry organizations, and academia. The research team also reviewed available literature, including FAA advisory circulars and guidance documents, airport planning studies, delay databases, and capacity and delay computer simulation modeling efforts. The research team used their findings and their own experience to prepare the report.

*ACRP Report 104* is divided into five chapters. Chapter 1 introduces the challenge of defining and measuring delay and describes the report's organization. Chapter 2 discusses how delay is defined and used by various stakeholders, identifies sources of delay data, and describes how delay is calculated. Chapter 3 explains how capacity is defined and calculated and discusses the challenges of measuring capacity (including the interplay of how delay thresholds are used to set capacity thresholds). Recommendations for using the various definitions and measures of capacity and delay are provided in Chapter 4. Lastly, future trends for improving capacity and delay metrics, particularly for effectively communicating with the public, are summarized in Chapter 5.

# CONTENTS

---

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

## SUMMARY

# Defining and Measuring Aircraft Delay and Airport Capacity Thresholds

This report presents the results and recommendations from ACRP Project 03-20, Defining and Measuring Aircraft Delay and Airport Capacity Thresholds. The objectives of this report are to (1) inventory and describe the different aircraft delay and airport capacity metrics used within the industry and (2) provide guidance on various delay and capacity metrics and when they should be used, particularly within the context of evaluating capacity enhancements.

This report summarizes and highlights key findings from the research to assist airport planners in their capacity/delay analyses. Specifically, the report describes how the term *delay* is used by various industry groups, both for actual operational flight delays and theoretical or estimated delays for airport planning studies. This report summarizes findings from an extensive set of interviews with individuals from different industry organizations. Available air traffic databases are described, along with examples for airport delay analyses. Information also is provided on how delays are used in estimating capacity for airport development projects, including a review of numerous airport planning documents. The reader is referred to *ACRP Report 79: Evaluating Airfield Capacity* for more information on airfield capacity calculations.

Although airport capacity often has been determined according to when a certain measure of delay is experienced, this research does not present values of "acceptable delay" and, in fact, discourages using that label in capacity/delay estimates. This report presents tables describing what actual operational delays may occur at an airport based on when planning delays of particular values are calculated from analytical or simulation studies. These delay estimates vary by certain airport characteristics, including size, traffic schedule patterns, and how capacity varies among different weather conditions. An analyst can use these tables to determine appropriate delay threshold recommendations for a particular airport of interest. By estimating which characteristics apply to a specific airport, one can estimate the actual delays that will be experienced at that airport. Also included are some suggestions for additional metrics that can benefit the industry.

This research focuses on capacity and delay of the airfield—primarily runways and taxiways. Although the researchers recognize that capacity can be defined for other parts/functions of the airport and that it is important to balance the capacity of the various elements—airside, landside, terminal—this project was specifically undertaken to provide guidance on airfield capacity and delay.

# CHAPTER 1

# Introduction

Average aircraft delay is often cited as an indication of airport capacity or used as a measure to support the assertion that new runways or other airport improvements are needed. Experienced airport planners may have successfully applied the concept of "acceptable delay" to help define airport capacity for some time. Yet there is little guidance as to the amount of delay that defines capacity, thus the planner must justify the methodology used to estimate capacity for each project. The FAA's *National Plan of Integrated Airport Systems (NPIAS)* and *Airport Benefit-Cost Analysis Guidance* provide some statements with delay numbers, but do not give definitive recommendations on how to determine capacity as a function of delay. In addition, the way flight delays are reported (as a function of scheduled flight/block time) often does not correlate well to a simulation model's delay output (usually reported as additional time above "nominal" travel time). This leads to confusion about what "delay" really means and what delay thresholds should be used to determine capacity. Some clear guidelines on aircraft delay measures and airport capacity estimation are needed by the airport industry.

Analyzing aircraft delays is complex—both when looking from a historical perspective as well as when estimating delays with forecast demand. There are challenges in analyzing what is an average delay: average annualized delay or average peak hour delay or average delay in a particular wind/weather condition for the average-day-peak-month flight demand? Another typical delay measure is the flight delay data reported by airlines to the Department of Transportation (U.S.DOT) and compiled by the Bureau of Transportation Statistics (BTS). These statistics generally are published by the media each month to compare the on-time performance of competing airlines. If using delay as a measure to define airport capacity, it is probably not practical to have one threshold that can be applied to all airports. When setting standards for delay thresholds, the metrics should work for benefit-cost analyses and environmental impacts. These metrics also should be applicable at airfield configurations that, due to their infrastructure, are able to accommodate greater levels of delay. There have been many historic and current disagreements between airports and airlines as to what level of delay is acceptable, balancing airports' long-term demand accommodation interests vs. airline cost and competition issues. It should be noted that not all delay is to be viewed negatively: a certain amount of delay is necessary if a system is to run efficiently when close to capacity.

In conducting this research, the team interviewed more than 60 industry professionals from the FAA, airports, academia, airlines, industry associations, as well as attorneys and airport capacity consultants/analysts regarding how they use/analyze delays and their challenges in delay reporting. The discussions focused on issues related to airport planning. In addition, the team reviewed various planning reports from U.S. airports of all sizes to document the delay metrics and other criteria used to plan for airport development projects. This report summarizes and highlights key findings from the research to assist airport planners in their capacity/delay analyses.

Different delay measures are used by various entities within the aviation industry. For analysts, delay is generally considered as excess travel time—the difference between "actual" operating time minus a "nominal" or "scheduled" operating time. Yet, the simple word "delay" is used to describe many different situations.

- Delay can either be a capacity indicator or an on-time performance indicator. When used to measure capacity, delay evaluates the effects of a specific flight demand as it operates on the airfield resource.
- Airline delay may occur before the flight leaves the gate, comparing "out" time or actual time of departure (ATD) with scheduled time of departure (STD). The gate delay could be an air traffic control (ATC)-required gate hold and also may be referred to as on-time performance.

- Tarmac delays, often are discussed as the “3-hour tarmac rule” that went into effect in 2010.
  - Excess taxi-out time between the gate and the runway may be due to runway capacity (departure queue delay), departure hold due to airspace constraint, or arrival airport restricted acceptance rate and may or may not be weather related.
  - Excess taxi-in delay time between landing (“on” time) and gate arrival (“in” time) when gate is not available for arrival flight.
- Some en route/airspace delay is accumulated before the flight is reported by FAA as delayed. Airspace delay can be composed of different ATC actions to achieve necessary aircraft separation—queuing, airborne hold, vectoring, speed control—much of which is not obvious to the traveling public.

Chapter 2 addresses aspects of airport delay that are most commonly encountered in airport planning. Information on operational delays and mathematical delay estimates are discussed from the perspectives of the various aspects of the industry. Chapter 2 also contains approaches and methods to calculating delay, including “how to” instructions for local airport staff to analyze operational delays using FAA databases.

Airport capacity analyses are described in Chapter 3, including metrics that have been used in various airport planning studies. The topics discussed in this chapter include definitions of airport capacity, a brief overview of approaches to calculating capacity, and capacity thresholds and guidance on the use of capacity metrics for different audiences. Readers should refer to *ACRP Report 79: Evaluating Airfield Capacity* for more detailed information on how to analyze airport capacity.

Chapter 4 provides recommendations for using/applying delay and capacity analyses at an airport. Information is provided on the relevance of particular delay and/or capacity measures by airport type, airport characteristics, weather/capacity ratio, and project lifecycle phase. Rather than recommending threshold values, tables describe what actual operational flight delays may be experienced when specific average planning delays are applied. Using these tables, an analyst can establish appropriate delay thresholds for a particular airport.

In conducting this research, various individuals in the industry suggested that the following additional delay metrics may be needed:

- Easily understandable by industry experts and lay people,
- Communicates the “feel” for the impact of delays on the traveling public and tells the story that will resonate the benefit of new projects, and
- Capable of use as a common measure at any airport.

In this regard, suggestions also are presented in Chapter 5 for additional delay metrics that may better communicate the significance of the delay problem at particular airports. Chapter 5 also includes a discussion of future trends in capacity/delay measures.

## CHAPTER 2

# Delay

The term *delay* is quite simple and generally applied when an event occurs later than it was planned, scheduled, or expected to happen. It is a common term used in everyday conversation, not a term that is unique to aviation. However, *delay* is used or interpreted differently by various stakeholders involved in airport planning studies, airline operational on-time performance analyses, and the public. In general, delays in aviation may describe one of two following situations:

- Actual operational or real-time delay events, often compared to flight schedule. For actual flights—current or historical—delays are often measured as the actual times compared to the planned or scheduled times. *Schedule* may refer to times filed in a flight plan or a published airline schedule.
- Mathematical or calculated estimates (using analytical or simulation models) for planning, often compared to unimpeded, nominal, or optimal travel time. Analysts often use computer simulation tools or other analytical procedures to evaluate delays and delay savings. These tools and methods typically calculate a nominal or unimpeded time, then measure any additional time as delay.

Although this report briefly discusses the actual operational events, the primary focus is on the analytical delay values used in airport planning.

This comprehensive chapter on delay focuses on delay metrics, delay data sources, and approaches and methods to calculating delay. It includes the following items:

- Delay used by various stakeholders
  - FAA Air Traffic
  - FAA Airports Office
  - NextGen
  - Airports
  - Airlines
  - Consumers/passengers
  - General public (including airport neighbors)
- Historical/operational delay data
  - Descriptions of available delay databases
  - Examples of data analyses
  - Strengths/weaknesses
- Calculations of analytical delay metrics
  - Spreadsheet/basic models
  - Simulation models
  - Average annualized delays
  - Other delay statistics
  - Comparison of mathematical delays to operational/historical data

## 2.1 How Delay is Used and Defined by Various Stakeholders

This section discusses definitions of delay used by various stakeholders involved in airport planning studies, as well as common understandings of delay by the public.

### 2.1.1 FAA

#### *Air Traffic*

In measuring flight delays, the FAA's goal is meeting both airline and airport (user) expectations and passenger (end-user) expectations. Usually, FAA's Air Traffic Organization (ATO) focuses on flights delayed 15 minutes or more *from the flight plan* that result from the ATC system detaining an aircraft at the gate, short of the runway, on the runway, on a taxiway, and/or in a holding configuration anywhere en route. This includes ground stop delays and delays in expected departure clearance time (EDCT). The cause of delay is also recorded (e.g., weather, volume, equipment, and runway). Data is reported for all U.S. ATC facilities and for all instrument flight rules (IFR)-filed aircraft in the United States. More detailed taxi and airspace travel times and calculated taxi delay based on *typical unimpeded times* for each airport also are recorded for 77 U.S. airports. This data is now maintained in several databases, which are more thoroughly described in Section 2.2.

The current target for the FAA's performance metric of National Airspace System (NAS) on-time arrival is that 88% of flights at the 30 core airports (determined by FAA to be 29 large hubs and Memphis International Airport) arrive no more than 15 minutes late, based on the flight plan filed with the FAA, and excluding minutes of delay attributed to weather, carrier action, security delay, and prorated minutes for late arriving flights at the departure airport. However, on-time arrivals are combined for all airports such that problems achieving the target at specific airports are not able to be identified and perhaps corrected, an issue noted by the U.S. Government Accountability Office (GAO) as early as 2010 when they recommended airport-specific metrics be adopted and reported.

In addition, FAA has estimated that 70% of all aviation delays are caused by weather events, and weather delays are excluded from the on-time metric altogether. However, there may be technology and/or new procedures that could be implemented such that the weather delays would not have such detrimental effects on flight delays. Attributing the lack of technology to a weather delay masks the issue that perhaps different procedures or technology are needed to allow flights to operate in low visibility.

### *Airports Office*

For airport planning, delay is generally considered as excess travel time—the difference between *actual* operating time minus a nominal or optimal operating time. This is generally evaluated using analytical tools, spreadsheets, or simulation analysis. The nominal or unimpeded time is not readily available from scheduled flight times. As described in the FAA's *Airport Benefit-Cost Analysis Guidance* (December 1999), "delay is the added trip time attributable to congestion at the study airport, where congestion constitutes any impediment to the free flow of aircraft and/or people through the system."

Several current FAA documents related to airport planning include discussion of delays, including the following:

- *National Plan of Integrated Airport Systems (NPIAS) 2013–2017*—Throughout the FAA's current NPIAS, there are discussions of airport delay, congestion, and capacity. However, there is no statement about what exact delay threshold defines capacity.
  - "Delay is an indicator that activity levels are approaching or exceeding throughput capacity levels."
  - "The majority of airports in the national airport system have adequate airport capacity and few delays. However, there are airports that continue to experience delays. In 2011, there were five airports with average departure delays of more than 12 minutes per operation and two airports with average arrival delays of more than 14 minutes."
  - "The Nation's air traffic delay problems tend to be concentrated at certain large hub airports. Delays occur primarily during instrument weather conditions (i.e., reduced ceiling and visibility) when runway capacity is reduced below that needed to accommodate traffic levels. Because of the number of connecting flights supported by these airports, delays among these busy large hub airports can quickly ripple throughout the system, causing delays at smaller airports nationwide."
- *FAA's Airport Master Plan AC 150/5070-6B with Change 1* (May 2007)—"Delay is typically expressed in minutes per aircraft operation, which can be translated into hours of annual delay and easily converted into dollar estimates to be used as a basis for comparison. Traditionally, 4 to 6 minutes of average delay per aircraft operation is used in annual service volume (ASV) calculation. When the average annual delays per aircraft operation reaches 4 to 6 minutes, the airport is approaching its practical capacity and is generally considered congested."
- *Airport Benefit-Cost Analysis Guidance* (December 1999)
  - "Should simulation modeling reveal that the baseline traffic forecast would lead to average airside, terminal, or landside delays of more than 20 minutes per operation or passenger, the rate of growth in the baseline forecast would need to be adjusted downward. This revision is necessary because approximately 20 minutes represents the highest level of average delay realized in actual practice, even at highly congested airports."
  - "Airports experiencing severe delay due to congestion will not be able to accommodate rising demand for air service. Average delay per operation of 10 minutes or more may be considered severe. At 20 minutes of average delay (approximately the highest recorded average delay per operation known to FAA at an airport in the United States), growth in operations at the airport largely will cease. Prior to reaching these levels, airlines would begin to use larger aircraft, adjust schedules, and cancel or consolidate flights during peak delay periods. Passengers would make use of alternative airports, seek other means of transportation (e.g., automobile or train), or simply avoid making some trips."
- *FAA Airport Benefit-Cost Analysis Guidance Addendum* (June 2010)—Related to determining systemwide impacts in a BCA, this document acknowledges that some delay at a specific airport propagates delay downline as the aircraft continues through the day's routing. Delay analysis related to airport planning typically is only focused on one specific airport, or "original" delay. This guidance contains multipliers for estimating "propagated" delay in a BCA.

FAA Orders *1050.1, Environmental Impacts: Policies and Procedures*, and *5050.4, National Environmental Policy Act (NEPA) Implementing Instructions for Airport Projects* do not specifically address delay values or performance goals. Technical analyses supporting the purpose and need in environmental studies often use the BCA guidelines noted above for determining when delays are excessive and unreasonable for air service providers and customers/passengers. Also, analyses for an environmental impact statement (EIS) at a large congested airport may use the BCA guidance regarding delays when estimating whether the traffic demand would continue to operate when simulated average delays exceed 20 minutes or whether they should attribute a cost to cancelled/diverted flights.

### *NextGen*

The Next Generation Air Transportation System (NextGen) is a comprehensive initiative across multiple federal agencies to make air travel in the United States NAS more convenient and dependable, while ensuring flights are as safe, secure, and hassle-free as possible. This transformative change, which is already providing benefits, integrates new and existing technologies, including satellite navigation and advanced digital communications. Some of NextGen's goals include enhancing safety, reducing delays, increasing capacity, saving fuel and reducing aviation's adverse environmental impact. NextGen involves many areas and disciplines, including new air traffic technology, weather information, data communications, environmental concerns, aviation security, and global harmonization.

More specifically related to airports, one of NextGen's delay reduction benefits is to reduce the impact of weather, achieving similar delays or capacity in instrument meteorological conditions (IMC) as in visual meteorological conditions (VMC). Technology and procedures will allow for reduced dependencies between aircraft operating on closely spaced parallel runways. Airports' runways that have not had instrumentation for arrivals during IMC may be able to have precision-based navigation (PBN) approach procedures to use those runways during low visibility/ceiling conditions. PBN includes area navigation (RNAV) and required navigation performance (RNP). RNAV enables aircraft to fly any course using ground- or space-based navigation aids. RNP is RNAV with onboard monitoring and alerting capability. Also, localizer performance with vertical guidance (LPV) approaches are being added to many general aviation airports. LPV is operationally equivalent to Category (CAT) I Instrument Landing System (ILS) approaches, and FAA plans to have LPV approaches to all qualified runway ends by 2016.

The optimization of airspace and procedures in the metroplex (OAPM) is an important method by which airspace and procedure design efforts are being incorporated into the NAS. Several OAPM efforts around major airports are currently ongoing across the United States.

The FAA is tracking airport performance for NextGen using key performance indicators of capacity, efficiency, and predictability at major airports. The metrics are based on taxi times/delays and flight travel times. The FAA has developed and continues to update a NextGen Performance Snapshot website that reports post-implementation performance data for metroplexes and airports. Currently, these performance snapshots are found at www.faa.gov/nextgen/snapshots.

Additional metrics were being reported in the areas of efficiency (average delays/times), predictability (standard deviations), and capacity (average daily operations and peak throughputs) for the top 77 airports. Currently, the metrics reported are reduced to those most useful for tracking NextGen progress and for only the top 30 airports, using the following metrics on an efficiency scorecard:

- Average gate arrival delay (minutes per flight),
- Average gate-to-gate time (minutes per flight),
- Average number of level-offs per flight (count per flight),
- Distance in level flight from top of descent to runway threshold (nmi per flight),
- Taxi-in time (minutes per flight), and
- Taxi-out time (minutes per flight).

Although FAA has these dashboards/performance snapshots for the major airports and notes the NextGen improvements that are in place at these airports, GAO and others have reported that the agency still does not make a link between improvements and changes in delays; much of the recent decline in delays is more attributable to the declines in the traffic than NextGen or other improvements.

## 2.1.2 Airports

An airport has an infrastructure that provides a certain throughput, but many operational delays—late arrivals or late departures—at airports are the result of issues out of their control (e.g., weather, airline scheduling practices) or elsewhere in the aviation system (e.g., airspace constraints, ATC, storms in other areas). In some cases, airports collect data on delays and are able to show that few delays are attributable to the actual airport, but are due to upline or downline constraints. Operational delays are typically measured through FAA databases (see Section 2.2) or by comparing actual times to airline schedules.

Airports typically focus both on throughput and average delay. In general, an airport measures its impact on delay based on the overall ability to stay below maximum airport capacity. If the airport's operations were under their maximum capacity all day, from the airport's point of view, there were no airport-caused delays, regardless of when a particular aircraft was scheduled to depart versus when it actually departed.

Those airports that have significant delays recognize that this affects their ability to compete for air service with other airports. International operations can have a big impact on, and be greatly affected by, delays. In some cases, if a flight misses its assigned slot time, the flight has to be cancelled and therefore process exceptions are made to make sure international departures are not delayed.

At many airports today, traffic demand is well below capacity. Where the demand is below VMC capacity, delays are small such that delay analyses, much less airline scheduling practices, are not of great concern. Other airports believe that most of these delays could be avoided by the airline scheduling additional time between flights. Most airlines take their own gate capacity at each airport into account when developing their schedules, but do not necessarily consider runway capacity. This results in schedules being developed that can be maintained during VMC capacity, but these same schedules far exceed IMC capacity.

Airports with similar VMC and IMC capacities tend to have somewhat reasonable delays during IMC. Also, airports that only encounter IMC a small amount of time can tolerate much higher IMC delays. However, airports with huge differences between VMC and IMC capacities that experience IFR conditions somewhat regularly experience significant delays. There is further information in Section 2.3 on analyzing delays in various weather conditions and combining them into one overall delay value.

Delays can be quite high during severe weather and it may take many hours for flights to get back on schedule. It is not unusual for extreme weather conditions, such as thunderstorms at the airport location or elsewhere, to result in cascading delays at airports across the nation. A delay anywhere along the aircraft routing for that day—no matter how small—can have a domino effect and by the time the aircraft has reached the end of the day's schedule, it could translate into hours of delays.

Although many international airports coordinate airline schedules and have some control to prevent airlines scheduling more flights than can be accommodated, that does not occur in the United States. Only at the few slot-controlled airports (High Density Rule) is there oversight to the airline flight schedules at airports. As an example, at LGA in 2000 when slots were removed, airlines scheduled 50% more flights than could be accommodated in an hour. That indicates that if the only control mechanism is market forces, then there will likely be significant delay at certain desirable airports.

### *For Master Planning and Environmental Studies*

Airports typically follow the FAA's guidance when considering a capacity enhancement project and use delay estimates as the major master plan tool to help identify runway and taxiway needs to meet forecast demand levels. The cost-benefit analyses should result in a positive return of economic savings, and delay savings is a large part of this calculation. Airports generally define delay as the difference between optimal/unimpeded travel times and expected times (often calculated with simulation tools), whether the delay is on the ground or in the air.

The current standard metric for measuring delay at an airport is average delay per operation. There is agreement that this metric is not adequate and does not tell the whole story. However, at a large airport, there is also general agreement that

- Average delays below 5 minutes per operation are tolerable,
- Average delays greater than 10 minutes are a problem, and
- Average delays over 20 minutes indicate the airport is experiencing very significant congestion issues to the point of not being able to operate due to gridlock.

Note that some of these metrics are based on FAA planning documents (e.g., *Airport Benefit-Cost Analysis Guidance, Airport Master Plan AC 150/5070-6B*) as well as general experience in aircraft operations/schedules regarding the level of delays that a particular airport or airline schedule can tolerate while still maintaining some reliability. Other times, airports simply consider whether the delay savings have a positive return, regardless of the absolute value of the delays.

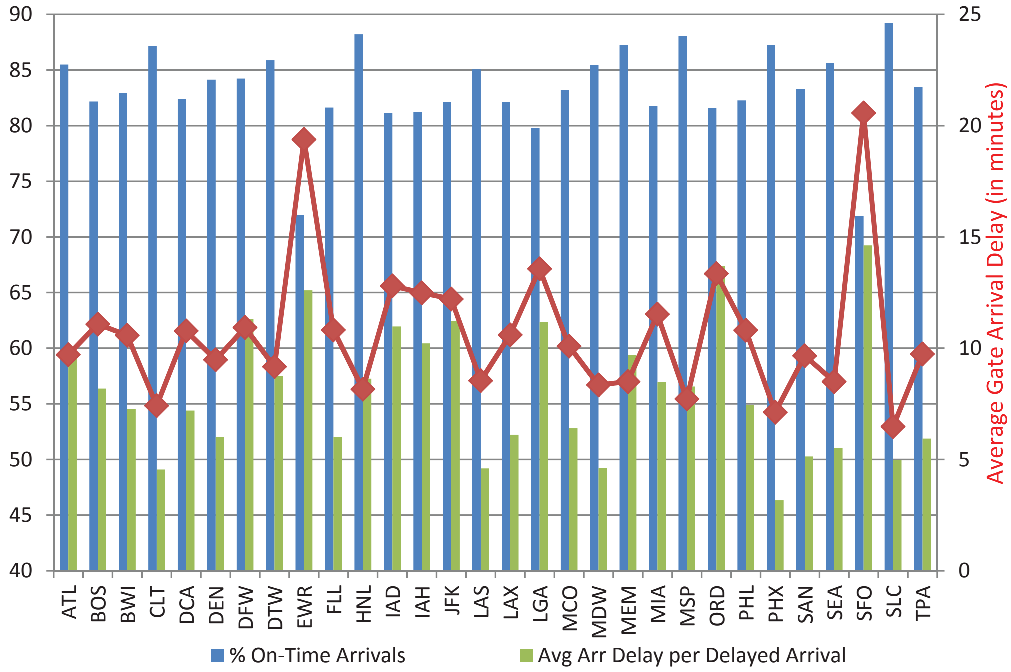
### *For Project Justification and Cost-Benefit*

Airports typically cannot justify projects that are needed just to accommodate the peak, especially knowing that airline scheduling practices could change. Airports do not build to meet peak demand, but try to provide an acceptable level of service for typical demand.

Each airport has its own unique issues that may complicate the analysis. For instance, airports with gates proximate to runway ends cannot tolerate as much delay as airports with plenty of taxiway queuing space. Some have just one runway; some have six or more, with most or all runways intersecting. This makes comparisons difficult. Ten minutes of *average* delay at one airport is not comparable to 10 or even 6 minutes at another airport.

### *For Comparison to Other Airports*

Significant delays can be considered reasonable given an airport's history of delay. Some airports have run for years with average delays 10 to 13 minutes per operation. Figure 2-1



Source: TransSolutions analysis of ASPM data

*Figure 2-1. Arrival delays for core 30 airports, 2012.*

shows the arrival delay statistics for the core 30 airports (designated by FAA) for 2012. Note, however, that this data is compiled from data provided by the air carriers, not from the flight-plan data or from the airports. The on-time percentage (blue bar) is evaluated as the flights that arrived within 15 minutes of their scheduled time. Note that for 2012, EWR and SFO had the lowest percentages of on-time arrivals and also the highest average delays per arrival flights (red dot). However, when looking at the amount of delay per delayed flight (green bar), ORD and EWR had similar values.

## 2.1.3 Airlines

Airlines look at delays from a number of perspectives. Primarily, they look at delays as compared to their scheduled times. In general, "flight delay" is variance from schedule—that is, the actual gate arrival or departure versus the scheduled time of arrival or departure. This simple calculation defines the airlines' departure or arrival on-time performance.

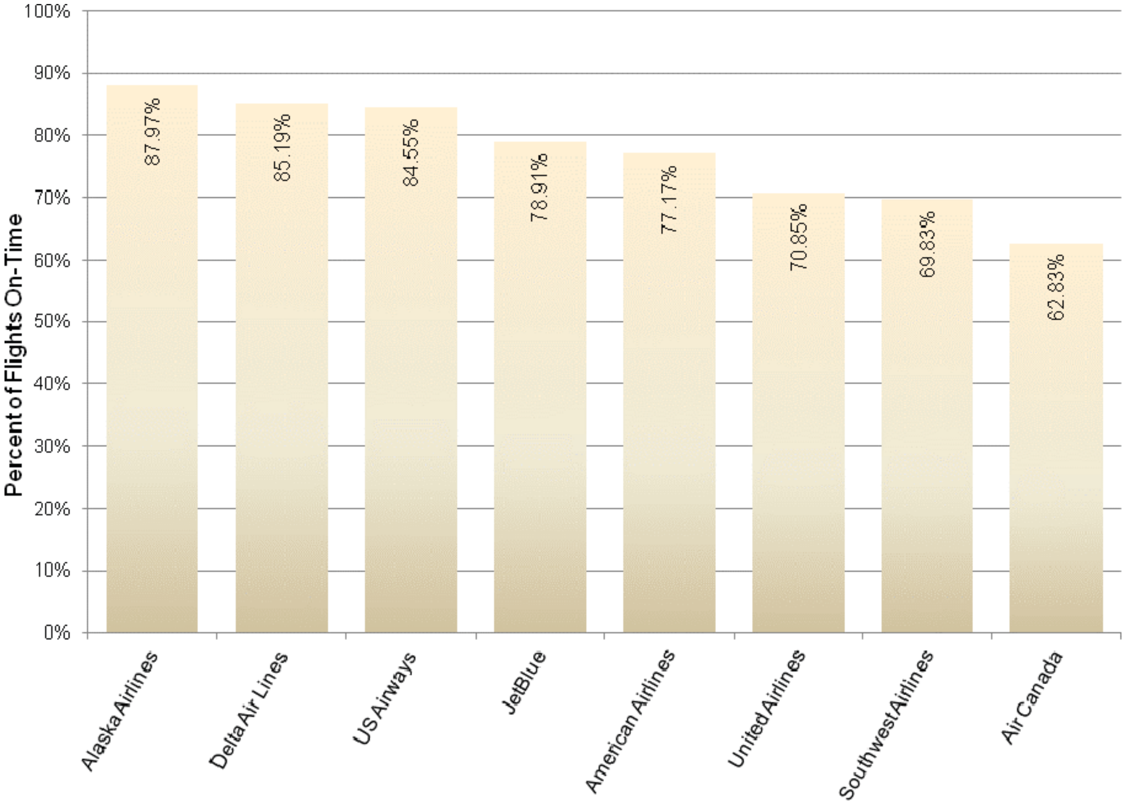
Airlines measure departure delay (e.g., leaving the gate within 5, 10, and/or 15 minutes of STD) because they know that it directly correlates to arrival performance. Airlines have some control in getting aircraft to leave the gate on time, for example, by setting policies to cut-off passenger boarding a specified number of minutes prior to scheduled departure.

### *On-Time Performance Rankings*

Airlines also focus on arrival delays, specifically, A+15 (arrival at the gate within 15 minutes after scheduled arrival), as that is the measure that the U.S.DOT reports. (For example, see Figure 2-2, which compares the on-time performance of the major carriers in North America.) Flights that are early are counted as on-time, even if they had to wait for a gate upon arrival, as long as they eventually pulled into the gate within 15 minutes of their scheduled time of arrival. If a flight arrives to the gate early, it is still considered on-time, and no "negative delay" offsets late arrivals in the calculations. In the competitive environment, airlines spend a great deal of effort to accurately schedule their flights and improve their on-time performance standings.

For airlines, average delay information is not as meaningful as individual flight delay information. Some airlines specifically focus on the first flight of the day for an aircraft (kickoff flights) because they recognize that this can lead to delayed flights all day. Airlines also record and analyze very detailed data on what caused the delays and trends in the types of delays, because they may be able to correct the items causing the delays. However, it can be very difficult to determine how to allocate delays if multiple items were impacting a plane's departure. For example, if the bags were still being loaded late but maintenance was fixing something as well, the delay will typically be coded to the item that took the longest, thus masking the other delay cause completely since it did not have a material effect.

Airlines also specifically measure taxi delays and en route delays if they are recorded by the pilots in the onboard systems. Long delays are monitored closely, especially since the new U.S.DOT tarmac rule can significantly fine airlines for long-delayed flights with passengers on board. However, delay metrics usually do not include cancelled flights.



Source: FlightStats

***Figure 2-2. Airline on-time performance (June 2012).***

### *Out-Off-On-In (OOOI)*

Data commonly used for evaluating aircraft travel times and delays at an airport is the out-off-on-in (OOOI) data. Many airlines use onboard systems, such as the Aircraft Communications Addressing and Reporting System (ACARS) to automatically record these times, which are defined as follows:

- Wheels "out" of the gate/parking position is the time an aircraft departed from the gate, typically measured when the parking brake is released. Also called the actual time of departure (ATD), which can be compared to the STD.
- Wheels "off" the runway is the time an aircraft departed from the runway.
- Wheels "on" the runway is the actual time an aircraft landed on the runway.
- Wheels "in" the gate or parking position is the time an aircraft arrived at the gate, typically measured when the parking brake is set. Also called the actual time of arrival (ATA), which can be compared to the scheduled time of arrival (STA).

Analysis of taxi times at an airport use "out-to-off" times for taxi-out or departure taxi time, and "on-to-in" times for taxi-in or arrival taxi time. Similarly, "out-to-in" times would require the entire time from one airport gate to another, which can be compared to the scheduled block time.

### *"Padding" the Schedules/Block Times*

The published STD and STA are the only parts of the airline schedule development that are publicly available. The duration from the STD to STA is the scheduled block time. Airlines include in the block time the expected taxi-out time, expected en route time, and expected taxi-in time at the destination airport. It is important for the scheduled block times to be accurate, but there are competing forces for setting the block times, as follows:

- Passengers purchase tickets or flights based on the STA and/or STD. These times need to be both realistic and convenient in order to meet passenger expectations.
- An airline's planning and staffing are based on scheduled times. For every minute in the block time, the crew and aircraft are not available to be scheduled for another flight/trip. Each minute in the block time is equivalent to millions of dollars.
- U.S.DOT rankings are based on percent on-time compared to the STA and STD.
- Turnaround times at gates and minimum connection times for passengers are based on the block times.

Airline block time for the same city-pair flight using the same aircraft type will vary by season of year and time of day.

Airlines add time to their block time schedules to accommodate for historical actual times, which include some delay resulting from flight restrictions, congestion, and a variety of other factors. Although there is concern that airlines "pad" the block times to artificially improve their on-time performance, it is a costly endeavor to add minutes to the block time. Each carrier must make a decision as to what is the most realistic block time to apply to a given flight. Figure 2-3 depicts the variation in the actual block time as recorded in the FAA's Aviation System Performance Metrics (ASPM) database for all flights in a calendar year (2010) with a scheduled block time of 150 minutes for a given airline (American Airlines) between the same city pair (DFW-MCO).

If airlines use the average block time, then they are guaranteed to be underestimating actual times for a large number of flights. If they use a larger number for the block time, their on-time performance will improve, but it will be quite costly because that aircraft, crew, etc., cannot be available for another scheduled flight. In this example, the airline could schedule to a block time of 135 minutes and 8.5% of the flights would have experienced a block time of 135 minutes or less, showing that that smaller amount of block time is achievable, but not consistently since over 90% of the flights took more time than that. Even if airlines publish a schedule with the average block time of 147 minutes, 44% of the flights would experience a block time longer than that. Since the published time is used by passengers in anticipating not only their airport arrival, but their subsequent arrival at their ultimate destination, passengers prefer to have a scheduled arrival time that is reliable.

In the example above, while 70% of the flights had a total travel time of 150 minutes (the scheduled block time) or less, only 53.8% of the flights arrived at or before their scheduled arrival time, due to departing late from the origin airport. Still, 64.2% of flights arrived no more than 5 minutes after scheduled arrival, 72.5% of flights arrived no more than 10 minutes after scheduled arrival, and 77.5% of flights arrived no more than 15 minutes after scheduled arrival, which is considered on-time by the common criteria of A+15 as reported by U.S.DOT. It is interesting to note that the median of the actual block times was 146 minutes.

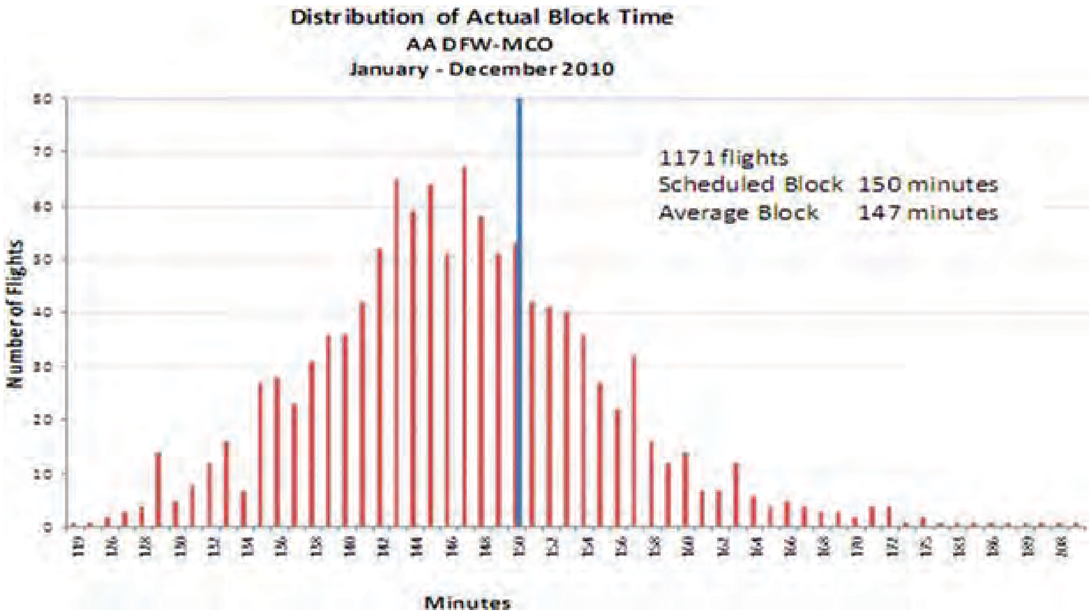
When airspace changes occur or a new runway is constructed, airlines react by modifying their block time calculations, although it may take a few schedule changes to fine-tune total travel times.

Airlines also are very sophisticated at analyzing taxi-in and taxi-out times at their major hub airports and adequately accounting for the expected taxi times in the block timings throughout the day. At busy airports, the taxi-out component of the block time may vary by over 30 minutes throughout the day to account for typically higher taxi-out times during peak hours at the airport.

However, when actual flight times are compared to block times, one does not obtain an accurate estimate of true delays, since the block times already include some typical or historical delays.

### *Flight Schedule Influence on Delays*

Airline scheduling practices contribute significantly to gate and airfield delays. Specifically, when airlines schedule a high



Source: ASPM

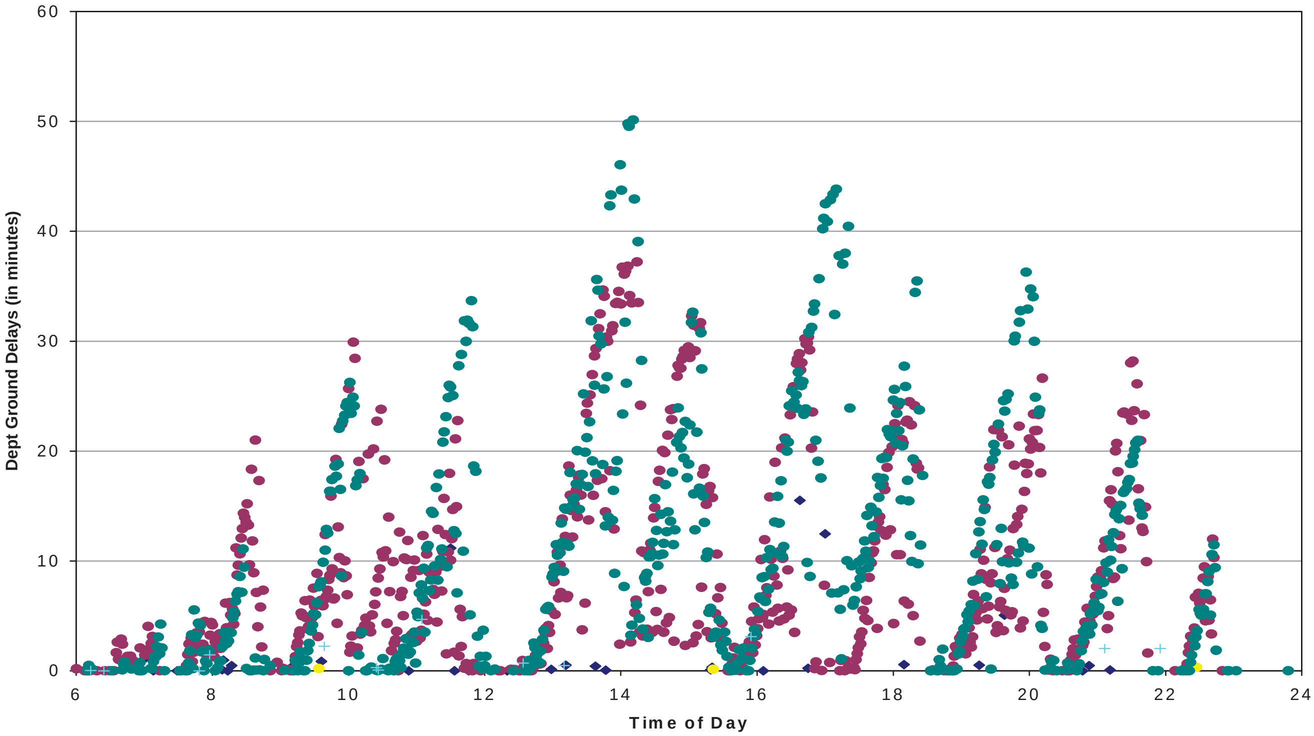
*Figure 2-3. Distribution of actual block time (2010).*

number of flights in a short period of time, airports experience congestion and delays. Airline business model practices such as hub-and-spoke scheduling also play a part in capacity constraint delays. For example, with tightly scheduled flights, one thunderstorm with lightning lasting just 15 minutes can cause delays for the 25+flights on the ground that cannot be loaded for departure. At the same time an additional 25+ flights continue to arrive, waiting on the tarmac for these same occupied gates. Even if gates are available to accommodate extra flights, the airlines typically do not have the extra ground crews available to handle the extra gates, thus driving significant delays. Notably, with non-hub carriers, this is not as much of an issue as the flights are spaced out with enough time between them that few delays are attributable to the domino effect.

However, airlines overschedule capacity because it makes economic sense. Consumers want flights that leave at specific, desirable times during the day and want connections scheduled that allow them to most quickly reach their destination. Studies have shown the tradeoff between delay costs and revenue benefit of overscheduling. In an unrestricted competitive environment, airlines overschedule capacity for peak times at airports. Hub-and-spoke scheduling tends to overschedule for peak arrival and departure times—causing some delay—while this tends to be less of an issue for point-to-point carriers. Banks of flights, or complexes, create mathematically optimal setups for passenger connections but can drive large delays. De-peaking tends to lengthen passenger layovers or connection times.

If airline banking schedules include lulls or valleys in the daily schedule to allow catch up (recovery periods), then this practice does not create intolerable delays. However, without valleys or cancellations, delays will propagate throughout the day. Delays can be influenced by airline culture or strategy: some airlines have a "must complete" attitude about their schedule and will take very long delays to avoid cancellations. Others will cancel some flights to keep the network on time. Also, some have employee cultures that tend to make up time during turns to avoid delays.

When the operational delays often motivate an airline to consider capacity improvement alternatives at an airport, they will typically rely on similar planning analyses (delay relative to unimpeded time) as those used by the FAA and airports. However, for airlines, average delay information is not as meaningful as individual flight delays. Airlines are concerned about maximum delays, maintaining schedule integrity, and being able to turn the aircraft on the ground within the scheduled time (i.e., even if an arrival flight is a few minutes late, they still want to make an on-time departure). Figure 2-4 plots simulated departure delays for each individual aircraft throughout the day, with the different symbols representing the runways used by the flights. It is quite easy to see how delays grow several times throughout the day during the departure peaks, when there are more departures scheduled in a few minutes



Source: TransSolutions

*Figure 2-4. Sample chart of individual aircraft delays.*

than what the airport can efficiently accommodate. Generally, the airport (and the airline flight schedule) is able to recover between the departure complexes as the delays go back to zero in between the complexes. If the airline were able to schedule the flights throughout the hour rather than bunched together in a few minutes, the average and maximum delays would be much lower.

In this example, while the maximum delay is 50 minutes, the average is only 10.3 minutes. In this scenario, the airport might promote that 10 minutes of departure delay is reasonable, but the airline could be concerned about the variance in the delays and the flights that are delayed longer than can be added into the block time.

When determining a reasonable amount of delay, airlines may use a low average delay goal at some airports but tolerate large amounts of delay at other airports—either due to their operations (connecting hub vs. destination/spoke airport) and/or marketing strategies to limit additional flights, airlines, and/or gates.

### 2.1.4 Consumers/Passengers

The most effective definition of delay may be "it's a delay if perceived as one by the traveling public." In many consumers' minds, the travel experience has gotten worse and, given that an increase in travel demand is expected, it is likely to worsen further. They perceive real delays as *anything beyond the scheduled times.* Consumers, in general, would like predictable departure and arrival times. Flights are purchased based on the expected departure and arrival times. Passengers would like to avoid lost productivity from unexpected delays.

A passenger considers it a delay if they depart or arrive late as compared to schedule and do not recognize any extra time that might have been built into the scheduled block time by the airlines. However, if a flight departs late, that is easily forgotten and forgiven if the flight arrives on time. But if the aircraft lands early but has to then wait for a gate, this again is often perceived as delay—even if the flight still reaches the gate prior to its STA. Passengers may use the word "delay" in reference to any of the following situations:

- Inbound flight is late so that no aircraft is available for the scheduled flight departure, causing a delayed departure.
- Mechanical or aircraft cleaning or missing crew (or some other problem) prevents the passengers from boarding the aircraft, delaying the departure.
- After the passengers board the flight, something prevents the aircraft from departing the gate on time.
- The aircraft leaves the gate, but experiences a long taxi-out time; when the aircraft finally takes off the runway, passengers perceive that the runway departure is delayed (even though this long taxi-out time may have been fully accounted for in the scheduled block time).
- The flight is delayed en route by ATC through speed control or vectoring; this is often unknown to the passengers, and is only recognized if communicated by the flight crew or when the flight arrives to the destination airport late.
- The flight is rerouted around weather, adding unexpected flight time, resulting in a delayed arrival at the destination airport.
- The flight lands at the destination airport, but has to wait for an open gate; this is often perceived as a delay even if the passengers are able to deplane prior to, or at, the scheduled arrival time.

That said, not all delays are equal. A 5-minute delay en route is typically acceptable (and may not even be recognized by the passenger), while the same 5 minutes experienced waiting for the aircraft door to open after the plane has arrived can be extremely frustrating to passengers. In general, passengers are more accepting of delay if the airline does a good job of communicating the reason for the delay and expected departure and/or arrival times.

Likewise, passengers do not necessarily perceive an early arrival in a positive way. Passengers do not tend to "credit" airlines with arriving early and, in fact, often mock the airline for over-estimating the travel time just to improve their on-time performance.

Although consumers dislike any delays, long delays inside an aircraft on the ground are of particular concern. The recently enacted passenger protection rule is a punitive way to force airlines to manage and avoid long tarmac delays. This law mandates, among other things, that airlines provide food, water, and other amenities to passengers kept waiting on tarmacs and give them the opportunity to get off the plane after a wait longer than 3 hours for domestic flights (4 hours for international flights).

Passenger tolerance also is not consistent at all airports. Historical delays are so commonplace that people expect to be delayed at some airports. There is some thought that, when given a choice of regional airports, passengers are willing to tolerate longer delays at closer, convenient airports rather than at airports farther out (and perhaps more inconsistent surface travel time to/from). If so, this implies that passengers somewhat consider their total travel time from origin (e.g., home, business, hotel) to destination (hotel, home, business) rather than merely the scheduled airline travel time.

However, many passengers are extremely sensitive to price. Although delays are of concern to passengers, they tend to make their ticket purchase decision based on price and scheduled arrival (or departure) time rather than delay rankings.

The airline consumer group Flyers Rights (formerly the Coalition for an Airline Passengers' Bill of Rights) has been focused on extremely long flight delays for several years. They recognize that there is a need to invest in infrastructure, especially noting the importance of gate capacity to improve airport capacity and delays. Perceptions associated with delays for consumers/passengers mostly center around unpredictable arrival/departure times and unexpected delay, leading to lost productivity of the passengers.

### 2.1.5 General Public

Each month, media reports compare the on-time performance and delays at different airports (Figure 2-5). Flight delays are regularly reported in the mainstream media, whether due to severe weather or just typical operating conditions. As previously stated, these delays are based on the airlines' flight schedules, which already have some delay included in them, but this is not apparent to the casual observer.

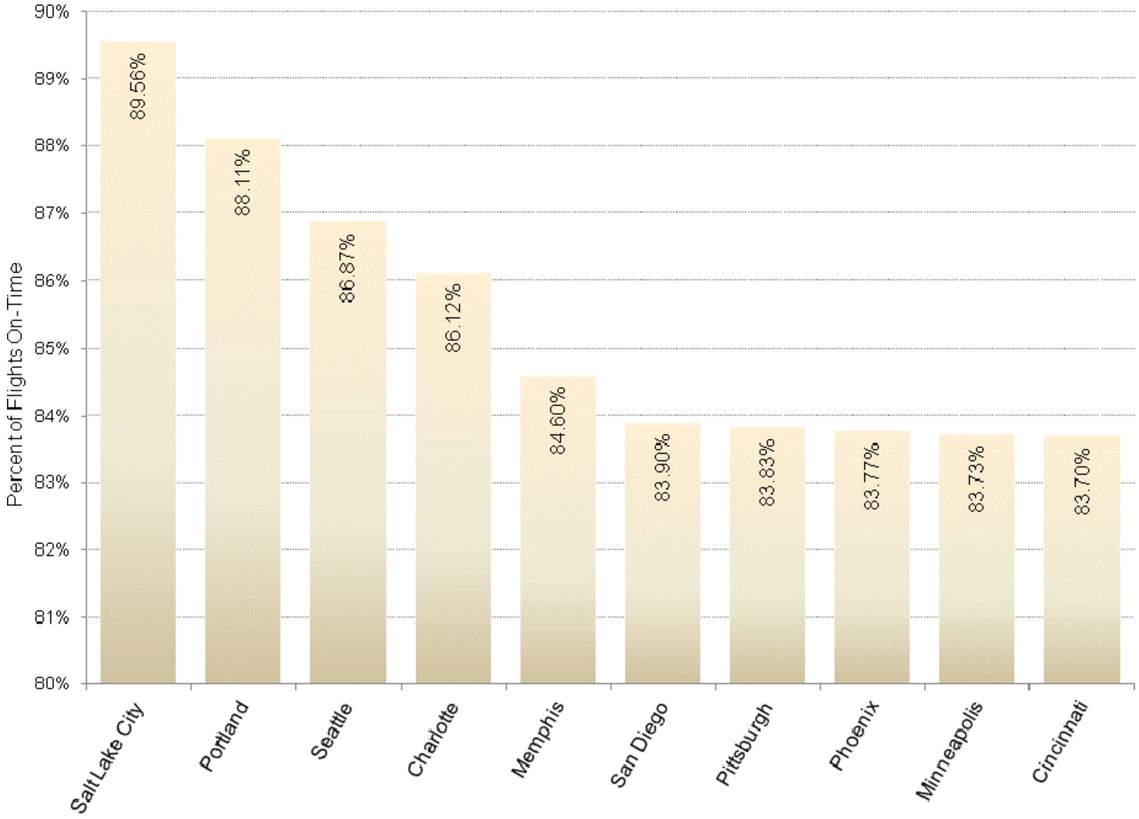
However, public opinion tends to remember the long operational delays or the extreme cases. Even on a day where several flights experienced an hour or more of delay, the average delay might have been only 1 or 2 minutes. And, as reported every year, the vast majority of flights arrive "on time," meaning within 15 minutes of their scheduled arrival. A large number of flights even arrive at the gate prior to their scheduled time.

When local communities are affected by increased flight operations (e.g., noise) or proposed airfield expansion, estimating expected delay savings of potential capital projects at an average of 1 or 2 minutes does not sound very large or worthwhile. But when the average dollar savings is applied to each and every flight throughout the year, it has a dramatic impact on fuel burn and overall passenger delay.

## 2.2 Historical/Actual Delay Data

Actual operational flight travel times and delays can be accessed through several data sources. This section contains a description of several FAA databases and other data sources with samples of data analyses. In addition, the databases are summarized in Appendix A. The following data sources are discussed in this report:

- TFMSC—Traffic Flow Management System Counts,
- PDARS—Performance Data Analysis and Reporting System,
- OPSNET—Air Traffic Operations Network,
- ASQP—Airline Service Quality Performance,
- ASPM—Aviation System Performance Metrics,
- BTS—Bureau of Transportation Statistics, and
- Local airport systems.



Source: FlightStats

*Figure 2-5. North America's top 10 on-time departure airports (June 2012).*

### 2.2.1 TFMSC

The FAA's Traffic Flow Management System (TFMS) is a data exchange system for supporting the management and monitoring of national air traffic flow. (Note: for those familiar with the Enhanced Traffic Management System [ETMS], TFMSC replaced that system in 2010.) TFMSC processes all available data sources such as flight-plan messages, flight-plan amendment messages, and departure and arrival messages. The FAA's airspace lab assembles TFMS flight messages into one record per flight. TFMSC is restricted to the subset of flights that fly under IFR and are captured by the FAA's en route computers. Visual flight rules (VFR) traffic is not included, and even some non en route IFR traffic is excluded. TFMSC includes information about commercial traffic (air carriers and air taxis), general aviation, and military to and from every landing facility, as well as airspace fixes in the U.S. and in nearby countries that participate in the TFMSC system.

After processing, the TFMS file provides detailed flight records, including time, distance, aircraft type and user type. The Air Traffic Laboratory (ATA-100) provides Boundary Crossing File (BCF) records for each flight in the NAS. A flight segment for this purpose is one aircraft traveling through one air route traffic control center (ARTCC), so a flight that travels through three ARTCCs would be divided up into three records.

The flight segment records are then grouped into flight records (one record per flight) using a unique flight identity code. The aircraft's maximum takeoff weight (MTOW) is also added to the flight record using an aircraft type reference file (this file also contains seating capacity, cargo capacity, load factors and fuel consumption). For international arrivals and departures, the model also estimates flight time and distance outside of U.S. airspace, which is later used to calculate user revenues and costs. The model then sums the number of operations, actual flight miles, great-circle flight miles and flight hours at each ARTCC, and these data are used for further processing as follows:

- Count of flights (departures, arrivals, and both departing and arriving in the same ARTCC),
- Actual miles flown,
- Great-circle equivalent of miles flown, and
- Hours flown.

The en route activity used is in the form of counts, hours, miles and great-circle miles for flights departing, arriving, both departing and arriving, or overflying an en route service delivery point (SDP). Additional records are created to turn a flight that both departs and arrives within one center into two operations for the en route SDP, which is a more accurate depiction of how en route activity is counted in other data systems. For terminal SDPs, two counts of TFMS operations are made: "TFMS Operations" are the number of flights that departed or arrived at that terminal SDP.

The TFMS data provides the capability to calculate types of operations (arrival, departure, or overflight for en route centers), terminal operations counts (arrivals, departures, and overflights) and instrument operations (primary, secondary, and over) on a flight-specific basis. In addition, for the en route and oceanic environments, it also is possible to derive the time within the center's airspace, actual distance flown within the center's airspace, and the great-circle route distance between the entry and exit point of the center's airspace.

#### *Actual/Historical Data vs. Calculated/Estimated Data*

The TFMS data provides the capability to calculate types of operations (arrival, departure, or overflight for en route centers), terminal operations counts (arrivals, departures, and overflights) and instrument operations (primary, secondary, and over) on a flight-specific basis. In addition, for the en route and oceanic environment it is also possible to derive the time within the center's airspace, actual distance flown within the center's airspace, and the great-circle route distance between the entry and exit point of the center's airspace.

TFMS raw databases, used by aviation analysts for airport delay calculation, are always filtered for duplicate and missing data. The most reliable times (i.e., field data) are

1. OOOI (gate out, wheels off, wheels-on, and gate in) times: provided by most airlines and relay information about the actual aircraft movement times. When OOOI times are not available, they are estimated according to the guidelines provided by FAA.
2. Actual gate departure time: if an airline does not provide OOOI times, estimated gate departure times are calculated as (estimated wheels-off time) minus (median taxi-out time by carrier by day by hour).
3. Actual gate arrival time: if an airline does not provide OOOI times, estimated gate arrival times are calculated as (estimated wheels-on time) + (median taxi-in time by carrier by day by hour).
4. Scheduled gate departure time: given by Official Airline Guide (OAG).
5. Scheduled gate arrival time: given by OAG.

Depending on the available information from the TFMS database, delay is computed as the difference between the actual time and scheduled time. One of the standard steps in computing actual departure or arrival delay is to adjust for taxi time. This is because airlines publish gate times, while an analyst frequently only has actual runway times; therefore, adjustments by taxi time are required as follows:

actual departure delay = [(actual gate departure time
– taxi time)] – scheduled gate
departure time

Table 2-1 provides an analysis example for one flight from IAD to SFO with TFMSC data. In this example:

actual departure delay for flight UAL225
= [dept time – (off time – out time)] – fs_dept_time
= [4:42:00AM – (4:41:00AM – 4:30:00AM)] – 3:05:00AM
= 1:24:00 hrs

actual arrival delay for flight UAL225
= [arr time – (in time – on time)] – fs_arr_time
= [10:23:00AM – (10:23:00AM – 10:19:00AM)]
– 9:16:00AM
= 1:03:00 hrs

An airport analyst interested in airborne delay can quickly and simply compute airborne delay by following schedule times and OOOI times; for example, if a flight departed 15 minutes late, and arrived 25 minutes late, its airborne delay was 10 minutes.

### *Strengths*

TFMSC includes data for flights that fly under IFR and are captured by the FAA's en route computers. This includes information about commercial traffic (air carriers and air taxis), general aviation, and military to and from every landing facility as well as fixes, both in the U.S. and in nearby countries that participate in the TFMS system. TFMSC can calculate airborne delay such as delay in each ARTCC or sector (because it has sector boundary crossing information) and speed. Data is collected electronically. This is an input into ASPM.

### *Weaknesses*

TFMSC is not appropriate for micro analyses of delays per runway. Although TFMS reliably captures the vast majority of IFR traffic and some VFR traffic, it has several limitations and challenges. First, due to limited radar coverage and incomplete messaging, TFMS may exclude certain flights that do not enter the en route airspace and other low-altitude flights. Also, of the 35,000 location identifiers reported over time, only the top few thousand, accounting for over 95% of traffic, are reliable. The others are waypoints or other references to locations not associated with an airport. Access to the TFMSC database is restricted by password and authorized by FAA.

### *Documentation, Data Access, and Point of Contact*

- To obtain a TFMSC login and password: https://aspm.faa.gov/Default.asp
- About TFMSC: http://aspmhelp.faa.gov/index.php/TFMSC
- Address: Office of Aviation Policy and Plans
  Federal Aviation Administration
  800 Independence Ave., SW
  Washington, D.C. 20591
  Phone: (202) 267-3336
  Fax: (202) 267-5370

## 2.2.2 PDARS

As a result of collaboration between the FAA and the National Aeronautics and Space Administration (NASA), PDARS collects data every 5 to 6 seconds from Air Route Traffic Control Centers (ARTCCs) and Terminal Radar Approach Control facilities (TRACONs). PDARS' raw data produces information such as the type of operation, aircraft identification, and actual runway threshold time. On the airport level, a significant piece of information lies in the information on aircraft-runway assignments. Delay measurements can be indirectly calculated when compared against the OAG databases. The raw PDARS database contains more than 90 fields for each flight.

PDARS software calculates a range of performance measures, including traffic counts, travel times, travel distances,

**Table 2-1. TFMSC data for one flight.**

| ACID | dept_arpt | arr_arpt | dept_time | arr_time | fs_dept_time | fs_arr_time | out time | off time | on_time | in_time |
|---|---|---|---|---|---|---|---|---|---|---|
| UAL225 | IAD | SFO | 4:42:00 AM | 10:23:00 AM | 3:05:00 AM | 9:16:00 AM | 4:30:00 AM | 4:41:00 AM | 10:19:00 AM | 10:23:00 AM |

Key:
dept_time: actual gate departure time
arr_time: actual gate arrival time
fs_dept_time: scheduled gate departure time
fs_arr_time: scheduled gate arrival time
out time: time aircraft leaves gate or parking position (gate out time)
off time: time aircraft takes off (wheels-off time)
on_time: time aircraft touches down (wheels-on time)
in_time: time aircraft arrives at gate or parking position (gate in time)

traffic flows, and in-trail separations. It turns these measurement data into information useful to FAA facilities through an architecture that features (1) automatic collection and analysis of radar tracks and flight plans, (2) automatic generation and distribution of daily morning reports, (3) sharing of data and reports among facilities, and (4) support for exploratory and causal analysis.

One of the main PDARS functions is to provide FAA facilities with the capability to both identify air traffic situations that can be changed or improved and quantify the consequences of operational adjustments from safety and efficiency perspectives. However, the PDARS database can be used to calculate delays when combined with additional databases. Figure 2-6 presents the steps for calculating gate delays. The following databases are combined for this particular delay calculation:

- ASPM: to obtain taxi-in aircraft time;
- PDARS: to obtain information on flight number, date, runway assignment, airline, type of aircraft, and actual threshold arrival time; and
- ASQP and OAG: to match flight number information, date, airline, and origin/designation to provided scheduled time at a gate.

Once gate delays are calculated for each flight, a better understanding of the delay process could be achieved by fitting the best theoretical probability distribution against the calculated empirical delay data (Figure 2-7). Estimation of a probability distribution for gate delays is useful in forecasting gate delays and can be used in planning or revising airline schedules, or in implementing alternative strategies for delay reduction.

The PDARS database provides detailed information on aircraft-runway assignments and therefore enables an airport analyst to conduct micro-level analyses of delays for each runway. To date, this is the only aviation database that provides such information. Figure 2-8 presents empirical probability distributions of gate delays for individual runways at SFO.

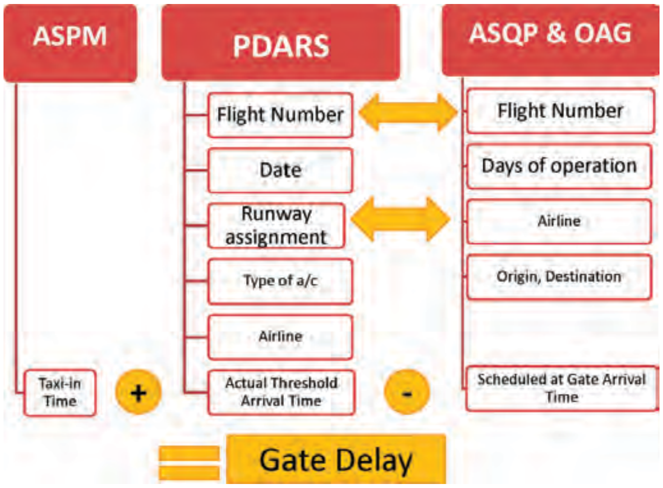
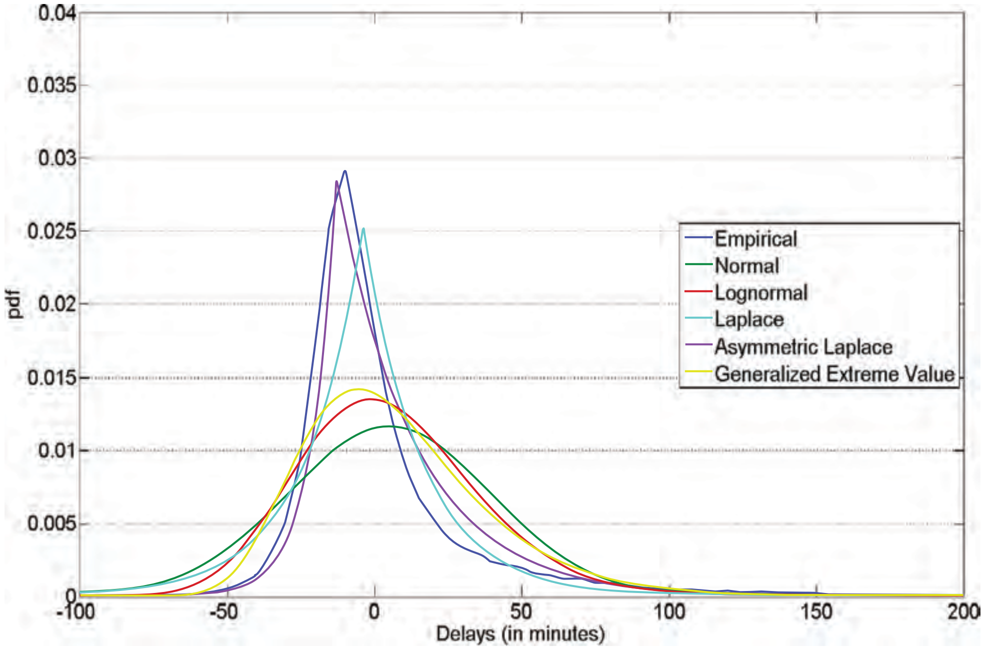
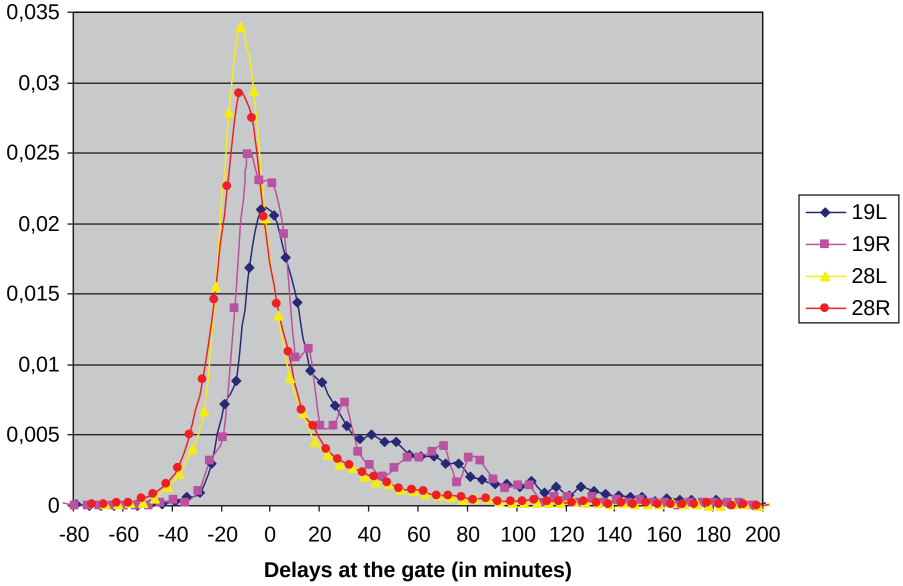


*Figure 2-6. Calculation of gate delays using ASPM, PDARS, ASQP and OAG databases.*



Source: J. Rakas

*Figure 2-7. Probability distributions for aggregate gate delays at SFO using PDARS.*



Source: J. Rakas

*Figure 2-8. Empirical gate-delay data at SFO for each runway.*

### Actual/Historical Data vs. Calculated/Estimated Data

PDARS software calculates a range of performance measures, including traffic counts, travel times, travel distances, traffic flows, and in-trail separations. It turns these measurement data into information useful to FAA facilities through an architecture that features (1) automatic collection and analysis of radar tracks and flight plans, (2) automatic generation and distribution of daily morning reports, (3) sharing of data and reports among facilities, and (4) support for exploratory and causal analysis. Delay measurements are indirectly calculated when compared against the OAG databases.

### Strengths

Data is collected electronically; information is updated every 5 to 6 seconds. Analysts can calculate delays on a micro level for each runway because of underlying information on aircraft-runway assignments. The raw database has over 90 fields, containing more information about each flight than the TFMSC database. Analysts generally find that PDARS is a better data source to measure system capacity in comparison with ASPM in that PDARS provides a higher level of fidelity that provides more accurate analytical data in comparison with ASPM.

### Weaknesses

PDARS is not publicly available—it is only available to FAA, NASA, and ATAC Corporation. It collects its own target report data from radars from 20 (of 22) domestic ARTCCs, 27 (of 185) terminal radar approach control (TRACON) facilities serving the 34 (of 35) domestic Operation Evolution Plan (OEP) airports, the Air Traffic Control System Command Center (ATCSCC), and the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. Therefore, only 34 airports' delay data is included in PDARS, far less than ASPM. Surface delay metrics are not as elaborate as in ASPM. Current efforts include better integration of ASDE-X data in order to create advanced surface metrics measuring airport efficiency and safety. Although it is an excellent tool for airspace redesign, it is less suitable for airport capacity and delay analyses.

### Documentation, Data Access and Point of Contact

- PDARS is only available to authorized FAA users at ATC facilities, but raw data could be available to FAA contractors.
- ATAC's article about PDARS: http://www.atac.com/docs/MTS%20Nov%20Dec%202010%20PDARS.pdf
- Address: ATAC Corporation
  2770 De La Cruz Boulevard
  Santa Clara, CA 95050-2624
  Phone: (408) 736-2822

  NASA Ames Research Center
  Moffett Field, CA 94035

  PDARS Program Office
  FAA Air Traffic Organization (ATO)
  Performance Analysis
  The Portals Building
  1250 Maryland Ave., SW
  Washington, DC 20024

### 2.2.3 OPSNET

OPSNET is the official FAA aircraft delay reporting system. Data comes from observations by FAA ATC personnel, who manually record the number of aircraft delayed 15 minutes or more relative to nominal or unimpeded taxi-out and taxi-in times estimated for each airport. OPSNET data measures the efficiency of the FAA ATC system; it does not measure delays based on the scheduled times, but on the flight-plan times submitted to air traffic. OPSNET reports delays for each airport by the following categories:

- Category of delay (e.g., departure delay vs. arrival delay);
- Class (e.g., air carrier vs. general aviation); and
- Cause (e.g., weather vs. traffic volume).

OPSNET records the following information and data:

- Airport operations: IFR and VFR arrivals and departures, and local operations at the airport as reported by Air Traffic Control Towers (ATCTs). It does not include overflights.
- Tower operations: IFR and VFR arrivals and departures, IFR and VFR overflights, and local operations worked by the tower.
- TRACON operations: IFR and VFR operations and overflights worked by the TRACON.
- Total terminal operations: Total operations worked by any facility based on the functions at the facility. If a facility has a tower and a TRACON present, the total terminal operations are a sum of the tower operations and the TRACON operations for that facility.
- Center aircraft handled: Domestic and oceanic departures and overflights and total aircraft handled by ARTCCs and center radar approach controls (CERAPs).
- Facility information: Provides information about each ATC facility, such as facility name and type, region, state, hours of operation, etc.
- Delays: Provides information about the reportable delays provided daily through FAA's OPSNET.

Delay results using OPSNET data are available through the FAA's ASPM website. If an airport analyst is interested in obtaining performance reporting for a selected airport, or a group of airports, the results could be displayed with the following report types: standard report, ranking, comparison, peak days report, ground delay, day of the week, and report facility.

As an illustration, Tables 2-2 through 2-5 present output results using various criteria that were selected from the main OPSNET delay menu: My Reports (report type), Facility (airport—can be selected from ASPM 77, OPSNET 45, OEP 35, or core database), Dates (days, months, year range, period), Filters (default, only FAA staffed facilities, only FAA contract staffed facilities, only data by ARTCC), Groupings (date, facility, state, region, class), Output, Run.

For example, to produce the Standard Report for Airport Operations for a selected airport (Table 2-2), the following steps are performed, select:

1. Facility (SFO airport),
2. Date (1/2012–1/2013),
3. State (CA); Region (AWP—Western Pacific code),
4. Service Area (WT—Western Terminal), and
5. Class (facility type or classification—Towers with Radar).

The output produces the total number of operations, divided between Itinerant (air carrier, air taxi, GA, military, total) and Local (civil, military, total).

To obtain a Standard Report for Airport Delays (Table 2-3), an aviation analyst may select the following items from the input menu: Facility (35 OEP airports) and Date (01/01/12–12/31/13). This standard report produces results for the following variables: Total Operations, System Impact Delays, Total Delays, Traffic Management Initiative (TMI) to Delays, Occurred at Delays (departure delay, airborne delay, TMI from delays, airborne destination to delay), delays by class (air carrier, air taxi, general aviation, military), Delay by Cause (weather, volume, equipment, runway, other), and Delay by Time (average) and Time (total).

To obtain the OPSNET delay data as a standard report for an airport (Table 2-4), an analyst selects a specific Facility (e.g., SFO airport only), and the time period (01/2012–12/2013) from the menu.

A simple Ground Delay Report (Table 2-5) may be obtained by selecting the following items from the menu: Date (01/2012–01/2013) and Facility (SFO airport). The output produces number of Delays, Minutes, and Average delay for Ground Stops, Expected Departure Clearance Times (EDCT) and Total.

#### *Actual/Historical Data vs. Calculated/Estimated Data*

OPSNET Delays provides information about reportable delays provided daily through FAA's Air Traffic Operations Network (OPSNET). A reportable delay recorded in OPSNET is defined in FAA Order 7210.55F as, "Delays to IFR traffic of 15 minutes or more, which result from the ATC system detaining an aircraft at the gate, short of the runway, on the runway, on a taxiway, or in a holding configuration anywhere en route, must be reported. The IFR controlling facility must ensure delay reports are received and entered into OPSNET." These OPSNET delays are caused by the application of initiatives by the Traffic Flow Management (TFM) in response to weather conditions, increased traffic volume, runway conditions, equipment outages, and other causes.

#### *Strengths*

The FAA's OPSNET database contains delay causality information. Delays are assigned to five major categories within

**Table 2-2. OPSNET Standard Report for Airport Operations, 01/00/12–1/31/13, SFO.**

| | | | | | | Itinerant | | | | | Local | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Facility | State | Region | Service Area | Class | Air Carrier | Air Taxi | General Aviation | Military | Total | Civil | Military | Total | Total Operations |
| 01/2012 | SFO | CA | AWP | WT | Towers with Radar | 24,660 | 7,237 | 1,207 | 276 | 33,380 | 0 | 0 | 0 | 33,380 |
| 02/2012 | SFO | CA | AWP | WT | Towers with Radar | 23,250 | 7,244 | 1,078 | 295 | 31,867 | 0 | 0 | 0 | 31,867 |
| 03/2012 | SFO | CA | AWP | WT | Towers with Radar | 25,245 | 7,533 | 986 | 312 | 34,076 | 0 | 0 | 0 | 34,076 |
| 04/2012 | SFO | CA | AWP | WT | Towers with Radar | 25,981 | 7,208 | 1,049 | 289 | 34,527 | 0 | 0 | 0 | 34,527 |
| 05/2012 | SFO | CA | AWP | WT | Towers with Radar | 27,391 | 7,519 | 1,182 | 266 | 36,358 | 0 | 0 | 0 | 36,358 |
| 06/2012 | SFO | CA | AWP | WT | Towers with Radar | 28,129 | 7,377 | 1,176 | 259 | 36,941 | 0 | 0 | 0 | 36,941 |
| 07/2012 | SFO | CA | AWP | WT | Towers with Radar | 29,333 | 7,903 | 954 | 241 | 38,431 | 0 | 0 | 0 | 38,431 |
| 08/2012 | SFO | CA | AWP | WT | Towers with Radar | 29,480 | 8,010 | 1,196 | 302 | 38,988 | 0 | 0 | 0 | 38,988 |
| 09/2012 | SFO | CA | AWP | WT | Towers with Radar | 26,979 | 7,174 | 1,132 | 250 | 35,535 | 0 | 0 | 0 | 35,535 |
| 10/2012 | SFO | CA | AWP | WT | Towers with Radar | 27,090 | 7,813 | 1,447 | 400 | 36,750 | 0 | 0 | 0 | 36,750 |
| 11/2012 | SFO | CA | AWP | WT | Towers with Radar | 24,900 | 6,844 | 1,010 | 270 | 33,024 | 0 | 0 | 0 | 33,024 |
| 12/2012 | SFO | CA | AWP | WT | Towers with Radar | 25,192 | 7,158 | 864 | 231 | 33,445 | 0 | 0 | 0 | 33,445 |
| 01/2013 | SFO | CA | AWP | WT | Towers with Radar | 24,199 | 7,168 | 1,170 | 283 | 32,820 | 0 | 0 | 0 | 32,820 |
| Sub-Total for Unknown | | | | | | 341,829 | 96,188 | 14,451 | 3,674 | 456,142 | 0 | 0 | 0 | 456,142 |
| Sub-Total for WT | | | | | | 341,829 | 96,188 | 14,451 | 3,674 | 456,142 | 0 | 0 | 0 | 456,142 |
| Sub-Total for AWP | | | | | | 341,829 | 96,188 | 14,451 | 3,674 | 456,142 | 0 | 0 | 0 | 456,142 |
| Sub-Total for CA | | | | | | 341,829 | 96,188 | 14,451 | 3,674 | 456,142 | 0 | 0 | 0 | 456,142 |
| Sub-Total for SFO | | | | | | 341,829 | 96,188 | 14,451 | 3,674 | 456,142 | 0 | 0 | 0 | 456,142 |
| **Total:** | | | | | | **341,829** | **96,188** | **14,451** | **3,674** | **456,142** | **0** | **0** | **0** | **456,142** |

Report created on Mon Apr 8 11:32:03 EDT 2013
Source: The Operations Network (OPSNET)

OPSNET: weather, volume, equipment, runway, and other. This is a major strength.

### *Weaknesses*

Delays are reported manually at ATC facilities at airports and can be inaccurate, are excluded if initiated by pilot/airlines, and are not reported if less than 15 minutes. Delay reporting methods are also subjective and differ by facility. Access to the OPSNET database is restricted by password and authorized by FAA.

### *Documentation, Data Access and Point of Contact*

- To obtain a login and password: https://aspm.faa.gov/Default.asp
- About OPSNET: https://aspm.faa.gov/opsnet/sys/main.asp
  http://aspmhelp.faa.gov/index.php/Operations_Network_%28OPSNET%29
- Address: Office of Aviation Policy and Plans
  Federal Aviation Administration
  800 Independence Ave., SW
  Washington, D.C. 20591
  Phone: (202) 267-3336
  Fax: (202) 267-5370

## 2.2.4 ASQP

ASQP contains data provided by the airlines by flight for airlines that carry at least 1% of all domestic passengers. The data is available from June 2003 and is updated on a monthly basis. The number of airlines providing data has varied from 10 to 20, with the current list of 14 carriers at http:/aspmhelp.faa.gov/index.php/ASQP:_Carrier_Codes_and_Names

Actual and scheduled time is available for gate departure and gate arrival, based on the airlines' block times (which include some expected delays). The airlines also provide the actual wheels-off time (so that taxi-out time can be computed) and wheels-on time (so that taxi-in time can be computed). In addition, the airlines provide causal data for all delayed flights arriving 15 minutes past their scheduled arrival time. The causes of delay categories are airline, extreme weather, National Aviation System, security, and late arriving flight.

Through ASQP, an analyst may select the following:

- Report output type (standard, causal, on-time NAS, BTS, BTS TranStats, schedule reliability report, or dispatch and schedule reliability);
- Dates;
- Airports;

## Table 2-3. OPSNET Standard Report for Airport Delays, 01/01/12–12/31/13, 35 OEP airports.

| | | System Impact Delays | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Occurred At Delays | | | | |
| Facility | Total Ops | Total Delays | TMI To | Dep | Abrn | TMI From | Total Occ At | Abrn Dest To Delays |
| ATL | 1003727 | 10192 | 6027 | 4165 | 0 | 9129 | 13294 | 2387 |
| BOS | 385816 | 3693 | 3231 | 462 | 0 | 5390 | 5852 | 478 |
| BWI | 287896 | 1831 | 1652 | 179 | 0 | 3854 | 4033 | 397 |
| CLE | 194949 | 96 | 50 | 0 | 46 | 2102 | 2148 | 72 |
| CLT | 597713 | 3810 | 2705 | 1105 | 0 | 3886 | 4991 | 1059 |
| CVG | 154483 | 73 | 13 | 38 | 22 | 2023 | 2083 | 93 |
| DCA | 314079 | 3574 | 1528 | 2046 | 0 | 6660 | 8706 | 790 |
| DEN | 666113 | 2123 | 1641 | 482 | 0 | 3060 | 3542 | 1125 |
| DFW | 705428 | 1745 | 1629 | 116 | 0 | 5892 | 6008 | 1456 |
| DTW | 460127 | 2010 | 1214 | 796 | 0 | 4359 | 5155 | 1046 |
| EWR | 454870 | 38010 | 30812 | 7198 | 0 | 6451 | 13649 | 2173 |
| FLL | 287224 | 2319 | 863 | 1456 | 0 | 4077 | 5533 | 470 |
| HNL | 301375 | 32 | 4 | 28 | 0 | 40 | 68 | 19 |
| IAD | 364297 | 851 | 732 | 119 | 0 | 4075 | 4194 | 382 |
| IAH | 552228 | 5180 | 1682 | 3498 | 0 | 4186 | 7684 | 1124 |
| JFK | 442688 | 9766 | 5282 | 4484 | 0 | 9119 | 13603 | 2414 |
| LAS | 568333 | 1951 | 824 | 1127 | 0 | 2840 | 3967 | 342 |
| LAX | 653793 | 2640 | 1671 | 969 | 0 | 5130 | 6099 | 227 |
| LGA | 404909 | 28391 | 20958 | 7433 | 0 | 9091 | 16524 | 3638 |
| MCO | 333749 | 56 | 56 | 0 | 0 | 3390 | 3390 | 355 |
| MDW | 267814 | 583 | 556 | 27 | 0 | 1476 | 1503 | 370 |
| MEM | 291232 | 681 | 565 | 116 | 0 | 1586 | 1702 | 142 |
| MIA | 427208 | 1567 | 481 | 958 | 128 | 2176 | 3262 | 879 |
| MSP | 457874 | 776 | 555 | 221 | 0 | 3052 | 3273 | 687 |
| ORD | 945902 | 22441 | 16524 | 5917 | 0 | 11373 | 17290 | 1841 |
| PDX | 232271 | 9 | 0 | 9 | 0 | 1052 | 1061 | 31 |
| PHL | 479038 | 15768 | 14013 | 1687 | 68 | 6029 | 7784 | 548 |
| PHX | 487192 | 5034 | 2498 | 2536 | 0 | 2285 | 4821 | 296 |
| PIT | 150284 | 30 | 0 | 0 | 30 | 1749 | 1779 | 52 |
| SAN | 202336 | 600 | 181 | 419 | 0 | 2212 | 2631 | 149 |
| SEA | 332781 | 118 | 13 | 105 | 0 | 1765 | 1870 | 64 |
| SFO | 456142 | 26770 | 23067 | 3703 | 0 | 2003 | 5706 | 1400 |
| SLC | 354808 | 348 | 167 | 181 | 0 | 1135 | 1316 | 271 |
| STL | 207954 | 4 | 4 | 0 | 0 | 1761 | 1761 | 92 |
| TPA | 204021 | 129 | 27 | 80 | 22 | 1478 | 1580 | 255 |
| **Total :** | **14630654** | **193201** | **141225** | **51660** | **316** | **135886** | **187862** | **27124** |

Report created on Mon Apr 8 11:42:36 EDT 2013.
Source: The Operations Network (OPSNET)

## Table 2-4. OPSNET delay data for SFO.

### OPSNET: Delays: Standard Report

### From 01/2012 To 01/2013 | Facility=SFO

| | | | System Impact Delays | | | | | | | System Impact Delays | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Occurred At Delays | | | | | By Class | | | | By Cause | | | | | Time | |
| Facility | Date | Total Ops | Total Delays | TMI To | Dep | Abrn | TMI From | Total Occ At | Abrn Dest To Delays | AC | AT | GA | Mil | Wx | Vol | Equip | Rwy | Other | Avg (Min) | Total (Min) |
| SFO | 01/2012 | 33380 | 1820 | 1794 | 26 | 0 | 157 | 183 | 167 | 1378 | 394 | 46 | 2 | 1792 | 6 | 0 | 3 | 19 | 88.00 | 161843 |
| SFO | 02/2012 | 31867 | 1059 | 915 | 144 | 0 | 88 | 232 | 52 | 743 | 287 | 29 | 0 | 990 | 13 | 8 | 7 | 41 | 57.00 | 60594 |
| SFO | 03/2012 | 34076 | 2813 | 2576 | 237 | 0 | 130 | 367 | 114 | 2205 | 564 | 41 | 3 | 2790 | 5 | 0 | 17 | 1 | 81.00 | 229294 |
| SFO | 04/2012 | 34527 | 1509 | 1299 | 210 | 0 | 87 | 297 | 96 | 1174 | 299 | 36 | 0 | 1302 | 39 | 0 | 168 | 0 | 68.00 | 102672 |
| SFO | 05/2012 | 36358 | 1672 | 1220 | 452 | 0 | 154 | 606 | 132 | 1250 | 379 | 43 | 0 | 1528 | 109 | 0 | 33 | 2 | 57.00 | 96100 |
| SFO | 06/2012 | 36941 | 2570 | 1918 | 652 | 0 | 164 | 816 | 100 | 2041 | 478 | 51 | 0 | 1467 | 149 | 0 | 732 | 222 | 76.00 | 195744 |
| SFO | 07/2012 | 38431 | 2502 | 2072 | 430 | 0 | 345 | 775 | 104 | 1904 | 557 | 41 | 0 | 2261 | 179 | 0 | 10 | 52 | 70.00 | 177080 |
| SFO | 08/2012 | 38988 | 2334 | 2165 | 169 | 0 | 223 | 392 | 36 | 1757 | 523 | 52 | 2 | 1526 | 158 | 0 | 650 | 0 | 67.00 | 157711 |
| SFO | 09/2012 | 35535 | 2855 | 2731 | 124 | 0 | 166 | 290 | 59 | 2135 | 663 | 55 | 2 | 1363 | 107 | 0 | 1374 | 11 | 60.00 | 172788 |
| SFO | 10/2012 | 36750 | 2763 | 2124 | 639 | 0 | 190 | 829 | 151 | 2080 | 602 | 81 | 0 | 2099 | 118 | 0 | 35 | 511 | 61.00 | 170050 |
| SFO | 11/2012 | 33024 | 2114 | 1882 | 232 | 0 | 70 | 302 | 124 | 1675 | 408 | 29 | 2 | 2072 | 12 | 0 | 24 | 6 | 81.00 | 171822 |
| SFO | 12/2012 | 33445 | 2170 | 1856 | 314 | 0 | 160 | 474 | 181 | 1681 | 457 | 32 | 0 | 2119 | 33 | 0 | 18 | 0 | 80.00 | 174695 |
| SFO | 01/2013 | 32820 | 589 | 515 | 74 | 0 | 69 | 143 | 84 | 402 | 171 | 16 | 0 | 334 | 20 | 0 | 235 | 0 | 42.00 | 24739 |
| Sub-Total for SFO | | 456142 | 26770 | 23067 | 3703 | 0 | 2003 | 5706 | 1400 | 20425 | 5782 | 552 | 11 | 21643 | 948 | 8 | 3306 | 865 | 70.79 | 1895132 |
| **Total :** | | **456142** | **26770** | **23067** | **3703** | **0** | **2003** | **5706** | **1400** | **20425** | **5782** | **552** | **11** | **21643** | **948** | **8** | **3306** | **865** | **70.79** | **1895132** |

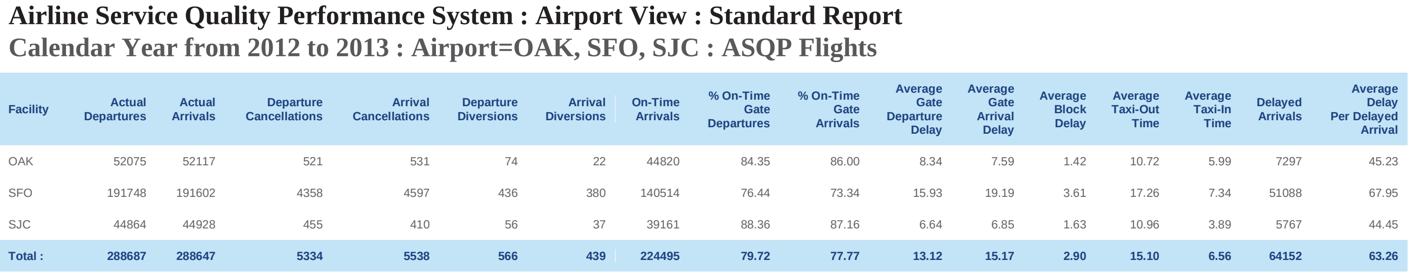
Key : Abrn = Airborne; AC = Air Carrier; AT = Air Taxi; Avg = Average; Dep = Departure; Dest = Destination; Equip = Equipment; GA = General Aviation; Mil = Military; Min = Minute; Occ= Occurred; Ops = Operations; Rwy = Runway; TMI = Traffic Management Initiative; Vol = Volume; Wx = Weather.
Report created on Mon Apr 8 11:53:26 EDT 2013.
Source: The Operations Network (OPSNET)

## Table 2-5. OPSNET data on ground delays at SFO, 2012–2013.

| | | Ground Stops | | | EDCT | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Facility | Delays | Minutes | Average | Delays | Minutes | Average | Delays | Minutes | Average |
| 01/2012 | SFO | 32 | 1078 | 33.69 | 1748 | 160027 | 91.55 | 1780 | 161105 | 90.51 |
| 02/2012 | SFO | 6 | 146 | 24.33 | 893 | 56877 | 63.69 | 899 | 57023 | 63.43 |
| 03/2012 | SFO | 9 | 286 | 31.78 | 2533 | 223195 | 88.11 | 2542 | 223481 | 87.92 |
| 04/2012 | SFO | 20 | 634 | 31.70 | 1248 | 96911 | 77.65 | 1268 | 97545 | 76.93 |
| 05/2012 | SFO | 8 | 192 | 24.00 | 1174 | 83996 | 71.55 | 1182 | 84188 | 71.23 |
| 06/2012 | SFO | 25 | 1752 | 70.08 | 1871 | 176460 | 94.31 | 1896 | 178212 | 93.99 |
| 07/2012 | SFO | 11 | 343 | 31.18 | 2010 | 164800 | 81.99 | 2021 | 165143 | 81.71 |
| 08/2012 | SFO | 15 | 498 | 33.20 | 2091 | 151822 | 72.61 | 2106 | 152320 | 72.33 |
| 09/2012 | SFO | 14 | 521 | 37.21 | 2689 | 169461 | 63.02 | 2703 | 169982 | 62.89 |
| 10/2012 | SFO | 41 | 1877 | 45.78 | 1995 | 147912 | 74.14 | 2036 | 149789 | 73.57 |
| 11/2012 | SFO | 1 | 24 | 24.00 | 1833 | 165598 | 90.34 | 1834 | 165622 | 90.31 |
| 12/2012 | SFO | 1 | 41 | 41.00 | 1802 | 166344 | 92.31 | 1803 | 166385 | 92.28 |
| 01/2013 | SFO | 28 | 1184 | 42.29 | 406 | 19814 | 48.80 | 434 | 20998 | 48.38 |
| Sub-Total for SFO | | 211 | 8576 | 40.64 | 22293 | 1783217 | 79.99 | 22504 | 1791793 | 79.62 |
| **Total :** | | **211** | **8576** | **40.64** | **22293** | **1783217** | **79.99** | **22504** | **1791793** | **79.62** |

Key: EDCT = Estimated Departure Clearance Time. More information about this report. Report created on Mon Apr 8 12:05:27 EDT 2013.
Sources: The Operations Network (OPSNET)

**Table 2-6. Standard Report for OAK, SFO, and SJC with ASQP.**



**Airline Service Quality Performance System : Airport View : Standard Report**
**Calendar Year from 2012 to 2013 : Airport=OAK, SFO, SJC : ASQP Flights**

| Facility | Actual Departures | Actual Arrivals | Departure Cancellations | Arrival Cancellations | Departure Diversions | Arrival Diversions | On-Time Arrivals | % On-Time Gate Departures | % On-Time Gate Arrivals | Average Gate Departure Delay | Average Gate Arrival Delay | Average Block Delay | Average Taxi-Out Time | Average Taxi-In Time | Delayed Arrivals | Average Delay Per Delayed Arrival |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OAK | 52075 | 52117 | 521 | 531 | 74 | 22 | 44820 | 84.35 | 86.00 | 8.34 | 7.59 | 1.42 | 10.72 | 5.99 | 7297 | 45.23 |
| SFO | 191748 | 191602 | 4358 | 4597 | 436 | 380 | 140514 | 76.44 | 73.34 | 15.93 | 19.19 | 3.61 | 17.26 | 7.34 | 51088 | 67.95 |
| SJC | 44864 | 44928 | 455 | 410 | 56 | 37 | 39161 | 88.36 | 87.16 | 6.64 | 6.85 | 1.63 | 10.96 | 3.89 | 5767 | 44.45 |
| **Total :** | **288687** | **288647** | **5334** | **5538** | **566** | **439** | **224495** | **79.72** | **77.77** | **13.12** | **15.17** | **2.90** | **15.10** | **6.56** | **64152** | **63.26** |

Report created on Mon Apr 8 12:11:02 EDT 2013
Source: http://aspmhelp.faa.gov/index.php/ASQP

- Grouping (by date, airport, etc.); and
- Filters (by ASQP or ASPM).

As an illustration, the Bay Area airports (OAK, SFO, and SJO) are analyzed using ASQP data for 2012–2013 (Table 2-6). Using the Standard Report format, an aviation analyst might be interested in the following delay metrics: On-Time Arrivals, Average Gate Departure Delay, Average Block Delay, Average Taxi-Out Time, Average Taxi-In Time, Delayed Arrivals, and Average Delay per Delayed Arrival.

### *Actual/Historical Data vs. Calculated/Estimated Data*

ASQP provides data such as departure, arrival, and elapsed flight times as shown by the OAG, the carrier's computer reservations system (CRS), and the carrier's actual performance; selected differences among the three sources, such as delay and elapsed time difference; and the causes of delays.

### *Strengths*

Actual and scheduled time is available for gate departure and gate arrival. The airlines also provide the actual wheels-off time (so that taxi-out time can be computed) and wheels-on time (so that taxi-in time can be computed). In addition, the airlines provide causal data for all delayed flights arriving 15 minutes past scheduled arrival time. The causes of delay categories are airline, extreme weather, National Aviation System, security, and late arriving flight. This is an input into ASPM.

### *Weaknesses*

ASQP covers flights within the Continental United States on airlines having at least 1% of the total scheduled domestic passenger revenues. Hence, at a large international airport such as EWR, the ASQP data covers only about 65% of the flights. For those flights that are not covered by ASQP, an analyst is not able to realistically link them into multi-leg itineraries. Significant categories of traffic that are missing from ASQP are international, cargo, and general aviation flights, as well as small commercial carriers. Access to the ASQP database is restricted by password and authorized by FAA.

### *Documentation, Data Access, and Point of Contact*

- To obtain a login and password: https://aspm.faa.gov/asqp/sys/
- About ASQP: http://aspmhelp.faa.gov/index.php/Airline_Service_Quality_Performance_%28ASQP%29
- Address: Office of Aviation Policy and Plans
  Federal Aviation Administration
  800 Independence Ave., SW
  Washington, D.C. 20591
  Phone: (202) 267-3336
  Fax: (202) 267-5370

## 2.2.5 ASPM

The FAA Office of Aviation Policy and Plans (APO) developed ASPM to provide data on flights among the 77 ASPM airports, and all flights by the 22 ASPM carriers, including flights by those carriers to international and domestic non-ASPM airports. (Note that http://aspmhelp.faa.gov/index.php/ASPM_Carriers provides a list of 30 carriers, some of which are no longer operating or have merged with other airlines also on the list.) Only specific air carriers' data is recorded in ASPM for 77 U.S. airports—in other words, it is not a comprehensive database for all filed flights in the United States.

ASPM captures actual times for out-off-on-in (OOOI), then it calculates taxi-out delay and taxi-in delay based on typical unimpeded times established for each airport. The database has estimates of typical unimpeded times for each typical runway configuration at each of the airports. Therefore, the delay figures are not comparing actual times to flight schedule or block time estimates, but to FAA's expected values at that airport. In addition, ASPM reports gate departure delay (actual "out" time compared to filed flight-plan scheduled "out" time), airport departure delay (actual "wheels off" compared to flight-plan scheduled "out" time plus unimpeded taxi-out), airborne delay (actual airborne time compared to flight plan filed estimated time en route or ETE), block delay (actual out-to-in compared to scheduled gate-to-gate block time) and gate arrival delay (actual in time compared to the filed flight-plan arrival time).

Using actual times directly from ARINC, ASPM calculates and reports the following:

- Excess travel-time delays and
- Arrival delay calculated as the difference between actual gate arrival times and either OAG scheduled arrival times or flight-planned arrival times

ASPM provides a block delay metric: the difference in the actual gate-to-gate time computed from ARINC OOOI data and the scheduled gate-to-gate block time from the OAG. It also provides data on flight cancellations. The ASPM database includes IFR traffic, some VFR traffic, airport weather, runway configuration, and arrival and departure rates. ASPM provides two types of flight-related performance information: efficiency counts (flights handled by air traffic controllers) and metrics counts (a basis for delay calculations that only include complete flight records).

An aviation analyst may select a wide variety of performance metrics from the FAA Operations and Performance Data website. One of the most common analyses is the airport delay analysis by hour, where the following steps are followed:

1. From the ASPM menu, select Analysis function;
2. Select target area: airport, city pair;
3. Select airlines: all, exclude;
4. Select time period: quarterly, hourly, monthly, yearly; and
5. Select type of analysis: for all flights, delayed flights, ETMS, weather, schedule, delay counts, etc.

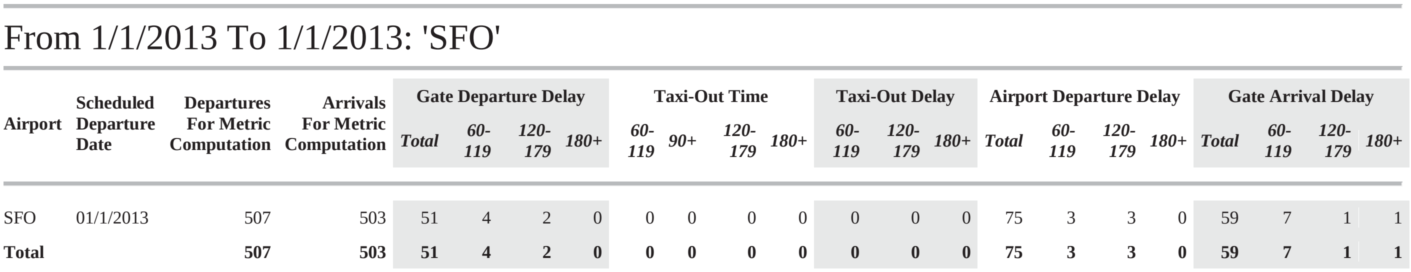
After running the results, a large number of delay metrics are output (Table 2-7), including the following: % On-Time Gate Departures and Arrivals, Gate Departure Delay, Average Taxi-Out Time, Taxi-Out Delay, Airport Departure Delay, Airborne Delay, Taxi-In Delay, Block Delay, and Gate Arrival Delay.

**Table 2-7. ASPM delay data by hour.**

From 2012 To 2013 : 'SFO': (Calendar Year)

| Local Hour | Scheduled Departures | Scheduled Arrivals | Departures For Metric Computation | Arrivals For Metric Computation | % On-Time Gate Departures | % On-Time Airport Departures | % On-Time Gate Arrivals | Gate Departure Delay | Taxi-Out Delay | Airport Departure Delay | Airborne Delay | Taxi-In Delay | Block Delay | Gate Arrival Delay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2263 | 1981 | 2008 | 2465 | 77.59 | 73.51 | 77.08 | 9.78 | 2.54 | 11.73 | 2.16 | 2.18 | 2.89 | 11.41 |
| 1 | 1770 | 281 | 1341 | 585 | 88.59 | 85.31 | 79.66 | 5.90 | 2.06 | 8.18 | 1.66 | 1.47 | 2.11 | 10.19 |
| 2 | 450 | 0 | 332 | 72 | 82.53 | 78.61 | 75 | 8.20 | 1.67 | 10.04 | 2.51 | 1.37 | 3.17 | 12.97 |
| 3 | 184 | 303 | 175 | 347 | 84 | 80 | 83.00 | 8.37 | 1.12 | 9.73 | 0.30 | 1.31 | 0.80 | 6.81 |
| 4 | 281 | 681 | 181 | 790 | 51.93 | 49.17 | 82.15 | 30.81 | 2.56 | 33.68 | 0.80 | 0.72 | 1.57 | 7.32 |
| 5 | 1125 | 790 | 1371 | 1180 | 84.76 | 76.08 | 78.47 | 8.39 | 4.17 | 11.95 | 0.94 | 1.60 | 2.17 | 8.57 |
| 6 | 13475 | 4356 | 13411 | 4532 | 92.91 | 85.22 | 91.62 | 4.01 | 5.44 | 7.78 | 2.84 | 2.25 | 2.39 | 4.52 |
| 7 | 14690 | 10391 | 15481 | 10128 | 87.93 | 81.53 | 90.43 | 6.29 | 4.84 | 9.66 | 3.66 | 3.79 | 2.93 | 5.12 |
| 8 | 18289 | 12309 | 18404 | 11937 | 87.89 | 80.36 | 83.98 | 6.13 | 4.98 | 9.72 | 2.71 | 4.09 | 3.36 | 8.87 |
| 9 | 15529 | 19688 | 15706 | 19464 | 85.08 | 77.59 | 76.90 | 7.44 | 4.81 | 10.90 | 3.74 | 3.45 | 4.12 | 13.84 |
| 10 | 18660 | 13607 | 18850 | 13573 | 78.22 | 66.76 | 71.33 | 10.87 | 5.73 | 15.58 | 3.91 | 3.81 | 4.26 | 18.59 |
| 11 | 14706 | 16795 | 14697 | 17260 | 75.35 | 64.61 | 73.62 | 11.71 | 5.59 | 16.33 | 3.33 | 3.35 | 3.57 | 15.72 |
| 12 | 18000 | 17176 | 18117 | 17211 | 73.94 | 62.26 | 70.95 | 12.74 | 6.13 | 17.92 | 3.47 | 2.92 | 3.55 | 18.27 |
| 13 | 17342 | 13461 | 17268 | 13809 | 73.23 | 59.92 | 72.42 | 12.75 | 6.47 | 18.18 | 2.93 | 3.05 | 3.65 | 16.80 |
| 14 | 13082 | 12691 | 13593 | 12870 | 71.99 | 61.66 | 75.13 | 13.11 | 5.30 | 17.62 | 2.77 | 2.53 | 3.17 | 14.93 |
| 15 | 13240 | 14950 | 13552 | 15295 | 74.53 | 65.86 | 74.72 | 11.69 | 4.77 | 15.59 | 2.47 | 2.72 | 3.03 | 15.87 |
| 16 | 14984 | 10778 | 15211 | 11287 | 77.48 | 69.17 | 77.14 | 11.04 | 4.54 | 14.56 | 2.86 | 2.02 | 2.88 | 13.02 |
| 17 | 9921 | 13590 | 9901 | 14002 | 80.35 | 75.39 | 77.28 | 9.47 | 3.32 | 11.78 | 2.61 | 1.68 | 2.77 | 13.74 |
| 18 | 10258 | 14527 | 10404 | 15197 | 80.72 | 74.69 | 75.30 | 9.10 | 3.51 | 11.77 | 2.91 | 1.77 | 3.18 | 14.23 |
| 19 | 12360 | 15729 | 12075 | 15437 | 79.40 | 71.44 | 77.35 | 9.83 | 4.13 | 13.05 | 3.55 | 2.10 | 3.37 | 14.18 |
| 20 | 8296 | 16768 | 8111 | 16528 | 80.38 | 74.22 | 76.29 | 9.61 | 3.61 | 12.15 | 2.96 | 2.41 | 3.90 | 15.02 |
| 21 | 8136 | 17921 | 8100 | 17422 | 79.88 | 75.02 | 75.15 | 8.85 | 3.35 | 11.28 | 3.39 | 2.83 | 4.00 | 16.00 |
| 22 | 13225 | 11268 | 13071 | 11051 | 80.02 | 67.44 | 73.14 | 9.29 | 6.17 | 14.20 | 3.21 | 3.75 | 4.40 | 16.02 |
| 23 | 7344 | 7037 | 7438 | 7151 | 81.12 | 73.69 | 74.90 | 8.83 | 4.31 | 11.97 | 2.48 | 3.08 | 3.38 | 13.98 |
|  | **247610** | **247078** | **248798** | **249593** | **79.98** | **71.13** | **76.26** | **9.67** | **4.97** | **13.55** | **3.11** | **2.84** | **3.49** | **14.36** |

**Table 2-8. SFO Delay Counts by Airport Report for 1/1/2013.**



From 1/1/2013 To 1/1/2013: 'SFO'

| Airport | Scheduled Departure Date | Departures For Metric Computation | Arrivals For Metric Computation | Gate Departure Delay | | | | Taxi-Out Time | | | | Taxi-Out Delay | | | Airport Departure Delay | | | | Gate Arrival Delay | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Total* | *60-119* | *120-179* | *180+* | *60-119* | *90+* | *120-179* | *180+* | *60-119* | *120-179* | *180+* | *Total* | *60-119* | *120-179* | *180+* | *Total* | *60-119* | *120-179* | *180+* |
| SFO | 01/1/2013 | 507 | 503 | 51 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 3 | 3 | 0 | 59 | 7 | 1 | 1 |
| **Total** | | **507** | **503** | **51** | **4** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **75** | **3** | **3** | **0** | **59** | **7** | **1** | **1** |

If an aviation analyst is interested in obtaining delay counts only (Table 2-8), a delay count option is selected under the type of analysis function. Results, in the form of counts, broken down by minutes, are then displayed for the following metrics: Gate Departure Delay, Taxi-Out Time, Taxi-Out Delay, Airport Departure Delay, and Gate Arrival Delay.

The most common performance analyses are displayed under the Management Report Function in the ASPM standard reporting. After an analyst selects a target airport from the U.S. map and a time period, the following information is displayed in a tabulated form (Table 2-9): % On-Time Operations, Weather, Efficiency, Capacity, Traffic Counts, Times, and Facility Reported Operations. The ASPM Standard Reporting for % On-Time Gate Operations, Taxi-Out Delay and Airborne Delay can also be displayed using graphs (Figure 2-9).

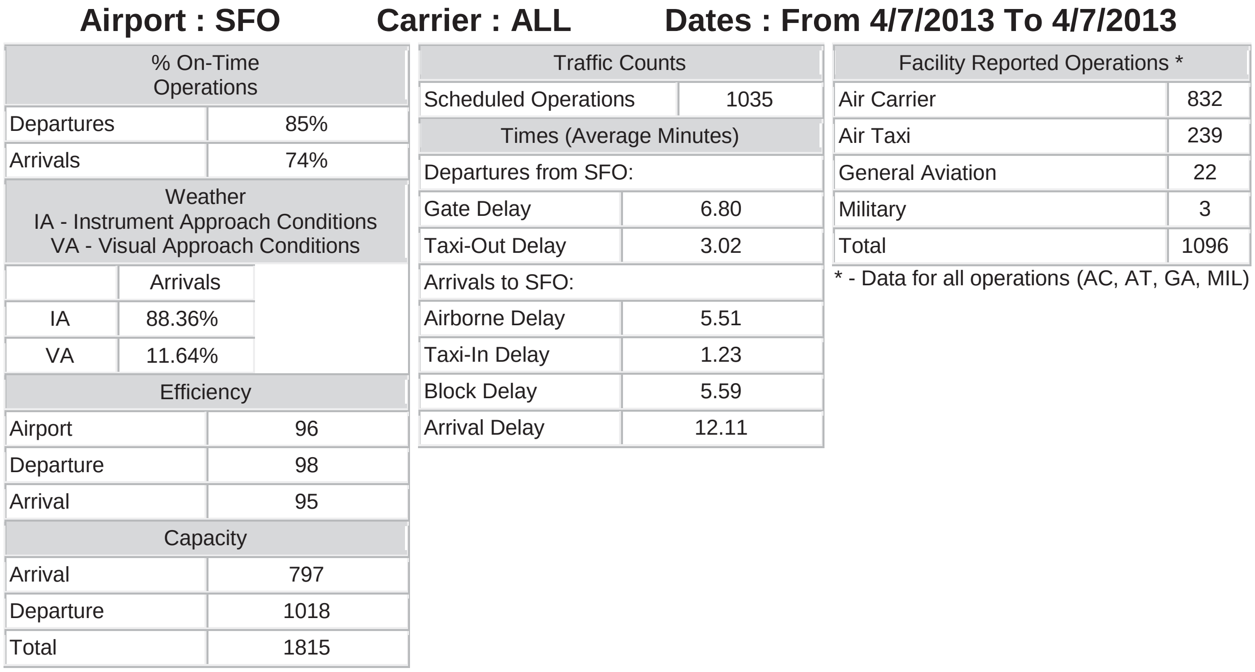
ASPM records are created using data from a variety of sources with varying update cycles. TFMS and ARINC supply next-day operational data, and Innovata provides flight schedule data, while ASQP provides finalized schedule data, OOOI data, and delay causes as reported by the carriers after the close of each month. ASPM is further enhanced with weather data and airport-specific information. ASPM data sources and updated cycles are displayed in Table 2-10.

### *Actual/Historical Data vs. Calculated/Estimated Data*

Calculated data for:

1. Actual gate-out time,
2. Actual gate-in time,
3. Actual wheels-off time,
4. Actual wheels-on time,
5. Average taxi-out time and average taxi-in time,
6. Unimpeded taxi-in time,
7. Unimpeded taxi-out time, and
8. Matching flight schedule data to flights in ETMS.

**Table 2-9. ASPM standard reporting under the management reports function.**



**Airport : SFO Carrier : ALL Dates : From 4/7/2013 To 4/7/2013**

| % On-Time Operations | |
|---|---|
| Departures | 85% |
| Arrivals | 74% |

| Weather<br>IA - Instrument Approach Conditions<br>VA - Visual Approach Conditions | |
|---|---|
| | Arrivals |
| IA | 88.36% |
| VA | 11.64% |

| Efficiency | |
|---|---|
| Airport | 96 |
| Departure | 98 |
| Arrival | 95 |

| Capacity | |
|---|---|
| Arrival | 797 |
| Departure | 1018 |
| Total | 1815 |

| Traffic Counts | |
|---|---|
| Scheduled Operations | 1035 |

| Times (Average Minutes) | |
|---|---|
| Departures from SFO: | |
| Gate Delay | 6.80 |
| Taxi-Out Delay | 3.02 |
| Arrivals to SFO: | |
| Airborne Delay | 5.51 |
| Taxi-In Delay | 1.23 |
| Block Delay | 5.59 |
| Arrival Delay | 12.11 |

| Facility Reported Operations * | |
|---|---|
| Air Carrier | 832 |
| Air Taxi | 239 |
| General Aviation | 22 |
| Military | 3 |
| Total | 1096 |

* - Data for all operations (AC, AT, GA, MIL)

*Figure 2-9. ASPM standard reporting samples.*

Metrics computed in ASPM are developed comparing actual time to scheduled time or flight-plan time. Taxi delays are determined based on unimpeded times.

Delays are calculated for

- % On-Time Gate Dept,
- % On-Time Gate Arr,
- Taxi-Out Delay,
- Taxi-In Delay,
- Gate Delay, and
- Block Delay.

### *Strengths*

ASPM efficiency rates were specifically created to measure an ATC facility's ability—and by extension, that of the air traffic system—to do what it says it can do. The ASPM database also includes airport weather, runway configuration, and arrival and departure rates.

### *Weaknesses*

ASPM covers only flights for ASPM airports (currently 77), and ASPM airlines (currently 22). Only some VFR traffic is included. Access to the ASPM database is restricted by password and authorized by FAA.

### *Documentation, Data Access, and Point of Contact*

- To obtain a login and password: https://aspm.faa.gov/Default.asp
- About ASPM: http://aspmhelp.faa.gov/index.php/ASPM_System_Overview
- Address: Office of Aviation Policy and Plans
  Federal Aviation Administration
  800 Independence Ave., SW
  Washington, D.C. 20591
  Phone: (202) 267-3336
  Fax: (202) 267-5370

## 2.2.6 BTS

The BTS provides several aviation databases, including Airline Traffic Data, Air Fares Data, and Airline On-Time Statistics. The Airline On-Time Statistics database provides useful information on delay causes and answers the following questions:

- How do we know the reason for a flight being late or cancelled?
- Which airlines report on-time data?
- Do the airlines report the exact cause of the delay?
- How are these categories defined?
- What have the airline reports on the causes of delay shown about flight delays?
- Is it true that weather causes only 6% of flight delays?
- How many flights were really delayed by weather?
- Why aren't all weather-related delays reported as a single number?
- Is more information available on the Air Carrier On-Time Reporting Advisory Committee?

### Table 2-10. ASPM data sources and update cycle.

| Data Source | Content | Update Cycle | Purpose |
|---|---|---|---|
| **Traffic Flow Management System (TFMS)** | Flight-level records assembled by combining electronic messages transmitted to the host (en route) computer. Data include aircraft ID (flight number or tail number), flight-plan times, AZ and DZ times, arrival and departure airport, and aircraft and flight type. | Daily update with preliminary next-day TFMS data and enhanced 5-day data.<br>Approximately 10 days after the end of each month, TFMS data for the previous month are finalized. | Source of flight-level data for passenger, freight, general aviation, and military flights that have filed a flight plan or otherwise transmitted data to the host computer. Includes scheduled and non-scheduled flights. |
| **ARINC** | OOOI data. | Updated daily. | Source of actual flight times for ACARS-equipped aircraft for eight airlines: AAL, ACA, DAL, FDX, SWA, UAL, UPS, and USA. |
| **CountOps** | Arrivals and departure information for individual flights. Also identifies arrival and departure runway end. CountOps includes all flights captured by OPSNET, but CountOps field only used to supplement ASPM flights (flights to or from the ASPM 77 airports or operated by one of the ASPM carriers.) | Updated daily. | Additional source of next-day on and off data for flights not captured by ARINC. |
| **Innovata** | A private aviation data provider of carrier flight schedules. Data were previously obtained from OAG. See FSDS. | Updated every 2 weeks for the current month and next 5 months (6 months total). | Source of schedule data for carriers flying domestic flights and international flights to or from the United States. |
| **ASQP** | Data provided by BTS. Schedule, flight plan, OOOI data, and delay causes as reported by carriers that handle at least 1% of total domestic scheduled passenger service. | Monthly file loaded approximately 25 days after the end of the month. ASQP correction files are occasionally submitted several months later, resulting in a reload of ASPM for the affected months. | ASPM records are updated with new or revised flight information from ASQP, including OOOI data, final schedule data from the CRS, and carrier-reported delay causes. |
| **Unimpeded Taxi Times** | Unimpeded taxi data by airport and carrier. | Every year (typically in March), new unimpeded taxi times are calculated based on observed data from the previous year. ASPM is reloaded from December forward to apply the updated taxi times. | Used for calculating taxi delays for individual flights. |
| **Operational Information System (OIS)** | Runway configuration data and arrival and departure rate data. | Updated daily for the last 30 days. | Used for summary reports of airport efficiency by hour and quarter hour. |
| **National Weather Service** | Airport weather data. | Weather data are retrieved from three sources: METAR – published hourly without quality controls; ASOS – hourly data with some quality controls, available next day but not current through the end of the prior day; and QCLCD – quality controlled month-to-date file also not current through the end of the prior day. The month is finalized on the 6th of the following month regardless of it being complete. Therefore, occasionally ASPM does not receive QCLCD data for the last day or two of the month. ASPM uses QCLCD when it is available, followed by ASOS, and then METAR to fill in where the other two sources are not current. For more information see ASPM Weather Processing. | Used for Airport Efficiency Daily Weather by Hour Report and calculating weather impact in the weather factors module. |

Source: http://aspmhelp.faa.gov/index.php/ASPM:_Data_Sources_and_Update_Cycle

- Is more information available on the causes of delays and cancellations?

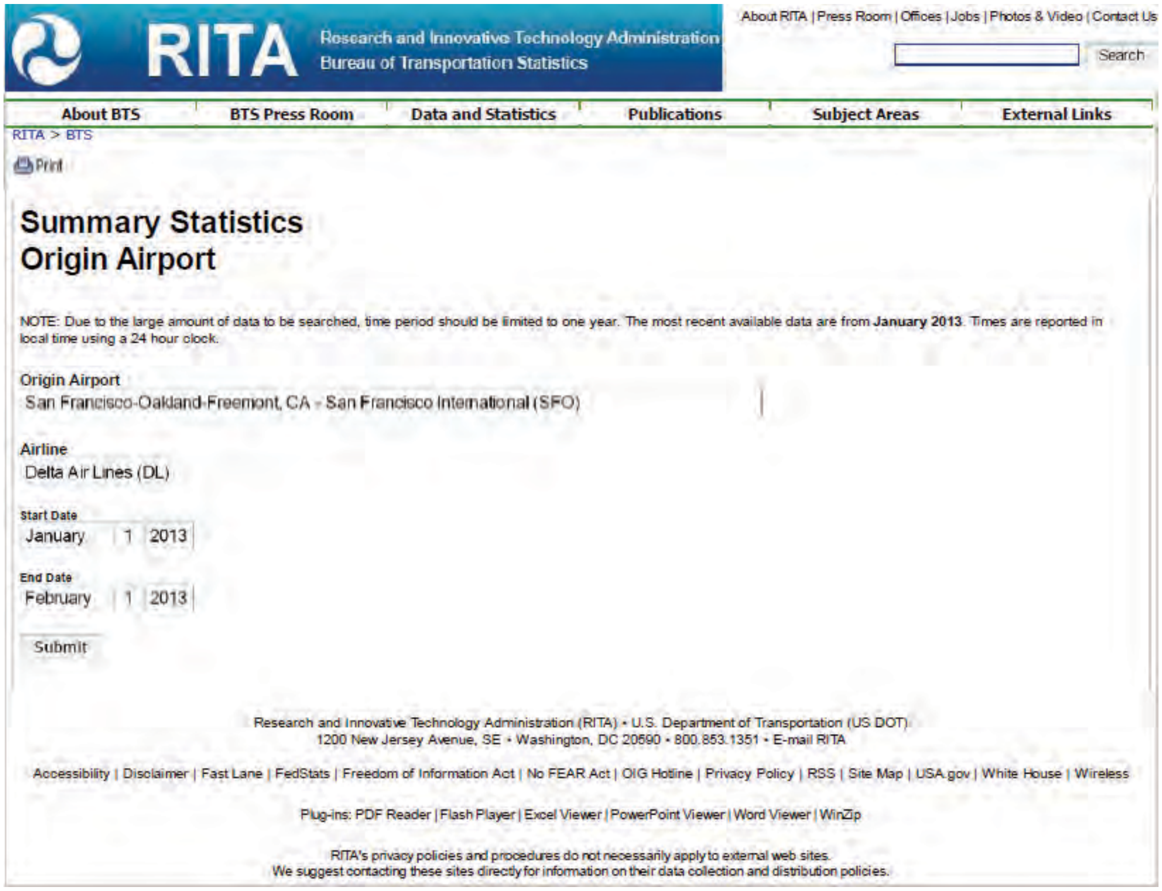
Airline on-time data are reported each month to BTS by the 16 U.S. air carriers that have at least 1% of total domestic scheduled-service passenger revenues, plus two other carriers that report voluntarily. The data cover nonstop scheduled-service flights between points within the United States (including territories) as described in 14 CFR Part 234 of DOT's regulations. Data are available since January 1995. The following statistics are available:

- Summary statistics—All (total number, average departure delay, average taxi-out, and average scheduled departure) and late flights (total and percent of diverted and cancelled flights).
  - Origin airport,
  - Destination airport,
  - Origin and destination airport,
  - Airline, and
  - flight number.
- Detailed statistics—Departure and arrival statistics (scheduled departure time, actual departure time, scheduled elapse time, departure delay, wheels-off time, and taxi-out time) by airport and airline; airborne time, cancellation, and diversion by airport and airline.
  - Departures,
  - Arrivals,
  - Airborne time,
  - Cancellation, and
  - Diversion.

Since mid 2003, BTS has also collected the causes of flight delays, as reported by the carriers.

Depending on a particular study scope, an aviation analyst may perform a series of analyses, by following these general steps:

1. Access the website at http://apps.bts.gov/,
2. Select Data and Statistics tab,
3. Select Airline On-Time Data option where you can choose summary statistics or detailed statistics,
4. If interested in summary statistics for an airport (as depicted in Figure 2-10), select the following:
   - Origin airport, destination airport, or origin and destination airport,



Summary Statistics
Origin Airport

NOTE: Due to the large amount of data to be searched, time period should be limited to one year. The most recent available data are from **January 2013**. Times are reported in local time using a 24 hour clock.

Origin Airport
San Francisco-Oakland-Freemont, CA - San Francisco International (SFO)

Airline
Delta Air Lines (DL)

Start Date
January 1 2013

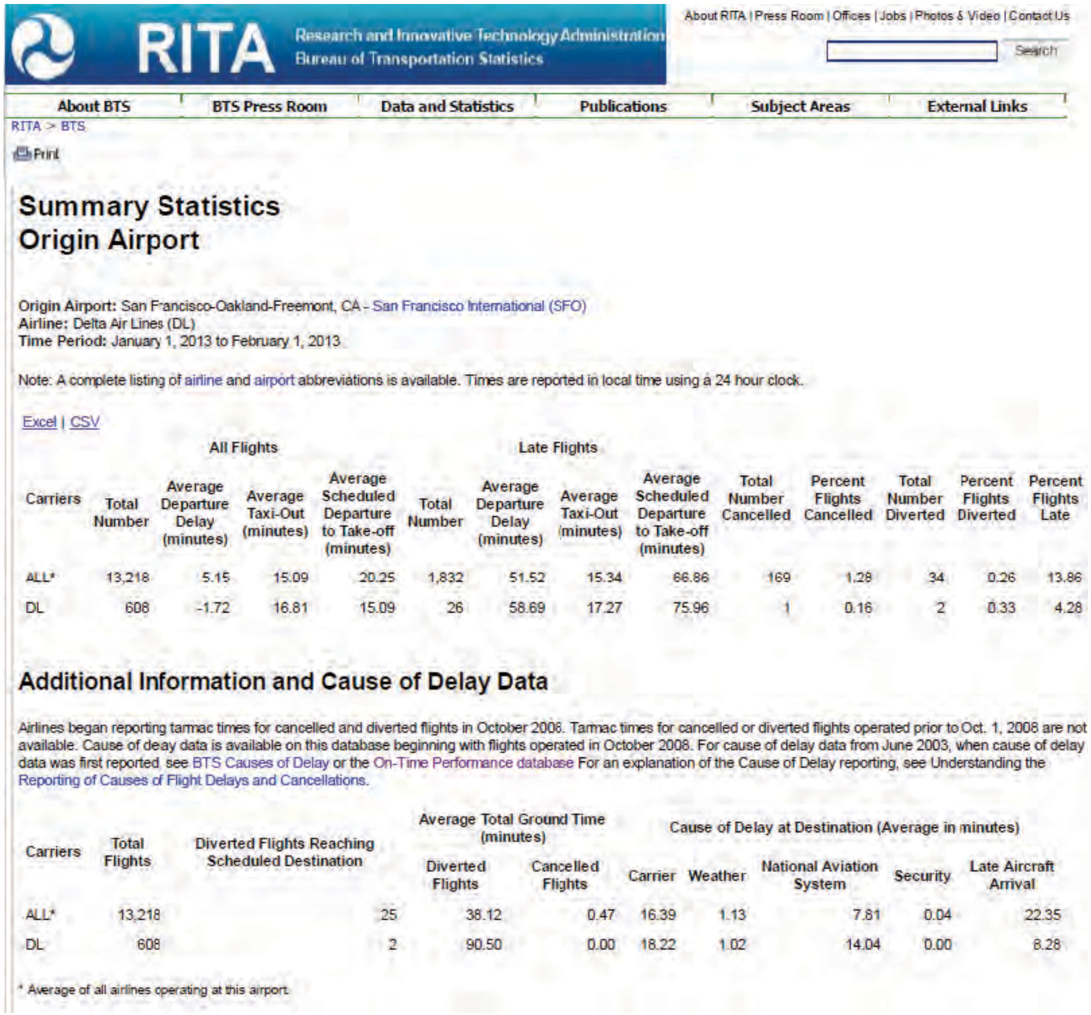
End Date
February 1 2013

Research and Innovative Technology Administration (RITA) • U.S. Department of Transportation (US DOT)
1200 New Jersey Avenue, SE • Washington, DC 20590 • 800.853.1351 • E-mail RITA

RITA's privacy policies and procedures do not necessarily apply to external web sites.
We suggest contacting these sites directly for information on their data collection and distribution policies.

Source: RITA BTS

*Figure 2-10. BTS summary statistics request interface.*



**Summary Statistics**
**Origin Airport**

**Origin Airport:** San Francisco-Oakland-Freemont, CA - San Francisco International (SFO)
**Airline:** Delta Air Lines (DL)
**Time Period:** January 1, 2013 to February 1, 2013

Note: A complete listing of airline and airport abbreviations is available. Times are reported in local time using a 24 hour clock.

| | All Flights | | | | Late Flights | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carriers | Total Number | Average Departure Delay (minutes) | Average Taxi-Out (minutes) | Average Scheduled Departure to Take-off (minutes) | Total Number | Average Departure Delay (minutes) | Average Taxi-Out (minutes) | Average Scheduled Departure to Take-off (minutes) | Total Number Cancelled | Percent Flights Cancelled | Total Number Diverted | Percent Flights Diverted | Percent Flights Late |
| ALL* | 13,218 | 5.15 | 15.09 | 20.25 | 1,832 | 51.52 | 15.34 | 66.86 | 169 | 1.28 | 34 | 0.26 | 13.86 |
| DL | 608 | -1.72 | 16.81 | 15.09 | 26 | 58.69 | 17.27 | 75.96 | 1 | 0.16 | 2 | 0.33 | 4.28 |

**Additional Information and Cause of Delay Data**

Airlines began reporting tarmac times for cancelled and diverted flights in October 2008. Tarmac times for cancelled or diverted flights operated prior to Oct. 1, 2008 are not available. Cause of deay data is available on this database beginning with flights operated in October 2008. For cause of delay data from June 2003, when cause of delay data was first reported, see BTS Causes of Delay or the On-Time Performance database For an explanation of the Cause of Delay reporting, see Understanding the Reporting of Causes of Flight Delays and Cancellations.

| Carriers | Total Flights | Diverted Flights Reaching Scheduled Destination | Average Total Ground Time (minutes) | | Cause of Delay at Destination (Average in minutes) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Diverted Flights | Cancelled Flights | Carrier | Weather | National Aviation System | Security | Late Aircraft Arrival |
| ALL* | 13,218 | 25 | 38.12 | 0.47 | 16.39 | 1.13 | 7.81 | 0.04 | 22.35 |
| DL | 608 | 2 | 90.50 | 0.00 | 18.22 | 1.02 | 14.04 | 0.00 | 8.28 |

* Average of all airlines operating at this airport.

Source: RITA BTS

*Figure 2-11. BTS summary statistics.*

– Airline, and
– Time period.

The output results display information as shown in Figure 2-11, with an average of all flights operating at the selected airport, and statistics for a selected airline, where flights are divided into all flights, and late flights.

Under the categories of All Flights and Late Flights, the following results are displayed: Total Number, Average Departure Delay (Minutes), Average Taxi-Out (Minutes), Average Scheduled Departure to Takeoff (Minutes).

Other information is related to the following metrics: Total Number Cancelled, Percent Flight Cancelled, Total Number Diverted, Percent Flights Diverted, and Percent Flights Late.

If interested in detailed statistics, an analyst may select information for departing aircraft (departures) for one airline at a selected airport, for a specific time period. A wide range of statistics can be extracted from the BTS database (Figure 2-12).

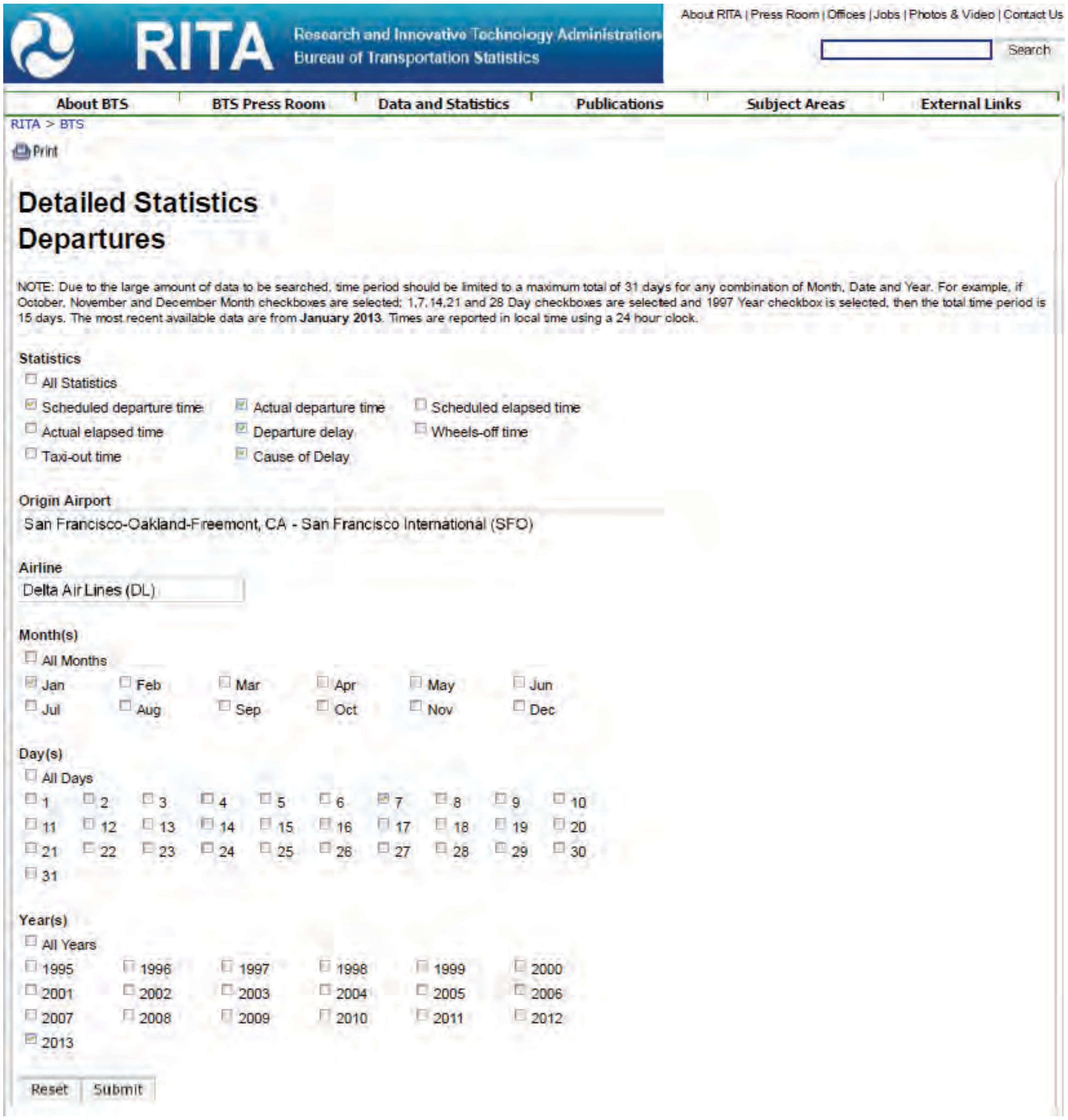
The detailed statistics for departures for a selected airport (Figure 2-13) display information on Destination Airport, Scheduled Departure Time, Actual Departure Time, Departure Delay (Minutes), Delay Carrier (Minutes), Delay Weather (Minutes), Delay National Aviation System (Minutes), Delay Security (Minutes), and Delay Late Aircraft Arrival (Minutes).

### *Actual/Historical Data vs. Calculated/Estimated Data*

Data was derived for some items as follows: all and late flights (total number, average departure delay, average taxi-out and average scheduled departure) and late flights (total and percent of diverted and cancelled flights).

### *Strengths*

This is the only publicly accessible database that contains flight cancellation information and percent of diverted flights. Better for aggregate analysis than ASPM.



**Detailed Statistics**
**Departures**

NOTE: Due to the large amount of data to be searched, time period should be limited to a maximum total of 31 days for any combination of Month, Date and Year. For example, if October, November and December Month checkboxes are selected; 1,7,14,21 and 28 Day checkboxes are selected and 1997 Year checkbox is selected, then the total time period is 15 days. The most recent available data are from **January 2013**. Times are reported in local time using a 24 hour clock.

**Statistics**
☐ All Statistics
☑ Scheduled departure time ☑ Actual departure time ☐ Scheduled elapsed time
☐ Actual elapsed time ☑ Departure delay ☐ Wheels-off time
☐ Taxi-out time ☑ Cause of Delay

**Origin Airport**
San Francisco-Oakland-Freemont, CA - San Francisco International (SFO)

**Airline**
Delta Air Lines (DL)

**Month(s)**
☐ All Months
☑ Jan ☐ Feb ☐ Mar ☐ Apr ☐ May ☐ Jun
☐ Jul ☐ Aug ☐ Sep ☐ Oct ☐ Nov ☐ Dec

**Day(s)**
☐ All Days
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☑ 7 ☐ 8 ☐ 9 ☐ 10
☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20
☐ 21 ☐ 22 ☐ 23 ☐ 24 ☐ 25 ☐ 26 ☐ 27 ☐ 28 ☐ 29 ☐ 30
☐ 31

**Year(s)**
☐ All Years
☐ 1995 ☐ 1996 ☐ 1997 ☐ 1998 ☐ 1999 ☐ 2000
☐ 2001 ☐ 2002 ☐ 2003 ☐ 2004 ☐ 2005 ☐ 2006
☐ 2007 ☐ 2008 ☐ 2009 ☐ 2010 ☐ 2011 ☐ 2012
☑ 2013

Source: RITA BTS

***Figure 2-12. BTS statistics selection.***

### *Weaknesses*

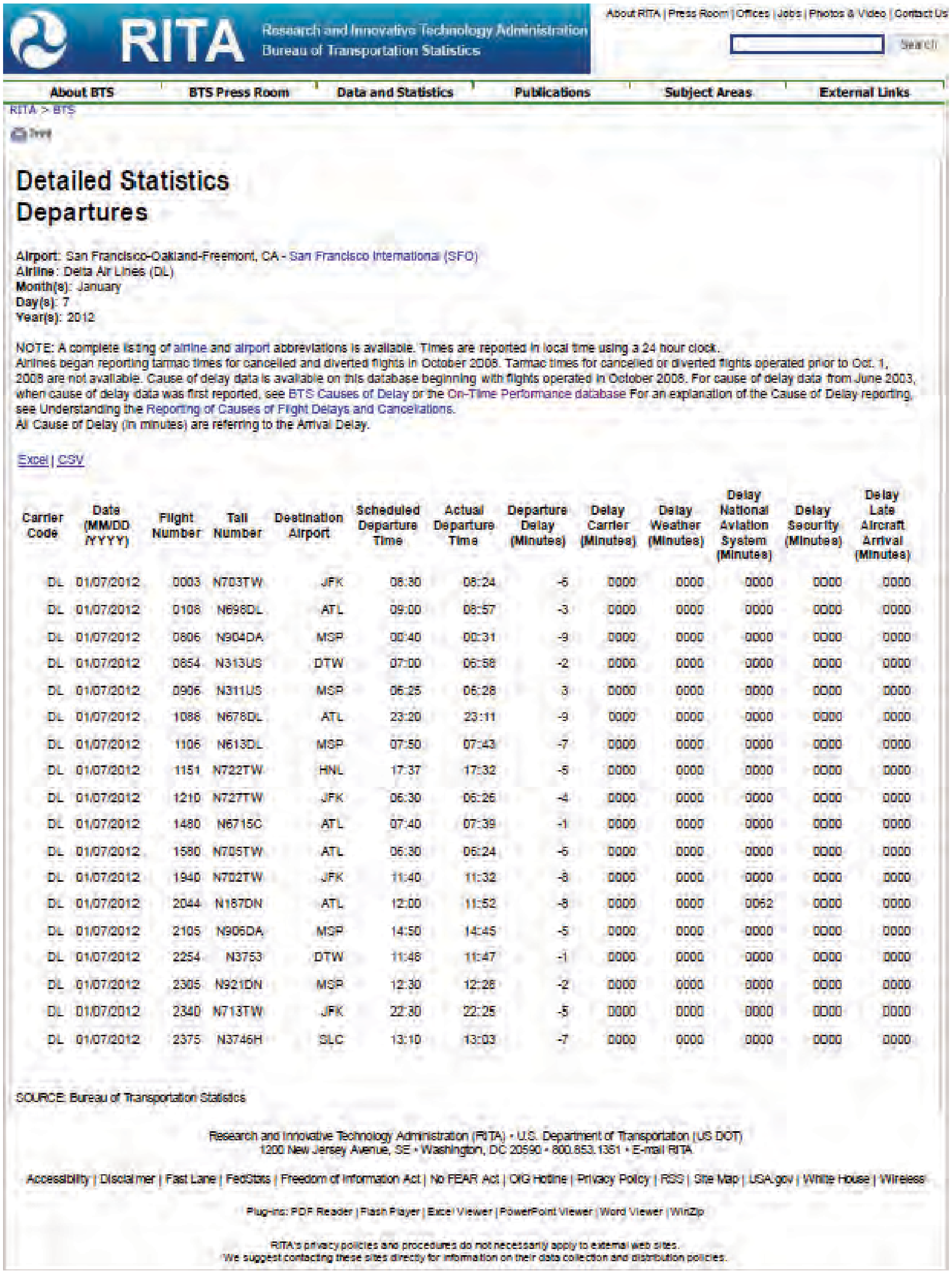
This contains data for only 16 U.S. air carriers that have at least 1% of total domestic scheduled service passenger revenues, plus two other carriers that report voluntarily. Contains less data than ASPM.

### *Documentation, Data Access, and Point of Contact*

- BTS is public data; user access is not restricted.
- About BTS: www.bts.gov
- Address: Bureau of Transportation Statistics
  Research and Innovative Technology
  Administration
  U.S. Department of Transportation
  1200 New Jersey Avenue, SE
  Washington, D.C. 20590

## 2.2.7 Local Airport Systems

The local airport may have computer systems installed for other functions (e.g., noise monitoring) that contain a record of aircraft operations and times. These data sources should not be overlooked when an analyst is evaluating delay times because the local data source may have a more complete set of the aircraft operations than some of the FAA or BTS sources that only have data for certain airports and/or airlines.



Detailed Statistics
Departures

**Airport:** San Francisco-Oakland-Freemont, CA - San Francisco International (SFO)
**Airline:** Delta Air Lines (DL)
**Month(s):** January
**Day(s):** 7
**Year(s):** 2012

NOTE: A complete listing of airline and airport abbreviations is available. Times are reported in local time using a 24 hour clock.
Airlines began reporting tarmac times for cancelled and diverted flights in October 2008. Tarmac times for cancelled or diverted flights operated prior to Oct. 1, 2008 are not available. Cause of delay data is available on this database beginning with flights operated in October 2008. For cause of delay data from June 2003, when cause of delay data was first reported, see BTS Causes of Delay or the On-Time Performance database For an explanation of the Cause of Delay reporting, see Understanding the Reporting of Causes of Flight Delays and Cancellations.
All Cause of Delay (in minutes) are referring to the Arrival Delay.

| Carrier Code | Date (MM/DD /YYYY) | Flight Number | Tail Number | Destination Airport | Scheduled Departure Time | Actual Departure Time | Departure Delay (Minutes) | Delay Carrier (Minutes) | Delay Weather (Minutes) | Delay National Aviation System (Minutes) | Delay Security (Minutes) | Delay Late Aircraft Arrival (Minutes) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DL | 01/07/2012 | 0003 | N703TW | JFK | 08:30 | 08:24 | -6 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 0108 | N698DL | ATL | 09:00 | 08:57 | -3 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 0806 | N904DA | MSP | 00:40 | 00:31 | -9 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 0854 | N313US | DTW | 07:00 | 06:58 | -2 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 0906 | N311US | MSP | 06:25 | 06:28 | 3 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1088 | N678DL | ATL | 23:20 | 23:11 | -9 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1106 | N613DL | MSP | 07:50 | 07:43 | -7 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1151 | N722TW | HNL | 17:37 | 17:32 | -5 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1210 | N727TW | JFK | 06:30 | 06:26 | -4 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1480 | N6715C | ATL | 07:40 | 07:39 | -1 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1580 | N705TW | ATL | 06:30 | 06:24 | -6 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 1940 | N702TW | JFK | 11:40 | 11:32 | -8 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 2044 | N187DN | ATL | 12:00 | 11:52 | -8 | 0000 | 0000 | 0052 | 0000 | 0000 |
| DL | 01/07/2012 | 2105 | N906DA | MSP | 14:50 | 14:45 | -5 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 2254 | N3753 | DTW | 11:48 | 11:47 | -1 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 2305 | N921DN | MSP | 12:30 | 12:28 | -2 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 2340 | N713TW | JFK | 22:30 | 22:25 | -5 | 0000 | 0000 | 0000 | 0000 | 0000 |
| DL | 01/07/2012 | 2375 | N3746H | SLC | 13:10 | 13:03 | -7 | 0000 | 0000 | 0000 | 0000 | 0000 |

SOURCE: Bureau of Transportation Statistics

Research and Innovative Technology Administration (RITA) • U.S. Department of Transportation (US DOT)
1200 New Jersey Avenue, SE • Washington, DC 20590 • 800.853.1351 • E-mail RITA

RITA's privacy policies and procedures do not necessarily apply to external web sites.
We suggest contacting these sites directly for information on their data collection and distribution policies.

Source: RITA BTS

*Figure 2-13. BTS analysis reports.*

Specifically, noise monitoring systems often contain the time the aircraft used the runway (wheels on for arrivals and wheels off for departures), aircraft type, flight number identifier, runway used, etc., for all flights; this can be correlated to other sources to obtain taxi-in and taxi-out times for specific runways and configuration. Noise monitoring systems and/or gate assignment programs can be used to analyze variances between actual gate in and out times to scheduled gate arrival/departure times.

## 2.3 How Delays Are Calculated

For airport planning purposes, analysts typically estimate delays of current and proposed airport layouts using methods ranging from basic analytical tools to sophisticated, detailed computer simulation models. This section provides information on which methodologies and models are most appropriate for different planning efforts. In addition, this section addresses which types of delays are most appropriate for specific purposes (i.e., when to use average delay vs. maximum delay, average annualized delays, etc.).

### 2.3.1 Spreadsheet and Basic Models

The FAA's *AC 150/5060-5 Airport Capacity and Delay* and the subsequent Airport Capacity Model (ACM) provide straightforward calculations to estimate average delays for particular runway layouts, based on fleet mix and several other items. Using this approach, average hourly, daily, and annual delays can be estimated. The calculations were based on ATC rules and procedures that were in place when the model and advisory circular (AC) were developed. Analysts are not able to adjust the delay estimates as new procedures, technology, and/or separation rules are implemented.

Some consultants and academic institutions have developed and applied basic queuing models. Typically, the models require the analyst to input the hourly throughput under different arrival-departure ratios, then the queuing model estimates average delays based on the traffic demand profile provided.

### 2.3.2 Simulation Models

When calculating aircraft delays for airport infrastructure projects, analysts often use computer simulation tools to evaluate delays and delay savings. Capacity driven delays can be predicted very accurately using these models. Regardless of the simulation tool used, a nominal or unimpeded time is calculated, then any additional time is measured as "delay." A discussion of how delay is calculated by commonly used airport simulation tools follows. Note that the four simulation models listed here all have some type of animation capability to visualize the aircraft moving through the airspace and on the airfield. (In addition to these four models, the FAA William J. Hughes Technical Center also uses RDSIM-Runway Delay Simulation Model and ADSIM-Airfield Delay Simulation Model for some of their airport delay analyses; those tools are generally not used outside the FAA.)

1. SIMMOD calculates the nominal travel time for each flight in the simulation, assuming that the aircraft is able to traverse along its path at its nominal speed on each link. Delay is then accumulated whenever the aircraft must experience a wait to maintain the required separations. Thus, delay equals the actual simulated travel time less the nominal travel time. If only one aircraft is simulated in the model, then it will traverse each link at the nominal speed, and its delay will be zero. Although not common, SIMMOD may report a negative delay when the simulation increases the aircraft speed to resolve a potential separation conflict, thus the travel time is then less than the nominal time. Delays are reported for arrival airspace delay, arrival taxi-in delay, gate delay (if no gate is available), departure taxi-out delay, departure queue delay, and departure airspace delay. Users can analyze delays by cause of the delay and the location/link where each delay occurred. For airport planning, analysts typically report the following:
    - Arrival airspace delay,
    - Arrival taxi-in delay, and
    - Departure taxi-out delay + queue delay.
2. Total Airspace and Airport Modeler (TAAM) calculates delays for virtually every segment of a flight starting with gate delay and finishing with taxi-in delay, which also includes delay incurred due to an unavailable arrival gate. TAAM bases delay on a comparison of incurred time versus unimpeded times calculated by the model, based on the conditions along the route of flight and the aircraft operating characteristics. Thus, TAAM calculates the shortest time a flight should incur during any phase (e.g., at gate, during taxi-out, sequencing, etc.) and then subtracts that from the time actually incurred by that flight and reports the difference as a delay for that segment of the flight. Delay calculations available through the TAAM reporting function include gate delay, taxi-out delay, runway delay, departure queue delay, in-trail delay, sequencing delay, positioning delay, flow management delay, gate-turn (link) delay, taxi-in delay, delay per taxiway segment, ground delay, and airborne delay. TAAM also offers a number of cumulative delay indices such as follows:
    - Departure delay per aircraft—the sum of gate delay, taxiway delay and departure queue delay. There is no airspace delay for departures.
    - Arrival delay per aircraft—the sum of taxi delay, arrival gate delay, and arrival sequencing delay.
    - Airport delay—the sum of arrival and departure delays. Does not include en route delay but does reflect delay due to sequencing action for arrivals.

3. ARCPort models a link-and-node representation of the airfield and airspace. Main sources of airfield delay are reported, including the following:
   - Air delay—on approach to the airport,
   - Taxi delay—on the airfield for arriving and departing aircraft,
   - Stand delay—on arrival waiting for a vacant stand, and
   - Takeoff delay—on departure for the runway clearance.
4. Comprehensive Airport Simulation Technology (CAST) aircraft simulation generates basic data on taxi times, average waiting times, queue length, flow rates, throughput times, process times, punctuality, delays, number of runway crossings, and runway occupancy times.

However, airline scheduling practice changes may have a major impact on the model's predictions of delays. For example, if 20 flights are scheduled within an hour, this may show very little delay; but if the 20 flights are scheduled within the first quarter of the hour, the model may show delays to be larger.

Also, the models typically do not show how delays that occur at one airport propagate and impact other airports. The New York region—including LGA, JFK, EWR, TEB, PHL—handle roughly 12% of all domestic flights but, according to the FAA, a third to nearly half of all delays around the nation each year are caused, in some way, by the New York airports. This can be very relevant on overall planning efforts to improve airline predictability throughout the network. Also, these simulation models do not consider that delays also can have an impact on consumers choosing other modes of transportation.

For cost-benefit analyses, the amount of delay on the ground and in the air is multiplied by typical operating costs to estimate economic savings that will be realized from particular capital improvements.

### 2.3.3 Average Annualized Delay

To easily compare airport development alternatives, having a single value for each option is useful. Analysts often will calculate a weighted average delay, based on the percent of time each wind/weather configuration is used throughout the year. The average annualized delay is a weighted average of the delays in the various wind/weather operating configurations used at an airport. Commonly, analysts will run entire days of flight demand for each of the typical wind/weather scenarios that occur at an airport. Then the average daily delay for each particular wind/weather configuration is multiplied by the annual percentage of time that wind/weather configuration is in use at that airport. This results in a weighted average annualized delay, which is the usual measure for comparing airport development alternatives.

Whether using simulation or spreadsheet or other analytical methods, delay analyses will typically be run for several wind/weather configurations that are used at an airport to evaluate delays in the various configurations. Even for an airport with a single runway or pair of parallel runways, the runway is likely used in both the primary direction and the opposite or secondary direction, depending on the winds. Often, at least four operating configurations are modeled as follows:

- Primary runway direction in VMC,
- Secondary runway direction in VMC,
- Primary runway direction in IMC, and
- Secondary runway direction in IMC.

Of course, some airports or airfield layouts will have more than four operating configurations. The analyst then has arrival and departure delay values for each configuration. An example of calculating an average annualized delay is depicted in Table 2-11.

With 60% of the flights experiencing 2.0 minutes of delay during the year (primary VMC), 20% of flights experiencing 2.5 minutes of delay (secondary VMC), 10% of flights experiencing 13 minutes of delay and 10% of flights experiencing 19 minutes of delay, the resulting weighted average is 4.9 minutes of average annualized delay.

Average annualized delays (Table 2-12) are extremely helpful for initial comparisons of development alternatives. However, such high-level delay measures can mask large delays that occur in a particular wind/weather configuration when that configuration does not occur very frequently during a typical year. In the above example, 80% of the flights experience, on average, 2.5 minutes of delay or less; but the high delays in IMC result in an average annualized delay almost twice that level. Due to operational issues that occur in that configuration (e.g., congestion, irregular operations recovery, etc.), the airport may choose to develop improvements to that configuration even if it has little influence on or reduction of the annualized delays.

Using the example again, when this calculation is conducted for each demand level (or number of flights) and for

**Table 2-11. Sample average delays (in minutes) for Demand Level 1.**

| | | Arrival | Departure | Per Flight* |
|---|---|---|---|---|
| Primary wind – VMC | 60% | 1.0 | 3.0 | 2.0 |
| Secondary wind – VMC | 20% | 1.5 | 3.5 | 2.5 |
| Primary wind – IMC | 10% | 6.0 | 20.0 | 13.0 |
| Secondary wind - IMC | 10% | 8.0 | 30.0 | 19.0 |
| **Average Annualized Delay** | | | | **4.9** |

*Assumes equal number of arrival and departure operations

**Table 2-12. Average annualized delays per flight.**

| | Current Traffic | Demand Level 1 | Demand Level 2 | Demand Level 3 |
|---|---|---|---|---|
| No Build/Do Nothing | 4.0 | 4.9 | 7.2 | 15.6 |
| Runway Option 1 | 2.5 | 2.7 | 3.7 | 5.9 |
| Runway Option 2 | 2.4 | 2.6 | 3.0 | 4.0 |

each scenario, the resulting average annualized delays could be reported in a table, but the resulting delays are generally plotted in a graph similar to Figure 2-14 so that the delay curves can be visualized. These types of capacity curves are very typically used in analysis of capacity constraint delays.

Analysts may then fit the calculated data to representative curves for presentation purposes, as shown in Figure 2-15.

## 2.4 Additional Delay Statistics

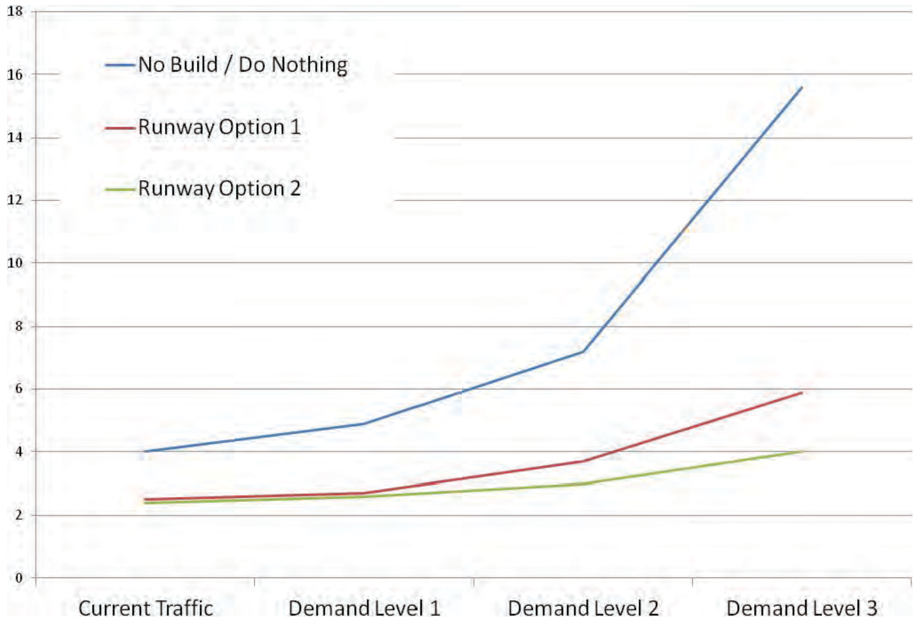
Although average delay may work well for airport planning, it is generally not detailed enough for airline decisions. Also, in the public arena, publicizing that an airport has an average delay of 10 minutes may seem to be "no big deal," when in fact it is very costly to airline operations. Expressing delays in millions of dollars in lost time and operating costs is typically more effective. Also, average annualized delay may not be effective measures for some airports with high levels of special event traffic or great variance of flights in different seasons (e.g., beach, ski, resort locations).

At a minimum, the average delay needs to have a corresponding maximum delay or average peak hour delays reported. For scheduled carriers, this is a better indicator of whether they can maintain schedule integrity and keep their turnaround times within scheduled times. Some delay measures that may be useful to carriers include the following:

- Average hourly delays for each wind/weather configuration (IMC and VMC),
- Peak hour delays,
- 95th percentile (i.e., 95% of the flights have a delay value less than the reported value; conversely, 5% of the flights are estimated/simulated to experience a delay above that value), and
- Maximum delay, meaning the maximum time that any aircraft is delayed.

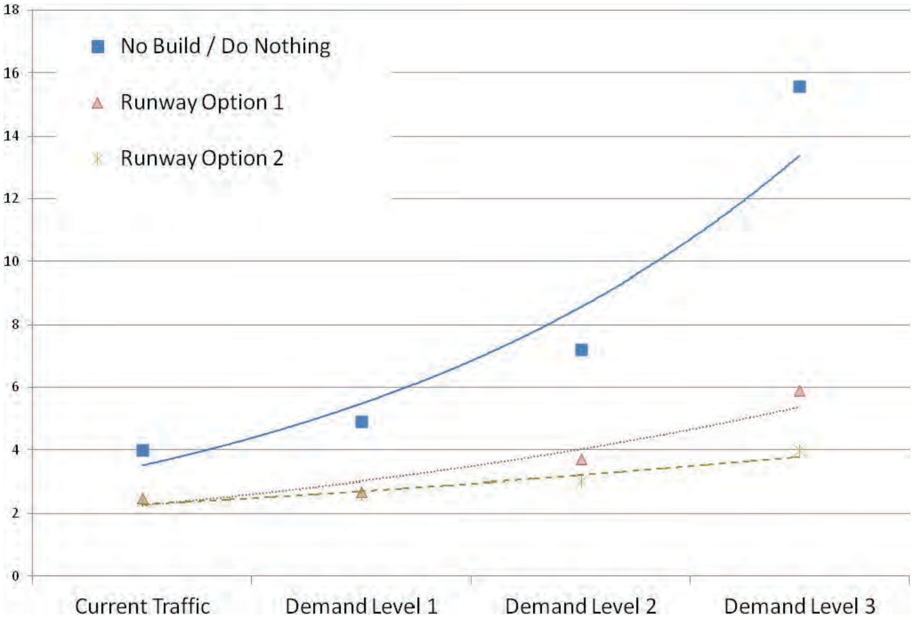
For any of the simulated/calculated delay items, the delays can be reported for different time periods, as follows:

- Daily average—may mask the delay problem during peak times when there is little or no delay during most hours of the day.
- Annual average—after analyzing delays in each of the major wind/weather configurations, then a weighted average of the daily average delay is calculated. Producing a single value, this is a convenient measure for comparing development alternatives.



Source: TransSolutions

*Figure 2-14. Average annualized delays for airport scenarios and future demand levels.*



Source: TransSolutions

*Figure 2-15. Average annualized delays fitted to curves.*

- Seasonal average or peak month average—similar to a weighted annual average, but would show average of peak months or peak seasons when it is important to accommodate demand for all times of the year.
- Hourly average—throughout the day, this provides an indication of delays during peaks and valleys of the daily flight schedule/demand. Since this produces 24 values for a single day, this is most useful as depicted in graphical form to see how the delay varies throughout the day.
- Average of peak hour—reports the maximum value from the hourly average just described. It is important that the particular hour has a significant number of operations.
- Individual aircraft delays—show the extreme maximum values and how the delays vary throughout the day with the flight demand; most easily displayed graphically. From the individual aircraft delays, one can obtain maximum delay, 95th percentile (only 5% of flights would have a higher delay than this), etc.
- Total delays—rather than express the delays in averages, one would report the total delay of all the flights for a day or for a year. This may translate into a very large number (e.g., thousands of hours) when calculated for the year.

## 2.4.1 Example: Delay Outputs from a Simulation Scenario

To demonstrate how delay measurements vary according to the way in which delays are reported, this section uses an example of a particular simulation run at an airport during VMC. (For informational purposes, this scenario was for an airport with a single runway, using a forecast traffic demand level approximately 60% higher than the current traffic level.)

Typical delay statistics from a simulation model report delays for all flights. Table 2-13 shows the simulated delay results for all flights in the simulation model.

It also has been suggested that only those aircraft that experience some delay could be included in the calculations. When this approach is taken, one must be very clear that they are reporting an “average of the delayed aircraft” and not an “average delay of all aircraft.” If only 50% of flights are delayed, then the average delay of all aircraft will be half of the average delay of the delayed aircraft.

The same delay statistics are shown in Table 2-14 for only the flights that experienced a delay. For this particular simulation run, over 80% of the departure operations experienced a delay, so the average delay for all flights (6.07 minutes) and

**Table 2-13. Simulated delay statistics for all flights.**

| | Taxi-Out Delay | Arrival Taxi Delay | Arrival Air Delay |
|---|---|---|---|
| Average | 6.07 | 0.08 | 4.23 |
| 95th Percentile | 20.97 | 0.57 | 22.72 |
| Maximum | 39.60 | 5.00 | 44.30 |
| Total Flights | 282 | 287 | 287 |
| Total Delay | 1714.2 | 22.5 | 1254.5 |

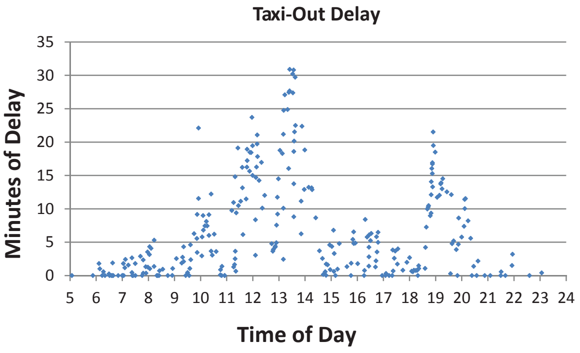
**Table 2-14. Simulated delay statistics for delayed flights only.**

| | Taxi-Out Delay | Arrival Taxi Delay | Arrival Air Delay |
|---|---|---|---|
| Average | 7.27 | 0.73 | 5.92 |
| 95th Percentile | 21.87 | 2.23 | 26.40 |
| Maximum | 39.60 | 5.00 | 44.30 |
| Total Delayed Flights | 236 | 31 | 212 |
| Total Delay | 1714.2 | 22.5 | 1254.5 |

the average delay for only delayed flights (7.27 minutes) are quite similar. Likewise, nearly 75% of the arrival flights experience an air delay, so again the average for all flights (4.23 minutes) and the average for only delayed flights (5.92 minutes) are similar. However, just over 10% of the arrival flights experience a taxi delay, so the difference is quite large: 0.08 minutes delay for all arrival flights compared to 0.73 minutes delay for just those 31 flights that experienced a delay.

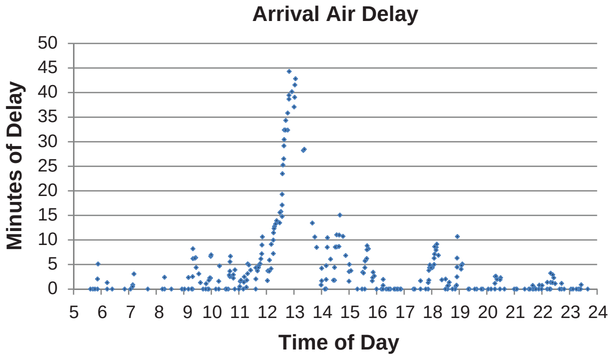
Figures 2-16 and 2-17 were produced for the same simulation run, but the tables above are for 10 iterations while the figures are for a single iteration. Thus, the maximum delays shown in Tables 2-13 and 2-14 may not be displayed in Figures 2-16 and 2-17 if the maximum delay occurred in a different iteration than is graphed.

The figures display the delay experienced by each aircraft in the simulation, plotted according to the time of day the aircraft used the runway. Figure 2-16 plots the taxi-out delay for each departure operation. Most flights before 10:00 A.M. experience taxi-out delay of 5 minutes or less. Later in the day, from 12:00 to 14:00, all flights experience some delay due to the peaked demand during that time of day.



Source: TransSolutions

*Figure 2-16. Individual flight delays for all departures.*



Source: TransSolutions

*Figure 2-17. Individual flight delays for all departures.*

Similarly, Figure 2-17 plots the arrival airspace/runway delay for all arrival flights throughout the day. Many flights are shown to experience almost no delay. However, again in the 12:00 to 14:00 timeframe, all arrivals experience some delay, with the delay steadily increasing as both arrivals and departures attempt to access the same runway during the midday peak, growing to nearly 45 minutes of delay.

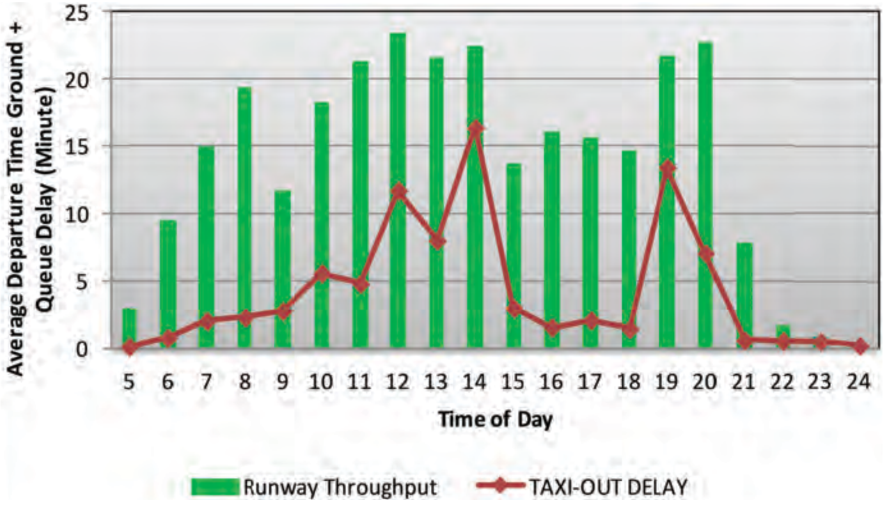
These types of plots can be quite useful for airlines since the 6-minute average taxi-out delay (from Table 2-13) does not demonstrate the extremes (approximately 30 minutes of delay) that several flights experience during the midday peaks. Also, the average arrival air delay of 4.23 minutes masks the high delay during the peak day where delays steadily climb from 5 minutes to nearly 45 minutes. Although the average may be useful for overall planning purposes, the additional information can be critical for gaining airline and/or public support.

Other charts that can be produced from the same simulation output include plotting hourly departure operations against hourly average taxi-out delays (Figure 2-18) and similarly, hourly arrival operations against hourly average airspace delays (Figure 2-19).

### 2.4.2 Comparing Simulation Delays to FAA Delay Databases

This section presents actual results from a simulation analysis at a large airport and compares this to the ASPM data for the same airport and time period. This particular airport experiences its peak month of traffic in March of each year. The SIMMOD simulation study baseline was conducted with a peak month schedule for 2007 and calibrated to actual hourly throughputs and observed taxi times.

In March 2007, the ATCT counts reported an average of 370 daily operations, ranging from a low of 336 daily operations to a high of 405 daily operations. The airport provided operations counts that average 358 daily flights. ASPM for the same month has data for an average of 308 daily operations.



Source: TransSolutions

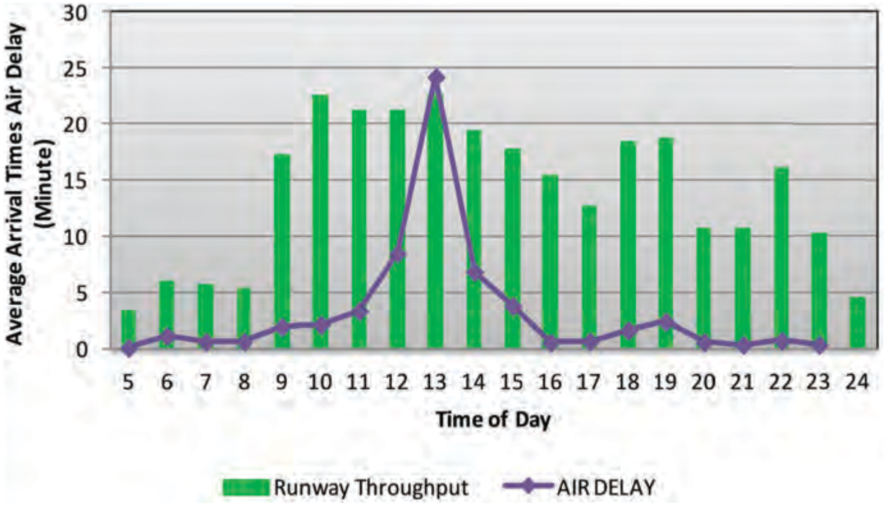
*Figure 2-18. Hourly departure operations and average hourly taxi-out delay.*

Recall that ASPM includes data for 22 domestic air carriers. For the year, this particular airport recorded 13.3% general aviation, military, and local flight operations that would not be included in ASPM. So with ASPM including data for about 85% of the total airport traffic, it is a good representation of the scheduled flights. For a comparable month, the simulated traffic demand had 358 flights, of which 14.5% were general aviation/military.

Key delay statistics from the simulation model are summarized in Table 2-15. Note that while specific weather data is not analyzed for a single month, a weighted average for VMC/IMC is shown for comparison purposes.

Taking each of these individually:

- Arrival air delay in a simulation model is a function of the amount of airspace modeled, whereas any similar ASPM statistic would encompass the entire en route travel delay from “off” time at the departure airport until “on” time at the arrival airport.
- Arrival ground delay in a simulation model is typically very small as the aircraft is directed immediately to an open gate or parking position. In actual operations, a flight may be stopped on a taxiway to await entry into a congested ramp or to wait for a specific gate to be vacated.
- Similarly, departure ground delay in a simulation model will not start accumulating until the aircraft can depart the gate without adjacent ramp congestion. In actual



Source: TransSolutions

*Figure 2-19. Hourly arrival operations and average hourly airspace delays.*

**Table 2-15. Simulation output for March 2007 (in minutes).**

| Average daily statistic | VMC | IMC | Weighted Average |
|---|---|---|---|
| | 96% of year | 4% of year | |
| Arrival air delay | 0.9 | 2.0 | 1.0 |
| Arrival ground delay | 0.1 | 0.1 | 0.1 |
| Departure ground delay | 2.3 | 4.0 | 2.4 |
| Taxi-in time | 3.7 | 3.6 | 3.7 |
| Taxi-out time | 8.1 | 9.9 | 8.2 |

operations, the pilot would typically release the brake to record an earlier "out" time (to improve on-time departure performance).

The one simulation output that can be compared most directly to ASPM data is average taxi-out time. For March 2007, ASPM shows average taxi-out time to be 14.1 minutes. However, even with this data, the brake may be released before the flight is ready to depart in actual operations, yet the simulation does not accumulate delay until the aircraft vacates the gate. There also may be ground stops to other airports such that the departures accumulate additional departure taxi time when they have vacated the gate but are awaiting clearance. These phenomena also make it difficult to compare ASPM's taxi-out delay and taxi-in delay times to simulated values. ASPM estimates unimpeded taxi times by calendar year for each carrier and airport based on observed values in the previous year during optimal operating conditions, whereas the simulation model calculates unimpeded times from the planned taxi routes. So the delay figures are not comparing actual times to flight schedule or block time estimates, but compared to FAA's expected values at that airport. For March 2007, ASPM estimates average taxi-out delay at 3.8 minutes and average taxi-in delay at 2.5 minutes.

Some additional items in ASPM cannot be compared directly to simulation output because they each represent a combination of planned times with actual operational times. For example, the on-time percentages could be used as inputs to the simulation model to offset flight earliness/lateness from the scheduled times, but they would not be simulation outputs for comparison with ASPM. Some of the additional ASPM data for the month of March 2007 includes the following statistics:

- 77% on-time gate departures (compared to flight plan): Flights that departed within 15 minutes past the flight-plan gate out time.
- 71% on-time airport departures (compared to flight plan): Flights that depart within 15 minutes of the flight-plan wheels-off time.
- 70% on-time gate arrivals (compared to flight plan): Flights that arrive at the gate less than 15 minutes late compared to the flight-plan gate out time plus the scheduled block time. The last schedule before wheels-off is used in the calculation, thus an EDCT hold may cause a late arrival.
- Average gate departure delay of 10.5 minutes (compared to flight plan): The difference between actual gate out time and the flight-plan gate out time, in minutes.
- Average airport departure delay of 13.4 minutes: The actual wheels-off minus the flight-plan gate out plus the unimpeded taxi-out time, in minutes. Negative values are allowed if the report includes early flights.
- Average airborne delay of 3.2 minutes: The difference between actual airborne time and the flight-plan estimated time en route, in minutes.
- Average block delay of 5.6 minutes: The difference between actual gate-to-gate time and scheduled gate-to-gate time, in minutes.
- Average gate arrival delay of 14.5 minutes (compared to flight plan): The sum of minutes of gate arrival delay of 1 minute or more, divided by all arrivals. Gate arrival delay equals the actual gate in time minus the flight-plan gate in time.

## CHAPTER 3

# Metrics to Define Airport Capacity

Airport capacity is a measure of the maximum number of aircraft operations that can be accommodated on the airport or by an airport component within a given period of time. The context of this report is airside or runway capacity. This chapter discusses definitions of airport capacity, some of the challenges and various threshold metrics used to define capacity, how the capacity values can be used in airport planning, and guidance on the use of capacity metrics for different audiences.

## 3.1 How Capacity Is Calculated

*ACRP Report 79: Evaluating Airfield Capacity* discusses how to analyze capacity including the factors that influence capacity, and readers are directed to that report for specific information on airport capacity evaluations. This section will briefly summarize common approaches and the strengths and weaknesses of each approach. Capacity calculations range from low-fidelity estimates based on simple assumptions about the runway layout through quick spreadsheet models to complex and high-fidelity simulation results.

### 3.1.1 Historical/Actual Observations

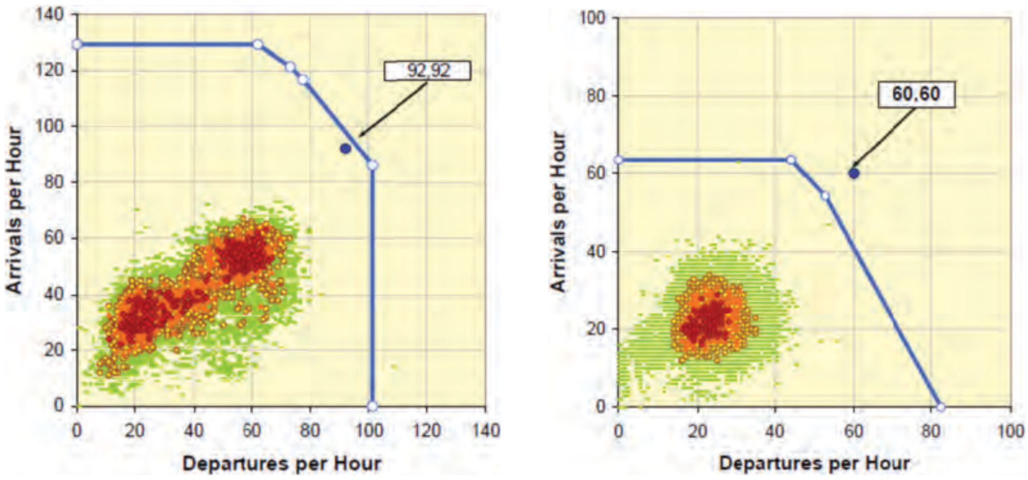
Airports and the FAA keep records of actual runway operations. Using the actual throughput counts of an existing airfield to estimate capacity may greatly underestimate capacity. The actual throughput is certainly achievable, since it occurred in the real world. However, without any additional knowledge of the delays or saturation condition, there is no way of knowing if more operations could have occurred had more flights wanted to land/depart. So if the demand (e.g., current or historical flight schedule) is lower than the capacity, then the observed throughput is not a good indication of capacity. For example, as shown in Figure 3-1, the airports displayed have actual throughput much lower than their theoretical capacity. Each dot shown in the lower left of the Figure 3-1 graphs represents an actual hour's operations consisting of a certain number of arrivals and departures, while the blue lines represent the capacity estimated by analytical methods. Simply estimating capacity from the actual operations counts would underestimate true achievable capacity. Rather than using actual throughputs as indications of capacity, planners usually determine capacity through more rigorous approaches.

### 3.1.2 Basic Models

The FAA's advisory circular *AC 150/5060-5, Airport Capacity and Delay, Change 2*, can be used for long-range planning purposes for simple capacity calculations of hourly capacity and ASV.

- Hourly capacity is defined as the maximum number of aircraft operations that can take place on a runway system with a specific runway use configuration in a 1-hour period.
- ASV "is a reasonable estimate of an airport's annual capacity. It accounts for differences in runway use, aircraft mix, weather conditions, etc., that would be encountered over a year's time."

The FAA's Airfield Capacity Model (ACM) has automated the methodology described in *AC 150/5060-5* to analytically calculate the maximum throughput of a runway system. Capacity is computed by determining the minimum time between successive arrivals and inverting this time to find the maximum number of arrivals per hour. The maximum number of departures that can be inserted between the arrivals is then calculated to give the arrival-priority capacity. If a specific ratio of arrivals to departures is specified, the



Source: Airport Capacity Benchmark Report 2004, FAA

***Figure 3-1. Airport capacity exceeding actual throughput.***

departure-priority capacity is calculated. The ACM produces hourly capacity at varying arrival-departure ratios. Hence, an airport runway layout has one capacity or maximum throughput when arrivals are given priority, another capacity when departures are given priority, and other capacities at other mixes, such as 50% arrivals and 50% departures. *AC 150/5060-5* and ACM rely on specific runway layout configurations and the ATC rules in place at that time.

### *Strengths*

These approaches provide initial capacity estimates when more exact information is not necessary and also for smaller airports or at airports where the demand is much lower than capacity. Also, they provide comparable estimates when comparing alternatives or airports. These approaches may overestimate capacity in comparison to what can reasonably be achieved during actual operations.

### *Weaknesses*

The base capacity curves were developed using older FAA rules and procedures (the AC was published in 1983 and last updated in 1995) and are not easily adaptable as new technology is developed and implemented at airports or as new aircraft types require changes in wake turbulence separations, etc. The methods tend to overestimate capacity because FAA has modified aircraft separation rules and reporting. Analysts are challenged to apply the method when the airport layout does not exactly match one of the 19 runway configurations in the AC. Although these approaches are still commonly used, the methodology is quite outdated.

Note: *ACRP Report 79* includes a new Prototype Airfield Capacity Spreadsheet Model that allows the analyst to update certain characteristics and ATC procedures that were rigid (hard-coded) in the ACM. The tool calculates hourly capacity and ASV. The model displays capacity charts similar to those shown in Figure 3-1.

### 3.1.3 Simulation Models

Simulation models for evaluating airfield and airspace facilities and air traffic procedures, such as SIMMOD and TAAM, allow for the evaluation of almost any airfield layout, procedures, aircraft characteristics, etc. The analyst can input (and generally override any defaults) to represent runway rolls, taxi paths, runway crossings/priorities, queuing rules, air traffic procedures (separations between aircraft on the same runway, different runways, airspace), runway usage, aircraft performance, touch-and-go operations and many more situations. In addition to the runways, most of the simulation tools also can analyze operations through the airspace, taxiways, and gate/ramp areas. Although one can use generic flights representing a specific fleet mix and demand level, analysts often use a detailed flight schedule of current or forecast traffic levels.

Most of the simulation tools report throughput or flow for specific units of time, but do not necessarily output a value for capacity. Analysts may input more demand than they estimate can be accommodated, then report the maximum throughput as the capacity. Alternatively, most simulation models output delay estimates (described in Section 2.2.2), so a threshold value for "acceptable delay" is pre-determined, then when that level of delay occurs in the model, the corresponding demand level is reported as the capacity.

#### *Strengths*

Almost any runway layout and operation can be modeled, including new procedures, technologies, and aircraft models. An analyst can choose what delay values to use for determining capacity. The sophisticated predictive capabilities of these models allows for extensive and reliable what-if analysis to support large capital expenditures.

#### *Weaknesses*

This method of determining capacity by using a threshold of acceptable delay is commonly used, but is highly dependent on flight schedule patterns. Yet, flight schedule changes should not result in different capacity estimates. Delay thresholds cannot be applied across the board to all airports—larger hub airports may tolerate higher levels of delay while smaller spoke airports may use a lower delay threshold. Also, passengers using airports that are close to metropolitan areas may tolerate higher delay thresholds than at farther-out airports.

Note: MITRE is expected to release a new *runway Simulator (rS)* capacity model in 2013. This simulation tool captures the dynamics of a complex airport, without the labor-intensive setup of a SIMMOD or TAAM model. *rS* randomly generates flights according to a specified mix to estimate hourly capacity as a Pareto frontier of arrival-departure throughput (the charts shown in Figure 3-1 were generated by *rS*). It does not calculate delays. The model uses a definition of capacity that is described as "average maximum sustainable throughput," where

- "Throughput" is a rate of aircraft operations per unit time.
- "Maximum" refers to the demand levels; the airport is experiencing demand at or greater than its capacity.
- "Sustainable" accounts for variability in performance and the separations between aircraft to account for the normal variability due to pilot, controller, and environmental variations.
- "Average" refers to the output being averaged over many hours of operations.

### 3.1.4 Reporting Throughput

Planners generally do not use the absolute maximum capacity as the primary value to measure capacity. Maximum capacity can be achieved only with a perfect mix of aircraft, arrivals/departures, and the minimum separation between aircraft. Given the human actions and reactions involved in the communication and coordination between ATC and pilots, as well as aircraft performance, there is much variance in real-world separations. Maximum capacity may also be called saturation capacity. While it is possible to achieve this number of operations when conditions are just right, it is not a capacity that can be maintained or sustained for several hours.

A more realistic measure may be called sustainable capacity. This is a measure of the hourly capacity that can be realistically achieved for several consecutive hours. Due to queuing phenomena of stochastic arrivals, practical capacity is generally 10%-20% lower than maximum capacity. This measure of capacity is designed to take into account the effects of ATC workload. Although desirable to operate at maximum capacity, studies have demonstrated that this level of performance cannot be maintained for more than 1 or 2 hours at a time.

## 3.2 Timeframe of Capacity Measure

The basic definition of capacity refers to the number of aircraft that can land/depart on a runway system during a specified time period. Capacity is typically only an issue when demand is higher than capacity. Thus, when discussing capacity, there often is a focus on peak periods, which are expressed in terms of hourly or annual operations, but other timeframes also can be used. The strengths and weakness of each category and the applicability to certain stakeholder groups also will be addressed.

### 3.2.1 Hourly

Hourly increments are generally short enough timeframes to account for the capacity effects of fleet mix, runway dependencies, arrival/departure mix, and variances in aircraft separations while the system is still experiencing a continuous demand. This also coordinates well with the peak-hour increments often used in airport traffic demand forecasting.

When measuring hourly capacity, most analysts recognize that the capacity varies depending on whether the hour consists mostly of arrivals or departures, or a more balanced arrival/departure mix. At slot-controlled airports, airlines may schedule a block of flights near the end or the beginning of the hour for marketing purposes. Thus, merely assigning slots to a 60-minute span can still result in operational delays due to airline scheduling practices. In these cases, the slots should be allocated to smaller time periods, perhaps in 10-minute blocks.

Some ATC facilities may report throughput in 10-minute or 15-minute increments, however the actual traffic demand can be heavily weighted to arrivals or heavy departures during such a small time increment.

To look at time periods longer than an hour, the arrival/departure mix would be more balanced; in other words, the longer the time period being considered, the more likely there will be an even number of arrivals and departures. However, there may be brief lulls in the flight demand over several hours such that the demand is not continuous.

### *Strengths*

Describing capacity in operations per hour is very effective for comparing the capacity under different wind/weather conditions, estimating the capacity change of a new technology, air traffic rule, or procedure, and ensuring that necessary capacity is maintained during construction phases. As depicted in Figure 3-2, it also is quite easy to compare the hourly operations in a flight schedule to hourly capacity. For airports that have highly peaked schedules throughout the day, hourly capacity is helpful to demonstrate to officials why periodic delay/congestion issues occur even though there are other periods with little activity.

### *Weaknesses*

As described, hourly capacities at a single airport can vary greatly depending on the percentage of arrivals vs. departures and the wind/weather conditions. It is unrealistic to list a single hourly capacity value for an airport, because it would have to be qualified as the hourly capacity under certain conditions. A weighted average of hourly capacities (based on the ratios of certain hours per year under certain conditions) is not be useful because it would typically either overstate or understate the actual capacity on any given day.

## 3.2.2 Daily

Daily capacity is infrequently used or reported. However, daily capacity may provide a means of reporting weighted capacity based on the typical wind/weather conditions during certain scenarios. One of the challenges with daily capacity is that generally there are fluctuations such that a demand is not continuous; in other words, there are gaps or lulls in the demand for several minutes or even hours. Even though an airport may be open to operations 24 hours/day, generally there are several hours (perhaps overnight) when there is very little traffic. If an analyst simply multiplies hourly capacity by 24 hours in a day or even by some typical operating time period (say, 6 A.M.–10 P.M.), capacity is likely to be overstated.

### *Strengths*

Daily capacity can be useful if an airport has a very typical wind/weather pattern such that certain runway(s) and weather conditions are used for mornings, then it switches to different wind/weather configurations throughout the day. Then the hourly capacity in each configuration could be summed to report a daily capacity, as long as that capacity does not include hours in which there is no traffic at the airport. Daily capacity also can be helpful for airports that have extreme traffic variations due to seasonality or special events to estimate the maximum operations achievable during their high traffic demand days.

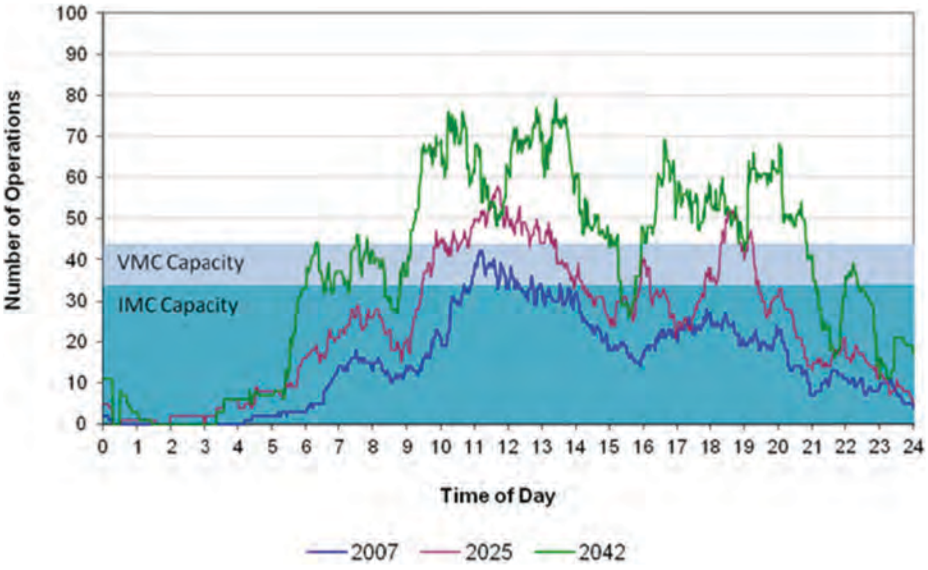


*Figure 3-2. Forecast demand vs. hourly capacity.*

*Weaknesses*

Daily capacity is not a straightforward output from any of the analytic approaches. For airports that have highly peaked schedules, the daily operations count or flight schedule may be well below daily capacity and it would mask the inability of the airport to accommodate the peaked demand during certain peak hours/times of day.

### 3.2.3 Annual

ASV can be estimated from the FAA's *AC 150/5060-5*, ACM, and some spreadsheet tools. Although simulation analyses do not use annual demand or output annual capacity, the daily flight schedule analyzed often represents a daily demand (or perhaps average day, peak month [ADPM]) of a particular annual operations forecast. Thus the simulation analysis of a particular daily flight demand is assumed to be an analysis of a certain annual demand.

Annual capacity must account for the various wind/weather conditions throughout the year and the percent of time (or percent of operations) in each condition so as to not overestimate or underestimate.

Annual capacity is most often stated in terms of aircraft operations or flights as the unit of measure. If the aircraft fleet mix changes, the annual operations capacity, as well as the airport's ability to accommodate that number of annual passengers, may have changed.

*Strengths*

Measures of annual capacity are useful for initial high-level estimates of airport capabilities and for comparisons between alternatives, especially in early planning stages. For small airports, ASV may be the only metric needed.

*Weaknesses*

When calculating ASV, an analyst must make some assumptions as to the number of hours in a day when peak operations will occur and the number of "equivalent" days in a year. Small changes in these types of values result in quite different annual capacity figures. Many in the industry these days believe that, in general, annual capacity measures are not that useful. Annual calculations mask the impact of peak or hub-based scheduling and, for most large airports, have little merit when looking at detailed planning.

### 3.2.4 Passenger Capacity as a Metric

To use a common metric for all airport functional areas, some commercial service airports prefer to use passengers as a metric of capacity, especially if the landside facilities are more of a constraining factor than are the airside facilities. This would be described as annual enplanements or million annual passengers (MAP). Or, for smaller increments, the airport could use passengers per hour or departure seats per hour. Translating airside or runway capacity in terms of operations to passengers merely requires one to multiply the number of operations by the average seats or passengers per aircraft. This metric provides the ability to combine number of passengers and number of flights. If the fleet mix changes, the airport may choose to report the number of operations to supplement their information on capacity.

*Strengths*

All areas of the airport—airside, landside, terminal processors—can be reported with the same metric to ensure the airport development provides a balanced capacity. Measuring capacity in number of passengers may more appropriately account for fleet mix changes. A large commercial airport provided the example shown in Table 3-1, which displays capacities of various airport components in the common metric of MAP.

*Weaknesses*

This requires the airfield capacity to be translated into an annualized MAP value. If the fleet mix (or average seats per aircraft) changes at an airport, the annual passenger metric also may change.

## 3.3 Capacity Coverage "Curves" (Graphs)

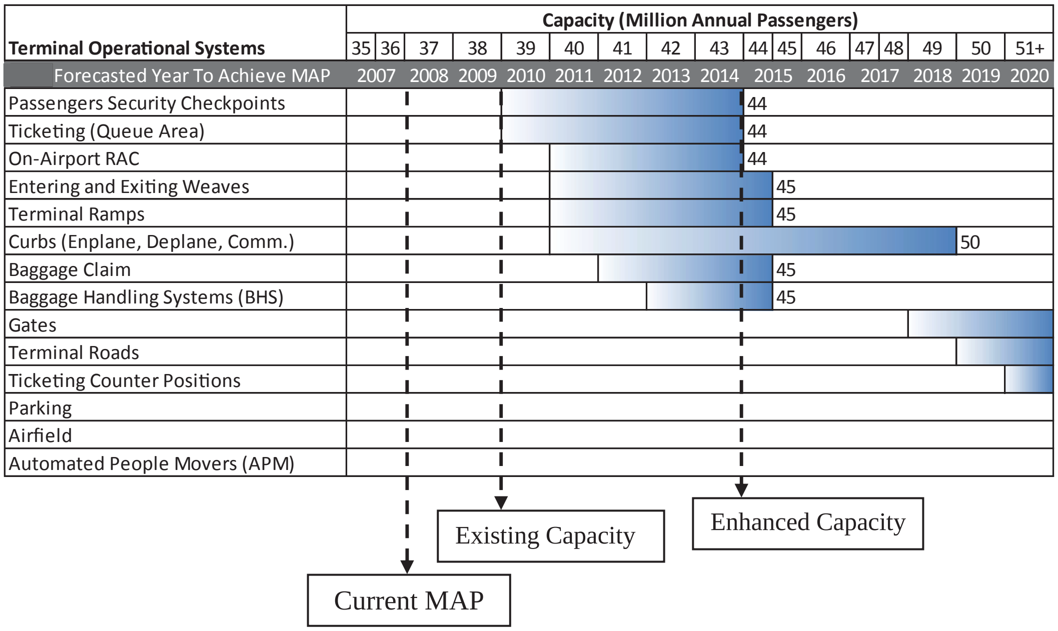
Many people outside the airport community do not recognize that capacity is not a single number at any given airport, but is really a range of capacity rates. Even for a given airport/layout, capacity varies in different wind/weather conditions, and varies according to the ratio or mix of arrivals and departures. Capacity coverage curves show the percentage of time that different throughputs can be achieved.

In the industry, we sometimes add to the confusion in that we may speak of it as a number. For example, while the FAA's *Airport Capacity Benchmark Report 2004* provides ranges of capacity in different weather conditions, it only reports capacity for the most commonly used runway configuration for each weather condition.

### 3.3.1 Wind/Weather Conditions

When the cloud ceiling and/or visibility are reduced such that IFR applies, there often is a reduced capacity from VFR

**Table 3-1. Capacity of all airport systems (in MAP).**



conditions, and even certain runway combinations may not be able to be used. Many airports have different capacities in VFR, IFR, and interim conditions that may be called marginal VFR.

For example, the FAA's *Airport Capacity Benchmark Report 2004* provided a summary table of hourly capacities at 35 U.S. airports, assuming an equal number of arrivals and departures. Ranges of capacity values were provided for each airport to represent the hourly capacity in the primary configuration for three weather conditions:

1. Optimum: Visual approaches possible when the ceiling and visibility are above the minima for visual approaches.
2. Marginal: Ceiling/visibility does not allow visual approaches, but is better than instrument conditions.
3. IFR: Radar separation required due to low ceiling and visibility.

The first few airports with their hourly capacity ranges from the FAA's 2004 report are shown in Table 3-2. As seen in this table, capacity at several airports is reduced by 5-10% in marginal weather conditions, as compared to optimal conditions. Then when in IFR rules, the capacity is only 60-80% of optimum capacity.

The reduction in capacity during marginal or IFR may be due to such things as the inability to land on certain runways in IFR conditions (e.g., converging or intersecting runways) or the extra separation required between arrivals on one runway and departures on a closely spaced parallel runway.

Although the capacity values reported in the Benchmark report were for only the primary runway usage configuration in each weather condition, frequently multiple configurations also are used, depending on the winds. Table 3-3 gives an example of hourly capacities for a simple airport with just two primary wind conditions in three weather conditions. Displaying this type of capacity information is overwhelming even for planners familiar with the situation.

One type of chart to provide this information visually is a capacity coverage curve (CCC), Figure 3-3, which shows capacity by percentage of time for which that configuration

**Table 3-2. Sample capacity benchmarks (hourly operations).**

| Airport | | Optimum | Marginal | IFR |
|---|---|---|---|---|
| ATL | Atlanta Hartsfield-Jackson International | 180-188 | 172-174 | 158-162 |
| BOS | Boston Logan International | 123-131 | 112-117 | 90-93 |
| BWI | Baltimore-Washington International | 106-120 | 80-93 | 60-71 |
| CLE | Cleveland Hopkins | 80-80 | 72-77 | 64-64 |
| CLT | Charlotte/Douglas International | 130-131 | 125-131 | 102-110 |
| CVG | Cincinnati/Northern Kentucky International | 120-125 | 120-124 | 102-120 |
| DCA | Ronald Reagan Washington National | 72-87 | 60-84 | 48-70 |

Source: Airport Capacity Benchmark Report 2004, FAA

**Table 3-3. Example of hourly capacities for an airport in each wind/weather configuration.**

| Wind/Weather Configuration | Percent of Year | Hourly Capacity – Arrival Priority | Hourly Capacity – Departure Priority | Hourly Capacity – Balanced Mix |
|---|---|---|---|---|
| Primary wind – VMC | 50 | 105 | 85 | 102 |
| Secondary wind – VMC | 20 | 76 | 65 | 76 |
| Primary wind – marginal | 10 | 90 | 82 | 90 |
| Secondary wind – marginal | 8 | 66 | 60 | 66 |
| Primary wind – IMC | 10 | 80 | 64 | 74 |
| Secondary wind - IMC | 2 | 30 | 30 | 30 |

is in use in a year. The same sample airport's balanced mix capacity is depicted in Figure 3-4 as a CCC with a series of blocks representing the year with the hourly capacity and percent of time that configuration is used. With the CCCs, it is possible to quickly spot the weather conditions that are problematic at an airport and the percent of time that the capacity drops and by how much.

A more complex CCC for the 1990 configuration of Chicago O'Hare International Airport is shown in Figure 3-4. Although this still does not cover all of the capacity possibilities of the airport (e.g., it does not display arrival priority or departure priority values), it does better represent the variances in the capacity as wind/weather changes throughout the day and from day to day. Many airports have winds that shift throughout each day, with several different configurations used throughout the day. For example, when the cloud ceiling lowers for a few hours during the day, an airport may lose the ability to use certain runways, which reduces capacity.

## 3.4 Delay Thresholds Used to Define Capacity

Planning reports and studies from a variety of U.S. airports were reviewed by the research team. Studies came from airports with fewer than 2,000 monthly operations to large commercial service airports with over 1,000 daily operations. The reports were examined to determine what types of capacity analyses were conducted and the method or threshold to evaluate if additional capacity was needed.

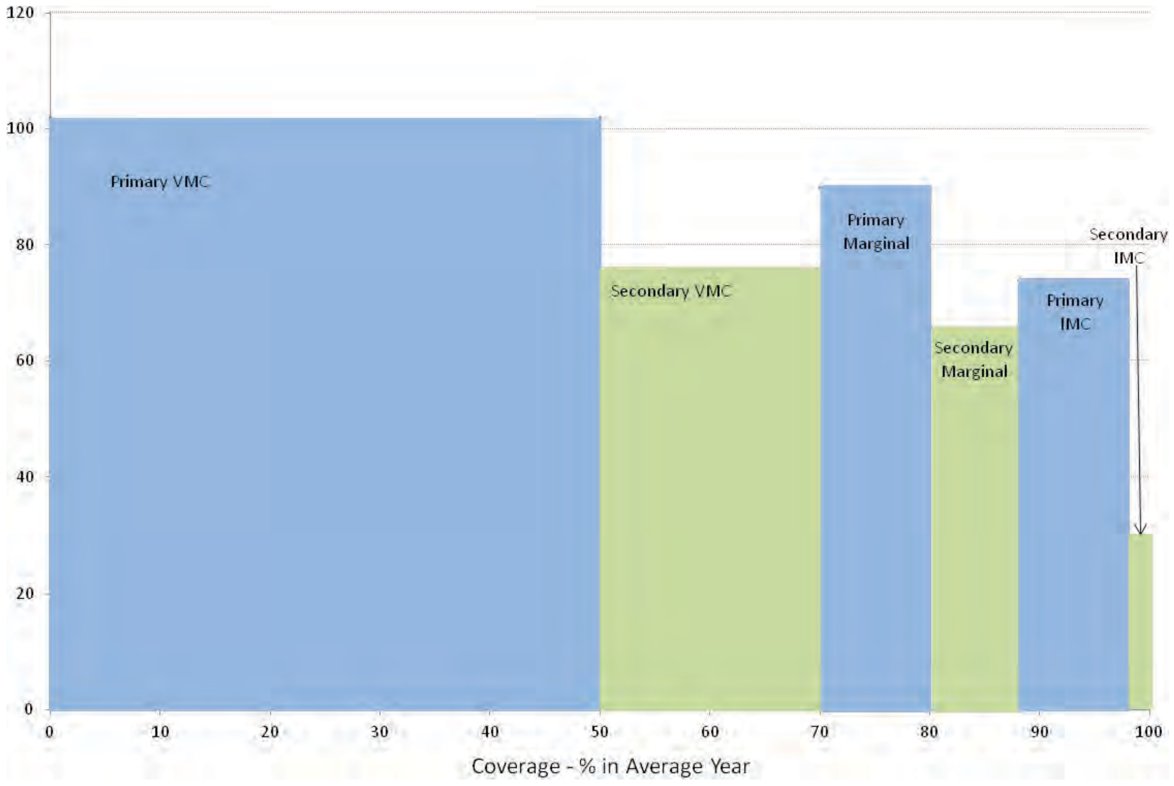
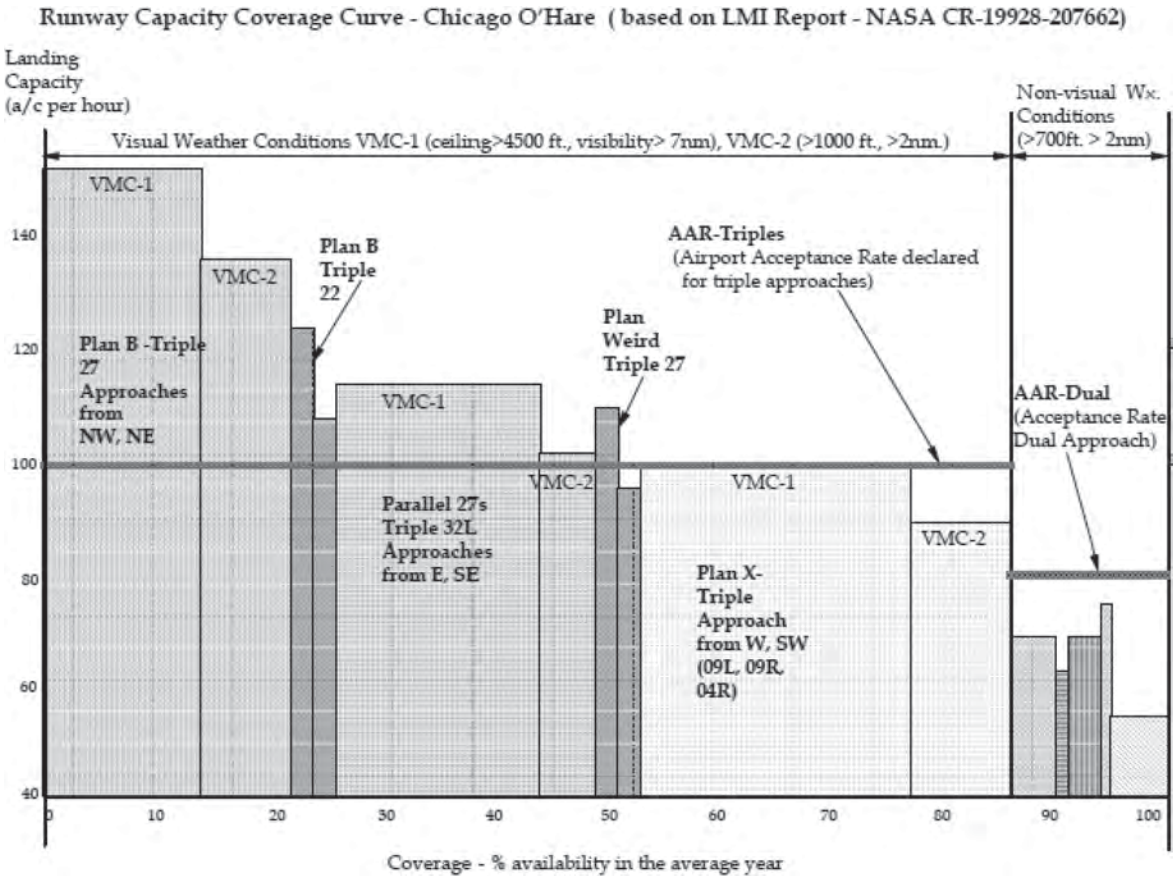


*Figure 3-3. Sample CCC.*



Source: Volpe/Boeing/LMI/FTA/FAA Report, "A Preliminary Design Process for Airspace Systems"

*Figure 3-4. Runway CCC—Chicago O'Hare.*

For initial/strategic planning and master planning, many airports under 200,000 annual operations have used the analytical approach in *AC 150/5060-5* to calculate ASV, then simply applied the FAA's guidance of starting to plan for capacity improvements (e.g., new runway) when the airport traffic demand reaches 60% ASV. However, the forecast growth trend also needs to be considered, as well. If the forecast growth is quite slow in that it will be another 40 years before reaching 80% ASV, then there is no compelling need to plan now for additional capacity.

For master planning, most commercial service airports with 150,000 or more annual operations have evaluated average aircraft delays using either analytical methods (such as in *AC 150/5060-5*) or computer simulation analyses. As stated previously, many of the simulation tools output delays rather than capacity, thus the criteria is often stated in average delay minutes per flight operation. As the planning progresses into Benefits Cost Analysis and Environmental Planning, simulation analyses are more common to quantify the delay savings.

However, the average delay threshold used to calculate airport capacity or planning criteria for new infrastructure varies from an annual average of 3–4 minutes to 10–15 minutes. Some have used a different average delay value for arrivals than departures; for example, 3 minutes average delay for arrivals and 6 minutes average delay for departures. The thought is that additional flying time in the air (delayed arrivals) is more costly than taxiing/queuing time on the ground for departures. When the simulated average delays per flight reach those thresholds or delay values, the analyst identifies that additional capacity will be required.

There tends to be general agreement that when average annual delays per operation exceed 10 minutes, an airport is experiencing severe capacity constraints; and at 20 minutes delay, there is a risk of gridlock.

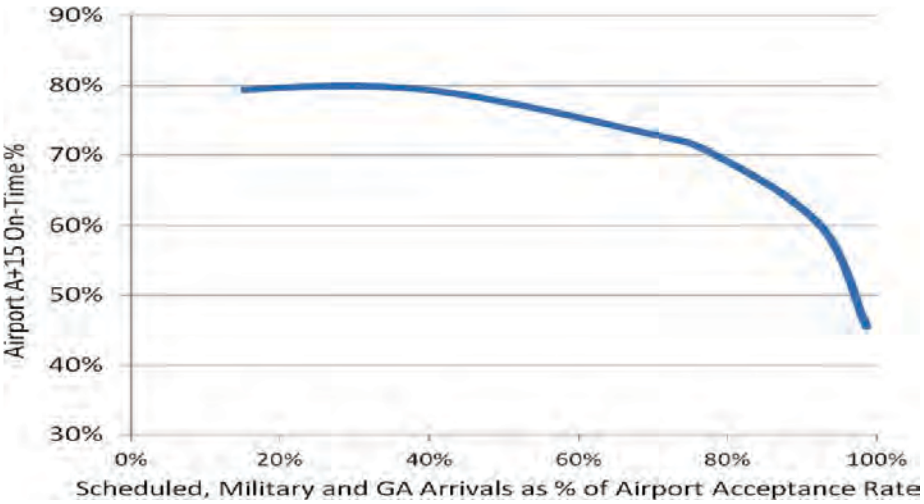
The delay thresholds that identify capacity or trigger the planning of additional capacity vary because the needs are different at each airport. The triggers vary according to the layout of the airport, taxiway infrastructure, regional airspace serving multiple airports, as well as the typical flight schedule. There is also some indication that the proximity of the airport to the local population influences how much delay is tolerated at that airport. Passengers at close-in airports may tolerate higher airport delays than at further-out airports, indicating that they consider total travel time in their overall view.

If an airline operates a peaked flight schedule (such as connecting complexes) at an airport, high delays during those peaked times greatly affect the airline's ability to meet scheduled times and maintain schedule integrity. So, this type of traffic demand might tolerate a lower overall average delay to ensure that the delays during those peak times do not negatively impact on-time performance. However, the flight schedule pattern should not influence the capacity. In other words, the capacity is established according to the layout and infrastructure and, while the throughput may change according to the procedures and technology, the flight schedule or traffic demand does not change the capacity.

## 3.5 Challenges in Capacity Measurements

Although many aspects of airside capacity are well developed, there remain some challenges and issues in airport capacity measurements and evaluations, including the following:

- Airport geometry, ramp capacity, and proximity of gates/ramp to runways—Runway capacity and gate capacity are fairly straightforward calculations; taxiway capacity and ramp capacity are not so well defined. One can observe that certain taxiway infrastructure systems provide lower capacity (e.g., a single taxiway parallel to a runway instead of dual parallel taxiways, small amount of space between the ramp and the departure queue), but it is difficult to put a value to this.
- Environmental effects on capacity—Capacity or throughput is sometimes constrained by environmental concerns (e.g., noise, emissions), just like air traffic procedures. Although the infrastructure or layout exists to achieve a higher capacity, environmental concerns put constraints on the airport that limit the throughput.
- Economics/business case vs. delay thresholds—Airport capacity projects should be based on economics and should be done if the improvement is cost beneficial regardless of the level of delay. Projects are based on business case analysis, whether for taxiway improvements or future runways. When delay savings exceed costs to build and operate, the project is justified.
- Capacity is not a single metric—Some reports describe capacity as a single measure, usually using either hourly or annual throughput. Although this becomes a simple way to compare airports or the capacity of a specific airport during different weather conditions, it oversimplifies the issues and ignores capacity variances that occur in actual operations. Metrics for capacity need to take into account minute-to-minute, day-to-day and/or season-to-season variance in capacity.
- Just-in-time capacity—Many analyses, from the FAA's *AC 150/5060-5* to some recent estimates by major airlines, show that airports need additional capacity when demand steadily reaches 80% of the capacity or acceptance rates. As depicted in Figure 3-5, the arrival on-time performance significantly drops off when the number of flights exceeds 80% of the stated capacity (FAA's airport acceptance rate [AAR]). Most major capacity projects take several years to plan, design, approve (through environmental processes), and construct. Often, it is difficult to get users or the community to support capacity enhancement projects until it is too late. Typically, U.S. airports have a just-in-time delivery of capacity. Projects are not planned while traffic is down because the projects are not justified then. But when traffic demand has returned, it is difficult to expedite the planning/development of new projects.



Source: TransSolutions, based on ASPM analysis

*Figure 3-5. Airport arrival performance as function of acceptance rates.*

CHAPTER 4

# Recommendations

This chapter provides recommendations for delay and capacity analyses methods and metrics to use at particular phases during airport development. A very direct, logical, and quantifiable relationship exists between capacity, demand, and delays, depicted in Figure 4-1. Capacity is the resource available; throughput measures how that resource is utilized (considering operational rules, procedures, etc.); delay is an output variable of demand and capacity, and there will be delays if/when demand is greater than capacity. Delay evaluates effects of a specific flight demand as it operates on the resource. Although flight schedule patterns affect delays, the schedules should not alter capacity. Specifically, if one knows two of the three factors—demand, capacity, delay—the other can be calculated.

Guidance and recommendations are provided regarding the relevance of particular delay and capacity measures by airport type, airport characteristics, and project lifecycle phase. The approach taken in this report is to suggest what tools are most appropriate at various points in the project development cycle, for specific items in each element, and for different types of airports. After presenting an overview of the relevant characteristics, the recommendations are presented as

- Measuring delays based on project lifecycle (Table 4-1);
- Operational delays that result from applying particular delay thresholds, based on airport type (Table 4-2); and
- Measuring capacity during project lifecycle (Table 4-3).

However, it is not practical to have one threshold that can be applied to all airports, and this report recommends against using *acceptable delay* as a term or measure. Rather than establishing a standard for what level of delay should trigger development, the metrics will provide a standard language that should be understandable to all the stakeholders.

Tables 4-1 through 4-3 contain the recommended approaches for measuring delay and capacity, as well as threshold metrics.

## 4.1 Airport Characteristics Affecting Capacity/Delay Analyses

The methods and metrics to analyze capacity and/or delay may differ depending on the type of planning scenario and certain airport characteristics. This section presents categories that will be used in this chapter to recommend analysis methods and metrics. Many of these recommendations are based on information reviewed from various airports, as described in Section 3.4.

### 4.1.1 Based on Point in Project Lifecycle

Airport development projects typically progress through a project lifecycle (Figure 4-2) involving several stages of airport and environmental planning, followed by design and construction activities, and resulting in project commissioning.

The planning component of this lifecycle is typically where the majority of capacity and delay analysis is performed. The planning process often begins with initial or strategic planning, moves into master or comprehensive planning, and then into environmental planning and documentation. For larger, more sophisticated airports, planning may further progress through more detailed planning and programming (often referred to as advanced planning or preliminary design), which typically yield detailed project-specific documents with programming, scheduling, phasing, and costing.

As the planning efforts move from initial planning through detailed planning and design, or to EIS preparation, the need for better detail in capacity and delay analysis increases. High-level analyses may be conducted for initial planning, but more detailed analyses often are needed as planning progresses to gain support from airline users and local citizens. More thorough analysis is used to support benefit-cost analysis, provide quantitative data for items like air quality impact evaluations, and also can be used to better determine when project design and construction activities should begin.

***Figure 4-1. Relationship of capacity, throughput, and delay.***

A second important variable in determining the need for more detail and sophistication in capacity and delay analysis revolves around the type of airport being studied. Major hub airports need a more detailed capacity and delay analysis, typically involving computer simulation, to help define project benefits and delay savings and to support good financial resources to fund these activities. On the other end of the scale, small general aviation airports are addressing very different

**Table 4-1. Recommended methods to measure delays based on project lifecycle point.**

| **Measuring Delay During the Project Lifecycle Point** | **Airport Type** | | |
|---|---|---|---|
| | **Large Commercial Service/Cargo Service Airports** | **Small Commercial Service Airports** | **General Aviation & Reliever Airports** |
| Initial Planning/Strategic Planning | Can use FAA and/or BTS databases (e.g., OPSNET) to compare historical delays.<br>Spreadsheet and queuing models.<br>Report average delays or overall total delays. | If airport included, can use FAA and/or BTS databases (e.g., OPSNET) to compare historical delays.<br>Spreadsheet and queuing models.<br>Report average delays or overall total delays. | Spreadsheet and queuing models, *AC 150/5060-5,* Chapter 3. |
| Master (or Comprehensive) Planning | Spreadsheet and queuing models if capacity need is beyond 10 years.<br>Simulation modeling with SIMMOD, TAAM, or other model if project need is within 10 years.<br>At a minimum, report average delays, but more detailed delays useful for gaining airline support. | Spreadsheet and queuing models if capacity need is beyond 10 years.<br>Simulation modeling with SIMMOD, TAAM, or other model if project need is within 10 years.<br>Report average delays. | Spreadsheet and queuing models, *AC 150/5060-5,* Chapter 3.<br>Report average delays. |
| Advanced Planning/Preliminary Design | Simulation modeling with SIMMOD, TAAM, or other model.<br>Review hourly delays and travel times in all wind/weather configurations when comparing alternative layouts. | Simulation modeling with SIMMOD, TAAM, or other model.<br>Average delays from major wind/weather configurations. | Spreadsheet and queuing models, *AC 150/5060-5,* Chapter 3. May use simulation for comparing design alternatives.<br>Average delays from major wind/weather configurations. |
| Benefits-Cost Analysis | Simulation modeling with SIMMOD, TAAM, or other model.<br>Average annualized taxi times and delays may be sufficient, depending on the project. Overall total delays also can be used. | Spreadsheet or simulation models.<br>Average annualized taxi times and delays may be sufficient, depending on the project. Overall total delays also can be used. | Spreadsheet and queuing models, *AC 150/5060-5,* Chapter 3.<br>Average annualized taxi times and delays should be sufficient. |
| Environmental Planning (EA/EIS) | Simulation modeling from master plan or new/updated simulation modeling.<br>Average annualized delays may be sufficient for analyses. Peak hour delays can be useful to gain public support.<br>Simulation output also can provide data for air quality analyses. | Spreadsheet or simulation models.<br>Average annualized delays should be sufficient. | Spreadsheet and queuing models, *AC 150/5060-5,* Chapter 3.<br>Average annualized delays should be sufficient. |

## Table 4-1. (Continued).

| | | | |
|---|---|---|---|
| Construction Phasing | Simulation modeling with SIMMOD, TAAM, or other model.<br>Report hourly delays and taxi times in all wind/weather configurations. Compare phasing delays to current delays to gain airline agreement. | Simulation modeling with SIMMOD, TAAM, or other model.<br>Report average delays in major wind/ weather configurations. | Spreadsheet or simulation models.<br>Average annualized delays should be sufficient. May focus on specific wind/weather configurations. |
| Operational Performance | Can use FAA and/or BTS databases (e.g., OPSNET) to compare historical delays.<br>Simulation modeling with SIMMOD, TAAM, or other model to analyze future schedules, fleet mix changes, or new procedures.<br>Delay analysis depends on the issue being evaluated, but will likely require hourly delays. | If airport included, can use FAA and/or BTS databases (e.g., OPSNET) to compare historical delays.<br>Simulation modeling with SIMMOD, TAAM, or other model to analyze future schedules, fleet mix changes, or new procedures.<br>Delay analysis depends on the issue being evaluated; average delays may be sufficient. | Spreadsheet or simulation models.<br>Delay analysis depends on the issue being evaluated; average delays may be sufficient. |

## Table 4-2. Delay thresholds for various airport types.

| **Major Capacity/Weather Characteristics** | **Airport Type** | | |
|---|---|---|---|
| | **Major Connecting Hub** | **Major O&D Airport** | **Medium/Small Hub Air Carrier Airport** |
| Examples | ATL, IAD, CLT, DFW | DCA, SEA | COS, ALB, ORF |
| • Typical/high incidence of IMC<br>• IMC capacity similar to VMC capacity | Average delay of 5 minutes ≈ max delays of 40 minutes in VMC or 90 minutes in IMC | Average delay of 5 minutes ≈ max delays of 30 minutes in VMC or 60 minutes in IMC | Average delay of 5 minutes ≈ max delays of 15 minutes in VMC or 60 minutes in IMC |
| Examples | ORD, PHL, EWR, MSP | JFK, SFO, BOS | CHS, PBI |
| • Typical/high incidence of IMC<br>• IMC capacity significantly less than VMC capacity | Average delay of 5 minutes ≈ max delays of 45 minutes in VMC or 120 minutes in IMC | Average delay of 5 minutes ≈ max delays of 30 minutes in VMC or 100 minutes in IMC | Average delay of 5 minutes ≈ max delays of 15 minutes in VMC or 60 minutes in IMC |
| Examples | SAN | MCO, FLL, TPA | TUS, JAX |
| • Low incidence of IMC<br>• IMC capacity similar to VMC capacity | Average delay of 5 minutes ≈ max delays of 30 minutes in VMC or 45 minutes in IMC | Average delay of 5 minutes ≈ max delays of 20 minutes in VMC or 30 minutes in IMC | Average delay of 5 minutes ≈ max delays of 15 minutes in VMC or 30 minutes in IMC |
| Examples | PHX, IAH | LAX, LAS | LGB, ABQ |
| • Low incidence of IMC<br>• IMC capacity significantly less than VMC capacity | Average delay of 5 minutes ≈ max delays of 30 minutes in VMC or 120 minutes in IMC | Average delay of 5 minutes ≈ max delays of 20 minutes in VMC or 60 minutes in IMC | Average delay of 5 minutes ≈ max delays of 15 minutes in VMC or 45 minutes in IMC |
| Examples | | RSW | AGS, ASE |
| • Airport with concentrated seasonal traffic | Average delays should be calculated for both peak and non-peak times. Delays in peak times are more relevant than annualized average delays. | Average delays should be calculated for both peak and non-peak times. Delays in peak times are more relevant than annualized average delays. | Average delays should be calculated for both peak and non-peak times. Delays in peak times are more relevant than annualized average delays. |

**Table 4-3. Measuring capacity during project lifecycle.**

| **Identifying and Measuring Capacity During the Project Lifecycle** | **Airport Type** | | | |
|---|---|---|---|---|
| | **Major Connecting Hub** | **Major O&D Airport** | **Medium/Small Hub Air Carrier Airport** | **GA Airports** |
| Initial Planning/Strategic Planning | Likely need hourly capacity estimates. | Likely need hourly capacity estimates. | Likely need hourly capacity estimates. | FAA ASV calculation, new ACRP 03-17 model. |
| Master (or Comprehensive) Planning | Likely need hourly capacity estimates, perhaps for both peak arrival hours vs. peak departure hours. | Likely need hourly capacity estimates, perhaps for both peak arrival hours vs. peak departure hours. | Likely need hourly capacity estimates. | FAA ASV calculation, new ACRP 03-17 model. |
| Advanced Planning/Preliminary Design | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need hourly capacity estimates, for peak arrival hours and peak departure hours. | FAA ASV calculation, new ACRP 03-17 model. |
| Benefits-Cost Analysis | Likely need hourly capacity estimates, perhaps for both peak arrival hours vs. peak departure hours. | Likely need hourly capacity estimates, perhaps for both peak arrival hours vs. peak departure hours. | Likely need hourly capacity estimates. | FAA ASV calculation, new ACRP 03-17 model. |
| Environmental Planning (EA/EIS) | Likely need hourly capacity estimates, perhaps for both peak arrival hours vs. peak departure hours. | Likely need hourly capacity estimates. | Likely need hourly capacity estimates. | FAA ASV calculation, new ACRP 03-17 model. |
| Construction Phasing | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need hourly capacity estimates, for peak arrival hours and peak departure hours. | FAA ASV calculation, new ACRP 03-17 model. |
| Operational Performance | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need peak capacity in 10- or 15-minute increments, for peak arrivals and peak departures. | Likely need hourly capacity estimates, for peak arrival hours and peak departure hours. | Hourly capacity. |

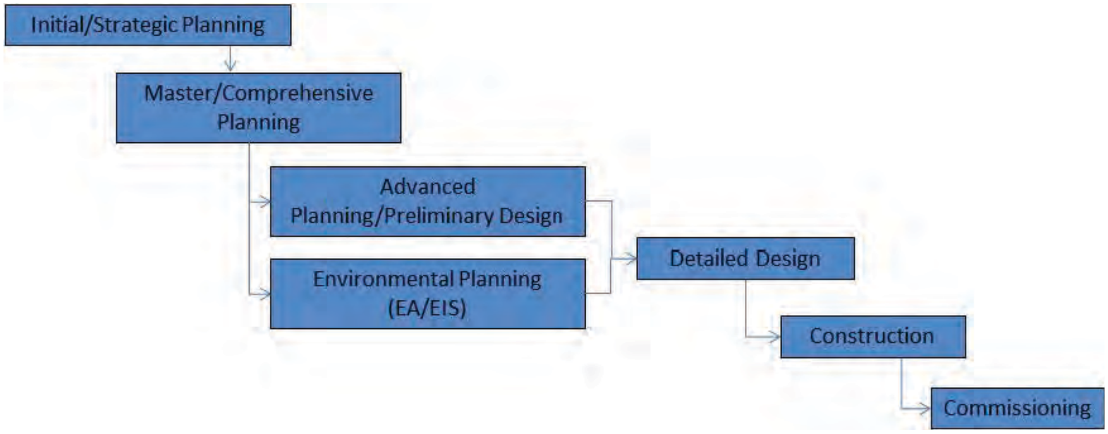


*Figure 4-2. Typical project lifecycle.*

issues that seldom revolve around runway capacity constraints and typically can use more simple capacity and delay tools. The following section discusses the relevant characteristics of the various types of airports for which capacity tools might apply.

### 4.1.2 Relevant Airport Characteristics

The level of average annual delay to use as a threshold for determining capacity at a given airport varies greatly. The following three principal factors that categorize airports into specific groups for purposes of providing general guidance about how to measure delays and determine reasonable levels of delay have been identified in this effort:

- Airport type,
- Good weather/bad weather capacity ratio, and
- Good weather/bad weather occurrence.

#### *Airport Type*

Put simply, different types of airports (major connecting hubs vs. small general aviation airports) can tolerate different levels of delay. Major connecting hubs that operate continuously throughout the day like Hartsfield-Jackson International Airport in Atlanta have a great need for schedule reliability. In contrast, local origin and destination (O&D) airports in major metropolitan areas that are difficult to expand where customers have no other or limited airport choices (San Diego or La Guardia in New York, for example) have a different delay threshold. This section identifies how delay thresholds might be approached for a range of airport types.

For consistency with FAA planning guidance, the FAA categorization of airports is first presented below. Then, a number of subcategories for purposes of measuring delay is proposed, based on operational characteristics and how they relate to delay levels.

#### *FAA Definition of Airport Categories*

The FAA classifies airports into several broad categories, including commercial service, primary, cargo service, reliever, and general aviation airports. These airport categories are briefly summarized as follows:

- Commercial service airports are publicly owned airports that have at least 2,500 passenger boardings each calendar year and receive scheduled passenger service. Passenger boardings refer to revenue passenger boardings on an aircraft in service in air commerce, whether or not in scheduled service. Passenger boardings at airports that receive scheduled passenger service are also referred to as enplanements.
  - Nonprimary commercial service airports are commercial service airports that have at least 2,500 and no more than 10,000 passenger boardings each year.
  - Primary airports are commercial service airports that have more than 10,000 passenger boardings each year. Hub categories for primary airports are defined as a percentage of total passenger boardings within the United States in the most current calendar year ending before the start of the current fiscal year.
- Cargo service airports are airports that, in addition to any other air transportation services that may be available, are served by aircraft providing air transportation of only cargo with a total annual landed weight of more than 100 million pounds. An airport may be both a commercial service and a cargo service airport.
- Reliever airports are airports designated by the FAA to relieve congestion at commercial service airports and to provide improved general aviation access to the overall community. These may be publicly or privately owned.
- The remaining airports are commonly described as general aviation airports. This airport type is the largest single group of airports in the U.S. system. The category also includes privately owned, public-use airports that enplane 2,500 or more passengers annually and receive scheduled airline service.

#### *Airport Classifications*

This study has taken the broad FAA airport categories and created subcategories within the commercial service type for purposes of identifying the best ways to measure capacity and delay. The following discreet categories will be used to identify and discuss delay thresholds:

- Commercial service/cargo service airports
  - Major connecting hub—one or more airlines has a significant presence at the airport with a business model for transferring passengers from each inbound flight to multiple outbound flights. Example airports include ATL, DEN, DFW, and PHX.
  - Major O&D airport—passengers are typically arriving or departing this large airport rather than connecting from one flight to another. While there is some connecting traffic, the vast majority of the passengers are O&D. Example airports include BOS, DCA, and MCO.
  - Medium/small/non-hub (“spoke” airport)—nearly all passengers are originating or terminating at this airport. Examples include COS, JAX, PBI.
- Reliever and general aviation airports

Several major airports serve both as a connecting hub and as O&D. Many O&D airports serve long-haul markets where the timing of flights is very sensitive, and where overseas arrival slot times may get missed if flights get significantly delayed. One must consider the overall traffic mix and the importance of such operational items as tight connections, frequency of ground holds to other airports, and criticality of on-time performance at downline stations in conducting delay analyses at these airports.

### *Good Weather/Bad Weather Capacity Ratio*

Airports that have similar capacities in good and bad weather are very different than those airports with dramatic differences in capacities in good and bad weather. Where capacities are similar, for example, an average annual delay of 10 minutes per operation generally means just that: average delays are 10 minutes, day in and day out, despite the weather, yielding good predictability and schedule reliability. In contrast, an average delay of 10 minutes at airports where capacities in good weather can be double those in bad weather might mean that average delays are 4–8 minutes in good weather, but delays of 45–60 minutes might accrue in bad weather, severely impacting service reliability. Categorizing airports by their good weather/bad weather capacity ratio will help identify what delay threshold to apply at airports in each group.

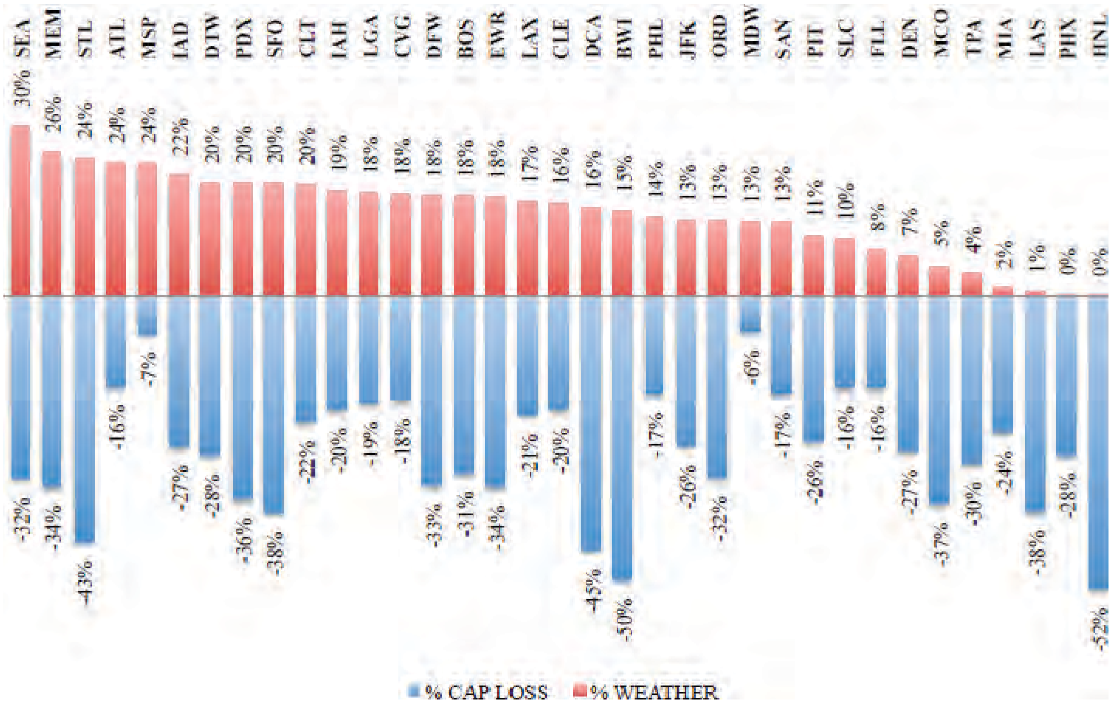
### *Good Weather/Bad Weather Occurrence*

Airports with very low incidence of bad weather (e.g., Phoenix Sky Harbor International) can tolerate high delays in very limited poor weather conditions without adversely affecting schedule reliability because of the rarity of bad weather. On the other hand, airports with high incidence of poor weather (e.g., Seattle) cannot tolerate very high delays in poor weather and still maintain schedule reliability while keeping airline operating costs reasonable.

In Figure 4-3, the darker bars depict the percent of time the airport typically experiences poor visibility—ceilings less than 1,000 feet and/or visibility less than 3 miles, while the lighter bars show the capacity reduction from optimal conditions and IFR conditions, as reported in the FAA's 2004 Benchmark Report. Categorizing airports by their good weather/bad weather incidence will further help to identify what delay threshold to apply at airports in each group.

## 4.2 Estimation of Delay for Different Purposes

After reviewing numerous airports' planning study reports for various phases or points along the airport lifecycle (described in Section 3.4), recommendations are included for delay analyses. No single delay metric can be applied to all airports. Characteristics of the airport and traffic demand profile as well as the project lifecycle step all affect the delay analysis. Also, certain delay statistics will be more useful to different audiences. Recommendations are presented in the following subsections for delay analyses methods and metrics for effective planning.



Source: American Aviation Institute (AAI)

*Figure 4-3. Airport capacity loss vs. occurrence of inclement weather conditions.*

### 4.2.1 Based on Point in Project Lifecycle

Recommendations for the method or tool to use for delay analysis at each point in the project lifecycle are presented in Table 4-1. Appropriate delay measures are also proposed. In general, less-detailed analysis can be used early in the planning processes. Although the recommendations primarily are to use analytical tools that would measure unimpeded delays, initial planning also can be effectively conducted with analysis of some of the operational delay databases described in Section 2.2. However, as the planning progresses, analyses should be more detailed and provide more detailed delay statistics. Suggestions also are provided for using certain delay metrics to gain acceptance of capacity enhancement options by stakeholders and the local community.

It is critical that an analysis specify whether the delay was analyzed from operational delay databases (e.g., FAA OPSNET, BTS) or from simulation/spreadsheet tools. For example, OPSNET only includes delay values for flights delayed 15 minutes or more such that average delays are quite high, whereas a simulation counts every second of delay and average delays may be a few seconds to a few minutes. Note that if initial measurements are reported from delay databases, there could be confusion if subsequent simulation analyses report much lower delay values.

### 4.2.2 Based on Airport Characteristics

Delay logically would be an output of an analysis of the capacity and demand, not an input that defines capacity—but it can be set to help determine when capacity would be needed to accommodate a certain level of demand. Delay thresholds are used to

- Define capacity,
- Establish operational goals, and
- Justify improvements/development.

The average annualized delay from a spreadsheet or simulation model provides no indication of the extremely high delays that may be experienced by individual flights at that airport under different weather conditions. Since average annual delays are still the most common method to compare alternatives, especially when multiple runway configurations are used throughout the year due to wind/weather conditions, Table 4-2 provides estimates of the operational flight delays that may be experienced when certain simulated/calculated delay values are simulated. Maximums have been estimated from numerous analyses such as those shown previously in Figure 2-4, based on typical traffic patterns at that airport type.

Delay thresholds truly need to be customized to the airport's operations. When the traffic demand pattern has sharp peaks, such as at connecting hub airports, the maximum delays or variances can be quite high. In such cases, the average delays may only be 5 minutes, but the actual operational delays during good weather can be as much as an hour and can reach 2 to 3 hours during IMC. If the delays reach a level that exceeds the length of schedule lulls between peaks, then the delays affect not just the current peak/bank but also subsequent peaks throughout the day. At airports where the traffic demand pattern does not have very high peaks, the delays may be more constant throughout the day.

Similarly, at airports with high occurrences of IMC traffic, the maximum operational delays can be very high. These airports may choose to focus their planning and capacity studies on IMC configurations if they contribute the bulk of the delays. However, if IMC does not occur very frequently, the planning may only focus on good weather conditions, knowing that the operational effects may be irrecoverable during those few hours when severe weather occurs.

In general, there are very low delays at general aviation (GA) airports because the demand is typically not constant throughout the day, week, or year. If spreadsheet analysis shows more than 2 minutes of average delay at a GA airport, then a significant percent of the traffic would be experiencing some delay either in the air or on the ground (e.g., waiting to depart) or not be able to operate at their desired time. Since delays are seldom experienced at most GA airports, that airport category is excluded from this table.

## 4.3 Capacity Metric Recommendations

Chapter 3 discussed various elements of airport capacity measurements. Analysts can apply different methods to measure capacity and report the metric in terms of annual or hourly throughput or some other measure. Recommendations for what capacity metrics to use for various airport types and project lifecycle phases are summarized in Table 4-3.

Note that *ACRP Report 79* includes a detailed decision support tool and checklists for choosing model sophistication based on airport characteristics and the issue being studied. Readers are referred to that report to further identify their appropriate type of capacity model.

Similar to the delay analysis recommendations above, more fine-tuned analyses are recommended as the planning progresses and to gain acceptance by certain stakeholders. For GA airports or those where capacity is not a concern, simple annual estimates will suffice.

## CHAPTER 5

# Future Trends in Improving Metrics

This research effort has identified some additional metrics that would be beneficial to the industry. Some of these are focused on communicating delays to the general public so they can gain a better understanding and appreciation of operational delays' impacts on consumers. Others are more useful for those inside the industry. And, of course, public metrics also are useful for industry analysts and vice versa.

Coming from stakeholders with very different viewpoints, there is concurrence that ideal capacity/delay metrics would be as follows:

- Easily understandable by industry experts and lay people;
- Able to communicate the impact of delays on the traveling public and tell the story that will resonate the benefit of new projects;
- Used as a common measure at any airport, such as measuring in numbers of passengers instead of number of operations; and
- Applied consistently across different airports.

Future metrics describing the impact on passengers will assist in understanding the money and time that air traffic delays cost passengers. It is important to clarify that none of the available data really get at the passengers' delay experience, which is how passengers relate to delays. Perhaps there should be new metrics regarding the ability to meet passenger/consumer expectations, to measure total trip time, missed connections, passenger tolerance, or passenger frustration.

A more positive metric would better serve the industry and consumers. "Delay" is a negative measure or is perceived negatively, while "level of service" would be a positive metric of passenger perceptions. The inverse could be a passenger tolerance measure of delays. Metrics about meeting passenger/consumer expectations could encompass the following:

- A more positive metric that better serves the industry and consumers,
- Metrics not influenced by flight schedules, and
- Metrics that the general public can understand and appreciate.

As previously noted, curb-to-curb or door-to-door measures likely will be key measures in the future. There is no agreement on how to factor in passenger time. Total trip time encompasses delays on more transportation modes than just the airport. Delay for a passenger may start when they leave their home/business—at the front door—and be encountered on roads, at parking facilities, or at ticket counters. Some passengers, if they have a choice of multiple airports at either the origin or destination market, take into account such items as the expected travel time to/from the airport, time getting through the airport, and expected airfield delays.

Future metrics also can be useful in gaining public support of airport development needs. For local communities affected by increased flight operations (e.g., noise), measuring expected delay savings of potential capital projects at an annual average of 1 minute or 5 minutes per flight operation does not sound very large or worthwhile even if it has dramatic impacts on fuel burn and overall passenger delay. A better metric that will resonate with the overall benefit of new projects is needed. Delays could be shown in distributions rather than a specific number: peak delays and the distribution of delays tend to show the impact better. Additional delay statistics are needed to supplement average delay, such as standard deviation (or ranges), maximum delays, peak-hour delays, bad weather delays, average delay on delayed flights, or overall total delays for all flight traffic. Another measure is the count or percentage of flights that arrive on time (as compared to unimpeded). Metrics in terms of passengers, such as numbers of passengers delayed, would also help to capture the overall impact of capacity constraint delays.

Using a common metric for all airport areas, something like millions of annual passengers (MAP), may allow passenger-based metrics to work for balancing all areas: airside, landside, and terminal processors. This would require airfield delay to be translated into an annualized MAP value. If terminals and other facilities become overcrowded, then the analysis will take into account capacity measures in terms of passengers.

Current measures used in the industry that have the best opportunity to meet the needs of the community and become a national standard for talking about delays include the following:

- The annual costs of delay at this airport is $X, while the average cost per year to provide new capacity is $Y.
- The percentage of flights that will encounter capacity constraint delays of X minutes or more will increase from Y% in Year-1 to Z% in Year-2.
- The average delay for delayed flights (or flights during peak periods) will increase from X to Y as well as the distribution and maximums of these delayed flights.

It also should be possible to represent the down-line impact of initial delays with these metrics, similar to how the current FAA's BCA guidelines give some estimates of propagated delay throughout the national aviation system.

Once demand reaches a certain capacity, the impact on delay is multiplied. What is observed in analyses through the years is that if the demand-to-capacity ratio is below 0.8, delays are tolerable, as shown in Figure 3-5. As ratios get to 0.8, airports can handle delays as long as the ratio is *not* maintained for long periods so that there are opportunities to recover before another peak demand. Ratios consistently greater than 0.8 generate delays due to capacity that tend to grow exponentially. This is true both on the ground and in the air. For example, the New York metropolitan area has so much airspace congestion that only a moderate disruption causes a big capacity/delay issue throughout the area.

Other metrics that can be used include translating environmental constraints into delay measures, or communicating delays as gallons of fuel used or emissions reductions.

There also is a need for better data on actual travel vs. actual delays. Analysts are left to analyze the data in enough detail so they can estimate the amount that is attributable to delay, since some amount of expected delay is imbedded in the flight schedules. This may involve analyzing block times from many years ago when there was less congestion, but even those flights likely included some delay. Or, possibly if there will be analysis of enough flights, including those during lull times of the day, one can estimate nominal travel time (some of the FAA databases have taken this approach). Similarly, FAA estimates nominal taxi times in ASPM, then delays are calculated from those estimates. But obtaining unimpeded taxi times from actual flights currently is not possible, or even practical. However, having better data sources on actual unimpeded travel times would standardize these types of analyses and the resulting metrics.

Congestion also may need to be defined in addition to capacity. There should be a way to explain the number of aircraft sitting on the airfield and their limiting impact (such as limiting the movement of other aircraft). There are good measures of delay for runway procedures, airspace infrastructure, and gate/ramp layout. However, it is difficult to measure delays only for the taxiway structure, since many of the taxi delays are really a function of the runways or the ramp/gates. It is somewhat apparent to those knowledgeable in the industry that some airports are quite constrained by their taxiways (e.g., DCA) while others have few taxiway constraints (e.g., DEN), yet it is difficult to measure delays only due to the taxiways.

Because the term *delay* is used for comparisons to schedule and nominal time, this causes confusion when trying to express delay savings to the public. There could be one term for delay that is a comparison to nominal/optimal time and another term for delay that is the comparison to flight schedule or extra time caused by airline operational issues. Although this project recognizes the advantages of adopting different terminology for operational delays or variances to airline schedules or simulation outputs, changing the way airlines or U.S.DOT use certain terms would be overly ambitious.

There is the potential to create statistics based on not only *dependability*, but also *predictability* and *consistency.* These factors have significant implications for all of the stakeholders. Metrics should give an indication of what is really important to stakeholders.

# APPENDIX A

# Delay Database Summary

| Data Base | Purpose for the Data Collection and Analysis | Who Reports the Data (or How Is It Collected) | What Data Is Reported | Differentiate between Raw Data vs. Any Data That Is Calculated |
|---|---|---|---|---|
| TFMS (Traffic Flow Management System) | TFMS is a data exchange system for supporting the management and monitoring of national air traffic flow | The FAA's airspace lab assembles TFMS flight messages into one record per flight | TFMS processes all available data sources such as flight-plan messages, flight-plan amendment messages, and departure and arrival messages. The FAA's airspace lab assembles TFMS flight messages into one record per flight. TFMS is restricted to the subset of flights that fly under IFR and are captured by the FAA's en route computers. All VFR and some non en route IFR traffic is excluded. TFMS includes information about commercial traffic (air carriers and air taxis), GA, and military to and from every landing facility, as well as fixes in the U.S. and in nearby countries that participate in the TFMS system.<br>Due to limited radar coverage and incomplete messaging, TFMS may exclude certain flights that do not enter the en route airspace and other low-altitude flights. In addition, of the 35,000 location identifiers reported over time, only the top few thousand, accounting for over 95% of traffic, are reliable. The others are waypoints or other references to locations not associated with an airport. | The TFMS data provides the capability to calculate types of operations (arrival, departure, or overflight for en route centers), terminal operations counts (arrivals, departures, and overflights) and instrument operations (primary, secondary, and over) on a flight-specific basis. In addition, for the en route and oceanic environment, it is also possible to derive the time within the center's airspace, actual distance flown within the center's airspace, and the great-circle route distance between the entry and exit point of the center's airspace. |
| PDARS (Performance Data Analysis and Reporting System) | Provides ATC decisionmakers at the facility level with a comprehensive set of tools and methods for monitoring the health, performance, and safety of day-to-day ATC operations | Collaboration between the FAA and the NASA; collection of radar data; developed by ATAC Corporation | It collects data every 2 seconds from Air Route Traffic Control Centers (ARTCCs) and Terminal Radar Approach Control facilities (TRACONs). PDARS' raw data produce information such as the type of operation, aircraft identification, and actual runway threshold time. On the airport level, a significant part of information lies in the information on aircraft-runway assignments. All TFMS data are included, consisting of the following flights: the subset of flights that fly under IFR captured by the FAA's en | PDARS software calculates a range of performance measures, including traffic counts, travel times, travel distances, traffic flows, and in-trail separations. It turns these measurement data into information useful to FAA facilities through an architecture that features (1) automatic collection and analysis of radar tracks and flight plans, (2) automatic generation and distribution of daily morning reports, (3) sharing of data and reports among facilities, and (4) support for exploratory and causal analysis. |

| Data Base | Purpose for the Data Collection and Analysis | Who Reports the Data (or How Is It Collected) | What Data Is Reported | Differentiate between Raw Data vs. Any Data That Is Calculated |
|---|---|---|---|---|
| | | | route computers. All VFR and some non en route IFR traffic are excluded. | Delay measurements are indirectly calculated when compared against the OAG databases. |
| ASPM (Aviation System Performance Metrics) | To report on the performance of approximately 29 airlines serving the 77 ASPM airports. | Data is collected from the following sources: ETMS, ARINC, Innovata, ASQP, Unimpeded Taxi Times, Operational Information System (OIS), Automated Surface Observing Systems (ASOS) | Original data obtained automatically by sensors for gate out, wheels-off, wheels-on, and gate in times.<br>ASPM flight records fall into two groupings: efficiency counts and metrics counts.<br>Metrics counts also exclude most GA and military flights, as well as records for international flights that only include data associated with the arrival or departure to/from a U.S. airport. Flight cancellations and diversions are excluded from both efficiency and metrics counts. | Calculated data for:<br>1 Actual gate out time,<br>2. Actual gate in time,<br>3. Actual wheels-off time,<br>4. Actual wheels-on time,<br>5. Average taxi-out time and average taxi-in time,<br>6. Unimpeded taxi-in time,<br>7. Unimpeded taxi-out time, and<br>8. Matching flight schedule data to flights in ETMS.<br>Metrics computed in ASPM are developed comparing actual time to scheduled time or flight-plan time. Taxi delays are determined based on unimpeded times.<br>Delays are calculated for:<br>• % on-time gate departures,<br>• % on-time gate arrivals,<br>• Taxi-out delay,<br>• Taxi-in delay,<br>• Gate delay, and<br>• Block delay. |
| OPSNET (Operations Network) | OPSNET is the official source of NAS air traffic operations and delay data. The data collected through OPSNET is used to analyze the performance of the FAA's ATC facilities. | Data come from observations by FAA ATC personnel who manually record the number of aircraft delayed 15 minutes or more relative to nominal or unimpeded taxi-out and taxi-in times established for each airport. | The data cover nonstop scheduled-service flights between points within the United States. The types of flights included are IFR, VFR; commercial traffic (air carriers and air taxis), GA, and military; arrivals, departures, and overflights; domestic and international. Data are available since January 1995.<br>The following data are recorded:<br>• Airport operations: IFR itinerant and VFR itinerant operations (arrivals and departures) and local operations as reported by ATC tower. Does not include overflights.<br>• Tower operations: IFR and VFR itinerant operations (arrivals and departures), overflights, and local operations worked by the tower.<br>• TRACON operations: IFR and VFR itinerant operations and overflights worked by the TRACON.<br>• Total terminal operations: Total operations worked by any facility. If facility has a | OPSNET provides information about reportable delays provided daily through FAA's Air Traffic Operations Network (OPSNET). A reportable delay recorded in OPSNET is defined in FAA Order 7210.55F as, "Delays to instrument flight rules (IFR) traffic of 15 minutes or more, which result from the ATC system detaining an aircraft at the gate, short of the runway, on the runway, on a taxiway, or in a holding configuration anywhere en route, must be reported. The IFR controlling facility must ensure delay reports are received and entered into OPSNET." These OPSNET delays are caused by the application of initiatives by the TFM in response to weather conditions, increased traffic volume, runway conditions, equipment outages, and other causes. |

| Data Base | Purpose for the Data Collection and Analysis | Who Reports the Data (or How Is It Collected) | What Data Is Reported | Differentiate between Raw Data vs. Any Data That Is Calculated |
|---|---|---|---|---|
| | | | tower and a TRACON, the total terminal operations is a sum of the tower operations and the TRACON operations for that facility.<br>• Center aircraft handled: Domestic and oceanic departures, overflights, and total aircraft handled.<br>• Facility information: Name, type, region, state, hours of operation, etc. | |
| ASQP (Airline Service Quality Performance) | To provide information about airline on-time performance, flight delays, and cancellations. | Based on data filed by airlines each month with the Department of Transportation's Bureau of Transportation Statistics. | Airlines provide data by flight for airlines that carry at least 1% of all domestic passengers (historically from 10-20 carriers).<br>Data reported:<br>• Gate arrival and departure data,<br>• Wheels-off times,<br>• Wheels-on times, and<br>• Carriers also report the causes of delay for delayed flights (carrier-related, extreme weather, NAS, security, and late arriving aircraft).<br>The data are available from June 2003 and are updated monthly. | ASQP provides data such as departure, arrival, and elapsed flight times as shown by the OAG, the carrier's CRS, and the carrier's actual performance; selected differences among the three sources, such as delay and elapsed time difference; and the causes of delays. |
| BTS (Bureau of Transportation Statistics) aviation-delay-related databases) | BTS | Airline on-time data are reported each month to the U.S. Department of Transportation (DOT), BTS by the 16 U.S. air carriers that have at least 1% of total domestic scheduled-service passenger revenues, plus 2 other carriers that report voluntarily. | The selected U.S. air carriers provide the data for nonstop scheduled-service flights between points within the United States (including U.S. territories).<br>Original data:<br>• Origin airport,<br>• Destination airport,<br>• Origin and destination airport,<br>• Airline, and<br>• Flight number. | Derived data:<br>All and late flights (total number, average departure delay, average taxi-out, and average scheduled departure) and late flights (total and percent of diverted and cancelled flights). |

## APPENDIX B

# Bibliography

ABC News, 2010, "America's Most-Delayed Airports: These Airports Are Plagued with Constant Flight Delays, Poor On-Time Records," ABC News, retrieved December 12, 2010, http://abcnews.go.com

Air Transport News, 2011, "Interview with Jim Bennett: Abu Dhabi Airports Company," Air Transport News, info@airtransportnews.aero

American Aviation Institute, 2012, *The State of U.S. Aviation: Comprehensive Analysis of Airline Schedules & Airport Delays*, Bethesda, MD.

Ball, M., 2010, *Total Delay Impact Study: A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States*, Final Report, National Center of Excellence for Aviation Operations Research (NEXTOR), University of Maryland (United States).

Berndt, K., *On Time Performance by Airline*, retrieved November 23, 2011, http://www.itsplaneandsimple.com/?p=137

Brown, D., *Get the Flick*, retrieved November 23, 2011, http://gettheflick.blogspot.com

County of Rockland, New York, et al., 2007, *Oral Argument Requested in the United States Court of Appeals for the District of Columbia Circuit*, U.S. Court of Appeals, District of Columbia Circuit No. 07-70121, Washington, D.C.

deNeufville, R. and Odoni, A., 2003, *Airport Systems: Planning, Design, and Management.*

Dunlay, W. J. and Keidel-Adams, P., "ACRP Project 03-17: Evaluating Airfield Capacity," Operations & Technical Affairs Committee Pre-Conference Seminar ACI-NA 20th Annual Conference and Exhibition, San Diego, October 16, 2011.

Federal Aviation Administration, 1983, *Advisory Circular: Airport Capacity and Delay*, Reprint Incorporates Changes 1 and 2, *AC No: 150/5060-5.* Federal Aviation Administration, Washington, D.C.

Federal Aviation Administration, 1999, *FAA Airport Benefit Cost Analysis Guidance* and *Addendum* (2010), Office of Aviation Policy and Plans, Washington, D.C.

Federal Aviation Administration, 2004, *Airport Capacity Benchmark Report*, Office of the Administrator, Washington, D.C.

Federal Aviation Administration, 2010, *National Plan of Integrated Airport Systems (NPIAS) 2011-2015*, Secretary of Transportation, Washington, D.C.

Federal Aviation Administration, 2011, *NextGen for Airports.* U.S.DOT, Federal Aviation Administration.

Federal Aviation Administration, 2011, *Optimization of Airspace and Procedures in the Metroplex (OAPM)*, Federal Aviation Administration, Washington, D.C.

Gonzalez, D. R., 2011, "Airport Law," *Worldwide Airports Lawyers Association Newsletter*, Year 1, No. 1 (May 2011) pp. 4–16.

Hanni, K. and Foreman, F. J., 2011, *2010 Real Air Travel Consumer Report Card*, FlyersRights.org, Napa, CA.

Horonjeff, R., McKelvey, F., Sproule, W., and Young, S., 2010, *Planning and Design of Airports* (5th ed.)

Kaye, K. and Sentinel, S., June 19, 2011, "Summer Storms More Likely to Cause Airline Delays Than Winter Weather," *South Florida Sun-Sentinel.com*, Retrieved June 20, 2011, http://www.sun-sentinel.com

Kumar, V., Sherry, L., 2009, "Airport Throughput Capacity Limits for Demand Management Planning," ICNS Conference, Washington, D.C., May 13-15, 2009.

Maxon, T., February 11, 2011, "American Airlines Up, Southwest Down in On-Time Rankings," *Dallas News*, retrieved March 21, 2011, http://www.dallasnews.com

Miller, M., June 10, 2011, "American Aviation Institute Cites High Airline Cancellations," *Airport Business*, retrieved June 10, 2011, http://www.airportbusiness.com

MITRE Center of Advanced Aviation System Development, 2007, *Capacity Needs in the National Airspace System Update Airports and ATO*, MITRE Corporation, McLean, VA.

MITRE Center of Advanced Aviation System Development, 2007, *Capacity Needs in the National Airspace System 2007-2025: An Analysis of Airports and Metropolitan Area Demand and Operational Capacity in the Future*, MITRE Corporation, McLean, VA.

Performance Review Commission and the Air Traffic Organization Strategy and Performance Business Unit, 2009, *U.S./Europe Comparison of ATM-Related Operational Performance*, Final Report, Federal Aviation Administration, Washington, D.C.

Schwab, R. W. et al., 2000, *A Preliminary Design Process for Airspace Systems Initial Assessment: Chicago Case Study Final Report*, Advanced Air Transportation Technologies (AATT) Program Office, National Aeronautics and Space Administration Ames Research Center, CA.

Sharkey, J., June 27, 2011, "Still Some Horror Stories, but Fewer Stranded Flights," The *New York Times*, retrieved June 28, 2011, http://www.nytimes.com

Snyder, B., *The Cranky Flier*, retrieved November 23, 2011, http://crankyflier.com

United States DOT, 2000, *A Preliminary Design Process for Airspace Systems: Initial Assessment—Chicago Case Study, Final Report*, Volpe National Transportation Systems Center, Boeing Company, Logistics Management Institute, Flight Transportation Associates, Federal Aviation Administration, prepared for Advanced Air Transportation Technologies (AATT) Program Office at National Aeronautics and Space Administration (NASA), Ames Research Center.

United States Government Accountability Office, 2010, *Aviation Safety—Certification and Approval Processes Are Generally Viewed as Working Well, but Better Evaluative Information Needed to Improve Efficiency*, United States Government Accountability Office, Washington, D.C.

United States Government Accountability Office, 2011, *Airline Passenger Protections: More Data and Analysis Needed to Understand Effects of Flight Delays*, retrieved November 23, 2011, http://gao.gov

United States Government Accountability Office, 2007, *Reagan National Airport: Update on Capacity to Handle Additional Flights and Impact on Other Area Airports*, retrieved November 23, 2011, http://gao.gov

United States Government Accountability Office, 2010, *National Airspace System: Setting On-Time Performance Targets at Congested Airports Could Help Focus FAA's Actions*, retrieved November 23, 2011, http://gao.gov

United States Government Accountability Office, 2011, *Next Generation Air Transportation System: FAA has Made Some Progress in Implementation, but Delays Threaten to Impact Costs and Benefits*, retrieved November 23, 2011, http://gao.gov

VanderMey, A., 2011, "Flight Patterns: Ever Wonder What's Behind the Rising Price of an Airline Ticket? The Cost Breakdown May Surprise You," The Chartist, *Fortune*, p 31.

Zupan, J. M. et al., 2011, *Upgrading to World Class: The Future of the New York Region's Airports*, Regional Plan Association, New York, NY.

Zogg, A. B., August 28, 2012, "Solving Commercial Aviation's $27 Billion Weather Problem." *The Hill*, retrieved August 28, 2012, http://thehill.com

## Models/Tools

ARCport is developed, maintained, and supported by Aviation Research Corporation US (ARC US). Contact Point Roberts, WA 98281. Phone: 360.945.2962.

CAST Aircraft can be purchased from Aachen Research Center, Bismarckstr. 61, 52066 Aachen, Germany. Phone: +49-241 16843-19.

Simmod *PRO!* runs the FAA's SIMMOD simulation engine and includes expanded capabilities. Tool can be purchased from ATAC Corporation, 755 N. Mathilda Avenue, Suite 200, Sunnyvale, CA 94085. Phone: 408.736.2822.

SIMMOD simulation engine is available from the FAA William J. Hughes Technical Center Simulation and Analysis Team (AJP-661, Capacity Modeling and Analysis Group, Atlantic City International Airport, NJ 08405. Phone: 609.485.5090.

TAAM, Total Airspace and Airport Modeler, can be purchased from Jeppesen, 55 Inverness Drive East, Englewood, CO 8011. Phone: 303.328.6578 or 303.799.9090.

Visual SIMMOD is a complete set of tools designed to work with the FAA's SIMMOD model and can be purchased from Airport Tools, 22434 Creston Drive, Los Altos, CA 94024. Phone: 408.736.5898.

# APPENDIX C

# Glossary of Terms

| TERM | DEFINITION |
|---|---|
| Actual Time of Arrival (ATA) | The actual time an aircraft arrives at its parking position or gate; when the parking brake is set. |
| Actual Time of Departure (ATD) | The actual time an aircraft leaves its parking position or gate. Term used in flight planning/following to document time of departure from a point. |
| Air Route Traffic Control Center (ARTCC) | A facility responsible for controlling aircraft en route in a particular volume of airspace at high altitudes between airport approaches and departures. |
| Air Traffic Control System Command Center (ATCSCC) | The FAA command center that balances air traffic demand with system capacity in the National Airspace System (NAS). It is committed to managing the NAS in a safe, efficient, and cohesive manner. |
| Air Traffic Control Tower (ATCT) | The FAA tower(s) at an airport from which air traffic controllers track and direct flight operations at the airport and the surrounding airspace. |
| Air Traffic Organization (ATO) | The operations arm of the FAA. ATO is America's air navigation service provider. The ATO is set up as a performance-based organization whose customers are commercial and private aviation and the military. |
| Aircraft Communications Addressing and Reporting System (ACARS) | A digital data link system for transmission of short, relatively simple messages between aircraft and ground stations via radio or satellite. |
| Airfield | The portion of the airport on which aircraft operate while on the ground. The airfield includes the runways, taxiways, ramp/apron, etc. |
| Airline Service Quality Performance (ASQP) | Operational flight database maintained by FAA that contains flight data reported by airlines that carry at least 1% of all domestic passengers. |
| Airport Surface Detection Equipment (ASDE) | A runway safety tool that enables air traffic controllers to detect potential runway conflicts by providing detailed coverage of movement on runways and taxiways. |
| Airspace | The space above the ground that planes use. Aircraft can fly in the airspace freely or on defined routes that are controlled by the FAA. For safety purposes, commercial and military aircraft almost always follow defined routes to travel from one airport to another. |
| Annual Enplanements | The number of passengers boarding an airplane including certified, commuter, air taxi, foreign, and in-transit planes annually. |
| Annual Service Volume (ASV) | A planning term that describes the number of annual aircraft operations possible at an airport with an acceptable amount of delay. The measure is specific to individual airports because it is derived from their own particular capacity characteristics. |

| | |
|---|---|
| Apron | The airfield facility where the loading and unloading of passengers and cargo, the refueling, servicing, maintenance and parking of aircraft, and any movement of aircraft, vehicles and pedestrians necessary for such purposes occurs. |
| ARINC | Global company that provides systems on-board aircraft for voice and data communications. Automatically records specific messages in flight useful for analyzing flight travel and delay. |
| Aviation System Performance Metrics (ASPM) | FAA database that contains detailed out, off, on, in times for flights at 77 U.S. airports. The system contains estimated nominal or unimpeded taxitimes for estimating flight delays. |
| Benefit-Cost Analysis (BCA) | A systematic process for calculating and comparing benefits and costs of a project. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much. |
| Block Time | The period from the moment the chocks are withdrawn and brakes released or moorings dropped, to the return to rest or take-up of moorings after the flight. |
| Bureau of Transportation Statistics (BTS) | Statistical agency of the U.S.DOT whose mission is to create, manage, and share transportation statistics' knowledge. BTS is housed within RITA. |
| Capacity Coverage Chart (CCC) | A way to summarize the range of capacities at an airport and the frequency with which various levels of capacity are available. The chart shows how much capacity is available for what percentage of time. |
| Concourse | The area located in an air carrier's terminal where the gates can be found. |
| Connecting Hub | An airport used by airlines to transfer/connect passengers from one airport/origin to another airport/destination. |
| En Route Airspace | The airspace used by aircraft between airports that are tracked by regional control centers rather than by air traffic control towers at the airports. The en route airspace is comprised of en route airways that are predefined routes that aircraft typically follow. |
| En Route Delays | An en route delay is a delay at an airport, area, or geographical point en route before proceeding to the destination. |
| En Route Service Delivery Point (SDP) | The demarcation points between services and ground-based user systems. |
| Federal Aviation Administration (FAA) | An agency of the United States DOT that has authority to regulate and oversee all aspects of civil aviation in the United States. |
| Ground Delay | The number of minutes of waiting or stopping incurred by an arriving or departing aircraft during its transit to/from the runway. Ground delay is comprised of ramp delay, taxi delay, and departure queue delay. |
| Hub | FAA uses this term to refer to airports that board at least 0.05% of all annual passengers in the United States (large hub >1%, medium hub 0.25%–1%, small hub 0.05%–0.25%). Airlines typically use the term for a large airport at which a legacy carrier connects a large portion of passengers between arriving and departing flights. Typically at a hub, the major airline/airlines represent the majority of the flight activity. |
| Hub-and-Spoke System | A system of air transportation in which local airports offer air transportation to a central airport where long-distance flights are available. |
| Instrument Flight Rules (IFR) | The rules and regulations established by the FAA to govern flight under conditions in which flight by outside visual reference is not safe. IFR flights depend upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals. |

| | |
|---|---|
| Instrument Meteorological Conditions (IMC) | An aviation flight category that describes weather conditions that require pilots to fly primarily by reference to instruments, and therefore under instrument flight rules (IFR), rather than by outside visual references under visual flight rules (VFR). Typically, this means flying in low visibility, low ceiling, and/or bad weather. |
| Level of Service | A performance metric used in facility planning/evaluation. For terminals, LOS refers to the space provided to a passenger in various areas of the terminal; can also be applied to other areas such as highways/curbsides and may refer to a utilization, delay, travel time, wait, etc. |
| Marginal VFR | Air traffic rules that apply when the ceiling is 1,000 feet to 3,000 feet above ground and/or visibility of 3–5 miles such that VFR can no longer be flown. |
| Maximum Throughput Capacity (or Saturation Capacity) | The expected/or average number of operations (takeoffs and landings) that can be performed in 1 hour on a runway system without violating ATC rules, assuming continuous aircraft demand. |
| Million Annual Passengers (MAP) | The number of annual passengers at an airport in unit million. |
| National Airspace System (NAS) | The network of U.S. airspace: air navigation facilities, equipment, services, airports, rules, regulations, procedures, etc., that enables safe and expeditious air travel. |
| Next Generation Air Transportation System (NextGen) | The name given to a new National Airspace System due for implementation across the United States in stages between 2012 and 2025. To implement this, the FAA will undertake a wide-ranging transformation of the entire U.S. air transportation system. This transformation has the aim of reducing gridlock, both in the sky and at the airports. |
| Official Airline Guide (OAG) | Originally a source (for a fee) to obtain published flight schedules for airports around the world. Now, the company offers several different types of flight schedule, statistic, and operations data. |
| On-to-In | The time it takes for an aircraft to travel from landing *on* the runway until the aircraft has parking *in* its gate/parking position. |
| Operations Network (OPSNET) | The official source of NAS air traffic operations and delay data. The data collected through OPSNET is used to analyze the performance of the FAA's ATC facilities. |
| Out-to-Off | The time it takes for an aircraft to travel *out* from a gate until the aircraft has lifted *off* the runway. Also known as taxi-out time. |
| Overflight | An aircraft traveling over an active airport whose presence may impact the capacity of that airport. In other words, an aircraft flying over an airport of interest, perhaps to travel to/from a nearby airport, for which separation and tracking must be taken into account for the airport of interest. |
| Pareto Curves/Pareto Frontiers | The set of choices that are Pareto efficient. The Pareto frontier is particularly useful in engineering: by restricting attention to the set of choices that are Pareto efficient, a designer can make tradeoffs within this set, rather than considering the full range of every parameter. In airport capacity terms, the Pareto curve displays the capacity at various tradeoffs of arrivals and departures. |
| Performance Data Analysis and Reporting System (PDARS) | Developed through collaboration with FAA and NASA, a database that collects real-time data from flights every 2 seconds. Data is captured for all IFR flights that fly through the en route airspace. |
| Practical Hourly Capacity (PHCAP) | The expected number of movements that can be performed during 1 hour on a runway system with an average delay per movement of 4 minutes. It is typically 80–90 percent of maximum throughput capacity. |

| | |
|---|---|
| Ramp | The area around an airport terminal at which aircraft park, are serviced, and are loaded/unloaded. This area includes the gates and surrounding support area. This term is typically interchangeably used with apron and tarmac, although there may be operational subtleties that technically result in differences between these three areas. |
| Research and Innovative Technology Administration (RITA) | RITA is an office within the U.S.DOT that encompasses BTS and several other transportation research/data organizations. |
| Runway Departure Queue Delay | The queues of departure aircraft that form at runways and the delays aircraft incur while waiting in these queues. When the departure demand temporarily exceeds the capacity of the runway, aircraft will queue. |
| Scheduled Time of Arrival (STA) | The desired time that an aircraft should cross a certain point (landing or metering fix) or park at its gate. It takes other traffic and airspace configuration into account. |
| Scheduled Time of Departure (STD) | The time of departure from the gate according to the published schedule. |
| SIMMOD | The FAA Airport and Airspace Simulation Model, which is a discrete-event simulation model that tracks the movement of individual aircraft as they travel through the airspace and on the ground. |
| Slot-Controlled/High Density Rule | The High Density Rule (or slot rule) is a federal regulation, 14 CFR §93.123, which limits the aircraft operations (landings or takeoffs) occurring each hour. The FAA use it as a measure to reduce delays. |
| Spoke | An O&D airport for an airline that has other hubs or focus cities. Typically for a spoke, the airline has flights to/from only their hubs and other focus cities and uses a limited number of gates. For example, Dallas/Fort Worth is a spoke for all airlines except American, and Atlanta is spoke for all airlines except Delta and Southwest. |
| Tarmac | See ramp. |
| Taxi-In/Taxi-Out | The final phase (taxi-in) of a flight is a reverse of the first phase (taxi-out). The aircraft taxies under its own power onto the taxiway and to a gate. Or the aircraft taxies under its own power from its gate to the runway. Generally, taxi-out includes the time in departure queue. |
| Terminal | A building/facility at the airport that accommodates passenger processing facilities. A terminal may include gates but is typically defined by the fact that it includes the landside facilities (facilities used to process originating/terminating passengers) and curbsides. |
| Total Airspace and Airport Modeler (TAAM) | A large-scale, detailed fast-time simulation package for modeling entire air traffic systems. It is used to model airspace and airports to facilitate planning, analysis, and decisionmaking. |
| TRACON (Terminal Radar Approach Control) | FAA facility that generally guides air traffic approaching and departing airports within a 30- to 50-mile radius and up to 10,000 feet (exact dimensions will vary). |
| Traffic Flow Management | The craft of managing the flow of air traffic in the NAS based on capacity and demand. The goal of TFM is to control the overall flow of traffic in the National Airspace System. |
| Traffic Flow Management System Counts (TFMSC) | FAA database that contains aviation traffic and delay data for all IFR-filed aircraft in the United States. |
| U.S. Department of Transportation (U.S.DOT) | A federal Cabinet-level department of the United States government concerned with transportation. Its mission is to ensure a fast, safe, efficient, accessible, and convenient transportation system. |

| | |
|---|---|
| Visual Flight Rules (VFR) | A set of regulations that allow a pilot to operate an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going. Specifically, the weather must be better than basic VFR weather minimums, as specified in the rules of the relevant aviation authority. |
| Visual Meteorological Conditions (VMC) | An aviation flight category in which visual flight rules (VFR) are permitted; ceiling greater than 3,000 feet above ground and visibility greater than 5 miles. Conditions exist in which pilots have sufficient visibility to fly the aircraft maintaining visual separation from terrain and other aircraft. Visual meteorological conditions are usually defined by certain visibility minima, cloud ceilings (for takeoffs and landings), and cloud clearances. |
| Wake Turbulence | A turbulence that forms behind an aircraft as it passes through the air. Wake turbulence is especially hazardous during the landing and takeoff phases of flight. |

*Abbreviations and acronyms used without definitions in TRB publications:*

| | |
|---|---|
| A4A | Airlines for America |
| AAAE | American Association of Airport Executives |
| AASHO | American Association of State Highway Officials |
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI–NA | Airports Council International–North America |
| ACRP | Airport Cooperative Research Program |
| ADA | Americans with Disabilities Act |
| APTA | American Public Transportation Association |
| ASCE | American Society of Civil Engineers |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| ATA | American Trucking Associations |
| CTAA | Community Transportation Association of America |
| CTBSSP | Commercial Truck and Bus Safety Synthesis Program |
| DHS | Department of Homeland Security |
| DOE | Department of Energy |
| EPA | Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FHWA | Federal Highway Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| HMCRP | Hazardous Materials Cooperative Research Program |
| IEEE | Institute of Electrical and Electronics Engineers |
| ISTEA | Intermodal Surface Transportation Efficiency Act of 1991 |
| ITE | Institute of Transportation Engineers |
| MAP-21 | Moving Ahead for Progress in the 21st Century Act (2012) |
| NASA | National Aeronautics and Space Administration |
| NASAO | National Association of State Aviation Officials |
| NCFRP | National Cooperative Freight Research Program |
| NCHRP | National Cooperative Highway Research Program |
| NHTSA | National Highway Traffic Safety Administration |
| NTSB | National Transportation Safety Board |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| RITA | Research and Innovative Technology Administration |
| SAE | Society of Automotive Engineers |
| SAFETEA-LU | Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005) |
| TCRP | Transit Cooperative Research Program |
| TEA-21 | Transportation Equity Act for the 21st Century (1998) |
| TRB | Transportation Research Board |
| TSA | Transportation Security Administration |
| U.S.DOT | United States Department of Transportation |