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Airport Aviation Activity Forecasting

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ACRP
SYNTHESIS 2

AIRPORT
COOPERATIVE
RESEARCH
PROGRAM

Airport Aviation Activity Forecasting

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 2

Airport Aviation Activity Forecasting

A Synthesis of Airport Practice

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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), and the Air Transport Association (ATA) 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.

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FOREWORD

By Staff Transportation Research Board

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis reviews current practices and methods in airport activity forecasting in the United States. The study addresses how airport forecasts are used and identifies common aviation metrics, aviation data sources, issues in data collection and preparation, and special data issues at nontowered airports. It includes an overview and discussion of available forecasting methods, including the primary statistical methods; market share analysis; econometric modeling; and time series modeling. The report focuses on appropriate forecasting methods, providing examples of actual airport forecasting studies. Evaluation of forecasts is also provided, including assessments of forecast uncertainty, accuracy, issues of optimism bias, and options for resolving differences when multiple forecast are available.

This synthesis reviews academic and professional literature on forecasting, as well as airport master plans, state airport system plans, and other sources of information showing how forecasts of aviation activity are produced.

William Spitz and Richard Golaszewski, GRA Inc., Jenkintown, Pennsylvania, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

AIRPORT AVIATION ACTIVITY FORECASTING

SUMMARY

This synthesis study provides a review of airport aviation activity forecasting in the United States. Forecasts of airport aviation activity have become an integral part of transportation planning. Most airport-specific forecasts are prepared on behalf of airport sponsors and state or regional agencies. The type and method of forecasting can depend importantly on the purpose for which the forecast is being made. For example, there may be sharp variations between forecasts used to support an annual budget versus a long-term facilities expansion.

In practice, an important factor affecting many forecasts is that they are developed in support of the master planning process that is used by FAA to identify capital projects that may qualify for funds from the agency's Airport Improvement Program. This is the primary federal funding mechanism for public-use airport improvements.

The primary statistical methods used in airport aviation activity forecasting include market share analysis, econometric modeling, and time series modeling. These methods can be used to create forecasts of future airport activity over time. Simulation models are a separate method of analysis used to provide snapshot estimates of traffic flows across a network or through an airport.

There are several activity measures typically included in airport aviation activity forecasts; the two most commonly used for commercial airports are aircraft operations and passenger enplanements. Based aircraft counts are important at general aviation airports because they drive the need for hangars, fueling, and other facilities.

One of the most important requirements in preparing forecasts is to obtain accurate historical data on aviation activity. There are many useful data sets available from the federal government and other sources. For forecasts involving econometric modeling, it is also necessary to obtain historical data and future estimates of the explanatory variables to be included in the model.

The market share approach to forecasting is a top-down method where activity at a particular airport is assumed to be tied to growth in some aggregate external measure (typically a regional, state, or national aviation growth rate). For this method to produce reasonable predictions, it is important that the presumed relation between airport activity and the larger aggregate measure be relatively constant over time.

Many airport forecasts use econometric methods that utilize explanatory variables—factors thought to explain changes in the demand and/or supply of aviation activities. These factors can be broadly grouped into macroeconomic and demographic factors, airline market factors, air transport production costs and technology, regulatory factors, infrastructure constraints or improvements, and potential substitutes for air travel. Although econometric modeling is potentially a very sound and powerful method, there are many ways in which the specific model can go wrong, and it is not always obvious how best to proceed when statistical tests or data issues indicate a problem.

Time series modeling is another forecasting approach that involves some form of extrapolating existing data into the future. In its simplest form, it is based only on values of the variable being forecast and projects the future based on current or past trends. Because one

does not need to collect data on other variables, it can be a low-cost method compared with econometric modeling. Although the approach is conceptually simple, specific statistical techniques that are employed to make it more accurate can be quite sophisticated. This method can be useful when there are unusual conditions that make the relationship between local activity and other external factors unstable.

Simulation models are a separate method of analysis used to obtain high-fidelity snapshot forecasts of traffic flows in a network or at an airport. Such models impose precise rules that govern how passengers or aircraft are routed, and then aggregate the results so that planners can assess the infrastructure needs of the network or airport to be able to handle the estimated traffic.

Airport forecasting studies often neglect the issue of uncertainty. Most often, forecasts are presented only as point estimates, although it is common to also present alternative "high" or "low" estimates that are based on differing assumptions about external factors thought to affect the forecast. Although this can provide a reasonable range of estimates, there are additional sources of uncertainty related to the statistical properties of the models employed that are often neglected entirely.

Accuracy is another often-neglected aspect of forecast evaluation, largely because it can only be done after the fact—when values can actually be measured and compared with their forecast estimates. This problem is particularly relevant for long-term aviation forecasts where accuracy cannot be fully assessed for many years. Once the data are accessible, there are a variety of metrics available to measure forecast accuracy.

There is a potential for optimism bias in airport forecasting that is countered by the issuance of FAA guidance documents, requirements for master planning, and other rules that local sponsors must follow when applying for grants.

In cases where more than one forecast is available for consideration, a number of alternative approaches can be pursued. These include critical analysis of each individual forecast to help identify possible errors or mistakes, consideration of each forecast's predictions by experts in the field who may possess significant domain knowledge regarding current and future airport activities, and combining multiple forecasts to yield consensus averages.

Several avenues for future research are suggested by this study including investigation into the reliability of data collection (particularly at smaller airports), detailed study of common statistical and data problems associated with econometric forecasting models, the potential use of time series models and how their predictions compare with other methods, and formal studies of how well typical aviation forecasts project future activity.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The purpose of this synthesis study is to provide an overview of current practices and methods in airport aviation activity forecasting in the United States. The study reviews academic and professional literature on forecasting as well as airport master plans, state airport system plans, and other sources of information showing how aviation decision makers, airport managers, sponsors, and their consultants actually produce forecasts of aviation activity.

This study does not necessarily reflect the views or requirements of the U.S. FAA with respect to airport aviation activity forecasting. In practice, however, it is recognized that many airport forecasts follow guidance directives issued by FAA to qualify for funds from the agency's Airport Improvement Program (AIP), which is the primary federal funding mechanism for public-use airport improvements. Further discussion of forecasting produced under these circumstances is included in the section Forecasting Under FAA Guidance.

Air transportation is an integral part of the global economy. Scheduled commercial passenger transport alone has grown over the past half century to more than 27 million flights in 2005 across the world, and more than 11.6 million flights to or from the United States alone. Other sectors, including cargo, air taxi, and general aviation, also have expanded rapidly. Airports are obviously a fundamental part of modern air transportation systems—some serve as hubs for extensive national and international transportation networks, whereas others function as the complementary spokes; still others serve as parts of multi-airport regional systems; and some serve as important connections to the outside world for otherwise isolated populations. Airports serve both commercial and private aviation—often referred to as air carrier and general aviation.

The construction, operation, and future expansion of airports can require substantial initial and ongoing investments, a large share of which is usually paid for with public monies. Consequently, for any individual airport, it is important to be able to forecast future demands for aviation services to assess the potential need for further investments in capacity or services to meet those demands. Accurate forecasts are essential for effective airport planning and decision making, and for the efficient provision of capacity.

The type of forecast and level of effort required to produce it depends importantly on the purpose for which the forecast is being made. Short-term aviation forecasts (typically referring to projections no more than five years into the future) are needed to support operational planning and often are used to assess personnel requirements at an airport or the need for incremental improvements or expansions of landside facilities and terminal areas, air cargo facilities, general aviation hangar space, etc. Since the terrorist attacks of September 11, 2001 (9-11), new security requirements may also require changes to landside facilities.

Depending on the size of the airport, intermediate-term (6–10 years out) and/or long-term forecasts (11–20 years) are used to plan major capital investments, such as land acquisition, new runways and taxiways, extensions of existing runways, and new terminal or tower facilities. Forecasts beyond 20 years are sometimes undertaken to assess the need for additional airports or other regional aviation facilities. Although forecasts over the short term can also be used in planning for large capital projects, longer-term projections are typically required to adequately assess the costs and benefits of such investments.

Another important part of the forecasting process is the assessment of uncertainty that is inherent in any forecast. Predictions are often presented as a single set of numbers, which give no indication as to their likely accuracy. By directly addressing and, if possible, quantitatively measuring the uncertainty associated with a given forecast, forecasters can give decision makers the ability to plan different strategies based on the range of uncertainty and to explore how the uncertainty may depend on particular assumptions built into the forecast.

FORECASTING METHODS

The majority of airport and regional and state aviation activity studies use fairly simple methods to produce forecasts, and address forecast uncertainty only in informal and nonsystematic ways. Data availability, particularly reliable time series for historical aviation activity, often dictates what forecasting techniques can be employed. In general, the level of sophistication depends on a variety of factors, including data availability, intended use of the forecast, and the level and types of activity at the airport.

With these provisos in mind, the forecasting methods considered here can be grouped into four categories:

- Market share forecasting—local activity calculated as a share of some larger aggregate forecast.
- Econometric model forecasting—aviation activity tied to other economic measures.
- Time series model forecasting—trend extrapolation of existing activity.
- Simulation—a separate method used to provide high-fidelity "snapshot" estimates of how traffic flows across a network or through an airport.

The studies prepared for smaller general aviation airports tend to rely on trend extrapolation or market share analyses. Many such forecasts do not attempt to assess uncertainty, although multiple scenarios may be considered by assuming different growth rates. These methods are also used by many regional and state planning agencies where aggregate forecasts of aviation activity across large numbers of airports are required.

Forecasts prepared for larger commercial airports are more likely to use formal statistical methods such as econometric model forecasting, reflecting better data availability. Uncertainty is still typically dealt with in an informal (nonstatistical) way by creating high and low forecasts based on alternative assumptions about how certain explanatory variables in the econometric model (or other external factors) may change in the future.

FORECASTING UNDER FAA GUIDANCE

The primary purpose of FAA's AIP program is to provide grants for public-use airport improvements. For facilities defined as large and medium primary hub airports, an AIP grant covers 75% of eligible costs (or 80% for noise program implementation). For small primary, reliever, and general aviation airports the grant covers 95% of eligible costs.

For those forecasts produced to support requests for AIP funding, the FAA's *Advisory Circular on Airport Master Plans* (2005) contains specific guidance on the entire forecasting process. Other FAA guidance documents, in particular *Forecasting Aviation Activity by Airport* (2001) and *Revision to Guidance on Review and Approval of Aviation Forecasts* (2004), provide further practical information that planners use in determining how to produce forecasts that meet FAA requirements. In addition, the *Advisory Circular on the Airport System Planning Process* (2004) provides guidance for state and regional planners; this document is discussed separately later in this chapter.

This overview of FAA guidance related to aviation forecasting does not constitute official FAA policy or guidelines. Airport sponsors should refer to the above-cited documents and contact FAA directly when preparing forecasts as part of the master planning process.

It is important to understand that preparing aviation forecasts is only a small part of the overall master planning process. An airport master plan is a comprehensive study that describes the short-, medium-, and long-term development plans at the facility to meet future aviation demand. It incorporates many specific elements that go well beyond the scope of the forecasting topics covered in this study including:

- Preplanning
- Establishment of a public involvement program
- Environmental considerations
- Analysis of existing conditions
- Aviation forecasts
- Assessment of facility requirements
- Development and evaluation of alternatives
- Airport layout plans
- Facilities implementation plan
- Financial feasibility analysis.

From a technical standpoint, it should be noted that AIP grant assurances require only that an airport sponsor have an approved airport layout plan, not necessarily an airport master plan.

This discussion focuses only on the development of aviation forecasts. When forecasts are produced as part of airport master plans to be submitted for FAA approval, specific forecast elements (identified in the FAA *Advisory Circular on Airport Master Plans,* AC 150/5070-6B, 2005) must be included, as shown in Table 1. Because of FAA's major role in funding airport projects that are identified in master plans and the role that these plans play in the distribution of AIP funds, these are the measures found in many airport forecasts.

Although the aviation activity elements listed in Table 1 specifically refer to annual estimates, FAA also requires master plan forecasts to include "appropriately defined peak period activity levels for facilities planning." It is usually the case that peak activity will be more relevant for facilities planning at an airport than overall annual totals. Depending on the situation, the appropriate measure of peak activity may refer to seasonal, monthly, daily, and/or time-of-day demands.

The master plan *Advisory Circular* also specifies that forecasts should be prepared for the short term (up to five years), medium term (six to ten years), and long term (beyond ten years). In practice, most forecasts cover a 20-year period from the base year. Sponsors are expected to present a "baseline" forecast that represents the most likely estimate of activity over the 20-year period. In addition, they may provide a range of "scenario" forecasts to assess the impact of higher and lower activity levels on development plans at the airport.

There are other FAA guidelines specified in the *Advisory Circular* including:

TABLE 1
AVIATION DEMAND ELEMENTS

Required	Included Where Appropriate
Operations (annual)	
Itinerant	Domestic vs. international
Air carrier	Annual instrument approaches
Air taxi and commuter (regional)	IFR vs. VFR operations
General aviation	Air cargo aircraft operations
Military	Touch-and-go operations (training)
Local	Helicopter operations
General aviation	Average load factor
Military	Fuel use
Passengers (annual)	
Enplanements	Passenger and cargo data
Air carrier	Domestic vs. international
Commuter	General aviation passengers
Enplanements	Helicopter
Originating	Air taxi
Connecting	Other—Number of student pilots/hours flown
Aircraft	
Based aircraft	Average seats/aircraft
Aircraft mix	
Critical aircraft	

Source: *Advisory Circular on Airport Master Plans* 2005, p. 37.
Notes: Cargo data typically include freight and/or U.S. mail tonnage or ton-miles; critical aircraft" refers to identification of equipment based on "substantial use" (defined as either 500 or more annual itinerant operations, or engaged in scheduled commercial service). IFR = instrument flight rules; VFR = visual flight rules.

- Review of previous airport forecasts, including the FAA's own Terminal Area Forecast (TAF) for the airport (the TAF is discussed further in chapter two).
- Selection of appropriate forecast method—FAA identifies regression analysis (econometric modeling), trend analysis, market share analysis, and smoothing as the most common techniques to be considered.
- Application of forecast methods and evaluation of results, including justification or explanation of decreasing or increasing trends in activity, and sensitivity analysis to measure the impacts of changes in the factors that influence activity.

More detailed step-by-step guidance on these topics is provided in the FAA document *Forecasting Aviation Activity by Airport* (2001). In addition, the FAA document *Revision to Guidance on Review and Approval of Aviation Forecasts* (2004) provides specific guidance on short-term forecasting, including directives regarding the use of historic seasonality patterns to extrapolate departures and passenger enplanements over a two-year forecast period.

The guidance and directives from FAA are broadly consistent with the forecasting methods, data concerns, and other issues addressed in the present study. There are, however, two major aspects of FAA guidance where forecasters must make specific efforts to satisfy the agency's requirements.

The first involves the activity measures shown in Table 1. Despite the vast changes in the commercial airline industry over the past quarter century, the list of data elements shown in the table has remained virtually unchanged during this time. Of particular concern for airport planners and forecasters are the co-mingling of air taxi and commuter and regional operations, as well as the distinction between air carrier and commuter activity. The FAA definition of "air taxi" refers to carriers that operate aircraft with 60 or fewer seats or a cargo payload capacity of less than 18,000 lb, and carries passengers on an on-demand basis only (charter service) and/or carries cargo or mail on either a scheduled or charter basis. "Commuter" operators as defined by the U.S.DOT are those with scheduled passenger service (five or more round trips per week on at least one route according to published flight schedules) while utilizing aircraft of 60 or fewer seats. Air taxi carriers are governed under Part 135 and commuter carriers are governed under Part 121 of the Federal Aviation Regulations.

In terms of airport planning and use, the co-mingling between air taxi and commuter makes little operational sense. The more relevant distinction would be between scheduled and nonscheduled service, which has a primary influence on the type of facilities that must be provided (e.g., terminal services). For this reason, for airport planners it would be useful to distinguish between air taxi (nonscheduled) operations and commuter (scheduled) operations.

Both commuter and air carrier operations involve scheduled service; the primary distinction is only in terms of the size of the aircraft used. The distinction between air carrier and commuter (regional) operations is becoming even more blurred as commuter markets are served more and more by larger regional jet aircraft with between 60 and 90 seats. This has been accompanied by changes in carriers' scope clauses with their pilot unions that specify the size of the aircraft that must be flown by union pilots. Recent relaxation of these clauses has allowed carriers' regional affiliates to fly these larger aircraft. Today, the categorization of commuter operations as referring to scheduled service with aircraft of 60 or fewer seats is rather arbitrary and does not correspond with the observed patterns of flying. Nevertheless, as with the commuter/air taxi co-mingling issue, it is important that forecasts that are to be reviewed and subject to FAA approval meet the necessary requirements regarding user group distinctions.

The second major FAA requirement affecting airport forecasting studies that are being conducted as part of master planning is that the baseline forecasts of operations, passenger enplanements (where relevant), and based aircraft must be compared with the FAA's TAF. They will be considered consistent with the TAF, and therefore approved as part of the master planning process, if the 5-year-ahead forecast differs by less than 10% from the TAF and the 10-year-ahead forecast differs by less than 15% from the TAF. (In some cases, these requirements do not have to be met; for example, if it is shown that the forecasts do not affect the timing or scale of an airport project, or in the case of smaller airports if the forecasts do not affect the role of the airport.) If the baseline forecasts do not meet these requirements, the differences will need to be adequately explained and resolved with FAA. Even if airport forecasting studies that are conducted as part of a master plan are consistent with the TAF, FAA may not automatically approve the plan without additional information and justification.

For state and regional planners, the FAA's *Advisory Circular on the Airport System Planning Process* (2004) provides specific guidance for forecasts made at the system (multifacility) level. These system plans typically focus less on individual airport forecasts, and much more on defining an airport's role within the system and prioritizing airport development. The *Advisory Circular* provides guidance on reviewing individual airport forecasts consideration of interactions between airports where appropriate, and advice on estimating activity at nontowered airports. System plan forecasts that are used in support of AIP projects are subject to the five-year 10% rule discussed earlier for TAF.

ROADMAP FOR ANALYSIS

The discussions in the following chapters focus on the most common practices and techniques used by analysts to produce airport aviation activity forecasts. Chapter two addresses how airport forecasts are used for varying purposes and identifies common aviation metrics, aviation data sources, issues in data collection and preparation, and special data issues at nontowered airports. It also discusses various drivers of aviation activity.

Chapter three provides an overview of available forecasting methods and then discusses each of the major methods in more detail. Selection of the appropriate method is also discussed, along with a presentation of some representative examples of actual airport activity forecasting studies.

Chapter four discusses the evaluation of forecasts, including assessments of forecast uncertainty, accuracy, issues of optimism bias, and options for resolving differences when multiple forecasts are available.

Chapter five provides concluding remarks and suggestions for future research.

CHAPTER TWO

INFORMATION AND DATA COLLECTION

USES OF FORECASTS

Airport aviation activity forecasts may be used for many different purposes. Typically, the forecasts are not final objectives in and of themselves. An essential ingredient to preparing forecasts is to understand the purpose for which they will be used. In economic terms, the forecasts of activity are usually meant to reflect the *demand* for aviation services. It is the demand for services that drives the forecasts and therefore helps airport planners provide the appropriate *supply* in terms of the infrastructure needed to meet the demand. Seen in this light, it is important to keep in mind that *observed* airport aviation activity is driven not just by demand, but by the interaction between demand for and supply of aviation services.

Forecasts are essential demand-side tools that planners and decision makers use to make supply-side assessments and judgments regarding:

- Long-Term Airport Planning and Capacity Needs
  - Airside facilities expansion—runways and taxiways, air cargo facilities.
  - Landside facilities expansion—terminals, concourses, parking, airport access.
- Short-Term Operational Planning
  - Airport personnel requirements.
  - FAA tower staffing requirements.
  - Identification of seasonal, daily, or hourly peaking effects.
  - Identification of aircraft and passenger travel time and delays.
- Financial Planning
  - Bond issues and use of public funds.
  - Annual budgeting.
  - Airport Capital Improvement Plans (ACIP)—planning tool for identifying capital needs (required to receive AIP funding).

Various measures of aviation activity tie directly or indirectly to the revenues and costs associated with operating an airport. For example, aircraft operations lead to landing fee revenues, fuel sales, and fixed-base operator (FBO) sales, and also drive costs associated with airside personnel, hangar facilities, etc. Passenger enplanements are tied to the revenues and costs associated with terminal amenities, parking facilities, etc.

In addition to the larger goals identified previously, certain forecast methods may be required (or at least be more suitable) for specific needs, such as identifying complex time dependencies in highly trended or seasonal data or forecasting high-fidelity estimates of aircraft and passenger travel times and delays after the overall activity levels have already been forecast. In any case, the different objectives identified here are not mutually exclusive. Clearly the financial planning function affects both short-term and long-term operational planning. Prudent budgeting practices for short-term operational needs typically require budgeted expenditures to exceed actual expenditures so that the organization does not run out of money or is unable to hire adequate personnel during any given budget cycle. To be “conservative,” this means that aviation forecasts that are produced to support short-term budgeting may typically err on the high side to support conservative budgeting requirements.

In contrast, long-term forecasts are often used to support bond offerings or expenditures of public funds. Because of the long lead times needed to plan, design, approve, and build physical capacity at airports, it can be very costly if the forecasts cause overestimates of the magnitude of the expansion needed. In such an environment, the prudent conservative approach is to not overestimate long-term capacity needs. In addition, debt service coverage may require conservative forecasts to ensure the ability to repay the debt. Therefore, the supporting forecasts may tend to err on the low side.

On the other hand, long-term forecasts are also used by airports and regional and state agencies primarily as a way to assess *potential* future aviation infrastructure needs. In this environment, many studies will focus primarily on *unconstrained* demand; that is, activity levels that would be projected to occur in the absence of any bottlenecks or capacity constraints. At airports that are currently congested or that may reach their capacity in the foreseeable future, such forecasts are often used to assess how much additional capacity would be needed to meet demand. This is very different from constrained forecasts that explicitly account for the effect of existing or likely future capacity constraints. In many cases, a single analysis may entail both types of forecasts—the unconstrained forecast is used to assess additional capacity needs, and the constrained forecast is used to assess how much activity may be curtailed if additional capacity is not forthcoming. In all cases, the forecaster must be clear in identifying to what extent existing or future bottlenecks and capacity constraints will be considered as factors affecting projected activity.

These distinctions between short-term/long-term and constrained/unconstrained demand can lead to stark differences in the associated activity forecasts that are produced. However, such differences do not necessarily imply that one is correct and another is incorrect (or that one is more correct than another). If one keeps in mind the different purposes for which forecasts are used, the variations and differences between them can be understood and explained to stakeholders and other interested parties.

Aside from evaluating point estimates of future activity, it is also important to consider the uncertainty associated with such estimates; a very important but often neglected area of aviation forecasting. A more thorough discussion of evaluating forecast accuracy and uncertainty is provided in chapter four.

METRICS

Aircraft operations and passenger enplanement counts are the primary elements used to measure activity at commercial airports. Although passenger operations and enplanements are obviously highly correlated with each other, there may well be situations where their projected growth rates differ from one another because of changes in average aircraft size (owing to the introduction of different aircraft types) and/or load factors. Growth in aircraft operations is more likely to directly impact the need for airside facilities such as runways, taxiways, and gates, whereas growth in passenger enplanements more directly affects the need for landside facilities such as terminal space, baggage claim areas, and parking.

For passenger service, both aircraft operations and enplanements are related to other common measures of activity such as available seat-miles (ASMs) and revenue passenger-miles (RPMs). ASMs are a measure of airline capacity and are equal to the number of seats available multiplied by the number of miles flown. For a given number of operations, ASMs can be computed if one knows the average seat size of the aircraft flown and the average stage length (distance) of the routes. RPMs are a measure of airline traffic handled and are equal to the number of seats sold to passengers multiplied by the number of miles flown. For a given number of ASMs, RPMs can be computed if one knows the average load factor (percentage of seats sold) for the operations in question.

Figure 1 shows the relationships among the various common aviation metrics that are relevant for commercial passenger transportation. There may be little correlation, however, between commercial passenger traffic and other metrics that may be important, such as nonpassenger (cargo) or noncommercial traffic (general aviation/military) at a given airport.

The count of based aircraft at an airport is another common forecast metric, and is particularly important at general aviation airports where it can drive the need for facilities such as hangars, fueling, etc. In addition, determination of potential changes in aircraft types can drive assessments of needed runway improvements or runway length at smaller airports. Even at small airports, however, it is important to focus on operational activity—there are many examples of general aviation airports with relatively high numbers of operations even though there are relatively few aircraft based at the airport.

Cargo activity is an important revenue source at certain airports with large cargo processing activities (e.g., Memphis International Airport), as well as at commercial airports with significant international operations. For such airports, the relevant metrics will typically include cargo operations and freight-tonnage, and it may be useful to distinguish between all-cargo flights and cargo that is carried as belly freight on passenger aircraft. Again, it is important for the forecaster to properly structure the forecast to focus on the most relevant activity measures for the purpose at hand.

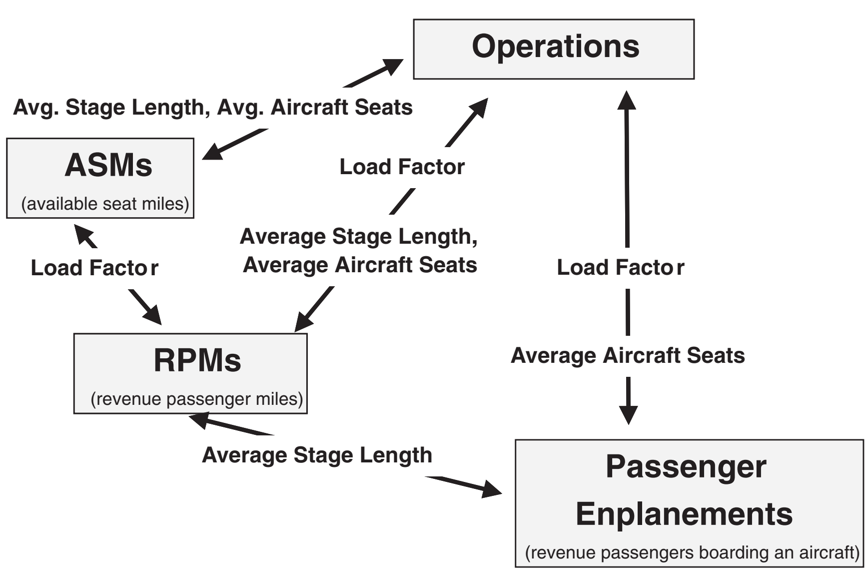

FIGURE 1 Relationships among common passenger aviation activity metrics.

Appropriately defined peak periods are an important aspect of facility planning and, depending on the situation, the appropriate measure of peak activity may refer to seasonal, monthly, daily, and/or time-of-day demands. For example, seasonal peaks may be important at vacation destinations; airports that have substantial international traffic may have substantial variations in daily demand, whereas airports serving as connecting hubs for large carriers will likely be subject to large hourly peaks.

Many airport forecasts identify the peak month for activity and then compute activity measures for the average day in that month. These peak month-average day metrics (sometimes also called the "design day") can be derived by dividing peak month operations or enplanements by the number of days in the month. An upward adjustment can be made if activity is heavier on weekdays than on weekends. Then, given the design day estimates, peak-hour metrics can be computed by applying a distribution by time of day. It is important to recognize that with this sort of approach, design day and peak-hour activity levels actually may be exceeded at certain times. Nevertheless, they may represent reasonable standards for planning future facility needs.

AVIATION DATA SOURCES

One of the most important requirements in preparing a useful and realistic forecast is to obtain accurate historical data for whatever metrics are to be projected. A common technique is to develop baseline forecasts for passenger demand, and then translate these into aircraft operations by applying estimates of aircraft size and load factors based on current or projected fleets. With this type of approach, it is important to recognize the necessity to obtain historical data not only for the primary metrics of interest (passengers and operations), but also for these ancillary factors.

In addition to the data generated by the airport itself, U.S.DOT and FAA collect a large amount of aviation activity information from a number of different sources as described here. Access to some of the data sets is restricted to authorized users; for others, the data can also be obtained from private third parties who provide data cleaning and checking, as well as formatting and reporting options for end-users.

The applicability and accuracy of publicly available data can vary considerably from case to case. Airport authorities often supplement such data by fine-tuning some of their own airport-specific data that are kept in-house and by conducting surveys of local airport users.

OPSNET (FAA)

OPSNET is the official source of historical National Airspace System (NAS) traffic operations and delays. Daily airport data, collected since January 1990, are available for:

- Airport operations (takeoffs and landings) at FAA-funded towers, classified by itinerant and local.
- Instrument operations—primary, secondary, and overflights. Instrument operations are those flown under an Instrument Flight Rules (IFR) flight plan or special Visual Flight Rules (VFR) procedures, or an operation where a terminal control facility controls IFR separation between aircraft. Primary operations refer to departures or arrivals at the airport where the approach control facility is located. Secondary operations refer to departures or arrivals at other nearby airports that are secondary to the primary airport. Overflights refer to a terminal IFR flight that originates outside the control facility's area and passes through without landing.
- Approach operations—approaches made to an airport by an aircraft with an IFR flight plan usually because of low visibility owing to severe weather. These data are classified into the four FAA-standard user categories—Air Carrier, Air Taxi, General Aviation, and Military.

These data are primarily recorded by tower operators; in some cases, the data collection is automated, in others, manual entries are made in logbooks. As with any manual data entry scheme, there may be data and classification reliability issues, although the data do undergo internal cleaning and cross-checking functions before being released.

OPSNET data are summarized in FAA's Air Traffic Activity Data System (ATADS), which can be accessed directly from the FAA website (www.faa.gov). It is important to note that the tower data included in OPSNET and ATADS only track activity at FAA and FAA-contracted towers (currently approximately 510 facilities nationwide). Although these facilities make up virtually all of the commercial activity in the United States, it should be noted that there are more than 3,300 facilities listed in the National Plan of Integrated Airport Systems that identifies all facilities eligible to receive grants under the AIP.

Enhanced Traffic Management System (FAA)

The FAA's Enhanced Traffic Management System (ETMS) data system is designed to track every flight that enters the U.S. en route system. The en route system is made up of Air Route Traffic Control Centers (ARTCCs) that are responsible for controlling aircraft flying under IFR at high altitudes. Each ARTCC is responsible for a defined airspace, and typically accepts traffic from and passes traffic to another ARTCC or to a Terminal Radar Approach Control (TRACON) facility. TRACONs are normally located near large airports and provide departure and approach control services for aircraft at less than 10,000 ft and within approximately 30–50 nautical miles of an airport. The ETMS system collects and stores data for individual flights, and includes information on the date, time, user identity (operator name and flight number or registration *N*-number), and latitude and longitude of where the flight entered and exited a given ARTCC.

In principle, ETMS data can be assembled to track the date and time of individual flights to and from a given airport. This can be particularly useful in identifying peak operations by time of day or day of week. However, the sheer volume of ETMS data (currently approximately 50,000 flights per day) can make it difficult to handle if one is interested in longer periods of time.

ETMS covers only those flights that interact with the en route system. With relatively few exceptions, local flights that fly entirely under VFR (unless flying in controlled airspaces) or that fly only under the guidance of airport towers will never be seen by the en route system and will not be accounted for in the ETMS data; in practice, this includes many local general aviation flights. Rough estimates of this coverage gap can be deduced by comparing ETMS flight counts with ATADS operation counts at airports (although such an approach does not account for those flights that may enter the en route system while traveling to or from nontowered airports not covered by ATADS). In principle, each ETMS flight should account for one operation at takeoff and one operation at landing. Based on FY2005 data, ETMS coverage for flights taking off or landing at large airports (those having at least a 1% share of U.S. passenger enplanements) is well over 90%. For middle tier airports not reaching the 1% threshold, but having more than 100,000 annual enplanements, ETMS coverage is on the order of 55% to 60%. At low activity airports (fewer than 100,000 enplanements), ETMS covers only about 15% of activity.

Enhanced Traffic Management System Counts (FAA)

The Enhanced Traffic Management System Counts (ETMSC) data set combines the raw ETMS data with OPSNET operations data to provide flight counts by hour and to track aircraft equipment by city pair. Daily OPSNET operations data are distributed to 15-min intervals based on the distribution of ETMS records. The system also identifies individual aircraft for fractional ownership, so that users can query the number of hours and when a particular aircraft is in use. ETMSC data are updated daily and can be accessed directly from the FAA website.

5010 Forms—Airport Master Record (FAA)

Every airport submits an Airport Master Record (Form 5010) to FAA, which includes counts of based aircraft and (for nontowered airports) annual aircraft operations. Internet access to the latest available Form 5010 data can be obtained from commercial organizations. It is important to point out that all operation counts submitted on Form 5010 are essentially self-reported by airport managers or sponsors. This is often the only source of historical operations data for nontowered airports, and many states have undertaken efforts to improve data collection for such airports. In addition, FAA is currently conducting a validation study for based aircraft by issuing directives to airport managers to count and list their aircraft by tail number.

Form 41 Schedule T-100 (U.S.DOT)

The T-100 data set contains aggregated monthly statistics on segment activity between airports for U.S. carriers. It includes data on departures (both scheduled and performed), available capacity and seats, number of passengers transported, and tons of freight and mail transported. Similar information for international segments (one point outside the United States) is collected from both U.S. and foreign carriers. In addition to the segment-based data, there is also a "market" version of the T-100, but it provides largely the same information as the "segment" version, because in most cases it does not accurately track true origin-destination (O-D) traffic. In particular, connecting passengers who change planes at an airport are treated as two separate passengers traveling first from point A to point B and then from point B to point C, rather than as a single passenger traveling from point A to point C.

One of the primary uses of the T-100 data set is to derive average load factors by carrier, airport, and/or city-pair segment. It should be noted that certain smaller commuter carriers and nonscheduled carriers are not required to submit T-100 data. Because of the aggregation to monthly totals, T-100 data cannot be used to assess daily or time-of-day peaks in demand.

Ten Percent Ticket Sample (U.S.DOT)

U.S.DOT collects a 10% sample of ticket coupons sold by major U.S. carriers; it includes the full itinerary (excluding intermediate stops on through flights) and the total dollar amount paid by each passenger. The sample is drawn from all tickets (both paper and e-tickets) issued by major U.S. carriers and includes Internet sales from carriers' websites or third-party travel websites. The DB1B database developed from the sample is issued quarterly and contains total counts of the number of passengers during the quarter who traveled on a specified itinerary at a specified total fare (including taxes). The data set includes "trip break" indicators to facilitate disaggregating each full itinerary into one or more O-D trips; in addition, a "dollar credibility indicator" is provided to help identify tickets that are outside credible limits (based on cents-per-mile criteria). Fare class indicators are also provided (first class vs. business vs. coach, restricted vs. unrestricted); however, these are typically of limited value because of variations in individual carriers' criteria for assigning fare classes and because of upgrades often provided to passengers that are not recorded on the original ticket.

The DB1B data are probably the best source of information on O-D traffic for U.S. city pairs. As with the T-100 data, however, because of the aggregation across time, they cannot be used to assess daily or time-of-day peaks in demand. In addition, certain commuter airlines do not submit ticket data for the sample; for those commuter carriers who have a ticketing relationship with one or more of the major carriers, however, this is often not a major concern because most of the commuter carrier's passengers will be connecting to one of the major's mainline flights at a hub airport, and so their ticket (only a portion of which is with the commuter carrier) will be captured in the DB1B data set. Finally, the DB1B data do not provide a complete picture of O-D demand in international markets because foreign carriers do not participate in the sample.

Published Airline Schedules

The Official Airline Guide (OAG) and Innovata are commercial entities that assemble worldwide airline schedules for publication. The schedules can be used to obtain information on commercial fleet assignment and scheduled activity by time of day and season. The data are available for up to six months in advance; therefore, it can sometimes be used to discover potential activity changes planned by airlines for the near term. However, the accuracy of future schedules typically diminishes significantly beyond about three months; some airlines do not even submit schedules that far in advance, and many that do provide estimates based only on current or past seasonal scheduling.

An important issue in using such data is that airlines and their commuter or codeshare partners may separately submit schedules that both contain the same flights offered for service, which can lead to double-counting. Since early 1998, OAG has required submitting carriers to include a descriptive identifier indicating the actual carrier for each flight. For those users who obtain the raw OAG data, it is still their responsibility to do the necessary crosschecks to eliminate double-counting where appropriate. Third-party providers of scheduled airline data typically provide this data cleaning as part of their service.

Terminal Area Forecast (FAA)

The TAF produced by FAA's Office of Aviation Policy and Plans is the official forecast of aviation activity for all National Plan of Integrated Airport Systems airports—this currently includes approximately 3,300 facilities. The forecasts are utilized for budgeting and planning purposes by the FAA, and can be accessed directly from the FAA website. The forecasts include annual projections for 20 years on a government fiscal year basis for enplanements (broken out by air carrier and commuter), itinerant aircraft operations (broken out by air carrier, air taxi/commuter, general aviation, and military), local operations (general aviation and military), instrument operations, and based aircraft counts. Historical data are available back to 1976. Airport master records are used as the initial source of information for based aircraft at all airports, and for aircraft operations at nontowered or contract-towered airports. OPSNET is the initial information source on operations for FAA-towered airports. The initial data may be supplemented or revised through information provided in airport master plans, state aviation activity surveys, or other supplemental sources.

Although the TAF can provide a basis of comparison for airports preparing their own forecasts, it is important to understand the limitations and uses of the TAF projections. First, they are primarily *unconstrained* demand forecasts—in other words, they are prepared without reference to existing or potential future airport capacity constraints. In this regard, their primary purpose is to help FAA project potential staffing workloads, budgeting, and overall NAS plan development. They are also used for establishment criteria purposes (e.g., to identify whether small nontowered airports may need a tower in the future).

It is also important to understand that the TAF for large commercial airports are fundamentally based on estimates of O-D demand and regional demographics; connecting traffic is forecast separately for those airports where it represents a significant share of total passenger traffic. Furthermore, for many smaller general aviation airports, the TAF projections are often simple flat-lined trends based on current activity. Finally, because the TAF projections are annual totals, they cannot be used to assess seasonal, daily, or time-of-day peaks in demand. For all of these reasons, users must use caution when evaluating TAF and assessing how useful they may be as a point of reference in specific cases.

For other purposes, the FAA's Airports Office has investigated the issue of capacity constraints and issued a study in 2004 on likely future capacity constraints at U.S. airports, *Capacity Needs in the National Airspace System* (2004). This analysis, often referred to as the FACT study (Future Airport Capacity Task), identified six airports where additional capacity was needed as of 2003, 15 additional airports and 7 metropolitan areas needing capacity increases by 2013, and 18 more airports and 8 metropolitan areas needing capacity enhancements by 2020. An update to the FACT study is scheduled to be released in 2007.

Other FAA Data Sources

FAA annually publishes *FAA Aerospace Forecasts,* a 12-year forecast of national aviation activity. It includes aggregate forecasts of passenger enplanements, RPMs, fleets, and hours flown for large air carriers and regional and commuter carriers; cargo revenue-ton-miles and fleets for large air carriers; fleets, hours flown, and pilot counts for general aviation; and operations for FAA and contract towers by user category. FAA also publishes the General Aviation and Air Taxi Activity and Avionics Survey, which includes current and historical data on general aviation and air taxi aircraft counts and hours by usage and aircraft type; some of the data are broken out by region and state.

Although neither of these sources contain any airport-specific data elements, the aggregate measures can be useful to airport planners who are employing market share forecasting methods where local activity is calculated as a share of some larger aggregate forecast.

DATA COLLECTION AND PREPARATION

Regardless of which forecasting method is used, there are a number of standard principles that planners should follow in preparing their data for analysis. First, it is usually best to use all relevant historical data; forecasting from a small number of data points is less likely to be successful. In some cases, however, it may be advisable to ignore older data; for example, if there is some important discontinuity, such as an industry deregulation that makes the early data irrelevant. Armstrong (1985) found that the longer the forecast horizon, the greater the need for more historical data to obtain accurate estimates.

Second, it is important to clean the historical data by checking for data measurement errors, missing data, outliers, and, if necessary, seasonality. As noted by Armstrong (1985), even small measurement errors can cause large forecast uncertainty; he reported a numerical example from Alonso (1968), where a 1% error in measuring current population could directly cause a two-period ahead forecast of the change in population to have a prediction interval of ±37%. This was not a real-world assessment using actual data, but rather a laboratory experiment where the true population parameters were assumed to be known. This was done to isolate the effects of the measurement error.

One way to guard against input errors is to collect data from more than one source, if possible. For example, one could check U.S.DOT measures of scheduled commercial passenger operations (from T-100) against OAG schedules. Flagging any significant differences would allow the user to manually investigate the cause.

Missing data are a fairly common occurrence; with time series data of the sort typically used in aviation forecasting, particular data points for a certain time period may simply be unavailable. In such a case, those observations with complete data would constitute a usable data set, but it might be possible to obtain useful information from the incomplete observations. If one is employing econometric forecasting techniques, there are a few statistical adjustments that can be tried to extract such information (Greene 1993).

Undetected outliers can also have an important impact on forecast accuracy. Many statistical software programs can automatically check for potential outliers by calculating means and standard deviations, and then flagging those observations that lie outside predetermined limits; graphical displays that show potential outliers can also be useful.

Once an outlier has been identified, one must investigate the reason. If there is some unusual identifiable historical event that is likely to have caused the outlier (e.g., the 9-11 terrorist attacks had an enormous impact on aviation activity across the United States), then one can account for this in structuring the specific model that will be used in the forecasting process. In general, external historical events such as wars, strikes, boycotts, weather or other environmental disasters, policy changes, etc., can have significant impacts on many forms of economic activity.

If a cause for a particular outlier cannot be found (or if one is doing a time series analysis that does not allow for external factors in the model specification), it is often advisable to simply exclude the observation from the analysis. Alternatively, a number of ad hoc procedures to adjust identified outliers have been suggested in the literature. One is to replace the outlier with the overall mean or median of the series. For positively or negatively trended data, it may be better to do the replacement with an average of the immediately adjacent observations.

Seasonality can also have significant impacts in studies where the time intervals of interest are less than a year. As noted earlier, seasonal peaks may be important at vacation destinations, whereas airports that have significant international traffic may have substantial variations in daily demand, and airports serving as connecting hubs for large network carriers may experience large hourly peaks. Nevertheless, in practice, most airport activity analyses develop models and make forecasts of annual activity and then translate these estimates to peak values based on current observed relationships between annual and peak activity. Such an approach is valid if one can reasonably expect the annual/peak relationship to be stable over time.

In cases where it is desirable to explicitly forecast daily, monthly, or quarterly activity, there are a number of ways to make seasonal adjustments. In econometric models, one can use dummy variables to essentially distinguish each relevant time period. Alternatively, one can attempt to "de-seasonalize" the observations themselves. Many software programs are available to do this; perhaps the best known and most commonly used is the Census Bureau's X-12 program (see Findley et al. 1998), which can be used to weight observations and adjust for seasonality, trend, and outliers.

Finally, when using explanatory variables in the analysis, an observation with an unusual value of an explanatory variable can have a significant impact on the estimates produced by the statistical estimator. Such "leverage points" may be worthy of further investigation; indeed, any observations that have a strong influence on the statistical estimates should be identified. There are a number of ways to identify and test for influential observations (see Belsey et al. 1980 and White and McDonald 1980), and many statistical software packages can automate the suggested procedures.

DATA ISSUES AT NONTOWERED AIRPORTS

Estimating flight activity at nontowered airports (or at towers with limited operating hours) can be difficult. TRB is currently conducting a separate synthesis study (ACRP S10-01, Counting Aircraft Operations at Small and Non-Towered Airports) on this issue. One method that has been used in the past is to identify a relationship between operations and some other independent factor, such as fuel sale records, based aircraft counts, or activity at a nearby towered airport. This often leads to inaccurate estimates, because the activity relationship with the independent factor may not be stable over time. Another option is to interview FBOs at the airport who may be able to provide accurate information about activity levels. In addition, FAA has published *Model for Estimating General Aviation Operations at Non-Towered Airports* (2001), a document describing a statistical model to estimate operations at nontowered airports based on data from other towered and nontowered airports.

Other more direct methods include visual observation or the use of one or more types of automatic counters. In most cases, it is considered too expensive to collect a true census of information over long periods; an alternative that is typically employed is to use sample counts to estimate activity. If sampling is used, it is important to develop a valid sample design to ensure that the sampled operations are representative of activity throughout the year. For example, general aviation aircraft operations typically vary based on weather, day of the week, and season. A common plan is to sample for 14 consecutive days, four times a year, once in each quarter (see Ford and Shirack 1984 and 1985 for further discussion of sampling techniques and counting instruments.)

Visual observation relies on human observers actually being present at the airport to count operations, a potentially very expensive way to collect data. Often it is most feasible to do visual counts only during daylight hours, which can lead to inaccuracies unless it is known that most operations occur only during the day.

There are a variety of counting instruments available for survey use. These include pneumatic tubes, inductance loops, and acoustical counters. A pneumatic tube placed on a runway registers a count as an aircraft rolls over it. The counter may not be 100% accurate owing to mechanical error, placement of the tube, recording of nonaircraft movements on the runway, etc. If placed on a taxiway instead of a runway, it will actually record ground movements to and from the runway, and so will not record touch-and-go operations or missed approaches. In addition, it cannot distinguish the type of operation (takeoffs vs. landings, local vs. itinerant).

The inductance loop counter is another alternative. Unlike a pneumatic tube, which is portable, an inductance loop is a wire that is installed in the pavement of the runway. Operations are counted as aircraft pass over the loop or fly over it within a few feet of the surface. Similar to pneumatic tubes, inductance loop counters will not record missed approaches, will miss most touch-and-go operations, and cannot distinguish takeoffs from landings or local vs. itinerant operations.

Acoustical counters are probably the most popular form of counting operations at small nontowered airports. These devices essentially use microphones placed at strategic points near the runway to record the sound of departing aircraft. Trained personnel and, more recently, software programs, can listen to the noise signatures and accurately identify departures, single versus multi-engine aircraft, and touch-and-go operations, while correctly ignoring nondeparture sounds.

DRIVERS OF AIRPORT AVIATION ACTIVITY

Many airport forecasts use econometric methods that utilize explanatory variables—these are measures of factors thought to explain changes in the demand and/or supply of aviation activities. There are many potential factors that may affect both the supply of and demand for aviation activities. Again, it is important to keep in mind the purpose for making aviation forecasts; if it is to provide guidance for long-term capacity needs, then the forecast should focus on the demand for services. On the other hand, it may be appropriate in some circumstances to explicitly account for existing or future supply-side constraints that may limit activity. In this case, there may be a wide variety of additional factors that may (or should) affect the forecasting process. The factors affecting aviation activity can be broadly categorized into the following areas:

- Macroeconomic and demographic factors such as the level of and growth in the economy, population, incomes, etc.;
- Airline market factors, including fares, flight frequency, and schedules;
- Air transport production costs and technology;
- Regulatory factors;
- Infrastructure constraints and improvements; and
- Substitutes for air travel.

Air travel is fundamentally a derived demand. In the case of business travel, it represents an input to productive activity; in the case of leisure travel, it is part of the consumption of a broader activity (e.g., taking a vacation or visiting friends or relatives). In both cases, air travel demand derives from the desire or need to be at a certain location for a certain purpose, and perhaps at a certain time. Leisure travelers may have more flexibility in their travel plans and so may be more willing than business travelers to trade off certain attributes of travel (e.g., time spent en route) for others (e.g., lower fares).

It is also important to note that some explanatory factors may primarily affect the demand for air travel as measured by enplanements, whereas others may primarily affect aircraft operations (takeoffs and landings). In this context, it is important to keep in mind that the demand for air travel is likely to respond to traditional economic variables such as price and income, whereas the number of aircraft operations depends on how carriers choose to serve that demand (by means of schedules, fares, and amenities) in the market.

Macroeconomic and Demographic Factors

For commercial airports that are directly connected to the rest of the commercial air transportation network, demand is likely to depend on broad macroeconomic factors that tie closely to business cycles. Most commercial airport activity forecasts include factors such as real gross domestic product (GDP) and real income, measured at the local or regional level, as primary drivers of demand. Where more specific geographic data are available, corresponding local or regional measures of GDP and income can be used. Some studies rely on estimates of total real GDP and/or income for the relevant region, whereas others use per capita measures combined with estimates of population growth. Other possible demand drivers include employment levels or unemployment rates; measures of consumer confidence, which is often seen as a leading indicator of future economic activity; and shares of income accounted for by high-income households. Many of these metrics are highly correlated with each other; therefore, analysts often use only a small number of them when constructing econometric models to project future aviation activities.

Regardless of which specific macroeconomic or demographic factors are employed, one potential issue that must be addressed is how to define the appropriate catchment area for the airport in question. When the airport in question is the only one providing commercial service in its geographic area, the catchment area probably coincides well with the metropolitan area for which standard macroeconomic measures are produced by local, regional, and/or national entities. However, in multi-airport regions one must also consider factors that may influence leakage of traffic from one airport to another and how passengers select one airport over another—such considerations are discussed in the following section.

Airline Market Factors

The price of air travel has an important explanatory impact on demand. As prices decline, traffic will increase, holding all else constant. Real fares (adjusted for inflation) or yields (price per mile) are the conventional measures for prices in the air travel industry. However, it is important to recognize that ticket prices are only one of a number of attributes that passengers may consider when deciding on how much air transportation to consume. The "full price of travel" is a standard concept in air travel demand studies; in essence, the idea is that passengers may also care about schedule convenience, the en route time in traveling to their final airport destination point, connecting time on the ground at intermediate airports, and ground access and egress times to and from the O-D airports. In studies of the full price of travel, the time spent in some or all of these activities is measured and valued, and then added to the fare paid by the consumer to arrive at a "full price" for the trip. The full price of travel approach is common in individual choice modeling of air travel demand, whereas more aggregate demand models tend to use the more traditional measures of (money) price and income.

Since the 9-11 terrorist attacks, the increased access time required to pass through security lines before departure has essentially led to an increase in the full price of travel. However, aside from this change, for many airport forecasting purposes it is often the case that the ancillary factors affecting the full price of travel can be safely ignored, because they are not likely to change significantly over the forecast horizon; the airport is fixed in location and large scheduling changes are not expected. However, in the case of forecasting for a new airport or an airport that faces direct competition from other airports in the same geographic region, passenger demand will be influenced by comparisons of flight frequency and schedule convenience, travel times, and other amenities at each airport. In such cases, comparative measures of the full price of travel between existing airports and the new airport (rather than just fares or yields) may be more relevant for projecting demand from specific catchment areas.

There are many other airline market factors that may affect future aviation activity at an airport and that are often considered in well-prepared forecasts. These include:

- Low-cost carriers or other new entrants—Assumptions about if and when such carriers may offer or expand service at an airport can have a significant impact on projected future activity.
- Regional jets—The impact of regional jets on the airline industry was quite significant starting in the late 1990s. Initially they were used primarily to connect low-volume markets to carrier hubs that were too far away for service by turboprop aircraft. More recently it has been recognized that although passengers prefer jet service to prop service, the high costs of small regional jets (per available seat-mile) has limited their usefulness. Many carriers are now seeking to reduce these costs through redeployment and re-bidding of contracts with their regional partners.
- Changes in service from competing airports—For those airports that compete regionally with other airports for traffic, any projected changes at those airports (such as increased fare competition, congestion, or service by low-cost carriers) can have important effects on activity at the airport in question.
- Industry consolidation—The airline industry has consolidated substantially since the 1980s when large numbers of new carriers entered the industry after deregulation took hold in the late 1970s. Mergers can have a significant impact on activity at a given airport (e.g., the

large decline in operations at Lambert–St. Louis International Airport following American Airline's takeover of TWA).

- Taxes and fees—There are several excise taxes and fees assessed by the federal government or airport operators that affect fares faced by passengers and operating costs faced by carriers. Currently these include:
  - Federal taxes to support NAS
    - Δ Passenger ticket tax—7.5% (applies to domestic travel).
    - Δ Passenger flight segment tax—$3.40 per enplanement (applies to domestic travel; certain rural airports are exempt).
    - Δ International arrival/departure tax—$15.10 per arrival and departure.
    - Δ Alaska/Hawaii international arrival/departure tax—$7.30 per arrival and departure.
    - Δ Cargo waybill tax—6.25% (applies to domestic freight).
    - Δ Commercial jet fuel tax—4.3 cents per gallon.
    - Δ Non-commercial jet fuel tax—21.8 cents per gallon.
    - Δ Non-commercial gasoline tax—19.3 cents per gallon.
  - Federal fees to support Homeland Security
    - Δ September 11 fee—$2.50 per enplanement (certain small airports exempt).
    - Δ Aviation Security Infrastructure Fee—carrier-specific fee.
    - Δ Animal and Plant Health Inspection Service passenger fee—$5.00 per international passenger arrival.
    - Δ Animal and Plant Health Inspection Service aircraft fee—$70.50 per international aircraft arrival.
    - Δ U.S. Customs and Border Protection user fee—$5.00 per international passenger arrival.
    - Δ Immigration user fee—$7.00 per international passenger arrival.
  - Local passenger facility charges
    - Δ Passenger facility charge—up to $4.50 per enplanement at eligible U.S. airports.

A study by Yamanaka et al. (2006) found that the average effective tax rate on domestic airline passenger travel in the United States is approximately 16%. This does not include taxes on international services or taxes and fees assessed directly on carriers.

Air Transport Production Costs and Technology

Even in the simplest airline market, production costs directly affect the amount of services that airlines are willing to supply. Two of the most important cost factors in the airline industry are fuel and labor. Many long-range aviation forecast studies consider the impacts of potential changes in fuel prices, although many larger carriers try to limit the impact of large swings in prices by hedging a portion of their fuel purchases. Any potential changes in labor costs brought about by scope clause changes and overall cost reductions (either negotiated between management and their unions or imposed as a result of the many bankruptcy filings that have characterized the domestic industry) must also be factored in.

An increasingly important cost faced by commercial carriers is the set of landing and usage fees charged by airports for use of their facilities. For many airports, such fees are set to directly recover the costs of operating the airport, which may include large current expenditures for, say, capacity expansion. This can lead to wide variations in the fees charged; for example, the landing fee at Atlanta Hartsfield Airport is $0.46 per 1,000 lb, whereas the fee at New York's LaGuardia Airport is $6.35 per 1,000 lb. These differences primarily reflect variations in the cost of operation. At Atlanta in 2005, airport operating expenses averaged approximately $2.20 per commercial enplanement, whereas the corresponding rate at LaGuardia was more than $16 per enplanement. Such large differences can affect carrier decisions about where to offer service. However, direct negotiations between airports and airlines often result in bilateral agreements where an airport may reduce or waive certain usage fees in exchange for service commitments by a carrier. All of these potential factors can have important influences on current or projected airport activity levels.

Advances in aircraft technology also can affect airport activity. As the major manufacturers design new equipment with lower net operating costs (through increases in fuel efficiency, increased cargo capacity, extended range, and advances in engine technology), airport forecasts must take into account the introduction of these new aircraft and their potential impacts on both operation and passenger counts. For example, three manufacturers have made significant investments in a new category of aircraft called Very Light Jets (VLJ), and more than 3,000 orders have already been placed. These jets, with a maximum takeoff weight of fewer than 10,000 lb and designed for single-pilot operation, will be able to operate from short runways. Some industry experts project that these aircraft will see widespread use in point-to-point air taxi service. New aircraft can also have impacts on commercial passenger demand through improvements in passenger amenities.

Commercial airlines have also made advances in the sophistication of their yield management programs, allowing them to more efficiently fill available seats on their flights. This is evidenced by the dramatic rise in domestic system load factors across the industry over the past decade (from 67.4% in 1996 to 77.3% in 2005—see *Aerospace Forecasts* . . . 1999 and *FAA Aerospace Forecasts* . . . 2006). This technical ability to fill more seats can have important implications for both operation and enplanement forecasts, although there is a practical upper limit to how much higher average load factors can go in the future.

Regulatory Factors

Aircraft operations at some airports are affected by regulatory constraints, including environmental rules regarding noise and emissions, time-of-day restrictions, and, in a few cases, direct quotas on the number of operations allowed.

Under Federal Aviation Regulation Part 150, FAA has established specific metrics regarding noise exposure at airports. Although FAA does not directly impose specific noise limit levels at airports, capacity expansions that use federal money must follow guidelines regarding changes in noise levels and attempt to mitigate increases. In addition, aircraft are classified into one of four noise categories—from Stage 1 (loudest) to Stage 4 (quietest). The Stage 4 noise rule adopted in 2005 requires that all new designs for jet aircraft and large transport aircraft submitted on or after January 1, 2006, meet Stage 4 limits.

More recently, concerns about emissions by aircraft on air quality and climate change have been raised that may potentially affect airport operations. Internationally, the International Civil Aviation Organization has promulgated increasingly stringent standards for emissions during takeoff and landing. Domestically, local authorities and environmental groups have responded to regulations under the Clean Air Act seeking to reduce emissions of nitrogen oxide (NOx) during takeoff and landing. NOx emissions during cruise conditions are also a growing concern. According to the NASA website, "proposed research and technology objectives are to reduce NOx emissions by a factor of three within 10 years and by a factor of five within 25 years."

In the past, some airports have attempted to impose noise-related or other restrictions on aircraft operations. Since the passage of the Airport Noise and Capacity Act of 1990, however, such restrictions cannot be imposed without rigorous study and approval from FAA. For many years, FAA-sanctioned limits on operations have existed at four large commercial airports—Ronald Reagan Washington National in Washington, D.C.; LaGuardia International and JFK International in New York; and O'Hare International in Chicago. Since the late 1960s, operations at these airports had been limited by means of the High Density Rule, which established slot controls (the right to take off or land) at each facility. In 2000, the U.S. Congress passed the so-called "Air 21" legislation, which mandated that slot controls be eliminated at Chicago's O'Hare, at JFK, and at LaGuardia; controls are to remain in effect at Washington's Reagan National. Since that time, FAA has sought voluntary carrier agreements to limit operations at O'Hare, and is seeking to implement new rules at LaGuardia to prevent airline overscheduling and large increases in congestion delays at these facilities.

Infrastructure Constraints and Improvements

Except in the case where one is preparing an unconstrained demand forecast, physical capacity constraints can have important consequences for forecasting future airport activity and the bottlenecks that can occur in a variety of ways. Runway capacity is often a limiting factor; this can occur owing to the number, length, or orientation of runways and taxiways, and weather, which often plays a central role in determining the number of hourly takeoffs or landings that an airport can accommodate. Gate capacity can be another limiting factor. Although many airports have "common use" facilities, others enter into agreements whereby specific airlines can control the use of particular gates; thus, they can limit access by their competitors, although such agreement may put limits on this practice by imposing certain minimum usage requirements. (In addition, airports receiving AIP funds must be in compliance with grant assurances that include requirements regarding competition.)

At airports where capacity limits come into play, there may be a natural tendency for airlines to collectively overschedule the airport. This is because each extra flight added early or in the middle of the day is likely to impose congestion costs on many flights scheduled to depart or arrive later that day; however, the carrier scheduling the extra flight will only take account of the impact it has on its *own* later flights. This can lead to a higher number of total flights than are optimal from a social welfare standpoint; a study by Brueckner (2002) supports this argument.

Capacity limits may also be reached on the landside as the number of passengers approaches the capacity of terminal or parking facilities. Increasing congestion at terminal curbsides and security checkpoints since the 9-11 terrorist attacks represents new capacity constraints that may affect future activity levels.

When activity at an airport begins to approach capacity increasing congestion results, this in turn increases the costs to both airlines and their passengers. The level of congestion and delay tends to increase as the level of operational activity continues to rise. The relationship between aircraft operations and delay is often captured in a "delay curve," as shown in Figure 2. Typically, such a curve is used to assess the monetary value of the delay (to passengers and/or airlines), and these values then can be fed into estimates of the full price of travel for passengers and the cost of production for airlines. FAA's *Advisory Circular on Airport Capacity and Delay* (1983) provides guidance on computing airport capacity and delay by means of an Annual Service Volume methodology, which accounts for variations in runway use and configuration, aircraft mix, weather conditions, etc.

Infrastructure improvements can also have important effects on activity forecasts. With expanded capacity, congestion levels may decrease, and this may induce an increase

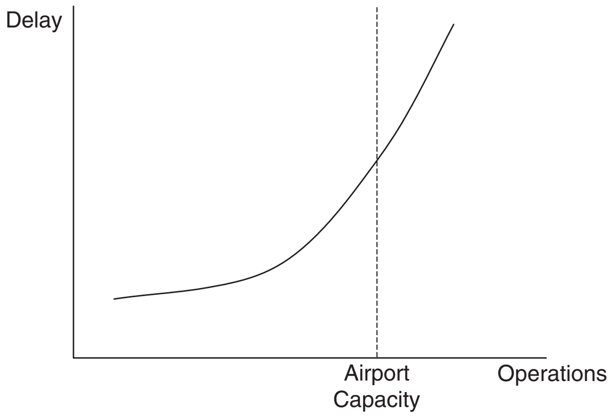

FIGURE 2 Relationship between airport capacity and delay.

in activity that would otherwise not occur, subsequently resulting in an increase in congestion levels. The effects of induced demand on airport activity and congestion levels are an important part of forecasting that should be accounted for in appropriate situations.

Substitutes for Air Travel

Traditionally, air travel has been thought to be subject to competition from competing modes only on shorter-haul routes, where travel by automobile, train, or, in some cases, bus may be a practical alternative. Mode choice studies by Morrison and Winston (1985) and others indicated that significant substitution may take place on shorter-haul routes. However, recent advances in communications technology suggest that teleconferencing may become a viable way to conduct business, which may therefore affect the demand for business travel, regardless of the length of haul. Some recent airport forecasting studies have attempted to account for this by explicitly directly reducing activity enplanements and/or operations projections after the fact.

The 9-11 terrorist attacks have also had an impact on air travel substitution, particularly in short-haul markets as travelers consider total travel time and the "hassle factors" associated with airport security procedures. A report by the International Air Transport Association ("The Air Transport Industry . . ." 2006) indicates that U.S. passenger enplanements in July 2006 were still 12% below the levels of July 2001.

CHAPTER THREE

AIRPORT ACTIVITY FORECASTING METHODS

OVERVIEW OF AVAILABLE METHODS

Four general approaches to forecasting airport activity are discussed here. From a statistical point of view these methods range from very simple to very sophisticated; however, it is important to keep in mind that the use of sophisticated statistical methods does not always result in better forecasts. As mentioned earlier, most real-world airport forecasts do not use the most sophisticated methods. Nevertheless, the techniques described in this chapter represent current best thinking on how to produce accurate forecasts. The related topics of evaluating forecasts and assessing the uncertainty associated with forecasts are discussed in chapter four.

The four major forecasting methods considered here are:

- Market share forecasting
- Econometric modeling
- Time series modeling
- Simulation modeling

This list is not exhaustive, but it covers most of the forecasting techniques that have been used by airport sponsors or managers in the United States. For an overview of other forecasting methodologies, see "The Air Transport Industry Since 11 September 2001" (2006).

Market share forecasting is a simple top-down approach to forecasting where current activity at an airport is calculated as a share of some other more aggregate external measure for which a forecast has already been produced (typically some regional, state, or national measure of aviation activity). Then an assumption is made about the airport's projected share of activity in the future.

Econometric modeling is a multistep process referring to an approach that posits a causal relationship between a dependent variable (the metric to be forecast) and a set of independent explanatory variables. The explanatory variables are likely to be among those described in chapter two that are thought to influence the demand for or supply of air travel. An equation relating the dependent and independent explanatory variables to each other first is estimated using statistical techniques; the equation then can be tested for a variety of statistical properties and accuracy. Finally, the estimated equation is used to forecast future values of the dependent variable.

In principle at least this approach may be more powerful (and potentially more accurate) than simple market share forecasting because it takes into account factors thought to directly cause changes in the activity metric being forecast, rather than relying only on more aggregate forecasts of other activity measures. However, the data requirements are also far greater. With this approach, one must obtain historical data for both the dependent and explanatory variables to statistically estimate the relationship. Additionally, to then use the estimated relationship to make forecasts of the independent variable, one must have access to forecasts of the independent variables.

Time series analysis is a third approach that essentially involves extrapolation of existing historical activity data without utilizing independent explanatory variables. A variety of different statistical techniques can be used in time series analysis, including simple trend projection, moving average, exponential smoothing, and Box–Jenkins analysis. More sophisticated "multivariate" time series techniques have also been developed that can incorporate explanatory variables in a restricted way.

In addition to these three methods, the use of simulation for forecasting is also relevant for airport planners and decision makers. However, simulation methods serve a very different purpose than the other techniques. Simulation models can be used when one needs to obtain high-fidelity estimates of the particular itinerary that passengers or aircraft may take across an airline network and the associated delays they may face, or how passengers may travel through a particular airport terminal, or how aircraft may traverse over an airport tarmac and runways. These models impose precise rules that govern how passengers or aircraft are routed, and then aggregate the results so that planners can assess the infrastructure needs of the network or airport to be able to handle the estimated traffic.

The typical metrics that are the outputs from the other forecasting methods discussed here (e.g., total enplanements and operations) are used as inputs to simulation models. "Forecasts" from simulation models represent snapshots of how a given amount of traffic flows across a network or through an airport, rather than a time series of monthly or annual projections of total traffic. The discussions in this chapter on appropriate selection of methods and data collection center only on forecasts over time, not the snapshot forecasts that arise from simulation models.

MARKET SHARE FORECASTING

Market share analysis involves measuring current activity at an airport as a share of some other aggregate measure (typically at the regional, state, or national level), and then assuming that the share will remain constant (or perhaps change in some prespecified way) so that airport activity will grow along with the projected growth in the aggregate activity. A number of variations on this technique also have been used; for example, using current indicators of activity to assign a predetermined share of an aggregate TAF growth rate.

For the market share method to produce reasonable predictions, it is important that the presumed relationship between airport activity and the larger aggregate measure to which it is tied be relatively constant. Often that relationship may change over time; because of this, some studies only look at the very recent past and use a small number of historical data points to establish the numerical constant that ties the relationship. In general, such an approach is not likely to result in accurate forecasts, because the actual relationship may well change again over the forecast horizon. This is a shortcoming of the market share method that is typically not directly addressed. Its extensive use in aviation forecasting is typically justified as a reasonable way of making forecasts in cases where there are data limitations (e.g., lack of accuracy in operation counts at nontowered airports), where past history does not correlate well with other observable factors, or where other more sophisticated methods may not yield statistically reliable results.

ECONOMETRIC MODELING

Causal econometric modeling with explanatory variables is sometimes referred to as regression analysis. This involves statistical estimation of a regression equation that posits a causal relationship between a dependent variable and a set of independent explanatory variables. For example, the demand for air travel (measured, say, in terms of enplanements) at a particular airport may be posited to be a function of some of the airline market factors described in chapter two.

In its simplest form, the nature of the relationship between the dependent variable and the independent variables is assumed to be linear. With just a single independent variable, this would be written as:

$$Y = \alpha + \beta X + \varepsilon$$

where:

Y is the dependent variable,
X is the independent variable,
α is the constant term of the equation,
β is the coefficient describing how a change in X affects Y, and
ε is a random error term (with a mean value of zero).

After collecting historical data on Y and X, this classical linear regression (CLR) model can be estimated statistically, resulting in estimates of the coefficients α and β representing a regression line through the observed data. This estimated equation then provides a way to make forecasts of Y based on observed or assumed values of X. One way to assess the accuracy of the estimated equation is to do an "in-sample" forecast by comparing the observed values of Y with the estimated values one would get by substituting in the observed X values and then computing Y from the equation. In addition to in-sample forecasts, one can make "out-of-sample" forecasts, estimates of future values of Y (beyond the historical data) that can be estimated by substituting in projected future values of the independent variable X. For example, if Y is annual enplanements and X is population, then future forecasts of population could be substituted into the estimated equation to yield forecasts of future enplanements.

Sidebar on Choice Analysis

Rather than directly estimating activity at a specific airport, another option often used in multi-airport regions is to estimate overall air transportation demand for the region and then distribute that demand among the various airports based on certain characteristics of the population and the airports. Both parts of such an analysis can still be estimated with econometric techniques (Maddala 1983).

An example of this type of approach is presented in Ishii et al. (2006), although the authors do not use the model directly for forecasting purposes. First, they measure the impact of airport and airline supply characteristics on air travel choices for both business and leisure passengers departing from one of three airports in the San Francisco area (Oakland International, San Francisco International, or San Jose International), and arriving at one of four airports in the Los Angeles area [Los Angeles International, Ontario International, Orange County, or Burbank (Bob Hope)]. The primary explanatory variables in the model include flight frequency, ground access time, airport delays, and fares. The principal findings indicate that changes in ground access times affect travel choices more than changes in travel delays, and that airport preference differs between leisure and business travelers.

In some cases, air transportation in a region may be cast as part of a more general model that involves other modes of transportation. The design of such a model would look something like the following:

- Trip generation—A model is used to estimate how many trips to and from the region are generated over some defined time period.
- Trip distribution—Once a decision has been made to travel, a trip distribution model is used to describe how travelers choose among various available destinations.

- Mode choice—Once a decision has been made about where to travel, a shares analysis is used to estimate the percentage of trips going by each available travel mode (e.g., air, automobile, or train).
- Traffic assignment—Once a decision has been made about which mode to use, another shares analysis is used to estimate the percentage of air trips departing and arriving at each airport in the region.

An example of this type of model is the Regional Airport Demand Allocation Model (RADAM) produced by the Southern California Association of Governments. This model generates air passenger and cargo demand estimates in geographic zones within Southern California (it bypasses the mode choice analysis by focusing directly on air travel demand) and then allocates the demand to airports in the region based on airport characteristics. Further discussion of this model is given in *Transportation Research Circular E-C040* (2002).

Assumptions and Potential Problems of Econometric Models

There are a number of important assumptions built into the linear regression model that may affect whether the estimates it produces are statistically reliable. For example, it is assumed that the dependent variable can be calculated as a linear function of a specific set of independent variables. There are several ways that this assumption could be wrong, including a changing or nonlinear relationship between the dependent and independent variables or using the wrong set of explanatory variables. These so-called "specification errors" refer to the form of the estimating equation possibly having been specified incorrectly. Although there are a number of statistical techniques that can be used to assess whether a regression model is likely to be misspecified, it is often difficult to determine exactly the nature of the specification error and therefore to find the "correct" specification.

There are a number of other statistical issues that may affect the reliability of the estimates from an econometric regression. Any standard econometrics textbook will discuss how to deal with such issues [see, for example, Stock and Watson (2006)]. A good supplementary book that describes many techniques in a less formal way is *A Guide to Econometrics* (Kennedy 2003).

Econometric Model Validation

Once the model specification has been established and the model's coefficients have been estimated with the appropriate statistical techniques, there are other steps that can be undertaken to assess the adequacy of the results before making any forecasts. First, it is important to establish how well the model fits the data using summary statistics such as R^2, which in the CLR model measures how much of the proportion of the variation in the dependent variable is explained by the independent variables.

One should also assess whether the estimated coefficients on the individual independent variables are reasonable. The signs of the estimates should correspond with the researcher's prior expectation (e.g., a rise in real income should lead to a rise in air travel demand; therefore, the coefficient on income should be positive), and the magnitude of the effect should correspond with expectations based on the analyst's judgment and/or previous analyses. Assessing the precision of the coefficient estimates is also important. The t-statistic is used for this purpose in the CLR model. Generally speaking, t-statistics greater than about 2.0 are considered "significant."

Although econometric modeling is potentially a very sound and powerful method, there are many ways in which the specific model that is estimated can go wrong. As should be clear from this discussion, there are a large number of potential statistical assumptions and data issues that should be checked in an econometric analysis. In some cases, the model may be found not to pass these statistical tests or data problems, and then it is not always obvious how best to proceed.

TIME SERIES MODELING

Time series modeling is a conceptually simple approach to forecasting that involves some form of extrapolating existing data out into the future. In its simplest form it is based only on values of the variable being forecast and projects the future based on current or past trends. Because one does not need to collect data on other variables, it can be a low-cost method compared with econometric modeling. In addition, it can often meet or even beat other more sophisticated approaches in terms of forecast accuracy over the short run simply because activity measures often exhibit a strong short-run trend component, whereas estimated relationships with other variables may not hold so tightly in the short run. As will be discussed here, although the approach is conceptually simple, specific statistical techniques that can be employed to make it more accurate are quite sophisticated. This method also can be useful when there are unusual conditions that make the relationship between local activity and other external factors unstable.

Time series analysis is more likely to be accurate when a long series of historical data are available, when no large changes in airport use or activity are expected, and when forecasting over a relatively short time period in the future. These factors make the technique appropriate when forecasting for short-term operational planning needs and/or annual budgeting; it is less useful for longer-term forecasts that are used to assess future infrastructure and capacity needs. In addition, because time series analysis ignores external factors, it cannot be used to compare alternative policies (e.g., how would activity at a congested airport change if a new runway were built) or to examine alternative environments (e.g., how would counts change if the local economy were to grow at a faster rate than expected).

In many cases, time series modeling can be as simple as making year-over-year or month-over-month trend projections based on past values. This is often sufficient when projecting for short-term budgeting or planning needs. In some cases, however, there may not be a consistent trend pattern of growth over time (e.g., at small general aviation airports). In this case, simply using the average of the observed historical data may be a reasonable alternate way to forecast future activity. One can measure the average change in percentage terms or in levels, and simply extrapolate this change to future time periods.

As noted by Armstrong (2001a), it will often make sense to weight the most recent data more heavily when making short-term forecasts. An effective way to do this is through "exponential smoothing," which results in forecasts that are a weighted average of past values with the weights declining geometrically. (This is in contrast to the so-called "moving average" technique, where groups of past observations are each assigned equal weights.) In exponential smoothing, there are one or more smoothing parameters that can either be assumed or estimated through statistical procedures. Both trend and seasonality issues can be addressed by using exponential smoothing methods.

An analysis by Grubb and Mason (2001) used an exponential smoothing method to project long-term aggregate passenger demand forecasts for the United Kingdom. Monthly data on passenger movements from 1949 to 1998 were assembled, providing nearly 600 time series observations. Both trend and seasonality were clearly apparent in the data. After the initial parameters were estimated, forecasts were generated out to 2015. The projections for 2015 were significantly higher than other forecasts that had been prepared by the United Kingdom Department of the Environment, Transport, and the Regions (2000); therefore, the authors then modified their model until the resulting projections were much closer to the agency estimates. The analysis shows how analysts may make ad hoc adjustments to statistical models to be more consistent with expert judgment or other existing forecasts.

Box–Jenkins Analysis

In the field of economics, the initial motivation for using time series techniques grew out of the concern that econometric modeling with explanatory variables ignored a fundamental property of time series data—namely, that they tend to grow over time and so do not have a fixed "stationary" mean value. In other words, traditional econometric modeling is typically based on some economic theory about how changes in certain variables may cause changes in other variables (e.g., a rise in income should lead to a rise in the demand for air travel), but the theory typically will not give much guidance on *dynamics;* that is, effects over time, which may be the single most important influence on the variable of interest.

The Box–Jenkins approach to time series analysis attempts to directly address this issue of time effects, and can also address issues of seasonality. The resulting general model is called an ARIMA (Autoregressive Integrated Moving Average) model. It is important to understand the very different nature of ARIMA time series modeling as compared with traditional econometric modeling with explanatory variables. Box–Jenkins modeling is essentially a sophisticated extrapolation method; it does not provide any information on specific factors that may explain why airport activity measures go up or down. Rather, it is a completely data-driven technique that exploits and uncovers time dependencies in the data. One drawback is that it typically requires quite a long data series to generate reasonable estimates. However, it can often outperform modeling with explanatory variables in terms of prediction and forecasting of the activity variable of interest. If one is only interested in forecasting accuracy (especially over short time horizons) it may be appropriate to consider time series techniques. However, if one wants to consider how alternative policies or economic environments may be expected to affect observed airport activity measures, pure time series techniques cannot help.

A study by Pitfield (1993) compared an ARIMA model of air passenger demand in the United Kingdom with a conventional regression model with explanatory variables. Weekly data on passenger travel on two airlines operating on specific air routes in the United Kingdom was gathered over a five-year period. Although out-of-sample forecasts were not made, the results indicated that the ARIMA model provided better in-sample predictions of the observed passenger counts.

SIMULATION MODELING

As mentioned earlier, simulation methods serve a very different purpose than the other techniques. Simulation models can be used when one needs to obtain high-fidelity estimates of the particular itinerary that passengers or aircraft may take across an airline network, how passengers may travel through a particular airport terminal, or how aircraft may traverse over an airport tarmac and runways. These models impose precise rules that govern how passengers or aircraft are routed and then aggregate the results so that planners can assess the infrastructure needs of the network or airport to be able to handle the estimated traffic.

It is difficult to generalize about these models because each is typically designed for a very specific purpose. One common thread is that the standard metrics that are the outputs from the other forecasting methods discussed here (e.g., total enplanements and operations) are typically used as *inputs* to simulation models. "Forecasts" from simulation models represent snapshots of how a given amount of traffic flows across a network or through an airport, rather than a time series of monthly or annual projections of total traffic.

Unlike econometric or time series methods, simulation models do not follow any standard framework that can be used as a guide; each model is essentially built from the ground up using its own rules and methods for distributing and forecasting activity. Such models trace the movement of individual aircraft at airports and in the national airspace route system. The primary inputs to the models include airline schedules and fleets, route structures, runway configurations, separation rules and control procedures, aircraft performance characteristics, and weather conditions. Typical outputs from these models include measures of aircraft movements over time, passenger travel time, and fuel consumption. By running multiple simulations, it is possible to investigate how and to what extent a particular capacity expansion project (e.g., adding a runway) may be able to accommodate additional aviation activity. Other simulation models have been developed to project queuing and service at landside facilities such as security checkpoints and terminal curbsides.

SELECTION OF APPROPRIATE METHOD

The selection of an appropriate forecasting method may depend on both technical and budgetary factors. From a technical standpoint, two primary drivers in determining which may be the most appropriate method are the purpose for which a forecast is being made and how the metrics being forecast relate to available historical data. Table 2 presents basic recommendations relating forecast methods to these factors. Although the table can be used to help forecasters determine the most suitable method, it should not be interpreted as a complete reference tool that applies to every situation. Each case will be different, and forecasters should consider other factors specific to their own situation that may be important in determining the best approach.

As noted in the table, for short-term operational planning or budgeting purposes, a simple time series trend analysis can be a low-cost method of obtaining reasonable forecasts if one is confident that future changes in activity are likely to be similar to the historical record. If there are concerns regarding seasonal, daily, or hourly peaking effects, more sophisticated time series techniques could be considered. For medium- or long-term forecasts that will be used to assess landside or airside capacity needs, or for financial planning purposes related to already-planned capacity expansions, market share forecasting or econometric modeling would be more appropriate.

In practical terms, budgetary constraints may also affect the particular method selected. Small airports may have very small budgets that limit their efforts to a basic review of already existing forecasts and development of a few derivative forecast elements.

Beyond these considerations, there are a large number of criteria that planners could consider in selecting an appropriate forecast method. Yokum and Armstrong (1995) reported findings from a collection of surveys that indicated that

TABLE 2
RECOMMENDED FORECASTING METHODS

Purpose of Activity Forecast	Historical Data Availability		
	INCREASING DATA REQUIREMENTS →		
	Stable Trend	Stable Relationship With:	
		External Forecasts	Causal Variables
Short-Term Operational Planning; Annual Budgeting	Time series trend extrapolation, or smoothing/Box–Jenkins if complex time dependencies	Market share forecasting	Econometric modeling
Identify Long-Term Capacity Needs; Financial Planning to Support Facility Expansion	Market share forecasting or econometric modeling	Market share forecasting	Econometric modeling
Examine Alternative Environments; Compare Alternative Policies	Econometric modeling		
Obtain High-Fidelity Estimates of Travel Time and Delays (aircraft or passengers)	Simulation modeling		

many different criteria may be important in the selection process including accuracy, timeliness in providing forecasts, costs, ease of interpretation, flexibility, ease in using available data, ease of use, reliability of confidence intervals, and ability to compare alternative policies or examine alternative environments.

Once a decision about the general type of forecasting method is made, statistical criteria may be useful in selecting the particular model. For example, there are a variety of "goodness-of-fit" measures that are often used to summarize how well a particular method fits the data. However, the use of formal statistical criteria to help choose the appropriate method has limitations. As noted by Armstrong (2001b), an overreliance on methods that are statistically significant can lead one to overlook other criteria; statistical significance is not the same as practical significance. It may well be more important to implement a forecasting method that is understandable by the intended audience. This is generally understood by airport planners and their experts who develop aviation forecasts; it is relatively unusual to see forecasts that rely on highly complex statistical techniques, although such approaches are more common in academic studies of aviation demand.

Although this discussion has focused on selecting the most preferred method, in some cases it will not be clear which method is the most appropriate. In such a situation, it may be advisable to implement and evaluate multiple methods to reveal the likely range of activity levels as assumptions and inputs are changed.

SELECTED EXAMPLES OF FORECASTING METHODS IN PRACTICE

This section reviews a small, but representative sample of airport master plans and regional system plans, focusing on the typical methods, data sources, and variables used to produce airport aviation activity forecasts. For confidentiality purposes, the discussion does not identify individual facilities. These examples are meant to show how different forecasting methods may be appropriate under different conditions. Other forecasting studies from professional and academic sources are referenced in other sections of this report.

Small Towered Airport with Commercial Service

This small airport provides commercial service primarily in support of a nearby, large higher education campus. A separate general aviation terminal and FBO caters to private business and recreational users. The commercial terminal currently houses four commuter carriers that provide connecting service to many destinations through their parent carriers' hubs. An airport-wide Master Plan Update was completed in 2003, and a Terminal Area Master Plan (TAMP), focusing only on commercial service was completed in 2005; these plans were subsequently approved by FAA.

The forecasting process in the TAMP analysis involved a varied mix of data sources and methods. Three different methodologies were considered, including trend extrapolation, market share projections, and econometric modeling, to predict future scheduled passenger enplanements. As noted in the TAMP study, the use of trend projections can be significantly influenced by abrupt changes in available service. Using 2003 as the baseline year, the trend projections estimated a large one-year increase in 2004 as a result of the introduction of new service by one of the commuter carriers, and then used the 10-year average growth rate at the airport from 1994 to 2003 as the basis for extrapolating enplanements out to 2023, the end of the forecast horizon. This resulted in an average annual growth rate of 3.1% over the entire forecast period.

The market share projection analysis found that the airport's share of national enplanements grew over the 1994–2003 period; this growth relative to national activity was assumed to continue for the first five years of the projection period and then to remain at a constant share of national enplanements for the rest of the forecast horizon. The FAA Aerospace Forecasts were used as the basis for projecting future enplanement activity. This resulted in an average annual growth rate of 3.5% over the entire forecast period.

The econometric modeling analysis considered three different local measures—population, employment, and income—as potential drivers of enplanement activity at the airport. Each indicator was regressed separately against historical enplanements, and it was found that income had the best fit to the data; therefore, future enplanements were projected using the estimated income equation along with forecasted local income levels from a third-party provider. This resulted in an average annual growth rate of 2.6% over the entire forecast period.

All of these forecasts were then compared with the prior projections from the 2003 Master Plan Update. In addition, a passenger demand analysis from the 2003 study was reviewed to assess the effect on enplanements from local passenger diversion to a competing airport, the volume of traffic traveling to specific destinations, and the potential for service improvements. This analysis supported the use of the TAMP forecasts.

Additionally, a high-growth scenario was developed that assumed significant roadway improvements in the surrounding region, as well as loss of commercial air service at certain neighboring airports. Under this scenario, average annual growth was estimated at 4.0% over the forecast period.

The various forecasts were also compared with FAA's TAF, which predicted a 3.5% annual growth rate for the airport. Based on this comparison and the other factors considered, the projections from the market share method (also showing a 3.5% growth rate) were identified as the recommended enplanement forecasts for long-term planning at the airport.

The enplanement forecasts were then also used as the basis for projecting air carrier operations and fleet mix by supplementing them with historical and expected trends in load factors, types of aircraft, and average seats per departure. Peak activity at the airport was also estimated from the baseline enplanement forecasts by using the peak month-average day approach described earlier. Peak-hour forecasts were derived based on an analysis of airline schedules and carrier-specific load factors provided by the scheduled carriers at the airport.

As is the practice with most airport master plans, forecast uncertainty was addressed only in an indirect way by including the high-growth scenario projections that relied on more optimistic assumptions about future enplanement growth.

General Aviation Reliever Airport

This general aviation facility serves as a reliever airport to a large commercial airport approximately 15 miles away. Although a draft master plan was completed in 2002, recent developments have necessitated important updates to that plan. In particular, several manufacturers are developing VLJ aircraft, advanced technology twin-jet aircraft weighing less than 10,000 lb that may be certified for single-pilot operations (although air-taxi carriers operating under Part 135 may be required to use two pilots). Some forecasters predict that several thousand VLJs will enter service over the next ten years, and a leading VLJ manufacturer has already announced plans to locate a manufacturing, testing, training, and maintenance center at this general aviation facility. This has a potentially large effect on operational activity at the airport; as a consequence, an update to the airport's master plan scheduled for 2006 was prepared that provides forecasts of based aircraft, fleet mix, local and itinerant operations, peak activity, operational mix, and instrument approaches. Primary focus was placed on projecting based aircraft, and the remaining activity measures were then projected (with some adjustments for the projected VLJ facility) by means of a relationship with the based aircraft estimates.

According to the draft report, historical data on based aircraft at the airport were available only for selected years; therefore, this ruled out forecasting methods such as econometric modeling and time series analysis that rely heavily on complete and accurate historical information for the metric being forecast. Instead, a market share analysis of the number of registered general aviation aircraft in the local area was undertaken; available annual data on this metric was compared against changes in both local population and United States active general aviation aircraft registrations. Although both relationships exhibited a relatively constant share over the historical period examined (1993–2005), the relationship with national aircraft registrations was selected as the preferred planning tool to forecast local aircraft ownership out to 2025. This resulted in an estimated average annual growth rate of approximately 1.3% over the entire forecast time horizon.

Historical based aircraft levels at the airport (for the years available) were then related to local aircraft ownership. Given this relationship, low and high forecasts for based aircraft were developed assuming, respectively, a constant and increasing share of projected local aircraft ownership counts. Further analysis then was undertaken by comparing these forecasts with the high and low forecasts from the 2002 master plan, as well as independent based aircraft projections shown in FAA's TAF and the department of transportation state airport system plan for the state where the airport is located. In all, seven different based aircraft forecasts were considered and a preferred forecast was developed from the range of based aircraft counts, including a final upward adjustment to account for the effects of the planned VLJ facility. The estimated average annual growth rate of based aircraft for the preferred forecast was approximately 3.7% over the entire forecast period.

As mentioned earlier, once the based aircraft forecast was completed, it provided the primary basis on which to project other measures. The draft report did not contain substantive discussion or numerical estimates of forecast uncertainty; however, such considerations may be forthcoming as the analysis is refined and updated in the future.

Regional Airport System Plan

The agency responsible for aviation systems planning in a large eastern metropolitan area prepared a system plan that was completed in 2001. As a result of 9-11 and other events an update was prepared in 2005, which was revised further in 2006. The update plan identifies capacity needs out to 2030 for 30 public and private aviation facilities throughout the region, including three commercial airports; of these 30 facilities, 14 are eligible for federal subsidies, whereas the others must rely on state or private investments.

The initial system plan focused primarily on consideration of general aviation activity at the facilities; conservative estimates of commercial activity (operations and enplanements) were taken directly from the commercial airports' own master plans. General aviation activity for the region as a whole was tied to regional population and employment forecasts, in which the agency had a long history of being able to make reasonable projections. These forecasts were then broken out to individual facilities based on local variations in the population and employment projections.

For the 2005 update, it was found that although increasing numbers of aircraft were based at the region's general aviation and reliever airports, operations per general aviation aircraft had declined since 2001, owing primarily to increased costs associated with general aviation flying and more restrictive flying rules imposed after 9-11. The 2005 forecast for general aviation operations used the same growth rate developed in the 2001 plan, but applied it to a reduced base of operations for 2005. Additional growth, however, was projected for general aviation jet operations owing to the anticipated introduction of VLJs and increases in corporate operations at some of the smaller suburban airports as the primary commercial airport in the region becomes more congested. This upsurge in demand at suburban facilities would be further induced by significant projected increases in population and employment away from the primary city center of the metropolitan area.

CHAPTER FOUR

EVALUATING FORECASTS

ASSESSING UNCERTAINTY IN FORECASTS

An often-neglected aspect of forecasting is the uncertainty associated with the forecasts themselves. Most often, forecasts are presented only as point estimates; for example, total annual enplanements are projected to be 500,000 in 2015. To deal with the likelihood that enplanements may well not be exactly 500,000, many forecasters also present alternative estimates that are based on differing assumptions about external factors thought to affect the forecast.

With market share forecasting, a different share factor may be used to relate local enplanements to the regional, state, or national forecast being used to drive the analysis, or the projected growth rate of the external forecast itself may be adjusted. A similar technique is often used with econometric model forecasts shown in airport master plans—differing future values of the explanatory variables are assumed, which in turn results in a different set of estimates of future activity using the derived equation. These alternative forecasts are often presented as high/low or optimistic/pessimistic scenarios. A common variant of this approach is to use a number of different forecasting *methods* and then present the range of results to show where the baseline forecast fits into the mix.

Providing a range of alternative forecasts is the most frequently used method to assess uncertainty in future activity levels. It is important, however, to recognize that there may be other sources of uncertainty owing to the statistical methods employed. These include:

1. Specification error—this occurs if the wrong functional form has been used, if one or more relevant independent variables have been excluded from the model, or if the structure of the relationship between dependent and independent variables changes over the time period in question.
2. Conditioning error—if the forecasted values of the independent variables are inaccurate this can lead to inaccurate forecasts of the dependent variable.
3. Sampling error—because the coefficient estimates of the independent variables are just that—estimates—the reliability with which they are estimated can affect the reliability of the forecasts of the dependent variable.
4. Random error—the modeling equation includes a random error term whose mean is zero; however, forecasts from the equation implicitly assume that all future values of the error term are exactly zero, which may not be true.

These sources of uncertainty are most often analyzed in the context of econometric modeling, and there are standard statistical methods available to assess these issues (Kennedy 2003). However, the same sources of uncertainty arise in shares forecasting, time series models, and simulation models as well. Chatfield (2001) provides an overview of computing prediction intervals for forecasts.

Another approach to addressing uncertainty in econometric models is through a formal risk analysis, where all the causal factors and relationships are allowed to vary simultaneously according to estimated probabilities, resulting in a range of likely forecast values. A paper by Lewis (1995) reported that such an approach was used successfully to forecast outcomes of a proposed capacity expansion at Vancouver International Airport in the early 1990s.

ASSESSING FORECAST ACCURACY

Although forecast accuracy would appear to be a primary criterion when evaluating forecasts and forecast methods, in practice this can only be done after the fact (ex post), when the values can actually be measured and compared with their forecast estimates. For forecasts with long time horizons, this means that their accuracy cannot be fully assessed for many years. In practice, very few airport activity forecasts are ever subjected to an ex post analysis of their prediction accuracy.

There are many different ways of measuring forecast accuracy once the future forecasted values are known. Some commonly used metrics include:

- Mean absolute deviation—the mean of the absolute values of the forecast "errors" (the difference between the forecasts and the actual values).
- Root mean squared error—the square root of the mean of the squared forecast errors. This measure implicitly weights large errors more heavily than small ones.
- Mean absolute percentage error—the mean of the absolute values of the percentage forecast errors.

In addition, there are other methods that involve regression estimates of actual changes in the variable being forecast against the predicted changes.

Aside from being used to assess the accuracy of a given forecast, the metrics mentioned previously can also be used to compare one forecast with another. However, there are some pitfalls associated with doing so. First, one should account for any differing use of historical data; if one model was constructed using more (or better) historical data than another, it would be unfair to compare the models directly based on the above metrics. Or, if one model estimates only annual projections whereas the other estimates on a quarterly basis, it would be difficult to directly compare their accuracy.

In addition to simply comparing their forecast accuracy, it may be useful in some situations to compare two models using other statistical tests. In the common situation where one is comparing two models that are "non-nested" (i.e., one is not just a statistical "special case" of the other), there are a number of test statistics that can be used to help one choose among competing models (Greene 1993).

ISSUES OF OPTIMISM BIAS

Medium- and long-term aviation forecasts are usually required for large aviation infrastructure projects, which are inherently risky owing to long planning horizons and the significant financial investments typically required. As noted earlier, the vast majority of airport aviation forecasts in the United States are conducted in support of airport master plans. In turn, these plans require FAA approvals to qualify for AIP funding grants, which can cover up to 95% of the costs of capital projects identified in the plans.

Both the funding process and the interests of the parties involved may contribute to a problem of optimism bias in airport forecasts. From a national perspective, the provisioning of a well-functioning air transportation system is a clear responsibility of FAA. The very existence of the AIP program is evidence that the federal government has a strong commitment to help airports improve, upgrade, and expand their infrastructure in support of the NAS. However, although the primary funding source for airport capital projects is the federal government, local airport sponsors hold the most detailed knowledge of the specific projects needed, and FAA relies on these sponsors to identify and oversee the capital projects that will best support development of the NAS. In this framework, it should not be surprising that the local authorities, who are in some respects competing with each other for limited AIP funding, may have an incentive to overstate future activity demand at their facilities to better justify their proposed capital projects.

This sort of situation is an example of a common "principal–agent" problem that arises in many business and government scenarios, where there is an information asymmetry among interested parties that leads to difficulties in decision making. The primary problem is how to get the agent (in this case the local airport sponsor) to act in the best interests of the principal (the federal government) to carry out the principal's ultimate goals, when the agent has an informational advantage.

The primary way in which FAA seeks to counter its informational disadvantage is through the issuance of guidance documents, requirements for master planning, and other rules that local sponsors must follow when applying for AIP grants. These efforts are intended to secure consistency across projects and to help identify those that are best suited for funding from limited AIP resources. Perhaps the most direct preventative measure to protect against optimism bias is the requirement that sponsors' five- and ten-year baseline forecasts must be within 10% and 15%, respectively, of FAA's TAF.

Although no other studies of optimism bias in forecasting airport activity in the United States were located, there have been many studies of potential biases in forecasting generally [see, e.g., Sanders and Ritzman (2001)]. As further evidence, a statistical study by Flyvbjerg et al. (2005) focused on 210 rail and road transportation infrastructure projects in 14 countries completed between 1969 and 1998. This study found that 90% of rail projects overestimated passenger traffic. The results for road projects were less one-sided, but still found an average forecast error of more than 20%.

Although a formal study of optimism bias in airport aviation activity forecasts is well beyond the scope of the present study, it may be useful for interested stakeholders to consider additional ways to provide incentives for airport sponsors to produce realistic activity forecasts.

COMPETING FORECASTS AND OPTIONS FOR RESOLUTION OF DIFFERENCES

As seen previously, there are a variety of methods available for forecasting airport aviation activity. Different methods can yield different results; even if the same method is used by two different forecasters, results will vary because each forecaster may use different data or a different model specification (e.g., a different set of explanatory variables in an econometric model or a different external forecast in a market share model).

The issue of reconciling differing airport activity forecasts is particularly relevant when airport sponsors must compare their forecasts with FAA's TAF as part of the master planning process. As noted earlier, when there are significant differences beyond the limits prescribed by FAA guidance, these differences must be resolved with the agency. The specific procedures that FAA may use to reconcile differences in these cases are beyond the scope of discussion appropriate for this study.

Nevertheless, the issue of reconciling different forecasts can be addressed in more general terms. There are a number of approaches available to try to resolve the differences. One is to critically analyze each forecast to assess which uses the better data sources, inputs, and methods that are best suited to the particular situation; perhaps one will uncover data or statistical error that would cast significant doubt on the reliability of the predictions. By doing so, it may be possible to determine that indeed one forecast should be preferred to another based on data reliability or methodological grounds.

Rather than look only at input and methodological features, another possibility is to assess the predicted values themselves from competing forecasts. In cases where there is significant domain knowledge, it may well be more important to focus on how reasonable the predictions appear to be according to expert opinions in the field. If a forecast does not pass a "common sense" test among knowledgeable experts, it may not make sense to rely on it no matter how clean the data or how sophisticated the methodology appears to be. There is a substantial amount of literature on using domain knowledge to make judgmental adjustments to statistical forecasts [Sanders and Ritzman (2001) provide a good overview.] Although it is likely that the use of appropriate domain knowledge in airport activity forecasting could provide some benefits, those benefits would have to be weighed against the potential biases that might be introduced (e.g., the optimism bias discussed earlier).

A third possible approach is to critically examine competing forecasts and then attempt to combine them into a composite forecast; in principle, combining can reduce errors that may arise from bad data or faulty assumptions. Armstrong (2001c) argues strongly for combining forecasts when it is uncertain which forecasting method is most accurate, when there are high levels of forecast uncertainty, and when it is important to avoid large errors. In the context of airport activity forecasting, all three of these conditions are likely to apply, especially when making long-term forecasts. Armstrong also argues that formal procedures should be used to combine forecasts (such as using simple average weighting schemes) rather than making judgmental assessments of appropriate weights. He presents evidence from an analysis of 30 different combined forecast studies and found that forecast errors were reduced by an average of 12.5% using average weights.

CHAPTER FIVE

CONCLUSIONS AND SUGGESTIONS FOR RESEARCH

Forecasts of airport aviation activity have become an integral part of transportation planning in the United States. The type and method of forecasting can depend importantly on the purpose for which the forecast is being made, and distinctions between short-term/long-term and constrained/unconstrained demand can lead to significant differences in the associated activity forecasts that are produced. Such differences, however, do not necessarily mean that one is more correct than another.

In practice, most airport and regional and state efforts use fairly simple methods to produce forecasts. Data availability and budget constraints often dictate what forecasting techniques are employed. Another factor that affects how airport forecasts in the United States are prepared is the set of rules and guidelines for preparing airport master and system plans set down by FAA.

The primary methods used to produce airport aviation activity forecasts reflect these constraints. The market share method is a top-down approach, where it is assumed that activity at a particular airport is related to growth in some aggregate external measure (typically a regional, state, or national aviation growth rate). Some studies that use this method look only at the very recent past and use a small number of historical data points to establish the numerical relationship between airport activity and the selected external factor. Although such an approach is not generally recommended, it must be recognized that the market share method is used extensively in aviation forecasting, particularly when the historical data are suspect or when past history does not correlate well with other observable factors. Additional research would be warranted on the reliability of historical activity data and on how to gather data more effectively in the future. This issue is of particular concern at smaller nontowered airports.

In cases where reliable historical data can be gathered, econometric modeling has been an effective tool for generating forecasts of airport activity. Although econometric modeling is potentially a very sound and effective method, there are many ways in which the specific model that is estimated can go wrong. A more detailed study of the many airport forecasts produced with this method could be undertaken to identify the most common sorts of statistical or data problems that affect aviation forecasts, which in turn would provide some useful guidance for future modeling efforts.

Another available technique is time series extrapolation. Simple trend analysis, such as year-over-year or month-over-month extrapolation, can be a useful approach, particularly for short-term forecasts. More sophisticated time series methods such as exponential smoothing and Box–Jenkins analysis have not been used often in aviation forecasting. However, for short-term forecasts where there are complex time relationships relating to seasonality and trend, these time series methods may be valuable. Further study that extends the analysis of Pitfield (1993) to allow direct comparison of out-of-sample, time series predictions with those from a conventional econometric model of aviation activity could be valuable in assessing the conditions under which one method might be preferred to another.

Assessing forecast uncertainty and accuracy are two separate but related issues that are often neglected in airport activity forecasting efforts. With regard to uncertainty, most studies provide only point estimates of forecasted values, although it is common to also present alternative “high” and “low” estimates. Although this can provide a reasonable range of estimates, there are additional sources of uncertainty related to the statistical properties of the models employed that are often neglected entirely. It is frequently argued that having access to reliable data is more important than the specific statistical model that is employed; however, further investigation into the significance of model-related statistical uncertainty for aviation forecasting efforts would be warranted.

Finally, research on just how well aviation forecasts project future airport activity would also be warranted; optimism bias and the possibilities for combining competing forecasts are important topics that to date have not been sufficiently investigated. Such research could be carried out by surveying past forecasts and comparing their projections with currently observed activity levels. These issues are particularly relevant for long-term aviation forecasts that are used to support major decisions regarding capital investments and potentially large expenditures of public funds.

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ACRONYMS

AIP	Airport Improvement Program
ARIMA	Autoregressive Integrated Moving Average
ARTCC	Air Route Traffic Control Center
ATADS	Air Traffic Activity Data System
CLR	Classical Linear Regression
ETMS	Enhanced Traffic Management System
FAR	Federal Aviation Regulations
FBO	Fixed-base operator
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
NAS	National Airspace System
NPIAS	National Plan of Integrated Airport Systems
OAG	Official Airline Guide
OPSNET	Operational Network
TAF	Terminal area forecast
VFR	Visual flight rules
VLJ	Very light jet

Abbreviations used without definitions in TRB publications:

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	Air Transport Association
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
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
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
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