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Economic Counsel to the Transportation Industry

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Using Disaggregated Socioeconomic Data in Air Passenger Demand Studies

Final Report

Appendix B: Airport Industry Use of Socioeconomic Data for Air Passenger Demand Studies

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B.1 Introduction

This appendix extends the findings of the literature review documented in Appendix A. That appendix reviewed studies, papers, and reports that examined the general relationships between socioeconomic factors and air travel demand. This appendix complements the material presented in Appendix A by reviewing studies and airport master plans that have developed models and forecasts for specific airports or airport systems. A particular emphasis is placed on identifying how disaggregate socioeconomic data have been used for these studies. This appendix also documents disaggregate and aggregate data sources that have been or could be used to understand how air passenger demand varies with socioeconomic factors. Although the application of some of these data sources to air passenger demand studies has been limited, some of these data were valuable resources for the research undertaken in the course of the project, and ultimately may contribute to the forecasting techniques that result from the research described in this report. The material contained in this appendix was originally submitted to the ACRP Project Panel as Technical Memorandum #2.

Among the objectives of the current study is the development of guidelines and recommendations on when and how airports can use disaggregated socioeconomic data in their planning and forecasting models. These guidelines should provide a balance between the modeling and data requirements for potential studies and the analysis and planning needs of the study users. To that end, the recommendations in the final report of the project address the data and technical requirements of different analysis techniques to help users decide when the benefits of more detailed data and more complex forms of analysis are justified. In many cases, this will assist airport users in deciding when it is beneficial for an airport to retain consultants to conduct more technical analyses rather than relying on in-house capabilities to conduct a less complex analysis.

Therefore, this appendix documents two separate but related activities. The first consisted of identifying and documenting the different disaggregated and aggregate data sources that have been or could be used to understand how air passenger demand varies with socioeconomic factors. The second activity involved a review, summary, and critique of how the airport industry currently makes use of socioeconomic data in air passenger demand studies as well as the implications for future air passenger demand studies.

The remainder of this appendix consists of three sections. The next section provides an overview and discussion of the different types of air passenger demand and socioeconomic data that have been or could be used in air passenger demand studies. Four types of data are covered: air passenger traffic data; national, state, regional, and local socioeconomic data; data from surveys of air travelers and households; and new sources of socioeconomic and travel data that are starting to become available but have thus far not been widely used for air travel demand studies.

The following section addresses how airports and other organizations involved in performing air travel demand studies or preparing forecasts of future growth in air travel demand at airports have made use of socioeconomic data in these studies. The section discusses the different types and purposes of air passenger demand studies and includes a review of a

representative sample of these various types of studies to identify and assess the current state of practice for the different types of studies.

The final section presents an analysis and critique of airport uses of socioeconomic data in air travel demand studies. Findings from the review of the current state of practice are used to identify implications for future air passenger demand studies and research gaps to be addressed in more detail in a subsequent project task. This discussion also serves to help frame the issues and questions that were addressed in the subsequent research undertaken in the project.

The bibliography for this appendix is presented in two parts. The first consists of citations for articles, reports and other documents reviewed or used in the research. The second part, presented as Attachment B-1, provides references for the airport planning and other airport or planning agency documents that were reviewed for the summaries presented in Section 3 of the appendix.

In addition there are two other attachments. Attachment B-2 contains an extended presentation of the recent Master Plan update for Portland International Airport, describing that report's innovative approaches to data development and forecasting. The third attachment examines the uses of socioeconomic data in the forecasting effort supporting the recent United Kingdom Airports Commission study of that nation's commercial airport system.

B.2 Sources of Air Passenger and Socioeconomic Data

The section documents sources of air passenger and socioeconomic data. These data will be explored in more detail in the research conducted in subsequent tasks of the project. Additional documentation of data sources will be included in the Guidebook (which is the principal deliverable of the research project), and will include the detailed data fields available in each data source, whether the data is publicly available, and how to access the data. In the case of data sources such as air passenger surveys, for which the specific content varies from survey to survey, the current documentation is based on a representative sample of these data sources. The size of this sample has been chosen to reflect the likely usefulness of the type of data for air passenger studies.

The review of sources of air passenger and socioeconomic data serves as a useful background resource for the next section that discusses the current state of practice of air passenger demand studies. That discussion makes frequent reference to different sources of air passenger and socioeconomic data. Thus, discussing these sources first helps make the subsequent discussion of the state of practice clearer.

The data reviewed represent a broad range of sources with different (and often complementary) properties. The data vary in terms of the degree of disaggregation of socioeconomic characteristics. They also include both free or low-cost data and more expensive commercial data. The discussion in the final section of this appendix addresses the tradeoffs that are faced by airport analysts when choosing between free or lower cost socioeconomic data and more costly sources that have been processed and organized to some degree by their commercial providers. When using data acquired from lower cost or free sources, in many cases airport analysts will have to devote some effort to preliminary data preparation and processing. Conversely, costlier data may arrive already pre-processed and organized into the categories or formats necessary for conducting the actual analysis.

a. Air Passenger Traffic Data

Since the objective of air passenger demand studies is to understand, and often model, the factors that influence the level of air passenger traffic at an airport or system of airports, it is obviously necessary to have data on the level and characteristics of the air passenger traffic, along with the factors that influence demand. However, the use of more disaggregated socioeconomic data in such studies also implies that the analysis will need to take a more disaggregated approach to measuring the air passenger traffic using the airport, since it is highly likely that air passenger activity in different market segments will have different growth rates and respond in different ways to changes in the socioeconomic factors that are determining the level of air passenger travel in each market segment and hence the overall level of air passenger activity.

Data about air passenger activity at individual airports, in individual travel markets and for the U.S. air transportation system as a whole is reported to the public by several U.S. government sources. These sources provide historical data on passenger enplanements and aircraft departures and arrivals, which are based on the passenger activity reports that are

required of U.S. air carriers on a monthly basis and on Department of Transportation ticket samples. These data are then reported to the public by the Department of Transportation's Bureau of Transportation Statistics.

These data for air passenger activity are part of the BTS TranStats data reporting system, which contains activity and cost data for most U.S. transportation modes. The aviation data within TranStats is described by BTS online in its aviation data source summary page (http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/airline_information/sources/index.html). These include T-100 passenger market and flight segment data (including enplaned passenger counts) for domestic and international activity, reported by U.S. carriers, and the DB1B Airline Origin and Destination Survey, based on a 10 percent ticket sample taken by reporting carriers, which reports passenger origin, destination, and other itinerary details. Detail about the contents and layout of these primary data sources for airport passenger activity will be provided in the Guidebook to be created later in this project. The data tables and data query tools available in TranStats permit the extraction of O-D passenger activity data for individual airport pairs, enabling a user to create detailed airport activity datasets, although because of the amount of data available, extracting data can be a complicated process. The data query tools in TranStats allow data to be downloaded for all airports within a state, from which data for specific airport pairs must be extracted by the user as an additional and non-trivial step.

Historical air passenger activity data is also reported by the FAA. As part of its Terminal Area Forecast (TAF), the FAA Office of Policy and Plans reports annual passenger enplanement data for individual commercial service airports, although to date these reports do not include information about passenger destinations. The TAF also reports forecasts of future annual passenger enplanements at each commercial service airport. The FAA's annual Aerospace Forecast document, also produced by the FAA Office of Policy and Plans, reports annual passenger enplanement and other data as a national aggregate series. The Aerospace Forecast also reports both historical passenger activity and passenger activity forecasts, again at an annual and national level of aggregation.

Ticket prices – passenger fares – are frequently an essential data element for analyzing air passenger demand. Important sources for these data are the ticket value databases maintained by BTS. These data and their collection are in many respects a holdover from the economically regulated passenger air travel marketplace prior to airline deregulation in 1978. The current databases originated from the 10 percent sampling of airline tickets required of domestic airlines by the Department of Transportation and a predecessor agency, the Civil Aeronautics Board (CAB). According to this requirement, passenger itinerary, fare class, dollar fare, and other ticket and airline data were collected from 10 percent of domestic airline passenger tickets. This data set was called the O&D Data Bank 1A Ticket Dollar Value O&D, or DB1A.

This 10 percent ticket sample has continued, but the reporting based on it was revised in 1998, with the DB1A replaced by the Airline Origin and Destination (O&D) Survey, or DB1B database. This database, which can be accessed in the BTS TranStats system, provides quarterly data on domestic air passenger itineraries between airports, including directional characteristics, flight distance, market fares, and the airline reporting the collected ticket. A similar data set that also includes international itineraries has access restrictions, and is available after application to the BTS.

The Department of Transportation's T-100 databases, collected from airline monthly filings of Form 41 Schedule T-100 reports, also provide data on domestic and international air passenger travel in the U.S. These passenger enplanement data are reported on a segment basis (from airport A to airport B, non-stop) and on a market basis (which includes travel from airport A to airport C, via airport B, if there is no change of aircraft required to complete the itinerary).

International air travel statistics for the U.S. are available, at a cost, from the U.S. Department of Commerce Office of Travel and Tourism Industries (OTTI), a division of the International Trade Administration (ITA).¹ These statistics are the product of the U.S. International Air Travel Statistics Program, referred to as I-92 data, and are based on data gathered from the Immigration and Naturalization Service's I-92 form. The data include arrival and departure estimates, detailed by country and port of debarkation and embarkation, for U.S. citizens and non-citizens and for U.S. flag and foreign flag carriers, scheduled and chartered flights.²

Finally, monthly international arrivals data is reported by OTTI as part of a collaborative program between the National Travel and Tourism Office and Customs and Border Protection (CBP) from the Department of Homeland Security, based on data collected through the CBP's I-94 form. These data include total monthly arrivals to the U.S., arrivals from specific visitor-generating countries, and arrivals at specific U.S. gateway airports. Breakdowns between international arrivals by business travelers and leisure travelers are also reported.

There are several commercial providers of data on flight and passenger activity. One category of such firms re-package and sell the airline data reported to the U.S. Department of Transportation, typically on a subscription basis. Although the source data is available at no cost from the U.S. DOT, the firms add value by summarizing the data, providing software to easily analyze and generate reports from the data, extracting data for a specific airport or group of airports, weighting the data to correct for missing data, or combining data in ways that would be difficult or time-consuming to do with the source data. These services may also include other data from other government databases or commercial data such as airline schedules. The re-packaged data is typically distributed on CD-ROM or available to subscribers for download or access online. Examples of firms providing these services include Data Base Products, Inc., Diio, LLC, and The Boyd Group. While subscriptions to these services can run to many thousand dollars per year, depending on the particular data included in the subscription, the ease of use often justifies the cost. An organization could easily spend as much or more in staff time downloading, extracting, and manipulating the same data from the TranStats website, and would still not have all the value-added features of the services.

¹ International travel and tourism is researched by the Department of Commerce because from an economic perspective, travel by non-U.S. citizens to the U.S. is an export, and travel by U.S. citizens to international destinations is an import.

² A related survey-based OTTI data collection and reporting project is the *In-Flight Survey of International Air Travelers*. This is an on-going program to gather data about air passenger travelers in U.S.-overseas and U.S.-Mexican markets. Survey data is collected on passenger trip planning, travel patterns, demographics and spending for populations traveling in these separate markets for both non-U.S. residents traveling to the U.S. and U.S. residents traveling from the U.S. Program reports and statistics are available at a cost from OTTI. Additional details of this program are discussed below in the report section on passenger surveys.

A second category of commercial firms provide more detailed passenger data that are obtained from the flight reservation process. These data are typically highly disaggregated, often at the level of individual transactions (although de-identified to protect the privacy of the passengers). These sources are usually associated with companies that are involved with the issuance and distribution of airline tickets, known as Global Distribution Systems (GDS). These firms had their origins in the years immediately following World War II, when electro-mechanical reservations management systems were developed by engineers and analysts at American Airlines (Santiago, 2015). This pioneering device was known as the Reservisor (Eklund, 1994). Improvements in these machines followed the rapid development of the computing industry in the postwar years. With their adoption by other airlines, more sophisticated airline computer reservation systems (CRS) began to be developed in the early 1960's, as the ability of data processing tools to successfully manage growing passenger demand was combined with the increasing ability to store detailed passenger and itinerary records for later analysis. The introduction of the Internet and web browsers in the mid-1990's led to the development of web-based CRS and stimulated the rapid growth and improvement of the ticket inventory management and record keeping services that GDS companies provided to airlines. These developments also gave individual travelers and businesses the ability to compare airfares and make reservations online with no reliance on intermediaries such as travel agents or airline ticket sales locations.

Along with performing ticket distribution services for airlines and travel services, these GDS companies now also provide historical data on passenger itineraries and ticket bookings to airlines, airports, and their consultants, usually at considerable cost. Use of a common data format, the marketing information data tapes (MIDT) format, allows data from different companies to be combined. These ticketing and itinerary data include such elements as

- The cities and countries involved in a flight segment
- The number of passengers
- Ticket transaction times and dates
- Flight information
- Service class booked.

Fare data is not reported in these sources, and no information about passenger characteristics is reported. There are several sources of commercially provided passenger activity data, including the Airlines Reporting Corporation (ARC), Amadeus, Sabre, IATA and others. Any individual provider may not have access to all passenger volume in a given market, so analysts using the data must adjust available data to estimate complete market conditions or data. Some vendors providing MIDT booking data provide some ticket pricing estimates in individual markets by service class. As noted above, these data are available at a cost, often considerable cost.

Two other databases providing similar passenger itinerary data are the Billing and Settlement Plan (BSP), run by the International Air Transport Association (IATA), and the Area Settlement Plan (ASP), which is run by ARC. BSP and ASP data are based on ticket settlements, and therefore accounts for tickets sold, adjusted for refunds and exchanges that may occur after the original ticket booking. BSP is primarily a clearinghouse for transferring funds between

travel agents and airlines, and BSP data will also include fare data (rather than estimates, as is the case for MIDT data) sorted into service class categories. BSP is an international clearing house, while the ASP is restricted to US itineraries. ASP is also a clearinghouse, linking US travel agencies and corporate travel departments with airlines. ASP also includes actual fare data, sorted into service classes (Kayloe, 2014). However, like the MIDT data, BSP and ASP do not provide any data or information about passenger characteristics.

b. National, State, Regional, and Local Socioeconomic Data

In this section, an overview of sources for socioeconomic data is presented. Greater detail about accessing and using the more pertinent of these data is provided elsewhere in the final report and subsequent appendices.

Aggregate national socioeconomic data is reported by a variety of federal sources, and covers such areas as the population, the level of gross national product (GNP), changes in price indices, employment levels and rates, and levels of economic activity in specific sectors of the economy. These data are reported on an annual, quarterly and sometimes monthly basis. These aggregate data are compiled in specific government agencies and departments – for example, data for employment statistics, household incomes and for price indices are gathered by the Department of Labor Bureau of Labor Statistics, GDP data are gathered by the Department of Commerce Bureau of Economic Analysis, and population data is developed by the Bureau of the Census – but historical values for these aggregate measures are tabulated and reported by several government organizations with economic responsibilities, such as the President’s Council of Economic Advisors and the Board of Governors of the Federal Reserve. These historical data series are therefore readily available at the websites of these and other agencies.

The agencies that originate data for these socioeconomic variables also report the data for regional, demographic and socioeconomic subsections of the country. These federally provided data are free to the user. In recent years, the level of detail reported by these federal data sources has grown and expanded as the capabilities of the internet to host rich databases have improved. The availability of a greater breadth of socioeconomic data has made the processes that must be used to identify and use these more refined datasets more complicated, but the webpages provide explanatory support and are intended to be user-friendly. Important examples of the categories of data that are available, and their sources, include

- **Population:** The Bureau of the Census 2010 Census Tool is an interactive tool that allows the user to examine and extract data on population size and characteristics (age, ethnicity and household composition) at the county or parish level for all states. The provision of these data at the local level makes the Bureau of the Census a fundamental source of many categories of disaggregated socioeconomic data, especially demographic data. Interactive Population Maps and other data tools make it possible to examine relatively complex population dynamics, such as migration patterns across counties in the U.S. These capabilities represent the application of recently developed visualization tools to recently collected population and demographic data, which limits their availability to past Census data in many ways. The Bureau of the Census web pages also provide detailed instructions for users regarding data availability, data acquisition

and data interpretation. Bureau of the Census databases can be browsed and searched at <http://www.census.gov/data.html> and data that is developed from the most recent 2010 Census can be accessed at <http://www.census.gov/2010census/data/>.

- **Employment:** The Bureau of Labor Statistics (BLS) maintains an extensive online data base for employment and compensation for 100 industries at the national, state, county, and local (selected) levels. The BLS databases also report values and indexes for consumer and producer prices, as well as data on labor productivity, occupational trends, and consumer expenditure patterns. Like the demographic data available from the Bureau of the Census for population characteristics, the BLS data provides a detailed picture of labor market conditions in aggregate and by industry sectors. BLS data can be accessed at <http://www.bls.gov/data/>. Much of the BLS regional data is available at links related to each of the eight BLS Regional Offices, which can be found at <http://www.bls.gov/data/#regions>.
- **Economic Activity:** The Bureau of Economic Activity (BEA) develops and maintains data bases for GDP, personal income and personal consumption expenditures at the national, state, county and Metropolitan Statistical Area (MSA) levels. GDP estimates for individual industries are provided at the state level, beginning in the early 2000's. Explorations of these data can be fine-tuned and focused by the user and extracted using BEA's online interactive data tools. BEA's national, industry specific, international accounts and regional data can be accessed at <http://www.bea.gov/itable/index.cfm> with an additional set of pages devoted to regional economic data available at <http://www.bea.gov/regional/>.
- **Economic and Socioeconomic Data:** Another source of socioeconomic data is the Federal Reserve System. As the central bank of the United States, the Federal Reserve tracks socioeconomic data as part of its management and oversight of the nation's financial system. The Board of Governors of the Federal Reserve maintains databases on financial system economic data, and these data may be of limited use for air passenger demand studies. Each Federal Reserve regional bank, however, is a source for regional economic and demographic data at the state and MSA level. The map in Figure B-1 below shows the twelve Federal Reserve Districts. The website of the Federal Reserve Bank for each District (listed with links at <https://www.federalreserve.gov/otherfrb.htm>) includes a section on Research and Data where extensive data about the states and metropolitan areas within a District can be downloaded (although most of these data come from the data services of the Bureau of the Census, the BLS, or the BEA described above). While there is similar content in the pages of each District Bank, the websites are not identical from district to district. Finally, the Federal Reserve Bank of St. Louis maintains a uniquely comprehensive collection of socioeconomic data, the *Federal Reserve Economic Data*, or *FRED*. These data cover economic variables in the U.S. and the international economy, and include more than 350,000 individual data series. As with the other Federal data sites described here, FRED data can be downloaded, and it is also possible to create new data variables and

data graphs. Accessing FRED data requires the creation of a user account, which can be done at <https://research.stlouisfed.org/fred2/>

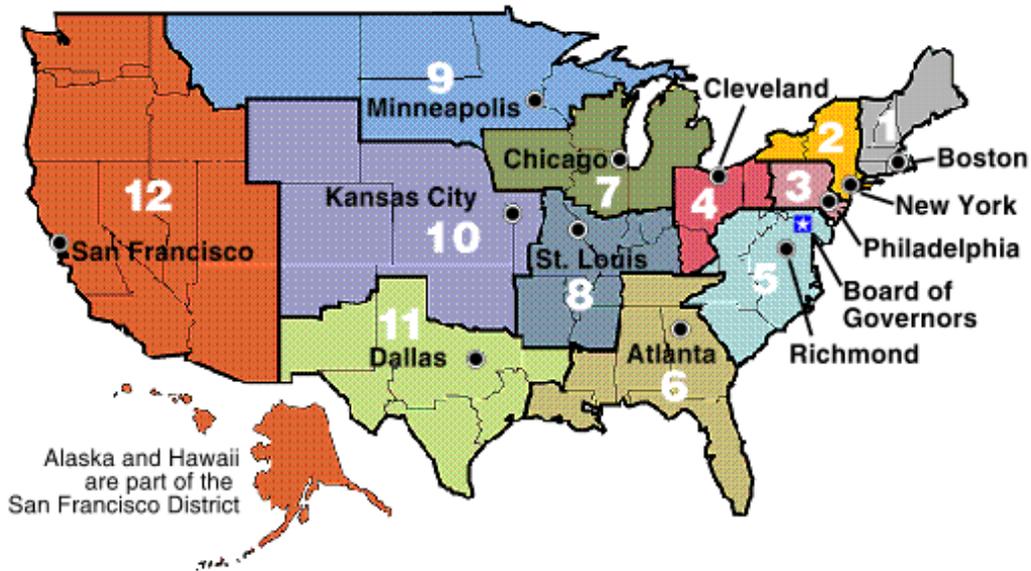


Figure B-1. Districts and District Banks of the Federal Reserve System

Figure B-1 shows the 12 Federal Reserve districts and their constituent states. (Because of its political importance at the time of the founding of the Federal Reserve System in 1913, the State of Missouri has two Federal Reserve District Banks, one in Kansas City and one in St. Louis.) These Federal sources for socioeconomic data are summarized in Table B-1.

Many of these socioeconomic data elements are also provided for individual states at demographic data pages hosted by the states themselves. These state level data pages typically, though not in all cases, report data taken from the federal data sources identified above, presenting the data from the perspective of the individual state. Some regional organizations, such as councils of governments and metropolitan planning organization areas also maintain online databases of regional information and data, including demographic and socioeconomic data, also typically but not always derived from federal data sources. These state and regional sources for socioeconomic data are reported in Tables B-2 and B-3 below.

While they do provide data at no cost, the federal, state and local data sources identified here can be cumbersome or difficult to use in some cases or for some users, depending on the complexity or specificity of the data of interest. However, there are commercial firms that provide access at a cost to these socioeconomic data, in what is often a more user-friendly format. These commercial providers also often provide projections of future values for some variables. Such projections of socioeconomic variables are necessary for developing forecasts of air passenger demand if these are based on models using historical relationships in these data.

Table B-1. Federal Agency Sources of Socioeconomic Data

Federal Agency	Socioeconomic Variables		Data Sources	Projections or Forecasts?	URLs
	Aggregate	Disaggregated			
Bureau of the Census (Department of Commerce)	population, real income, employment, GDP	population ranges, income ranges, ethnicities, geographic location (state and MSA)	Census, surveys	Population projections	http://www.census.gov/data.html
Bureau of Labor Statistics (Department of Labor)	employment, compensation, price indices	Aggregate data by regions, by state and by industry	business and personal surveys	Future employment and industries	http://www.bls.gov/data/ http://www.bls.gov/data/#regions
Bureau of Economic Analysis (Department of Commerce)	national, state and MSA total and per capita GDP, personal income, consumer spending	No	Other agencies and organizations	No	http://www.bea.gov/
Federal Reserve Board of Governors and 12 District Banks	National and regional population, per capita product, regional per capita personal income, employment (National data in FRED database)	No	Other agencies and organizations	No	http://www.federalreserve.gov/econresdata/default.htm http://www.federalreserve.gov/otherfrb.htm https://research.stlouisfed.org/fred2/

Table B-2. State Agency Sources of Socioeconomic Data

State	State Socioeconomic Data Source Agency	Website	Uses national sources other than census?	Uses local sources?	Conducts its own research or forecasting?
Alabama	Alabama State Data Center (University of Alabama)	http://cber.cba.ua.edu/asdc/	No	No	No
Alaska	Alaska Department of Labor and Workforce Development: Research and Analysis	http://laborstats.alaska.gov/	Yes	Yes	Yes
Arizona	Arizona State Data Center	https://population.az.gov/state-data-center	No	Yes	No
Arkansas	Arkansas Census Data (University of Arkansas)	http://iea.ualr.edu/arkansas-census-data.html	No	No	No
California	California Department of Finance - Demographic Research Unit	http://www.dof.ca.gov/research/demographic/dru/index.php	Yes	Yes	Yes
Colorado	Colorado State Demography Office	https://www.colorado.gov/pacific/dola/state-demography-office	Yes	Yes	Yes
Connecticut	Connecticut State Data Center (UCONN)	http://ctdata.org/	No	Yes	No
Delaware	The Delaware Census State Data Center	http://stateplanning.delaware.gov/census_data_center/	Yes	Yes	No
Florida	Florida Department of Economic Opportunity - Data Center	http://www.floridajobs.org/labor-market-information/data-center	Yes	Yes	No
Georgia	Governor's Office of Planning and Budget - Census Data	http://opb.georgia.gov/census-data	No	No	Yes
Hawaii	Department of Business, Economic Development & Tourism	http://census.hawaii.gov/	No	No	No

State	State Socioeconomic Data Source Agency	Website	Uses national sources other than census?	Uses local sources?	Conducts its own research or forecasting?
Idaho	Idaho Department of Labor	http://lmi.idaho.gov/census	No	No	No
Illinois	Illinois Data Center	https://data.illinois.gov/	No	Yes	No
Indiana	StatsIndiana (Indiana University)	http://www.stats.indiana.edu/	Yes	Yes	Yes
Iowa	Iowa State Data Center	http://www.iowadatacenter.org/	No	No	No
Kansas	Kansas State Library - Statewide Data	https://kslib.info/446/Statewide-Data	No	No	No
Kentucky	Kentucky State Data Center	http://www.ksdc.louisville.edu/	No	No	No
Louisiana	Louisiana State Census Data Center - Demographics and Census Geography	http://louisiana.gov/Explore/Demographics_and_Geography/	Yes	Yes	Yes
Maine	Maine Office of Policy and Management	http://www.maine.gov/economist/census/	No	Yes	Yes
Maryland	Maryland State Data Center	http://census.maryland.gov/	Yes	Yes	Yes
Massachusetts	University of Massachusetts Donahue Center	http://www.massbenchmarks.org/statedata/data.htm	No	Yes	No
Michigan	Michigan Department of Technology, Management and Budget	http://www.michigan.gov/cgi/0,1607,7-158-54534--,00.html	No	Yes	No
Minnesota	Minnesota State Demographic Center	http://mn.gov/admin/demography/data-by-topic/population-data/2010-decennial-census/index.jsp	No	No	Yes
Mississippi	The State Data Center of Mississippi (University of Mississippi)	http://www.olemiss.edu/depts/sdc/	No	No	No
Missouri	Missouri Census Data Center	http://census.missouri.edu/	Yes	No	No

State	State Socioeconomic Data Source Agency	Website	Uses national sources other than census?	Uses local sources?	Conducts its own research or forecasting?
Montana	Montana Census and Economic Information Center	http://ceic.mt.gov/	Yes	No	Yes
Nebraska	Nebraska Databook	http://www.neded.org/business/data-a-research	Yes	Yes	No
Nevada	Nevada State Data Center	http://nsla.nv.gov/Library/StateDataCenter/Nevada_State_Data_Center/	No	No	Yes
New Hampshire	New Hampshire State Data Center	http://www.nh.gov/oep/data-center/	No	Yes	Yes
New Jersey	Department of Labor and Workforce Development, New Jersey State Data Center	http://lwd.dol.state.nj.us/labor/lpa/content/njsdc_index.html	No	Yes	Yes
New Mexico	UNM Bureau of Business and Economic Research	http://bber.unm.edu/bber_data.html	Yes	Yes	Yes
New York	New York State Data Center	http://labor.ny.gov/nys-data-center/index.shtm	No	Yes	Unknown
North Carolina	North Carolina State Data Center	http://www.osbm.nc.gov/facts-figures/state-data-center	No	Yes	No
North Dakota	North Dakota Census Office	http://www.commerce.nd.gov/census/Demographics/	No	No	No
Ohio	BGSU Center for Family and Demographic Research	http://www.bgsu.edu/content/bgsu/en/arts-and-sciences/center-for-family-demographic-research/help-resources-tools/ohio-state-data-center.html	No	Yes	Yes
Oklahoma	Oklahoma Data	https://data.ok.gov/	No	Yes	
Oregon	Oregon Census State Data Center	https://www.pdx.edu/prc/oregon-census-state-data-center	Yes	Yes	Yes
Pennsylvania	Pennsylvania State Data Center	https://pasdc.hbg.psu.edu/Default.aspx	Yes	Yes	Yes

State	State Socioeconomic Data Source Agency	Website	Uses national sources other than census?	Uses local sources?	Conducts its own research or forecasting?
Rhode Island	Rhode Island, Division of Planning, Rhode Island State Data Center	http://www.planning.ri.gov/geodeminfo/data/	Yes	No	Yes
South Carolina	SCIWAY	http://www.sciway.net/statistics/	Yes	Yes	No
South Dakota	South Dakota Labor Market Information Center	http://dlr.sd.gov/lmic/menu_demographics.aspx	No	Yes	No
Tennessee	Tennessee State Data Center	http://tndata.utk.edu/sdcdemographics.htm	Yes	Yes	Unknown
Texas	Texas State Data Center	http://osd.texas.gov/	No	No	Yes
Utah	Utah Demographics and Statistics	http://governor.utah.gov/DEA/sdc.html	No	No	No
Vermont	Vermont State Data Center	http://www.uvm.edu/crs/sdc/	Yes	Yes	No
Virginia	Commonwealth Data Point	http://data.virginia.gov/	No	Yes	No
Washington	Washington Data	https://data.wa.gov/	No	Yes	No
Washington D.C.	Washington D.C. Office of Planning - DC Data	http://planning.dc.gov/page/dc-data	No	Yes	No
West Virginia	West Virginia State GIS Data Clearinghouse	http://wvgis.wvu.edu/data/data.php	No	Yes	No
Wisconsin	Wisconsin Demographic Services Center	http://doa.wi.gov/Divisions/Intergovernmental-Relations/Demographic-Services-Center	No	No	Yes
Wyoming	Wyoming Department of Administration and Information	http://eadiv.state.wy.us/demog_data/demographic.html	No	No	Yes

Table B-3. Council of Governments and Metropolitan Planning Organization Sources of Regional Socioeconomic Data

Council of Governments or Metropolitan Planning Organization	Largest City	State(s)	Socioeconomic Data Source(s) Available	Website	Conducts its own research or forecasting?
Atlanta Regional Commission	Atlanta	GA	ARC Info Center	http://www.atlantaregional.com/info-center/arc-region	Yes
Baltimore Metropolitan Council	Baltimore	MD	BMC Maps and Data	http://www.baltometro.org/information-center/maps-and-data	Yes
Boston Region MPO	Boston	MA	Boston Region MPO Data Catalog	http://www.bostonmpo.org/data_catalog	No
Chicago Metropolitan Agency for Planning	Chicago	IL	CMAP Demographic Data	http://www.cmap.illinois.gov/data/demographics	No
North Central Texas COG	Dallas	TX	NCTCOG Regional Data Center	http://rdc.nctcog.org/Index.aspx	Unknown
Denver Regional COG	Denver	CO	DRCOG Data, Maps, and Modeling	https://drcog.org/services-and-resources/data-maps-and-modeling	Yes
South East Michigan COG	Detroit	MI	SEMCOG Data and Maps	http://www.semcoog.org/Data-and-Maps	Yes
South East Texas Regional Planning Commission	Houston	TX	SETRPC Information & Data	http://www.setrpc.org/ter/index.php?option=com_content&view=article&id=48&Itemid=63	No
Southern California Association of Governments	Los Angeles	CA	SCAG Data Library	http://gisdata.scag.ca.gov/Pages/SocioEconomicLibrary.aspx	No
Miami-Dade MPO	Miami	FL	Miami-Dade MPO Facts and Trends	http://miamidademppo.org/mdcctft/index.html	No
Metro Council	Minneapolis	MN	Metro Council Data	http://www.metrocouncil.org/Data-and-Maps/Data.aspx	Yes

Council of Governments or Metropolitan Planning Organization	Largest City	State(s)	Socioeconomic Data Source(s) Available	Website	Conducts its own research or forecasting?
New York MTC	New York	CT/NJ/ NY	New York MTC Regional Demographics	http://www.nymtc.org/data_services/RD.html	Yes
North Jersey Transportation Planning Authority	Newark	NJ	NJTPA Demographics	http://www.njtpa.org/data-maps/demographics.aspx	Yes
Delaware Valley Regional Planning Commission	Philadelphia	PA/NJ	DVRPC Data Products	http://www.dvrpc.org/asp/DataBulletins/	Yes
Maricopa Association of Governments	Phoenix	AZ	MAG Regional Data Center	http://datacenter.azmag.gov/	Yes
Southwestern Pennsylvania Commission	Pittsburgh	PA	SPC Data Library	http://www.spcregion.org/data_datalib.shtml	Yes
San Diego Association of Governments	San Diego	CA	SANDAG Demographics and Other Data	http://www.sandag.org/index.asp?classid=26&fuseaction=home.classhome	Yes
San Francisco Bay Area MTC	San Francisco	CA	MTC Maps & Data	http://www.mtc.ca.gov/maps_and_data/	No
Puget Sound Regional Council	Seattle	WA	PSRC Data	http://www.psrc.org/data	Yes
East-West Gateway COG	St. Louis	MO	EW Gateway Data Center	http://www.ewgateway.org/DataCenter/datacenter.htm	No
Metropolitan Washington COG	Washington, DC	DC/MD/ VA	MWCOG Modeling Data and Resources	https://www.mwcog.org/transportation/activities/models/data.asp	No

A widely-used commercial private provider of socioeconomic data is Woods & Poole Economics, Inc., based in Washington, D.C. Woods & Poole provides historical data and future projections for population, income, employment, retail sales and households for States, regions, Metropolitan and Micropolitan Statistical Areas, and the nation as a whole. These data are downloadable and are provided at a cost to the user.³

The Woods & Poole socioeconomic data are reported with several distributional details, such as area population by age cohort, gender, or ethnicity, the numbers of area households within a span of income ranges, area employment by industry or sector, and others. They describe their county level data in the following way: “Comprehensive data and projections 1970 to 2050. More than 900 variables including population, income, employment, retail sales, and households. Available for every county, state, and metropolitan statistical area.” (<https://www.woodsandpoole.com/pdfs/DP15.pdf>).

c. Airport Air Passenger Surveys

Airports, metropolitan planning organizations and other agencies undertake air passenger surveys periodically for a variety of reasons. These surveys assemble data on the characteristics of air passengers using a specific airport or set of airports. In addition to gathering information about the air travelers using the airport, these surveys may also collect information about those accompanying air passengers to the airport or meeting them on arrival. The data obtained from these surveys is inherently disaggregated, at the level of individual air passengers or air parties, although typically survey data is reported in more aggregated form. Techniques for undertaking such surveys and some the issues involved have been addressed by the earlier Airport Cooperative Research Program (ACRP) Report 26 *Guidebook for Conducting Airport User Surveys* (ACRP, 2009a). ACRP Report 26 covers a range of airport user surveys, not just surveys of air passengers.

Air passenger surveys are generally administered in one of two ways, either by interviewing air travelers or by asking air travelers to complete a survey questionnaire themselves. The latter approach requires less survey field staff to administer, and therefore will often obtain a larger sample or be less costly to perform. Conversely, the interview approach has the advantage that the interviewer can clarify questions if the respondents are not clear on what is being asked. The interviewee can also ask respondents follow-up questions if their responses are unclear or seem implausible. The use of pre-programmed questions on an electronic device, such as a tablet computer, also allows for more complex questionnaire design and eliminates the data entry needed to process hand-written survey forms.

Air passenger survey sample sizes can vary from a few hundred to many thousand responses. Larger sample sizes provide more representative results and allow greater coverage of different air travel markets, times of day, and days of the week. Larger sample sizes also allow a more granular analysis into how traveler characteristics vary across different markets, trip purpose, ground trip ends, and other trip characteristics.

³ Details on Woods & Poole data and costs are reported at <https://www.woodsandpoole.com/>. The Woods & Poole webpages include examples from data packages that illustrate the range of socioeconomic data elements included in their products, including projections taking these elements into future years.

One important air passenger survey is the Survey of International Air Travelers undertaken annually by the Office of Travel & Tourism Industries (OTTI) of the U.S. Department of Commerce (<http://travel.trade.gov/research/programs/ifs/>). This survey provides a large sample of both outbound U.S. residents and inbound foreign visitors traveling between the U.S. and overseas countries (i.e., excluding Canada and, until recently, Mexico). The survey collects detailed trip purpose information and the number of air trips to/from the U.S. by the respondent in the prior 12 months (and until 2012 the prior five years), as well as a range of socioeconomic data. The major value of this survey lies in the fact that it has been performed using a consistent survey instrument every year since 1983. Therefore, it provides a unique resource to study how international air travel propensity and air traveler characteristics have changed over time.

Survey Purposes

Air passenger surveys are often conducted to support a specific planning study, such as an airport master plan update, an airport ground transportation study, or a regional airport system planning study. Therefore, the questions asked and the level of detail with which specific issues are addressed often vary with the purpose of the survey. In some cases, airports or other organizations perform surveys on a regular basis to monitor changes in the composition of the passenger traffic using the airport over time. Many airports undertake air passenger surveys on a regular basis, in some cases several times a year, to monitor passenger satisfaction with the airport facilities and services. Although these surveys primarily focus on passenger satisfaction and concerns, they also typically collect some data on passenger characteristics.

The majority of airport air passenger surveys are not usually undertaken specifically to support air travel demand studies. However, air traveler characteristics collected by these surveys can provide useful information for air travel demand applications (this will be explored in greater detail in subsequent tasks). There are, however, two notable applications of air travel demand studies in which air passenger survey data is typically collected. The first application includes airport leakage or air service development studies. These studies typically conduct air passenger surveys to identify the distribution of air traveler ground trip origins or destinations in the region served by the airport and other traveler characteristics. The second application includes airport demand allocation studies. These studies, which are conducted in regions served by multiple airports offering commercial air service, are interested in the distribution of air traveler ground trip ends in the region as well as which travelers use which airports. The development of a formal airport demand allocation model typically includes a component that models the choice of airport ground access and egress mode as well as the choice of airport, since airport choice is influenced by airport accessibility as well as the air services available at the different airports. Thus an air passenger survey to support such studies will typically collect data on air passenger ground access or egress travel as well as air party characteristics and details of the air trip being made.

Another reason why air passenger surveys are also undertaken at airports is to assemble data on visitor spending for use in airport economic impact studies, as discussed in ACRP Synthesis 7 *Airport Economic Impact Methods and Models* (ACRP, 2008b) and ACRP Report 132 *The Role of U.S. Airports in the National Economy* (ACRP, 2015c).

Unlike most airport air passenger surveys, the OTTI Survey of International Air Travelers is primarily performed to provide data in support of tourism development and promotion, as well as to quantify the economic contribution of foreign visitor spending, although it also provides valuable data on overseas travel by U.S. residents. Similarly air passenger surveys undertaken in support of airport economic impact studies have a primary focus on visitor spending, although they will typically also collect data on other traveler characteristics. Although these surveys may not collect any data on travel by local area residents, they may be a valuable complement to data from household travel surveys, since they explicitly cover visitor trips, which are usually not addressed by household travel surveys.

Survey Questions and Data Elements

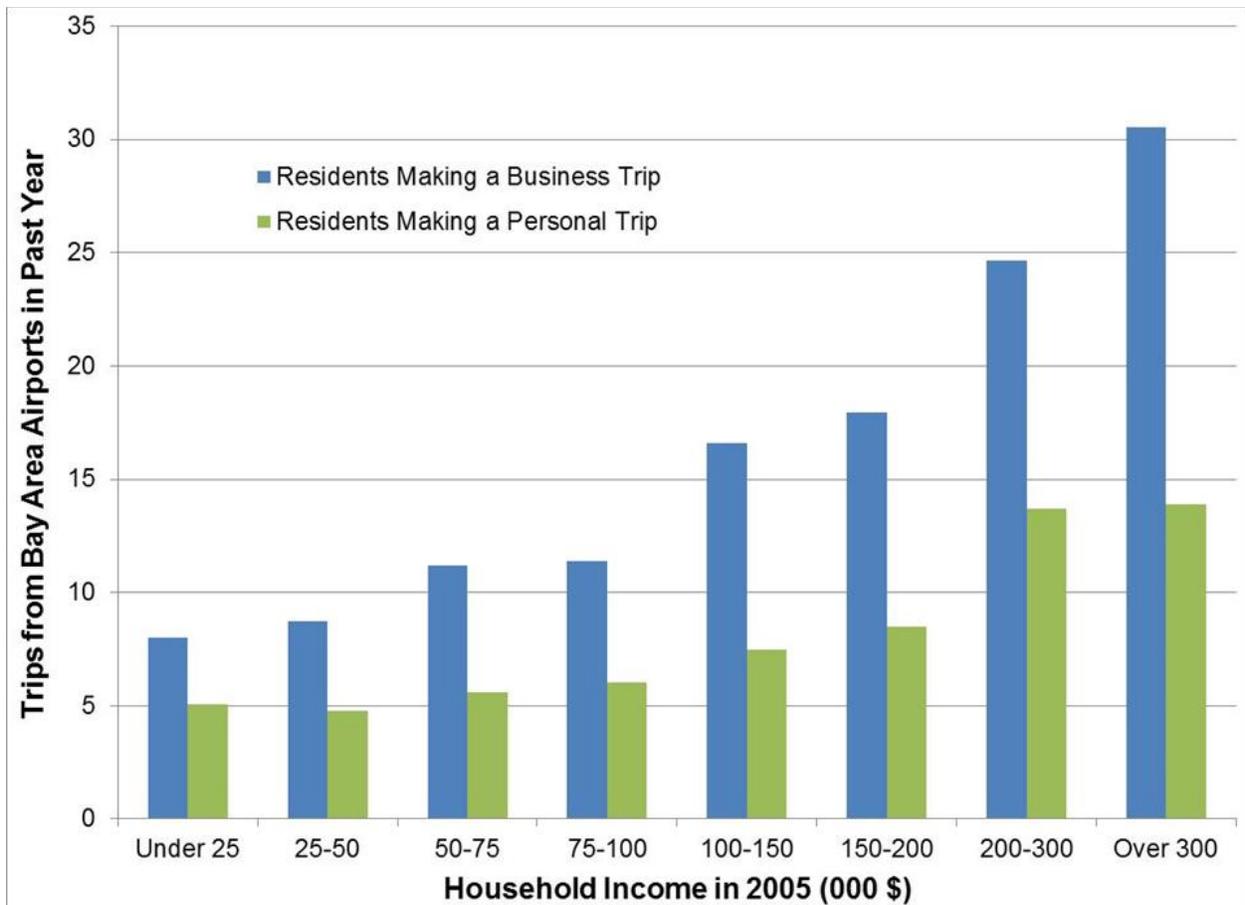
Most airport air passenger surveys collect some socioeconomic data from the respondents, although the specific questions vary across surveys. The majority of surveys gather household income and trip purpose information. Some surveys ask respondents how many air trips they have made in the previous year (or some shorter period), which provides information on *trip propensity* (the frequency with which air trips are made by an individual traveler). When combined with the socioeconomic data collected in the survey, this presents the opportunity to study how trip propensity varies with the socioeconomic characteristics of the traveler. For example, Figure B-2 illustrates how trip propensity varies with reported household income for San Francisco Bay Area travelers using San Francisco International Airport and Oakland International Airport from an air passenger survey performed by the Metropolitan Transportation Commission at both airports in 2006.

Review of Recent Air Passenger Surveys

As part of the current task, information on a fairly representative sample of relatively recent air passenger surveys was assembled. Since such surveys are typically only performed periodically and are sometimes regarded as proprietary information, the most recent survey for a given airport for which results are publicly available is often several years old.

The frequency with which surveys are performed for a given airport varies across airports from every year or two to less than once a decade. Thus at those airports where surveys are performed fairly regularly it is possible to track changes in the composition of the passengers using the airport over time as well as identify differences in the profile of the passengers using different airports. At other airports where the surveys are performed less frequently, it is less clear whether differences in the profile of the passengers using different airports are a result of changes in the composition of the passenger traffic over time or actual differences in the profile of passengers using each airport. A further complication arises in comparing the profiles of passengers using different airports given by different surveys when those surveys are performed at different times of the year. Thus apparent differences in the profiles of passengers using the airports could be due to seasonal differences in the composition of the passenger traffic.

The frequency with which surveys were performed at the airports for which the sample of air passenger surveys was obtained as well as the time of year the surveys were performed and the sample size of the most recent survey is shown in Table B-4.



Source: Gosling, Geoffrey D., *Use of Air Passenger Survey Data in Forecasting Air Travel Demand*, Paper 14-5741, Transportation Research Board Annual Meeting, January 2014.

Figure B-2. Variation of Trip Propensity with Income – Bay Area Air Passengers

The frequency with which surveys are performed at different airports varies from one-time surveys undertaken to support specific planning studies, such as those for Burbank Bob Hope Airport (BUR) and the New York/New Jersey airports, to the quarterly surveys performed by the Port of Portland. In recent years the surveys at Orange County John Wayne Airport and the three Baltimore/Washington region airports were performed every other year, while the surveys at Boston Logan International Airport (BOS) were performed every three or four years and those at Los Angeles International Airport (LAX) were performed every five years.

The sample size also varies widely from just over 400 respondents in the 2012 survey at Phoenix-Mesa Gateway Airport (AZA) to over 22,000 in the 2011 survey at LAX. However, the sample size for the majority of the airports in the selected surveys shown in Table B-4 lies between about 3,500 and 9,000 respondents.

It should be noted that other surveys may have been undertaken at some of the airports listed in Table B-4 for which information was not available to the Research Team, were undertaken by other survey sponsors, or had a more limited focus such as customer satisfaction.

Table B-4. Frequency, Time of Year, and Sample Size of Selected Air Passenger Surveys

Survey Sponsor	Airport(s)	Latest Survey	Previous Surveys	Time of Year	Sample Size
Atlanta Hartsfield-Jackson International Airport	ATL	2009	Annual 1999-2005	Jul	5,735
Burbank-Glendale-Pasadena Airport Authority	BUR	2012		May	751
County of Orange (John Wayne Airport)	SNA	2013	1994, 1998, 2000, 2003, 2005, 2007, 2009, 2011	Jul	460
FAA / Port Authority of New York and New Jersey	EWR JFK LGA	2005	1993, 1997	Apr-Jun	5,600 6,106 4,384
Los Angeles World Airports	LAX	2011	1993, 2001, 2006	Aug, Oct	22,624
Maricopa Association of Governments	AZA PHX	2012		Mar-May	402 5,361
Massachusetts Port Authority	BOS	2013	1979, 1984, 1987, 1990, 1993, 1996, 1999, 2003, 2007, 2010	Apr/May	8,783
Metropolitan Transportation Commission (SF Bay Area)	OAK, SFO	2006	1975, 1980, 1985, 1990, 1995, 2001, 2002	Aug-Oct	3,587 4,628
Metropolitan Washington Council of Governments	BWI DCA IAD	2013	1981/82, 1987, 1992, 1998, 2000, 2002, 2005, 2007, 2009, 2011	Oct	8,790 6,639 9,313
Port of Portland	PDX	2015	Annual	Quarterly	2,500
San Diego Regional Airport Authority	SAN	2012	2009	May/June	7,929

Source: Research Team analysis of survey documentation.

Table B-5 shows the trip purpose, trip propensity, and socioeconomic variables that were obtained in each of the sample surveys. It can be seen that some air passenger characteristics were obtained in the majority of surveys, while others are less commonly asked.

Even where two surveys obtain information on a given air passenger characteristic, the question is not always asked in the same way and the response options that are provided on the survey questionnaire may differ. Thus combining data from multiple surveys may require some interpolation or aggregation of the survey results. In particular, where surveys ask the respondent's age or household income, the age or income ranges provided as response options often differ. Furthermore, in the case of household income the ranges may differ between successive surveys at the same airport, to reflect increasing income levels. Even where the same income ranges are used in successive surveys, adjustments will be needed across surveys to compare changes in the distribution of income levels in constant dollars.

Where surveys ask respondents how many air trips they made in the previous year, this usually refers to air trips using the airport where the survey is being performed, or where a region is served by multiple airports, it is common to ask the number of air trips using each airport serving the region. Air passenger surveys typically collect information from departing air passengers, which include both residents of the region served by the airport and visitors to the region who are returning home. Although the number of air trips per year using the airports in a region provides a measure of air travel propensity for residents, this is not the case for visitors,

most of whom will also make air trips to other destinations than the region where the survey is performed.

Table B-5. Air Traveler Characteristics in Selected Air Passenger Surveys

Survey Sponsor	Airport(s)	Year	Trip Purpose	Household Size	Household Income	Age	Gender	Trips in Past Year	Primary Language
Atlanta Hartsfield-Jackson International Airport	ATL	2009	8						
Burbank-Glendale-Pasadena Airport Authority	BUR	2012	7	✓	8	6	✓		
County of Orange (John Wayne Airport)	SNA	2013	5		5	6	✓	✓	✓
FAA / Port Authority of New York and New Jersey	EWR, JFK, LGA	2005	3		12	7	✓	✓	✓
Los Angeles World Airports	LAX	2011	9		7	6	✓		
Maricopa Association of Governments	AZA, PHX	2012	8	✓	8	7	✓		
Massachusetts Port Authority	BOS	2013	2	✓	8	✓	✓	✓	
Metropolitan Transportation Commission (SF Bay Area)	OAK, SFO	2006	8	✓	8		✓	✓	
Metropolitan Washington Council of Governments	BWI, DCA, IAD	2013	6	✓	8	6		✓	
Port of Portland	PDX	2015	3		✓	✓	✓	✓	
San Diego Regional Airport Authority	SAN	2012	7		5	8	✓	✓	

Note: A checkmark (✓) indicates that the respondent characteristic was included in the referenced survey. A number indicates the number of response options offered for that characteristic.

Source: Research Team analysis of survey documentation.

OTTI Survey of International Air Travelers

In addition to data on traveler spending, the annual OTTI Survey of International Air Travelers collects data on the following air traveler characteristics:

- Residence (city/state/postal code/country)
- Country of citizenship
- Country of birth
- Main destination of trip (city/country)
- Main purpose of trip; other purposes of trip
- Number of adults and children in travel party
- First trip by air to/from the U.S.?
- Number of round trips by air to/from the U.S. in past 12 months
- Occupation
- Age
- Gender
- Total household income

- Ethnicity/race (U.S. residents)

The survey questionnaire was revised starting with the 2012 survey. All of the above questions with the exception of ethnicity/race were asked prior to 2012 although the response options for trip purpose and occupation were different. Prior to 2012 the questionnaire also asked the number of trips to/from the U.S. made by the respondent in the previous five years. Also, prior to 2012 the questionnaire presented 11 ranges for total household income in U.S. dollars and asked respondents to mark the appropriate one. Alternatively, respondents could indicate their total household income as a specific amount in a currency other than U.S. dollars. From 2012 all respondents indicated their total household income as a specific amount and gave the country of the currency in question. This greatly facilitates comparing changes in income distribution over time. However, the survey does not ask about the number of adults and children in the household, which would have been helpful to adjust the reported household income for household size.

The question on occupation provides 10 broad categories, including “other.” Only five categories cover different types of businesses and the wording of the categories combines the role of the respondent in an organization with the type of activity undertaken by the organization. For example, one category is “Sales and Office Occupations,” while another category is “Natural Resources, Construction, and Maintenance Occupations.” Several of the categories are so vague that many survey respondents are likely to have a hard time deciding which one applies and it is unclear how the resulting data could be used.

The survey data is collected in two ways. The first method involves the direct participation of the airlines, which arrange for their flight attendants to distribute the questionnaires on selected outbound flights from the U.S. and return the completed questionnaires to the survey contactor for processing. The second method involves distributing the questionnaires in airport departure gate areas for selected flights and collecting the completed questionnaires as the respondents board the flight. In order to increase the level of responses at certain airports, the OTTI partners with the airport authorities to survey additional international flights on a monthly basis. This Supplemental Airport Survey Program (<http://travel.trade.gov/research/programs/ifs/survey.html>) currently involves 14 major international gateway airports.

The OTTI produces a number of summary reports based on the survey data which are available at no cost on the OTTI website. In addition, detailed tabulations in a standard format can be purchased from the survey contractor in either PDF or Microsoft Excel format. The price varies with the format and level of detail, but an annual report with all tabulations in Excel and PDF for both non-resident inbound travelers and U.S. resident outbound travelers currently costs \$8,100 (\$3,160 in PDF alone). Annual reports for inbound travel from specific countries cost \$745 per country as a PDF and \$1,745 in Excel. Various other reports are also available for purchase and custom reports can also be prepared for a fee.

The standard reports consist of a large number of tables showing the responses to the survey questions cross-tabulated against four different sets of column headings (termed “banners”). The tabulations show the total number of respondents for each column and the percent for each category for a given question shown in the rows.

The four banners for inbound visitors to the U.S. comprise:

- All visitors, first or repeat visit, purpose(s) of trip, use of air travel or rental car during visit, whether on a package tour
- Area of residence in Europe (total and for 11 specific countries)
- Area of residence in Asia, Oceania and Middle East (total for each region and nine specific countries, six in Asia, Australia, Israel, and Saudi Arabia)
- Area of residence in South America, Central America, Caribbean, Africa or Russia (total for each region and five countries in South America, Trinidad & Tobago, and South Africa)

The first banner for U.S. resident outbound travelers is the same as for the inbound visitors but the other three are organized on a different basis, as follows:

- State of residence (12 specific states)
- City of residence (12 specific cities or metropolitan regions)
- World region and countries visited (eight world regions and four specific countries, three in Europe and the People's Republic of China)

The survey responses are weighted in the tabulations to reflect the total number of international air passengers to and from each overseas country based on the Department of Homeland Security traveler arrival and departure records.

In spite of the large overall sample size (over 34,000 U.S. resident and over 38,000 foreign visitor respondents in the 2011 survey), the number of responses from U.S. residents of any given city, much less any zip code, or foreign visitors with a destination in any given city, is relatively small except for the largest cities. Therefore results for smaller cities are likely to be statistically unreliable and are not generally reported by OTTI. Nonetheless, the OTTI survey provides both a detailed profile of international air travelers in general and a time series of annual data on trends in the profile of international air travelers. It can therefore be a valuable complement to air passenger surveys performed at individual airports, particularly since at many airports travelers making international air trips form a relatively small proportion of total air passengers using the airport.

As an illustration of the type of disaggregate socioeconomic information that can be obtained from the OTTI survey, Table B-6 shows the changes in the international air traveler trip purpose, gender, and age from 2005 to 2011 while Figure B-3 shows the change in the distribution of the reported household income of international air travelers over the same period.

As expected, the distributions of household income shown in Figure B-3 generally show an increase in income levels in constant 2010 dollars from 2005 to 2011, although the increase is greater for foreign visitors than U.S. residents. Even so, the household income levels of U.S. residents in 2005 were somewhat higher than those for foreign visitors in 2011. In 2011, for a given cumulative percentile of the distribution, the household income for U.S. residents was about \$15,000 to \$20,000 higher than for foreign visitors, at least below the 70th percentile. Above this level, the difference appears to increase, although the distributions are unreliable

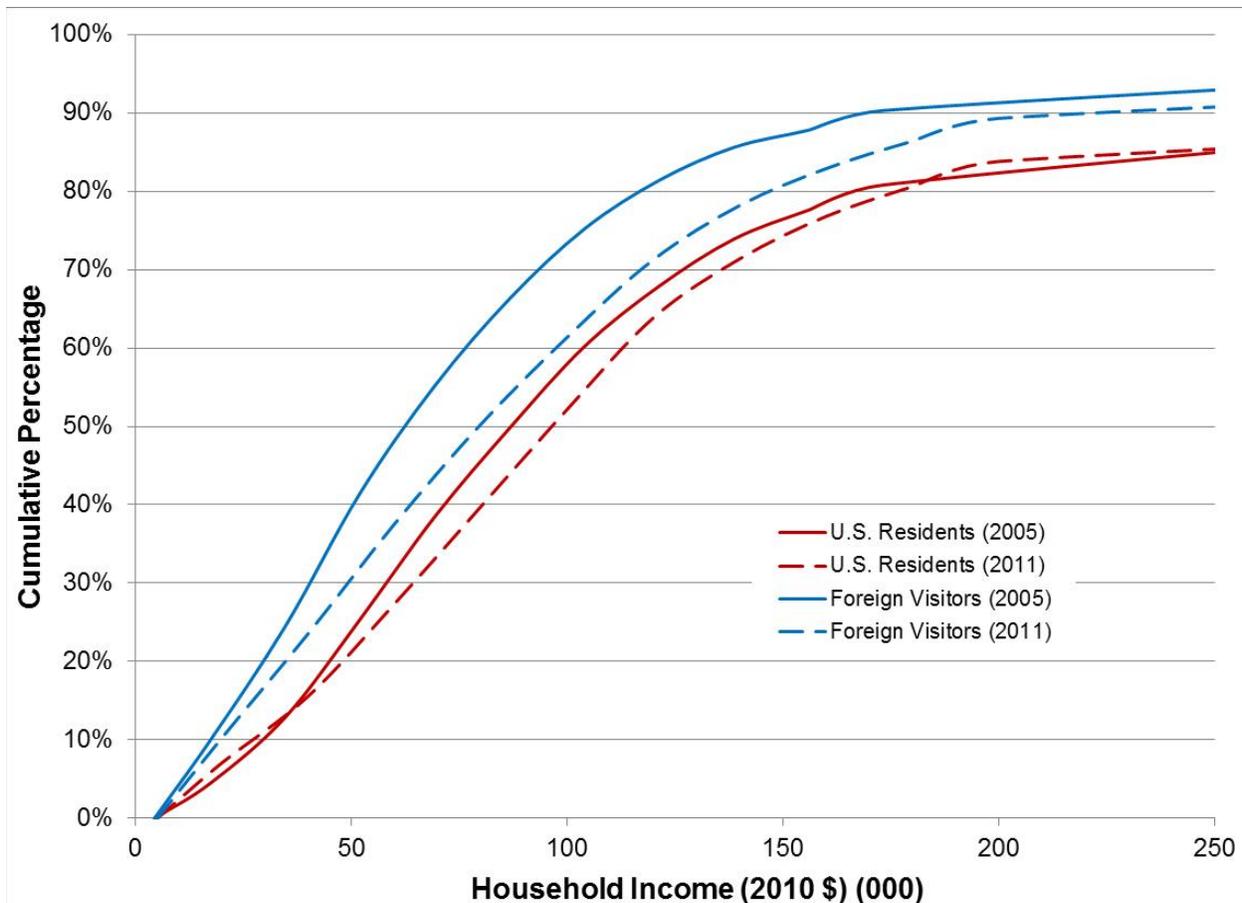
above the 80th percentile, since the highest income category in the tabulations was \$200,000 and over, so the shape of the distribution above this level is unclear. The income distributions for U.S. residents appear to show slightly higher income levels in 2005 than 2011 (in 2010 dollars) between the 80th and 85th percentile, but this could simply be a result of the conversion of reported 2005 income levels to 2010 dollars and assumptions regarding the shape of the distribution above \$200,000.

Table B-6. Changes in OTTI Survey Respondent Characteristics from 2005 to 2011

Air traveler characteristics	U.S. Residents		Foreign Visitors	
	2005	2011	2005	2011
Main trip purpose				
Business/professional	20.9%	17.5%	21.0%	16.8%
Convention/conference	1.9%	1.1%	5.0%	4.2%
Leisure/recreation/holidays	40.1%	39.4%	47.2%	53.1%
Visit friends/relatives	32.1%	34.6%	23.0%	20.9%
Study/teaching	2.5%	3.6%	2.3%	3.8%
Religion/pilgrimage	1.0%	2.1%	0.2%	0.2%
Health treatment	0.4%	0.6%	0.4%	0.3%
Other	1.0%	1.0%	0.8%	0.8%
	100%	100%	100%	100%
Gender				
Male	56.6%	49.0%	58.8%	55.1%
Female	43.4%	51.0%	41.2%	44.9%
Age				
18 - 24	7.8%	9.8%	9.0%	11.7%
25 - 29	7.7%	9.8%	11.5%	12.4%
30 - 34	9.5%	10.0%	12.7%	13.8%
35 - 39	10.9%	9.1%	14.0%	12.0%
40 - 44	12.9%	10.2%	14.2%	12.9%
45 - 49	12.9%	11.1%	11.4%	11.0%
50 - 54	11.5%	10.6%	9.3%	8.7%
55 - 64	17.0%	18.1%	12.9%	12.0%
65 and over	9.7%	11.2%	4.9%	5.4%
	100%	100%	100%	100%

Source: OTTI tabulated survey results for full year 2005 and 2011.

It is possible that the propensity for international travel by U.S. residents with household incomes above \$200,000 has not increased that much between 2005 and 2011, since their incomes are sufficiently high that travel cost is not a major consideration in deciding whether to make an international trip so any increase in income did not generate many more trips. On the other hand, increased real incomes of those with household incomes below about \$150,000 could have resulted in a corresponding increase in international travel. This would reduce the percentage of all international air trips that were made by travelers with household incomes over \$200,000, shifting the 2011 distribution upward and accounting for the apparently higher income levels between the 80th and 85th percentile in 2005.



Source: Research team analysis of OTTI tabulated survey results.

Figure B-3. Change in OTTI Survey Respondent Household Income from 2005 to 2011

Airport Customer Satisfaction Surveys

Many airports conduct customer satisfaction surveys on a regular basis. Although the sample size in these surveys is generally small (a few hundred respondents), the frequency with which these surveys are typically performed may make them a useful data source. For many years the Airports Council International has maintained a program of customer satisfaction surveys, now named the Airport Service Quality (ASQ) Survey, in which many of its member airports participate (<http://www.aci.aero/Airport-Service-Quality/ASQ-Home>). These surveys are generally undertaken four times per year using a standardized survey questionnaire with a minimum of 350 respondents for each survey. As of 2015, 27 U.S. airports participated in this program.

The ASQ survey asks respondents to rate 30 aspects of their airport experience at the airport where they were surveyed. These aspects include access, check-in, passport/identification inspection, security, wayfinding, airport facilities, and the airport environment.

In addition, the ASQ survey includes the following questions about the current air trip being taken by respondents and traveler characteristics:

- Airline, flight number, departure date and time, destination on flight
- Whether originating or connecting from another flight
- Main reason for trip (business, leisure, or both)
- Section of aircraft traveling in (first class, business/upper class, economy/tourist)
- Number of return air trips made in the past 12 months, including the current trip
- Nationality/country of citizenship
- Country of residence and postal/zip code
- Gender and age group (eight age ranges)

The survey does not ask respondents who are connecting between flights where they started their trips, nor whether their destination on the flights they are about to board is their final destination (although in some cases this can be inferred from the respondents' postal codes). The survey also does not ask about respondents' income levels, although in many cases it would be possible to approximate these income levels from the respondents' postal codes. From the perspective of the current project, the most relevant information collected by the survey is the number of air trips made in the past 12 months, and how this varies by age group, gender, nationality, and residential postal area.

A similar survey has been conducted by the International Air Transport Association for the past three years (IATA, 2014b), although the scope is global air travel in general rather than focused on a specific airport. In 2014, the survey gathered information from over 5,000 air travelers from over 140 countries. The focus of the survey is on the needs, preferences, and concerns of leisure and business travelers. It is unclear how much socioeconomic or air travel data the survey collected from respondents and how useful the survey might be for understanding how socioeconomic factors influence air travel propensity in the U.S.

Airports that conduct their own customer satisfaction surveys on a regular basis include Burbank Bob Hope (BUR), Dallas/Fort Worth International (DFW), Dayton International (DAY), Eugene Mahlon Sweet Field (EUG), John Wayne Orange County (SNA), Nashville International (BNA), San Diego International (SAN), San Francisco International (SFO), and the four commercial service airports operated by the Port Authority of New York & New Jersey (PANYNJ): Kennedy International (JFK), LaGuardia (LGA), Newark International (EWR), and Stewart International (SWF). The frequency and sample size of these surveys varies. The most recent survey for BUR was undertaken in July 2007 and included over 1,200 respondents. The survey for SAN is undertaken quarterly but only includes 200 respondents. The surveys for EWR, JFK, LGA, SFO and SWF are undertaken annually. The sample size for the 2011 survey at SFO was 3,872, whereas the sample size for the 2012 surveys at the PANYNJ airports varied from 4,837 at JFK to 303 at SWF.

The extent to which these surveys ask questions about respondent trip and air party characteristics also varies, both in terms of the questions asked and the response options offered, as shown in Table B-7 for four such surveys for which details are available.

Table B-7. Air Traveler and Trip Characteristics in Selected Airport Customer Satisfaction Surveys

Air Traveler Characteristics and Trip Details	Burbank (BUR)	Nashville (BNA)	San Diego (SAN)	San Francisco (SFO)
Gender	✓	✓	✓	✓
Age	6 ranges	✓	✓	7 ranges
Household income	8 ranges	7 ranges	(1)	4 ranges
Race		6 options	6 options	
Education	4 levels	6 levels	6 levels	
Air trips per year		6 ranges	SAN only	SFO only
Residence location	Zip code	Zip code	Zip code	Zip code
Trip purpose	5 types	4 types	5 types	12 types
Flight destination				✓
Trip destination		City		

Note: 1. Income ranges given on show card (copy of card not available).

Source: Airport customer survey questionnaires for each airport.

Only three of the four surveys asked about the number of air trips made by survey respondents in the previous year, and two of these only asked about trips using the airport where the survey was performed. In both cases, residents of the region served by each airport have other airports serving the region or within a fairly short distance, so even for these respondents the number of reported air trips per year is likely to understate the total air travel propensity. When the survey questionnaire provided a number of categories for responses to a particular question, the range of values forming each category often differed across the surveys, complicating the comparison of results from different surveys.

In addition to surveys undertaken by individual airports, several organizations have undertaken or continue to undertake airport customer satisfaction surveys covering multiple airports. From 2001 to 2010, J.D. Power & Associates published the North America Airport Satisfaction Study but discontinued it after 2010, apparently because they found that airports did not find value in purchasing the study or advertising rights (ACRP, 2013a). The 2010 study ranked airports in three size categories on the basis of an overall airport satisfaction score calculated from air traveler evaluations obtained from an online survey of respondents who had taken a round-trip flight during 2009. The survey is reported to have collected some demographic data on the respondents (ACRP, 2013a) but the details are not given.

Two other firms currently undertake online airport customer satisfaction surveys. The Canmark Research Center, operated by Canmark Technologies, Inc., based in Toronto, (www.canmarktech.com) conducts an airport survey (www.airportsurvey.com). Invitation cards are distributed to travelers at airports with a serial number that survey respondents enter when starting the online survey. However, air travelers may also take the survey without an invitation card. Respondents are entered in a sweepstake for a certificate for two domestic economy

roundtrip tickets on an airline of the survey sponsor's choice. Results of the survey are not published, but the results for a given airport may be purchased by the airport in question.

SKYTRAX Research, Inc., based in London, England, (www.skytraxresearch.com) conducts the Skytrax World Airport Survey (www.worldairportsurvey.com). Air travelers can complete the survey online. There is no cost to an airport to be included in the survey, nor any inducement provided to travelers for completing the survey. Airports are free to encourage customers to complete the survey, but are prohibited from offering their customers any enticement or incentive to vote in the survey. The survey evaluations for each airport are published on the World Airport Survey website and used by SKYTRAX to determine the annual Skytrax World Airport Awards, which designate the world's best airport in several categories and rank the top 100 airports worldwide. The 2015 World Airport Awards are based on 13 million survey responses completed by 112 different nationalities of traveler during the period from May 2014 to January 2015 that cover 550 airports worldwide. The published individual survey evaluations for a given airport indicate the country of residence of the respondent and (since June 2015) the type of traveler (classified as business, solo leisure, couple leisure, or family leisure).

d. Other Surveys

In addition to intercept surveys of air passengers undertaken at airports, there is a wide range of travel surveys undertaken at a national, statewide, or regional level to support various types of transportation planning activities. These surveys commonly take the form of an interview survey that asks household members to report the details of their travel on a particular day or days (as well as socioeconomic characteristics). These surveys are often supplemented by a travel diary completed by each member of the household. Some of these surveys collect data on recent long-distance trips, including air trips. A widely used example is the 2001 National Household Travel Survey (<http://nhts.ornl.gov>) which included details of all trips of over 50 miles taken by respondents in the previous four-week period.

Other types of surveys include surveys of households or businesses in their expenditure patterns, which could include expenditures on air travel. Although these surveys do not typically provide information in the details of the air trips made, they could provide useful information in trends in spending on air travel over time by different segments of the population or different types of businesses.

Household and Other Traveler Surveys

In addition to national household travel surveys, several states have conducted recent statewide long-distance travel surveys, including California (www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/chts.html) and Oregon (www.oregon.gov/ODOT/TD/TP/pages/travelsurvey.aspx). Some metropolitan regions have also conducted household travel surveys in support of their regional travel modeling programs. The Metropolitan Travel Survey Archive at the University of Minnesota (www.surveyarchive.org) provides a valuable resource on many of these regional surveys.

One important limitation of household travel surveys undertaken in a metropolitan region, or even statewide, is that they will only capture trips made by residents of that region or state, and will therefore exclude trips made by visitors from outside the region or state. Thus, analysis of the composition of visitor trips to the region will need to be based on different data. Visitor and convention bureaus and similar organizations sometimes undertake surveys of visitors to a city or region. The survey respondents generally include a fairly high percentage that came by air. These data can supplement household travel surveys by providing information on visitor trips. However, these surveys often focus on visitors staying in hotels or other lodging, and may not include visitors staying with friends or relatives in the region.

National Travel Surveys

The U.S. Department of Transportation (DOT) has undertaken a series of household travel surveys since 1969 to collect data on both long-distance and local travel by U.S. households. The 2001-2002 National Household Travel Survey (NHTS) provided updated information that had previously been collected by two prior series of surveys, the Nationwide Personal Transportation Survey (NPTS) sponsored by the Federal Highway Administration and conducted in 1969, 1977, 1983, 1990, and 1995 and the American Travel Survey (ATS) sponsored by the U.S. DOT Bureau of Transportation Statistics (BTS) and conducted in 1977 and 1995. The NHTS was repeated in 2009 but whereas the 2001-2002 NHTS included all trips over 50 miles made by household members during a four-week recall period in addition to all travel during a designated 24-hour period, the 2009 NHTS only included travel during a designated 24-hour period, resulting in far fewer long-distance trips being included in the survey.

In addition to the 2001-2002 NHTS, from August 2000 to October 2003 the BTS undertook a monthly or bi-monthly Omnibus Household Survey of 1,000 randomly selected households that included information on air travel as well as respondent and household socioeconomic characteristics (www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/subject_areas/omnibus_surveys/household_survey/index.html). This survey was repeated in October 2009 but has not been performed since.

Statewide Travel Surveys

Statewide long-distance travel surveys can provide a valuable source of information on the demographic and socioeconomic characteristics of travelers making long-distance trips, some of which may involve air travel. Because such studies are typically performed as household surveys, they can provide, directly or indirectly, information on the frequency with which long-distance trips are made and hence an indication of how air travel propensity varies with household characteristics. Since such surveys generally address trips by all modes, they may also provide an indication of the extent to which air service levels affect the use of air travel for long-distance trips of varying length, and possibly the extent to which travelers use surface modes to access more distant airports for air trips.

Such surveys typically involve respondents completing a travel diary for a specific day. Since survey respondents may well not make any long-distance trips in the designated day, some surveys also ask about recent long-distance trips. However, even if a survey does not ask specifically about long-distance trips, some respondents are likely to have made a long-distance

trip on the designated day of their travel diary, so some data on long-distance travel will be collected, although the sample size will be very small relative to the overall survey sample size. In 2014 there were approximately 247.1 million domestic air trips⁴ and 68.2 million outbound international air trips by U.S. residents (U.S. Department of Commerce, 2015). The adult household population of the U.S. in 2014 was about 237.3 million.⁵ Thus on average each adult in the household population made 1.33 air trips in 2014, or 0.0036 outbound air trips per day. Assuming 3.5 percent of these were same-day trips,⁶ the average probability that a given household survey respondent would have made an air trip on a given travel diary day is only about 0.7 percent, or 140 reported air trips for a household travel survey obtaining one-day travel diaries for 20,000 adults.

In cases where a household travel survey asks respondents to report the details of long-distance trips made over a reasonably long period of time, such as the eight weeks prior to the travel diary day, the number of reported air trips will give an indication of the air travel propensity of the survey respondent.

Although statewide long-distance travel surveys are often undertaken to obtain information on longer-distance travel within the state in question for statewide transportation planning purposes, the level of detail collected on long-distance trips (including those to destinations outside the state) is generally much less than for the trips reported by means of a travel diary for an assigned day, although the long-distance trips are typically of greatest interest from the perspective of air travel demand.

The following sections provide an overview of five representative recent statewide travel surveys.

California

The California Department of Transportation (Caltrans) undertakes the statewide California Household Travel Survey (CHTS) every ten years (Caltrans, 2016). The most recent survey was undertaken from January 2012 following a pre-test in late fall 2011, and ending on January 31, 2013. The survey obtained complete travel data from 42,431 households. In addition, partial data was collected from a further 20,651 households (NuStats, 2013). Travel data was collected from households in all 58 California counties as well as parts of three adjacent Nevada counties. Data was collected by a combination of computer assisted telephone interviewing (CATI), an online survey, and three types of global positioning system (GPS) devices: a wearable device, an in-vehicle device, and an in-vehicle device plus an on-board diagnostic (OBD) unit. 36,714 households did not use GPS devices, 3,855 used wearable GPS devices, 422 used in-vehicle devices, and 1,440 used in-vehicle devices with an OBD unit. All participating households were asked to record their travel for a pre-assigned 24-hour period and complete a long-distance travel log covering trips by household members to a location 50 miles or more away in the eight weeks prior to the assigned travel day. Households participating in the GPS-

⁴ Research team analysis of airline data on the U.S. DOT, Bureau of Transportation Statistics *Transtats* website.

⁵ Research team analysis of U.S. population estimates on the U.S. Census Bureau website.

⁶ Research team analysis of trip duration data from selected air passenger surveys.

assisted survey used the wearable GPS devices for three days or the in-vehicle devices for seven days.

Households were initially recruited by telephone and those agreeing to participate were mailed copies of the travel diaries and long-distance travel log. Target households were mailed an advance letter about one week prior to placing the initial recruitment call. This served to inform households about the survey and provided an option for households willing to participate in the survey to complete the recruitment survey online or call a toll-free number to complete the recruitment survey by telephone at their convenience. The recruitment survey collected a range of information about each household that agreed to participate in the survey, including the following:

- Household address, type of residence, and home ownership status
- Household size
- Number of years at current address (and previous address if at current address for less than six years)
- Number of cell and landline phone numbers in household
- Use of public transportation
- Bicycle and vehicle availability and a range of details about available vehicles
- Plans to purchase a new vehicle in next five years
- Name, age, gender, and race of each household member
- Relationship among household members
- Country of birth of each household member and year moved to U.S. if not born in the U.S.
- Number of household members possessing a driver's license
- Employment status of each household member, together with details of employment, including employment location, hours worked per week, typical work days, transportation mode to work, and availability of flexible hours
- Student status and highest education level of each household member, together with details of school location, grade level, and whether home or online schooling
- Any household member with a disability, including type of disability and use of or eligibility for transportation options for the disabled

A reminder was sent to participating households the day before their assigned travel day. As part of the recruitment survey, participants were given the option of receiving the reminder by telephone, e-mail or text message. The recruitment survey also asked if all members of eligible households would be willing to participate in the GPS component of the survey, by either each household member using a wearable GPS device or placing an in-vehicle GPS device in each household vehicle. Households participating in the GPS component of the survey were offered an incentive of \$25 per person or \$25 per vehicle upon completion of the survey and return of the GPS devices.

The travel diary for the assigned travel day provided one page for each of 11 successive places visited during the day, together with instructions and an example of a completed page. The household member recorded where they were at 3 a.m. on the travel day and up to three activities that they engaged in there before leaving for the first trip segment, using codes

provided for different activities and including the time periods during which they engaged in each activity. Each page requested the following information for each place visited:

- The time they arrived at that place
- The type of place, together with the place name and address (unless it was the household member's home, primary job location, or school)
- How the household member traveled there, using codes provided for each mode of travel
- How many other people and other household members traveled there together, and which household members these were
- If reached using a private vehicle, which household vehicle was used, where the vehicle was parked, how much was paid to park, how the payment was made, and how much of any out-of-pocket payment was reimbursed by the household member's employer
- If reached using public transport, which transit system and route or line number was used
- Up to three activities engaged in at that place, using codes provided for different activities and including the time periods during which they engaged in each activity
- The time they left that place for the next place visited

The travel diary also included a page where the household member could record up to ten additional places visited during the day with less extensive information for each place, but including the times of arrival and departure, the name and address of the place, how they got there, and the activities engaged in there.

The long-distance travel log provided space for recording up to eight long-distance trips of 50 or more miles made by any household member during the eight weeks preceding the travel diary day, starting with the most recent trip. Thus if the household members made more than eight such trips, only the most recent eight trips would be recorded. The information requested for each trip comprised:

- The date of departure
- The place name and address where the trip started
- The place name and address of the final destination
- The main purpose of the trip (using trip purpose codes provided)
- The number of people traveling with the respondent
- The number of household members traveling with the respondent and which ones (using person codes from the travel diaries)
- The method of travel that was used for the longest distance (using codes provided for each mode of travel)

Respondents were instructed to treat each direction as a separate trip. This effectively limited the long-distance travel log to a maximum of four round trips. Since it covered all trips of 50 miles or more, it is quite likely that many households made far more long-distance trips than this during an eight week period. Respondents who made more than eight long-distance trips during the eight-week period were instructed to record the details of the additional trips on a

separate sheet of paper. Given the total costs of performing the survey, it is hard to understand why the long-distance travel log did not include additional pages to cover more trips. An additional problem with the long-distance travel log is the wording of the instructions for entering the number of people traveling together. This refers to the number of people traveling with “you” (the person completing the log), excluding the respondent. However, this implies that the respondent was traveling on all the trips, which may not have been the case. It would have been less ambiguous to have asked about the total number of people traveling together, including the respondent if applicable.

Following the travel day (or the period of GPS data collection for households using the GPS devices), the travel diary long-distance travel log information was collected through a retrieval survey that was conducted in one of three ways:

- Online on the survey website using the household personal identification number (PIN) provided with the survey materials
- A telephone interview initiated by the survey contractor or by the household calling a toll-free number provided with the survey materials
- The household returning the travel diary and long-distance travel log by mail with a follow-up telephone interview after the information had been entered into the computer database to clarify any details and obtain additional information

The retrieval survey also gathered additional data on the activities undertaken during the course of the travel day, based on the survey. According to the retrieval survey script in the survey Final Report, for long-distance trips taken using airplane, bus or train, the retrieval survey requested the following additional information:

- The time the trip started
- The airport, bus or train station departed from
- How the party traveled to the airport or station
- The airport, bus or train station arrived at
- How the party traveled from the airport or station to the final destination

Since this information was not requested on the long-distance travel log, presumably the retrieval survey relied on the recall of the respondent, who may not have known the details of long-distance trips made by other household members at the time of the retrieval survey.

De-identified data from the survey has been posted on the Transportation Secure Data Center at the National Renewable Energy Laboratory (www.nrel.gov/vehiclesandfuels/secure_transportation_data.html).

Massachusetts

The Massachusetts Travel Survey (MTS) was undertaken between June 2010 and November 2011 and collected travel activity data from 15,033 households statewide, covering trips made by 37,023 household members who each completed a travel diary for an assigned travel day (NuStats, 2012). A subset of 695 households participating in the survey used wearable GPS devices on their assigned travel day and the following weekday to provide more detailed travel information and assess the amount of underreported trips from the travel diaries. The

travel days were evenly distributed between each weekday. No travel data were collected for weekends. The survey did not include a specific long-distance component, other than any longer distance trips that the responding households happened to make on their assigned travel day.

Households reported their travel for the assigned day by mailing back the travel diaries or through a telephone retrieval survey. The GPS devices were shipped to 780 households and were successfully used by and recovered from 695 households. A number of devices were returned unused. An incentive of \$25 per household member was paid to all households participating in the GPS survey when all the GPS devices were successfully used and returned and travel diary information was submitted by mail or telephone.

A representative sample of households was identified and sent an advanced letter informing them that they would be contacted by telephone to request their participation in the survey and collect information about the household. This letter provided a telephone number that households could call to participate in the recruitment survey, a contact card that households could return with a telephone number on which they could be reached, and link to a website where they could enter their contact information. Attempts were made to contact each household in the sample by telephone, whether or not they provided contact information. Those households that were successfully reached by telephone and agreed to participate in the survey were asked to provide a range of information about their household by means of a CATI recruitment survey and were mailed travel diaries for each household member to complete on their assigned travel day. Reminder telephone calls were made the day before the assigned travel day. Following the assigned travel day, households were again contacted by telephone for a retrieval survey to collect the travel diary details or they could return their travel diaries by mail. If travel diaries were returned by mail, the data was entered into a database and a follow-up telephone call made if necessary to clarify responses or complete missing information. Households were offered an incentive of \$25 that was paid when all travel diary information had been provided.

The recruitment survey collected the following information from each household:

- Household size
- Number of bicycles and vehicles
- Household use of transit at least once per week
- Type of home and home ownership status
- Number of cell-phone, land-line, and fax numbers used by household members
- Household income
- Age, gender, and race of each household member
- Relationship of household members
- Which household members have a driver's license or transit pass (and type)
- Employment status of each household member, hours worked per week in primary job, and number of jobs worked
- Type of work and location of primary job, days worked each week, and how normally travel to work for each employed household member
- Availability of flexible work hours or telecommuting for each household member
- Use of disability placard or license plate or use of special transit services for the disabled or elderly by any household member

- Use of bike for transportation or recreation in previous week by each household member
- Highest level of education and current student status for each household member, as well as type, name, and location of school attended (if any), and how normally travel to school
- Details of each household vehicle, including make, model, year, fuel type, and main household user

The travel diaries followed the typical format for such diaries. The diary provided a page for each place visited on the assigned travel day, starting with the location where the respondent was at 3 a.m. The initial page allowed respondents to enter that location and the time that they left the location (if they did), as well as the main and one other activity that they engaged in before they left, using defined activity codes. The initial page also asked whether respondents shopped on the Internet on their assigned travel day in place of making a trip outside the home. Subsequent pages allowed respondents to enter details of up to 11 places they visited during the day. Each page requested the following information for each place visited:

- The name and address of the place visited (and whether this was their home, workplace, school, or a transit stop)
- The time they arrived at that place
- How they got there, using defined codes for means of travel
- The number of people who accompanied them and the number of these who were household members
- If the place was reached using public transit, which type of transit was used and how the fare was paid
- If the place was reached by private vehicle, which household vehicle was used or whether another vehicle was used (and if so, why a household vehicle was not used), where the vehicle was parked, how much was paid for parking, how any parking fee was paid and how much of this was not reimbursed by the respondent's employer, whether any toll roads were used and if so which one and the toll paid, and whether a high-occupancy lane was used during the trip
- Up to two activities undertaken at that place, using defined codes
- The time they left that place

The travel diary also included a page where the household member could record up to ten additional places visited during the day with less extensive information for each place, but including the times of arrival and departure, the type, name and address of the place, how they got there, and the activities engaged in there.

The defined codes for the means of travel did not include airplane or other long-distance public transportation, such as intercity bus or rail, but it did include a code for "other" means of travel. Respondents using the "other" code were instructed to specify the means of travel, although there was no space provided on the relevant section of the travel diary pages to do so. The retrieval survey script documented in the Final Report on the survey also did not include any codes for long-distance travel modes, or apparently any provision to specify the nature of any "other" mode used. It did however ask where respondents using a toll road entered and exited the toll road, although this was not requested on the travel diary. Respondents would therefore have

to provide this information from memory or if they knew it for trips made by other household members. The retrieval survey also asked whether any stops were made traveling between each place, such as errands, stopping for fuel or a meal, or picking up or dropping off someone. This also was not mentioned on the travel diary, so here too the respondents would be answering from memory or their knowledge of trips made by other household members.

Michigan

Starting in 2004, the Michigan Department of Transportation has undertaken a series of statewide household travel surveys termed MI Travel Counts (www.mitracounts.com). The first survey was undertaken in 2004-2005 and updated in 2009. The latest survey was undertaken in 2015, starting in January and continuing throughout the year. The goal of the 2015 survey was to obtain travel data from 21,000 households across the state. Households were initially contacted by mail with follow-up telephone calls and those that agreed to participate were mailed an information packet that included an identification code (PIN), instructions, and paper copies of travel logs for each member of the household to complete on their assigned travel day. After their assigned travel day, respondents could enter their household information and travel details on the MI Travel Counts website or by calling a toll-free telephone number and providing the information to a survey representative.

Participating households provided information on household composition and other characteristics and each household member completed a travel log for an assigned day. In addition, each household completed a long-distance travel log that covered all trips over 100 miles made by household members in the three months prior to the assigned travel day. A subsample of households was provided with wearable GPS devices for each household member that recorded details of the trips taken on the assigned day. These were returned after the assigned travel day and after the GPS data were processed the household was contacted and requested to provide information on each trip recorded by the GPS device from their travel log.

Information on household composition and characteristics collected included the age, gender, and employment status of each household member, the vehicles owned by the household members, and the household income.

The travel log for the assigned travel day followed the typical format for daily travel diaries and allowed for up to 12 trip segments, starting at 3 a.m. The household member recorded where they were at 3 a.m., then for each subsequent trip segment, the household member recorded:

- The name and address of the place visited (or indicated that this was their home, workplace, or school)
- The time they arrived at that place
- How they got there
- The number and names of people who accompanied them
- Up to two activities undertaken at that place
- The time they left that place

The activities at each place visited were recorded using predefined codes printed on the travel log. The means of travel were free-form entry fields on the travel log, although these were coded when the data were reported. The home address of the household the name or address of each household member's workplace and/or school was obtained when the household composition and other household information was obtained during the initial telephone contact or subsequent reporting of travel log details.

The long-distance travel log included the following information for each long-distance trip:

- Destination city and state
- Household members traveling on trip
- Dates of departure and return
- Main reason to making the trip
- How the travel party got to the destination and got around at the destination
- The number of times that this trip was made in the previous three months

The reason for the trip and means of travel were free-form entry fields on the travel log, although these were coded when the data were reported. If a trip involved multiple destinations, respondents were instructed to report the furthest destination.

Once all the information had been reported for all household members, an incentive payment of \$20 was mailed to the household.

Oregon

The Oregon Travel and Activity Survey (OTAS) was undertaken between April 2009 and November 2011 and surveyed approximately 18,000 households to determine their travel and activities on a designed travel day (www.oregon.gov/ODOT/TD/TP/pages/travelsurvey.aspx). Participating households were drawn from a list of household addresses randomly selected to ensure responses from throughout the state. Each member of participating households completed a travel diary for the assigned travel day.

Households were contacted by telephone to request their participation and if they agreed, to conduct a recruitment survey that collected details of the household, including the number of household members, their ages and race or ethnicity, where they work or go to school, and the number and types of vehicles owned by the household. Travel diaries for each member of the household preprinted with the household member's name and the assigned travel day were then mailed to participating households. Following the travel day, households were contacted by telephone to administer a retrieval survey to collect the travel diary information. Alternatively, participants could call a toll-free number at a convenient time to report their travel diary information or return their travel diaries by mail.

The travel diary followed a similar format to the travel diary used in the 2010-2011 Massachusetts Travel Survey with the following differences:

- Household members were asked whether they could have traveled to each place on their travel day by some other means and, if so, how (they were instructed to

- only specify one alternative means of travel)
- Respondents who used a private vehicle to travel to a given place on the travel day were asked whether they got out of the vehicle there, but were not asked how they paid for parking, whether their employer reimbursed them for any parking costs, or whether they used any toll roads or high-occupancy lanes
 - Respondents who reported traveling to a given place on the travel day by a private vehicle that was not one of the household vehicles were not asked why they did not use a household vehicle
 - Respondents who used a means other than private vehicle to travel to a given place on their travel day were asked whether they would have had to pay for parking had they driven there and, if so, how much per hour
 - Respondents who used public transit to travel to a given place on their travel day were asked the line or route, the fare and how it was paid, and if they used a pass, the type of pass and how much it cost

There was no specific long-distance travel component of the survey, so the only information that was obtained on long-distance trips was for those trips that happened to be taken by household members on their assigned travel day. As with the Massachusetts Travel Survey, the travel diary codes for means of travel did not include codes for long-distance public transportation modes but did include a code for “other” means of travel and requested that respondents specify the “other” means of travel used. The travel diary format provided some space where respondents could write in the type of “other” means of travel used.

Utah

The Utah Travel Study (UTS) was undertaken in 2012 by Resource System Group, Inc. (RSG) for six state and regional agencies in Utah: the Wasatch Front Regional Council, Cache Metropolitan Planning Organization, Dixie Metropolitan Planning Organization, Mountainland Association of Governments, the Utah Department of Transportation, and the Utah Transit Authority (RSG, 2013). The principal component of the study was a Household Travel Diary survey that was completed by 9,155 households between March and July 2012. This was supplemented by seven other survey components: a long-distance travel survey that was completed by 4,386 households, a college travel diary survey, a bike/pedestrian debrief survey, a bike/pedestrian barriers survey, an attitude debrief survey, an onboard survey of riders of the Dixie SunTran bus system, and a residential choice stated preference survey. The two debrief surveys and the residential choice survey were conducted with a subset of participants in the Household Travel Diary survey. The bike/pedestrian barriers survey was conducted with a combination of a subset of participants in the Household Travel Diary survey and other participants who were recruited through outreach to various organizations, including bike clubs and neighborhood groups.

The Household Travel Diary survey was performed by mailing travel diary forms to participating households to be completed on their assigned travel day. Households could subsequently enter their household and trip details online via a web-based survey or call a toll-free telephone number to report their trip details via a CATI survey or request a call-back survey at a convenient time. A random sample of residential addresses throughout Utah was initially selected and each address was assigned a travel day on a Tuesday, Wednesday, or Thursday

distributed through the survey period. A pre-notification postcard was mailed to each household to arrive 6 to 7 business days prior to the assigned travel day that informed the household to expect an invitation packet in the mail. The invitation packet was mailed to arrive 3 to 4 days before the assigned travel day. This included an invitation letter, a sheet with answers to “frequently asked questions” about the survey, and three travel log sheets for household members to record their travel on the assigned travel day. The invitation also informed households that once they had reported all their travel survey information, they would be sent a \$10 Amazon gift card in appreciation for their participation

The invitation letter included the study website for more information and to report travel, together with a password for the household. Additional copies of the travel log sheet could be printed from the study website. All study materials were provided in both English and Spanish. Two reminder postcards were sent to each household, one timed to arrive approximately on the assigned travel day and one timed to arrive 2 to 3 days after the assigned travel day to remind the household to submit their travel details. Invitations were sent to 124,888 residential addresses and 9,155 households completed the survey, for a response rate of 7.3 percent.

When a household first responded to survey, either online or by telephone, the first adult household member to respond was asked to provide information about the household, including:

- Number of adults and children
- Location and type of home
- Years at current residence and month in the year living full-time at residence
- Household income
- Preferred way to be contacted regarding the survey and best time to be reached
- The number of vehicles owned by the household, with the year, make, model, fuel type, and miles driven in the past year for each vehicle
- Gender, age, and race/ethnicity of each household member, together with name or initials for use in recording travel diary information
- Employment status of each household member and number of jobs held
- Educational status of each household member
- Whether each household member holds a valid driver’s license and the household vehicle typically used
- Whether each household member has a disability that limits the type of transportation they use

Each adult household member 18 and over was then asked to answer questions about their travel on their assigned travel day. These first asked the respondent to list all the places visited on the assigned travel day, followed by the location of each of these places by entering the address or locating the place on a Google Map display on the survey web page. Then the respondent was asked to provide the details of each trip, including:

- Start and end times
- Main purpose of the trip
- Main means of travel
- If traveled by private vehicle, the household vehicle used, whether the respondent was the driver or a passenger, and any parking or toll costs

- If walked or traveled by bicycle, whether the respondent used a sidewalk or bicycle path
- Which other household members and the number of people from outside the household who accompanied the respondent on the trip

After providing the details of each trip, employed respondents were then asked a number of questions regarding their travel to and from work, including the number of days per week they commute, the time of day they typically arrive at and leave work, and how they typically travel to and from work. Respondents who were students were asked similar questions about their travel to and from school.

A simplified retrieval survey was used to report any travel on the assigned travel day by any children under 18 in the household who were not accompanied by an adult member of the household. The survey questions were to be completed by an adult member of the household and did not record the locations of the places visited, only the type of place, together with the trip times, trip purpose, and means of transportation. The locations were omitted to protect the privacy of minors.

A subset of 36 percent of the invitation packets included a card that notified households that they would be asked to provide information on their long-distance travel in addition to the travel on their assigned travel day. The card defined long-distance travel as non-commute trips to a destination 40 or more miles from the home and indicated the information that would be requested for each long-distance trip. The members of households selected to participate in the long-distance travel survey reported their long-distance travel at the end of their data retrieval survey. Long-distance travel reports were received from 2,638 households.

A separate stand-alone long-distance travel survey was conducted in September and October. Participants in the Household Travel Diary survey were asked as part of the household information survey component if they would be willing to participate in future surveys and approximately 84 percent said they would and provided a valid e-mail address. 60 percent of these were sent an e-mail invitation to participate in the stand-alone survey (the remaining 40 percent were invited to participate in the bike/pedestrian barriers survey). Thus some households who had participated in the earlier long-distance survey were also invited to participate in the stand-alone survey and 631 such households in fact did. A further 1,117 households only completed the stand-alone survey, giving a total response to the long-distance survey of 4,386 households. The stand-alone survey used the same questions as the long-distance component of the Household Travel Diary survey. Households invited to participate in the stand-alone survey were told that on completion of the survey by all members of the household, the household would be entered into a drawing for an Apple iPad.

The long-distance survey differed from the travel log approach used in the California and Michigan household surveys in four ways. First, it was completed online or by telephone interview and participants did not prepare a travel log in advance. Second, participants were first asked to report how many trips they had made over the previous year to a specified set of cities. Third, participants were then asked to report their long-distance trips to other destinations, but did not all report these long-distance trips over periods of the same length. Fourth, participants were instructed not to include regular work commute trips.

In the first section of the long-distance survey, participants were asked how many trips they had made in the previous year to the following cities:

- Salt Lake City, UT
- Provo, UT
- St, George, UT
- Denver, CO
- Boise, ID
- Las Vegas, NV
- Reno, NV
- Phoenix, AZ
- Los Angeles, CA
- San Francisco, CA

The list was dynamically adjusted to exclude any cities that were within 40 miles of the participant’s home. No further information was collected on these trips.

Participants were then asked when they last made a long-distance trip, with the following options:

- In the last week
- In the last 2 weeks
- In the last month
- In the last two months
- More than two months ago

They were then asked to list all the one-way trips they had made in the period they had indicated (e.g., the last week, the last 2 weeks, etc.) entering the trip origin and destination city. For each of these trips in succession they were then asked to state the trip purpose, the main means of travel, the departure date, and the number of people traveling. For trips that involved air travel or other intercity public modes (e.g., Amtrak), no information was collected about the airport or station used.

Summary

The survey dates, sample sizes, and other key information for the five representative travel surveys are summarized in Table B-8.

Table B-8. Summary Information for Selected Household Travel Surveys

Survey	Year(s)	Number of Households	Long-Distance Travel Survey	Long-Distance Trip Definition	Long-Distance Trip Log Period
California	2012-2013	42,431	Yes	50 miles	8 weeks
Massachusetts	2010-2011	15,033	No		
Michigan	2015	21,000 (goal)	Yes	100 miles	3 months
Oregon	2009-2011	18,000 (about)	No		
Utah	2012	9,155 / 4,386	Yes	40 miles	Varies

Only the surveys for California, Michigan, and Utah collected a significant amount of data on long-distance travel. Although the 2010-2012 California Household Travel Survey had the largest number of participating households of the three surveys, the design of the long-distance travel log and the definition of long-distance trips may have comprised the amount of data collected for long-distance trips.

Although none of the surveys asked how many long-distance trips the respondents had made in the previous year, the number of long-distance trips recorded in the long-distance travel logs for the relevant period gives some indication of the annual long-distance travel propensity of the survey respondents.

Metropolitan Travel Surveys

A large number of metropolitan planning organizations have undertaken household travel surveys in order to collect data for use in developing regional travel models. Most such surveys use a travel diary approach for an assigned travel day for each respondent. Because of the focus on regional travel, these surveys do not typically gather information on long-distance trips other than those that happen to get reported in the survey. The Metropolitan Travel Survey Archive (www.surveyarchive.org) provides information on past travel surveys performed by 44 regional planning agencies throughout the U.S., although many of the surveys listed are now quite dated.

In a number of states recently, regional planning agencies have utilized household travel data for their region collected as part of a statewide travel survey in place of performing their own surveys. This is the case for the larger metropolitan planning organizations in California and Oregon, which have performed their own household travel surveys in the past, and in Utah, as discussed above. Texas has developed an interesting approach in which the Texas Department of Transportation maintains a Travel Survey Program with the support of the Texas A&M Transportation Institute (TTI) that includes household, workplace, external travel, and commercial vehicle surveys scheduled on a 10-year recurring basis to support travel modeling for each of the state's 25 metropolitan planning organizations (tti.tamu.edu/documents/tti-transportation-planning.pdf).

The surveys performed by regional agencies generally use a similar approach to the statewide household travel surveys discussed above. The following sections provide a brief overview of five representative recent metropolitan household travel surveys.

Atlanta

The Atlanta Regional Commission conducted a Household and Activity Travel Survey in 2011 in conjunction with the Georgia Department of Transportation (PTV NuStats, 2011). Travel diary information was collected from 10,278 households for an assigned travel day. The survey was performed in two phases between February and June, and between July and October. A subset of 1,061 households also provided GPS data on their travel for a 3-day period (wearable devices) or 7-day period (vehicle devices) starting on their assigned travel day. Households were initially contacted by telephone or by mailing a letter, brochure, and postcard. The mailing stated that the household would receive a call requesting their participation and initiating the survey, but could also call a toll-free number at a convenient time or respond by agreeing to participate

and providing household information online. Participating households were then mailed travel diaries and instructions. Households agreeing to participate in the GPS component of the survey were also sent the GPS devices.

Participating households were assigned a non-holiday, weekday to record the travel by all household members age 14 or over. The travel data was collected using a retrieval survey by telephone using CATI or completed by the household members online.

The format of the travel diary was similar to that used in the 2010-2011 Massachusetts Travel Survey described above.

Indianapolis

The Central Indiana Travel Survey was conducted in 2008 and 2009 for the Indianapolis Metropolitan Planning organization (NuStats, 2011). A total of 3,929 households within a nine-county region of central Indiana provided travel diary information for their assigned travel days between April and December 2009. A subsample of 244 households also provided GPS data on the travel by each household member on their travel day using wearable GPS devices. Households were initially contacted by mailing a letter, brochure, and postcard requesting their participation and notifying them that they would be contacted by telephone. Those that agreed to participate in the subsequent telephone call were asked to provide information about the household in a CATI recruitment survey. They were then assigned a travel day and mailed travel diaries and instructions. Those agreeing to participate in the GPS component of the survey were also sent the GPS devices.

Participating households were assigned a non-holiday weekday to record their travel. The travel diaries were completed by all household members age 12 and older, with the travel for those under age 12 being completed by a parent or guardian. The travel data was collected following the assigned travel day by a CATI retrieval survey. The format of the travel diary was similar to that used in the 2010-2011 Massachusetts Travel Survey.

New York, New Jersey, and Connecticut

The 2010/2011 Regional Household Travel Survey collected travel data from households in a 28-county tri-state area of New York, New Jersey, and Connecticut. The survey was undertaken as a joint effort of the New York Metropolitan Transportation Council (NYMTC), the North Jersey Transportation Planning Authority (NJTPA), and partner agencies in Connecticut, and Dutchess and Orange Counties in New York State (NYMTC & NJTPA, 2014). The survey was undertaken by a consultant team comprising PTV NuStats, GeoStats, and Parsons Brinckerhoff and collected travel data from 18,965 households between September 2010 and November 2011. A subsample of 1,930 households also provided GPS data on the travel by each household member on their travel day using wearable GPS devices. Households were initially contacted by mailing a letter which described the survey, encouraged participation, and provided both a toll-free telephone number and a website for more information. These letters were then followed up with telephone calls. Those households that agreed to participate in the survey were then asked to provide information about the household in a CATI recruitment survey. They were then assigned a travel day and mailed travel diaries and instructions. Those

agreeing to participate in the GPS component of the survey were also sent the GPS devices. Households for which a telephone number was not associated with the mailing address could only participate if they contacted the survey team by calling the toll-free number or using the survey website. The survey website allowed participating households to both enter their household information and travel diary information online if they chose to do so.

Participating households were assigned a non-holiday weekday to record their travel. The travel diaries were completed by all household members regardless of age, with the travel for those under age 16 being completed by a parent or guardian. Household members in the GPS subsample between the ages of 16 and 75 were provided with a wearable GPS device and a simplified form of travel diary termed a GPS Memory Jogger. Household members on the GPS subsample under age 16 or over age 75 were provided with paper travel diaries. The travel data was collected following the assigned travel day by a CATI retrieval survey or online.

Seattle

In spring 2014 a household travel survey was performed for the Puget Sound Regional Council, the metropolitan planning organization for the four-county Seattle region, by a consultant team led by RSG, Inc. The survey collected travel data from 6,094 households between April 8 and June 12 by means of an online survey (RSG, 2014). A representative sample of households in the region was invited to participate in the survey and each household was assigned one of 29 travel dates over the ten-week period of the survey. The travel dates were a Tuesday, Wednesday, or Thursday, and excluded the Tuesday after the Memorial Day holiday. Households were contacted by mailing a pre-notification postcard to arrive about seven days before their assigned travel date. They were then mailed an invitation packet to arrive about four days before their assigned travel date that included an invitation letter, a sheet with answers to questions about the survey, and a set of travel logs for recording household members' travel on their assigned travel day. Participating households could provide their household and travel information online or by telephone. The invitation letter included a unique password for each household that they could use to submit their information online. It also included a toll-free number that they could call to submit their information. The operators who took the calls entered the information by completing the same online survey as those households who entered their information directly on the survey website. About 14 percent of the participating households provided their information by telephone. Participating household members could return to the online or telephone survey multiple times and resume where they left off.

The address-based sample used for the survey invitations included a landline telephone number for about 28 percent of the addresses. For those households, telephone calls were made to invite them to participate in the survey if they had not already responded to the mailed invitation either online or by calling the toll-free number.

The information collected for each household and the travel by each household member on the assigned travel day generally corresponded to the information typically collected in household travel surveys. The survey questions did not specifically address long-distance travel, other than trips that happened to get reported by household members for their assigned travel day.

Washington, D.C.

During 2011 and 2012 the Transportation Planning Board at the Metropolitan Washington Council of Governments (MWCOG) conducted a survey of approximately 4,800 households in 14 communities in the Washington region to collect updated information on travel patterns (MWCOG, 2016a). The survey used a similar approach to an earlier household travel survey of some 11,000 households in the region that was conducted in 2007 and 2008. In the 2001-2012 survey, seven communities were surveyed in 2011 and seven in 2012.

A sample of households was randomly selected to participate in the survey and was mailed a household survey questionnaire that gathered information about the household composition, household members, household vehicles, and other details. The households were asked to complete the questionnaire and return it by mail. If households did not respond and a telephone number was available for the household, they were called and invited to participate in the survey. If they agreed, the household information survey was administered by telephone.

The households were then assigned a travel day and mailed travel diaries for each household member with instructions for completing them. The household information survey asked for a telephone number where the household could be reached. After their assigned travel day, each household was called and a travel data retrieval survey conducted by telephone using CATI to collect the travel diary information. The travel diary contained one page per place visited on the assigned travel day and followed a typical format for travel diaries, with separate pages to record where the household member was at 3 a.m. on their assigned travel day and the details of travel to up to 14 successive places visited, including the activities undertaken at each place, with an additional page for more limited details of trips to up to ten additional places.

Summary

None of the five representative metropolitan travel surveys included a long-distance travel component, apart from long-distance trips that happened to take place on the assigned travel day. Given the sample sizes in the five surveys, which varied from 3,929 to 18,965 households, the number of such trips that were reported is likely to be relatively small.

In addition, all five travel surveys only collected travel information for weekdays, and one only collected travel information for travel on Tuesdays, Wednesdays, or Thursdays. This may well exclude a significant amount of long-distance travel.

Online Surveys of Air Travelers

Online surveys of air travelers are sometimes undertaken in support of research projects or other studies. For example, as part of ACRP Project 03-19 *Passenger Value of Time, Benefit Cost Analysis, and Airport Capital Investment Decisions*, a web-based survey was undertaken of individuals who had made a domestic air trip in the prior six months. The survey respondents provided details about their most recent trip, including the trip purpose and air party size, as well as the number of air trips they had made in the previous 12 months for business and leisure. The survey also collected information on various socioeconomic characteristics of the respondents, including personal and household income, gender and age, and household composition.

Although online surveys of air travelers typically collect information on air trips made by respondents, they are really a form of a household survey in that each respondent represents one household and the probability of a respondent participating in the survey does not vary with the number of annual air trips made (although this information may be reported in the survey). In contrast, an intercept survey of air passengers conducted at an airport is essentially a survey of air passenger trips, not of individual travelers. Someone who makes ten air trips per year through the airport where the survey is being conducted is ten times more likely to be sampled than someone who only makes one air trip per year through that airport. Of course, online surveys may experience problems of self-selection bias, since the respondents to the surveys have agreed to participate (often in return for some inducement or remuneration) and are often recruited using firms that maintain e-mail lists of people who have agreed to participate in a range of surveys on many different topics. Therefore, the responses to such surveys involving air travel need to be carefully analyzed to ensure that the respondents are representative of air travelers in general.

In the case of the survey undertaken for ACRP Project 03-19, the distribution of the origin and destination (O&D) of the most recent domestic air trip reported by survey respondents was compared to the overall pattern of domestic O&D travel and found to be reasonably representative of domestic air travel in general (ACRP, 2015b). Although the sample size of the survey was fairly small, 1,171 respondents, the respondents were distributed throughout the U.S. Thus, the survey from ACRP Project 03-19 provides a more representative sample of national air passengers compared to surveys conducted at a specific airport, which necessarily involve a large proportion (typically around half) of respondents who live in the region served by the airport. Although the ACRP survey respondents were on average older individuals with higher incomes than the general U.S. population, this reflects the air traveler population, which other surveys have shown to be older and have a higher average income than the population in general. The proportion of the survey respondents who were female (55%) was somewhat higher than the population in general. Whether this reflects the domestic air traveler population is unclear. Although many airport air passenger surveys collect data on the respondent gender, they typically only obtain one response from each air party and thus only report the gender of the person completing the survey or answering the survey questions on behalf of the party. In the case of a family or couple traveling together, it is possible that a male member of the party would be more likely to respond to the survey.

Consumer Expenditure Survey

One disaggregate data source that provides fairly detailed socioeconomic data and some air travel data is the Public-Use Microdata (PUMD) provided by the U.S. Bureau of Labor Statistics Consumer Expenditure Survey (CES) (<http://www.bls.gov/cex/>). The PUMD includes detailed disaggregate socioeconomic information at the household and/or individual level. The PUMD also includes information on airfare expenditures.

Although the PUMD only provides the expenditure on airfares, rather than details of the trips taken, it could be used to see how airfare expenditures vary with socioeconomic factors. Another attraction of the CES data is that it is national in scope, with annual data going back many years using a consistent survey methodology. Thus, these data could be used to explore whether the relationships among airfare expenditures and household characteristics have been changing over time. One caveat with the use of CES data is that the survey only covers consumer

expenditures. Reimbursed travel or business travel paid directly by employers is not included, so the data covers only personal travel.

The CES expenditure files also include information on each air trip or vacation taken by a household, including the number of trips and the duration of each trip, as well as the airfare (and other) expenditures for each trip. This would allow expenditures on air travel to be expressed in terms of the average number of air trips involved, which could then be compared to the data in air trips from the U.S. DOT 10% O&D survey. Thus the CES data would provide a complementary perspective that considers air travel expenditures rather than air trips *per se*.

e. New Sources of Socioeconomic Data

As discussed in Kressner and Garrow (2014), there has been increasing interest in using non-traditional data sources for travel demand modeling applications. The interest is motivated in part by the explosion of large, third-party data sources. These big datasets, which range from mobile phone signal traces and global positioning system (GPS) data to transit smart card or credit card spending patterns, collectively provide detailed spatial and temporal data about individuals' behaviors and mobility patterns, often in real-time. This section provides an overview of new sources of socioeconomic data, including credit card transaction and cell phone data that may be useful for airport demand modeling applications.

Credit Card Transaction Data

In many sectors of the economy, it is becoming increasingly recognized that the credit card transaction records maintained by credit card companies contain detailed information about spending patterns by individual card holders that can be potentially highly valuable for marketing and other purposes. Although the credit card companies of course know the identity of each card holder, privacy considerations prevent the release of data in a form that would allow the individual card holder to be identified. Even so, the credit card companies recognize the potential value of suitably de-identified information derived from the transaction data and are actively exploring ways to market this information. At the same time, potential users of this information are exploring ways to utilize the transaction data and link these data to broader socioeconomic characteristics, given the constraints that the specific individual making each transaction is not known.

Multiple firms have explored ways to link credit card transaction information to disaggregate, individual-level consumer characteristics, with varying levels of success. For example, both American Airlines and the Airlines Reporting Corporation (ARC) explored whether they could merge socio-economic data to individual ticket transactions. The key challenge is that the zip code associated with the airline ticket purchase is that of the merchant, not the individual traveler. Thus, all customers who purchase an airline ticket through Expedia have an Atlanta zip code associated with the ticket purchase. Other information, such as the passenger's name and origin airport, can be provided to companies that maintain databases of customer addresses and demographics (e.g., see Binder, *et al.*, 2014; Kressner and Garrow, 2014; and MacFarlane, Garrow and Mokhtarian, 2015 for example applications in travel demand modeling). The company can use this information to link to their customer database which contains socio-economic information. However, the individual's name and home metropolitan

area may not provide enough information to uniquely identify a home zip code or census region for the passenger – especially for common last names, such as Smith or Li (Carvalho, 2015; Howard, 2015). ARC estimates that his approach results in a unique match for approximately 10% of its tickets. For some applications, most notably determining catchment areas, this match rate is sufficiently large to provide useful information for airports (Howard, 2015).

Sometimes, additional information about the customers is available which enhances the ability to identify detailed travel histories for individual travelers. For example, a major credit card approached ARC because they were concerned that, due to the recent wave of mergers in the airline industry, many of their elite customers were no longer allowed to use their elite credit card to access airlines' airport lounges. The major credit card company wanted to identify which airports its elite customers were using, so that it could invest in an airport lounge for its elite customers. The major credit card company sent a list of credit card numbers and customer names to ARC, which ARC then matched to its ticketing database. The ability to use customer name and credit card numbers allowed ARC to identify travel histories for these elite customers, e.g., how often they travelled and which airports they most often used. The credit card company merged these travel histories with its internal customer database to link its elite customers' travel histories and socio-demographic information. Armed with this information, the credit card company built a number of airport lounges for its customers in the U.S. (Howard, 2015).

These are some examples of how credit card information has been used for concession planning/facility location in the airline industry. Depending on the level of transactional detail that is available, these data could also potentially be used to identify how often individuals travel by air, which airport(s) and airline(s) they use, and whether they pay for parking at or near the airport.

Cell Phone Data

Over the past decade, there has also been increased interest in using mobile phone signal traces and global positioning system (GPS) data from cell phone data to anonymously track individual customers through time and space. According to Bill King of AirSage (King, 2014; King, 2016) several airports and planning organizations have used cell phone data to identify catchment areas and/or to identify the number of passenger that have traveled in a specific travel corridor. The latter is particularly helpful for understanding the overall market potential in high speed rail corridors served both by both auto and air, as in the case for a study conducted for the Atlanta – Charlotte corridor (King, 2015). For privacy reasons, the identification number assigned to a particular cell phone is scrambled every 30 days, which effectively limits any data analysis to one based on cross-sectional (versus longitudinal) data.

There is also a growing number of airport ground access studies that have made use of cell-phone data to identify travel patterns to and from airports. With some processing, it is possible to distinguish between trips by air passengers from those by airport employees and between trips by residents of the region and visitors to the region. Past studies using cell-phone data have included an analysis of the geographic distribution of ground trip ends for travel to and from Ontario International Airport in California in a regular weekday, a regular weekend day, and the day before Thanksgiving, and an analysis of travel between Detroit Metropolitan Airport and hotels in downtown Detroit (King, 2014).

These are some examples of how cell phone data has been used to identify ground transportation movements to an airport, or passenger volumes by mode in a specific corridor. Due to the need to protect individuals' privacy, limited demographic and socio-economic is available; however, some information can be obtained by identifying a (large) geographic area in which the individual likely lives, such as the individual's home zip code. These data could also be helpful for identifying resident trips from home to airport, resident trips from work to airport, and non-resident trips from the airport.

Other Data Sources

There are numerous other potential sources of disaggregated data on traveler behavior. These sources include airline ticket booking and reservation data, other location-tracking devices that take advantage of cell phone signals, social media data, vehicle license plate data that is routinely collected in airport parking facilities, web search data from visitors to web sites, and transaction data collected in the course of airport concession sales or other airport operations.

ARC has also worked with airports to understand the (likely) movements of connecting passengers in its terminals. This is useful for concession planning. By modeling which gates connecting passengers arrive and depart from, airports can forecast high foot traffic areas. ARC built a model of connecting passenger movements by linking its ticketing data, which provided the sequence of flights the customer purchased, to gate information. ARC also explored whether it could assign a "value" to connecting passengers by associating aggregate sociodemographic Census information (such as the average household income for the passengers' home zip code). However, the low match rate with passenger names and origin airports made it difficult for ARC to identify large differences in customer demographics across connecting airports (Howard, 2015).

Other airports have explored whether they can use location-based devices, such as Beacons, to assist in airport operations planning and concession planning. Some airports, including London Gatwick, have installed low-cost Beacons throughout their concourses (McCartney, 2015). These Beacons allow the airports to passively collect precise information about the location of individuals who have cell phones with Bluetooth-enabled technologies. That is, beacons provide "complete" journey information for a sample of passengers, i.e., when did the passenger enter the airport, when did the passenger enter (and leave) security, which security line did the passenger use, which stores did the passenger pass by or visit, which restrooms did the passenger use, how long was the passenger in the gate area, when did the passenger board the aircraft, etc. This precise location information is anonymous, meaning no information other than the location about the passenger is known. (Cosmas and Wollersheim, 2015). However, individuals who choose to identify themselves or provide details about their trip can receive "customized GPS-like directions to their gate," as in the London Gatwick application (McCartney, 2015). Nonetheless, this information can be used to help airports to better understand their operations (such as where and when queues form) and plan the layout of their concessions and passenger facilities. The precise location of this technology also allows airports to push surveys to customers, e.g., to survey passengers boarding a particular flight when they are in the boarding area (Cosmas and Wollersheim, 2015).

Many airports, most notably Akron-Canton use social media (including Twitter, Facebook, LinkedIn, etc.) to connect with their passengers. Through parsing unstructured texts, these data feeds can help airports identify general sentiments of passengers towards an airport, e.g., do passengers like the concession offerings? Social media also allows airports to more directly interact with the local community, and better understand who their most vocal and advocates are. This can be particularly helpful during the airport expansion planning process (Cosmas and Wollersheim, 2015).

License plate information has been used to build catchment area for an airport. For example, Frankfurt Airport uses the license plates of individuals parking at the airport to model its catchment area. This is possible because German license plates use one to three letters to link the vehicle to the county in which the vehicle is registered. The license plate data can then be used to predict catchment areas, which can be validated by results with airport surveys of its customers. This approach can also be used in airports other countries that have a way to associate license plates to geographic areas, such as the U.S. on a State level (Cosmas and Wollersheim, 2015). Similar to the use of beacons in airports, those customers who elect to provide more information can receive more personalized services. For example, passengers who provide their itinerary information at the time they park in Düsseldorf airport can have a robot park their car and return it curbside after they land (McCartney, 2015).

Web search data can also be used to determine which individuals are searching for multiple airports. Many airlines are using these data to better understand airport choice in multi-airport regions (e.g., see Hotle and Garrow, 2014).

Many airports have duty free stores that scan boarding passes of passengers making purchases. These data are often used to model customer purchase behavior as a function of the customer's destination, flight number, nationality, and gender (Cosmas and Wollersheim, 2015).

These are some examples of how disaggregated data on traveler behavior has been used in the airline industry. These examples include both revenue-generating applications (e.g., through concession planning and/or targeted marketing) as well as cost-reduction applications (e.g., through improving operational efficiencies and better allocation of airport staffing levels). Passively collecting data provides the advantage of collecting "more" and potentially "more complete" information about travelers, but as with any data sources, is not perfect. The need to protect individual's privacy often prevents the ability to directly link disaggregate socioeconomic information to individual-level transaction data.

B.3 Airport Uses of Socioeconomic Data in Air Passenger Demand Studies

The previous section reviewed aggregate and disaggregate data sources that have been or can be used to support the types of air passenger demand analyses being addressed by this research project. This section examines how those data sources have been used in past air passenger demand studies and, more broadly, how those studies have included socioeconomic factors in their analyses.

This review focuses on studies undertaken by or for airports, state and metropolitan planning organizations (MPOs), and related agencies. These studies are typically documented in technical reports, memoranda, or presentations which are not always publicly available or published in a form that will appear in a conventional literature search. The review includes forecasts prepared by the Federal Aviation Administration (FAA) and other national government agencies (both at a national level and for individual airports and regions), as well as the forecasts of air travel demand prepared by industry organizations and commercial aircraft manufacturing firms.

a. Contribution of Socioeconomic Factors to Air Travel Demand Forecasting

An individual's demand for personal transportation, like his demand for other goods and services, is customarily explained and modeled as a function of two variables: the cost of transportation and the income of the traveler. In aggregate analysis, such as that of passenger demand for transportation in a nation or region, aggregate passenger demand is frequently modeled as a function of transportation cost and some measure of regional or national income (or other measures of general economic activity, such as GDP).

This economic approach to modeling passenger transportation demand serves as a foundation of transportation economics, as reported in a selection from that literature (Button, 1993; Holloway, 2003; Kanafani, 1983; McCarthy, 2001; Quinet and Vickerman, 2004). As was seen in the air passenger demand literature review contained in Appendix A of the final report, this formulation – relating travel demand to the cost of transportation, defined broadly, and to the income or economic fortunes of those traveling – is also used in the focused analyses of air passenger demand in specific regions and in specific markets.

For the analysis of demand in specific markets, regions or nations, empirical application of this approach to demand modeling relies on the use of aggregate socioeconomic data variables such as population, aggregate income, or GDP. While these are aggregate variables for which data are usually readily available, relying on aggregate values alone, omits what may be important differences in air travel demand that can exist within populations, both from region to region and over time. Examples of such factors for disaggregating socioeconomic data include income ranges, age ranges, place of residence, travel purpose, and household status, among others. These subgroups may have different propensities to travel by air due to differences in income or tastes. When this is true, extending the traditional demand models by using these disaggregated data elements may enable modelers to capture these differences in the willingness and propensities to travel by air. Such refinements may improve modeling results in ways that

give airport decision makers additional information about the travelers they serve, both as air passengers (who are obtaining air travel services from airlines) and as users of airport concessions and other services before and after their flights.

The significance of travel purpose as a potential category of disaggregated socioeconomic data for use in air passenger demand analysis is noteworthy because the demand for air transportation (like the demand for transportation generally) is regarded as a “derived demand.” This characterization means that in nearly all cases, individuals use air transportation not as an end in itself, but as a means to some other end, such as conducting business at a far location, visiting distant friends or family, or traveling to a distant destination for tourism or personal reasons. For this reason, the results from analyses that include disaggregated socioeconomic data about air passengers can be affected by the principal travel purposes of those using that airport.

Addressing these questions about the value or effectiveness of conducting more detailed analysis and modeling of air passenger demand by using more disaggregated socioeconomic characterizations of passengers and passenger populations is the purpose of this ACRP project. Realizing this increase in modeling detail will require use of passenger socioeconomic data that is more disaggregated than is most of the data now used in air travel demand analysis and modeling.

b. Types and Purposes of Air Passenger Demand Studies

Air passenger demand studies are undertaken for a wide range of different purposes within the aviation community and can be classified into several different types. The remainder of this section identifies six broad types of such studies and discusses how the different purposes influence how each type of study is performed and the type and sources of data typically used for these studies.

Projections of Future Demand for Air Travel

At the broadest level, air passenger demand studies are undertaken by governmental agencies or industry organizations in order to project future levels of demand for air travel. These demand projections support medium to long-range planning for future development, funding, and staffing needs of the aviation system. Examples include the national forecasts of aviation activity, such as those prepared annually by the FAA (in their *Aerospace Forecast*) (FAA, 2015a) or those prepared periodically by the United Kingdom (UK) Department for Transport (DfT, 2013). Another example is the annual forecasts of air travel by world region prepared by the International Air Transport Association (IATA, 2015b).

These studies typically express demand for air travel in broad terms, such as revenue passenger-miles (or revenue passenger-kilometers) or total passenger enplanements, without consideration of differences across specific markets, either at the airport level or region-pair or city-pair level. Similarly, the explanatory variables used in these studies generally use broad aggregate measures, such as average airline yield (average airline passenger revenue per passenger-mile flown) or gross domestic product. The projections developed by these studies may be used by airport operators, airlines, or other industry organizations to obtain a general

sense of the potential future growth in the demand for air travel or as a check on the reasonableness of more specific forecasts prepared at a local level. However, the lack of geographic specificity of the projected activity from these national-level studies means that the likely future growth rates at a given airport or region may well differ significantly from the growth projected by studies at the national or world regional level.

Recognizing this limitation, some government agencies also prepare more detailed forecasts at the airport level. In the U.S., in addition to the annual national-level *FAA Aerospace Forecast*, every two years the FAA prepares a *Terminal Area Forecast* (FAA, 2014) that projects a range of future activity measures, including enplaned passengers, for each airport included in the National Plan of Integrated Airport Systems. The UK national aviation forecasts (DfT, 2013) not only develop projections of future domestic air travel and travel between the UK and a number of different geographical world markets, but include a procedure to allocate these forecast passenger trips to each commercial service airport within the UK.

In addition, many of the major aircraft manufacturers, particularly Boeing and Airbus, prepare annual forecasts of global air travel demand by major market segments as part of their projections of the future demand for new aircraft, as discussed further below in the section on *Projections of Future Demand for Aircraft or Other Aviation-Supporting Goods and Services*.

Airport Master Plans and Facility Development Plans

Forecasts of future levels of air passenger traffic and associated aircraft operations at an airport form a key step in developing or updating airport master plans as well as creating detailed facility development plans. These projections of future activity levels are not only required to determine and design the needed facilities to handle the expected traffic, but are also a critical input in assessing the environmental impacts that will be generated by the anticipated levels of activity at the airport and the construction and operation of the future airport facilities. Therefore, these forecasts often receive a considerable degree of scrutiny by both the airport management and airport stakeholders, including residents and elected officials of the communities surrounding the airport.

Although these forecasts address a broader range of activity measures than air passenger traffic (that include air cargo activity and commercial aircraft operations), the forecasts of air passenger traffic are typically the primary factor determining the future level of commercial aircraft operations and the need for expanded or modernized facilities. These forecasts are usually based on an analysis of past changes in total air passenger traffic at the airport in relation to underlying changes in the socioeconomic characteristics of the region served by the airport and changes in the average cost of air travel. At airports with a significant proportion of connecting traffic, separate forecasts are usually prepared for O&D traffic and connecting traffic, since it is recognized that different factors determine the level of each type of traffic. The level of sophistication of the analysis varies widely across different airports, as discussed in more detail in Section 3.c below.

Although the FAA TAF includes a forecast for each airport included in the National Plan of Integrated Airport Systems (NPIAS), many airports commonly develop their own forecasts as part of an airport master planning study to supplement those created by the FAA. This allows the

airports to vary the assumptions underlying the forecasts, provide justification or explanation of the forecasts to affected stakeholders, and/or to generate more detailed forecasts than has been available in the past from the TAF. As discussed in Section 3.c, recent changes in the TAF potentially provide more detail than has been available in the past and allows users to vary the underlying assumptions used in generating the TAF forecasts for a given airport. This could reduce the need for airports to develop their own forecasts as part of a master planning study.

Airport Air Service Development and Passenger Leakage Studies

Many airports undertake more detailed studies to examine the market potential for expanding air service at the airport. These studies are generally referred to as air service development studies and attempt to identify underserved markets from the airport where demand may be sufficient to support expanded or new air service. The airports can then use the results of these studies to support efforts to interest airlines in providing the expanded air service. Although such studies do not necessarily require the preparation of formal forecasts, and customarily have a much nearer-term and market specific focus than do airport master planning studies, they necessarily involve some analysis of air passenger demand at the airport. This could include an analysis of passengers making air trips to or from the airport who use connecting flights at another airport and would most likely be attracted to new nonstop air service in those markets. This analysis is commonly performed using air travel itinerary data from the 10% O&D survey (DB1B) in the U.S. or air travel booking data for travel elsewhere in the world. These data are necessarily disaggregated at the level of airport-pair markets.

Air passenger leakage studies are a more specialized form of air service development studies that examine the extent to which air travelers with trip ends in the immediate region served by an airport use a more distant airport where air service is better (or they perceive it to be better). Better air service could involve cheaper fares, more frequent service, different airlines, or nonstop flights in markets that are not served directly from the airport experiencing the loss of traffic to the more distant airport. Since the air travel itinerary data commonly available do not indicate the ground trip end, other sources of information are needed to identify the extent of the use of more distant airports by air travelers with trip ends closer to the airport undertaking the study. These could include surveys of households and businesses in the region to determine which airports they have used for recent trips, or a comparison of the passenger traffic at the different airports examined in the study in O&D markets that have varying levels of air service (including those not well served or served at all at the airport undertaking the study) at each airport.

Airport Choice and Airport Ground Access Mode Choice Studies

In cases where large metropolitan regions are served by multiple commercial service airports, studies are sometimes undertaken to develop models of air traveler choice of airport in order to allocate the forecast regional passenger traffic to each airport. Although these studies are generally limited to large metropolitan regions, in fact airport choice often occurs in other contexts as well, as implied by the discussion of passenger leakage studies above. These airport choice models generally take a disaggregated approach and are based on an analysis of the airport choices of a sample of air party trips, such as obtained from an air passenger survey. The factors influencing air passenger choice of airport have been well described in ACRP Report 98

Understanding Airline and Passenger Choice in Multi-Airport Regions (ACRP, 2013b). These factors can be divided into three broad categories: the air service available at each airport, airport accessibility, and air party characteristics. Because these factors vary across travelers (such as the location of their ground trip end in the region which affects the relative accessibility of the different airports), most airport choice models predict the probabilities of an air party choosing each of the alternative airports in the region given specific air party characteristics. The relevant air party characteristics include such factors as travel party size, which affects airport ground access costs, and potentially socioeconomic factors such as household income.

Airport ground access mode choice models have generally broader application, since they are relevant to ground transportation planning at any airport, whether or not it is part of a multi-airport system. The form of such models is similar to airport choice models but excludes factors describing the air service. These models predict the probabilities of an air party with given characteristics choosing each of the available airport ground access modes. The structure of such models and the variables commonly included are described in *ACRP Synthesis 5 Airport Ground Access Mode Choice Models* (ACRP, 2008a). As with airport choice models household income is commonly included as a factor in the mode choice process, together with such factors as travel party size and air trip duration. Socioeconomic factors that have been included in some models include gender and age.

In some cases, an airport ground access mode choice model is included as part of an airport choice model in a nested choice structure to reflect the role of airport ground access mode choice options on the perceived accessibility of different airports for a given air party. This approach has the added advantage that such a model not only allocates regional airport demand to each airport but also generates the projected airport ground access trips by mode between each air party trip end location (typically based on regional travel analysis zones) and each airport. This information can be used to estimate the resulting air emissions or vehicle-miles of travel (VMT) on the regional highway system.

Aviation and Airport System Planning Studies

State and regional aviation and airport system planning studies generally include forecasts of future air travel demand in the state or region, since the forecast growth in air travel demand determines the future need for airport and other aviation facilities. Depending on the sponsoring agency, such studies are called aviation system plans or airport system plans. State-level studies are more commonly called aviation system plans, whereas metropolitan-level regional studies are more commonly called airport system plans. However, the choice of term is immaterial to the scope of the studies. Not all aviation or airport system plans include commercial service airports and the air travel demand served by those airports, but instead focus only on general aviation (GA) airports and GA activity. This focus often reflects the stronger state role in funding and sometimes regulating GA airports. Since these studies do not consider commercial air travel demand they are not included in the studies described in this section.

The general approach to forecasting the total air travel demand for a state or region is not fundamentally different from that used for airport master plans or airport development plans. Indeed, in the case of multi-airport regions, the only difference is the fact that the region is served by more than one commercial service airport, whereas a state can be thought of as a larger

multi-airport region. (Some states are actually smaller in geographic extent than some of the larger metropolitan regions). The key difference between air travel demand forecasts for state and regional aviation and airport system plans and those for a single airport is that the system plans generally include an allocation of the state or regional total demand to the airports serving the state or region. This allocation may involve a formal airport demand allocation model or the allocation may be made on some other basis, such as recent trends in existing traffic shares or policy decisions.

Airport demand allocation models typically include an air party airport choice model that reflects the factors that influence the airport choice process of individual air passengers. These factors are discussed in some detail in ACRP Report 98 *Understanding Airline and Passenger Choice in Multi-Airport Regions* (ACRP, 2013b) and can be broadly divided into two groups: those influencing the relative accessibility of each airport for a given air party, and those determining the different air service available at each airport for the air trip being undertaken by the air party. Of course, the relative weight given to each factor by a given air party will be influenced by the characteristics of the air party as well as the trip being taken. Since the relative accessibility of each airport varies with the air party's ground trip origin or destination and the details of the trip being undertaken and the air party characteristics vary from air party to air party, the circumstances faced by each air party are generally different. Therefore, airport choice models are usually formulated as disaggregate models that predict the probabilities of a given air party choosing each airport serving the region where the ground trip end is located. As noted earlier, airport choice models often use a nested structure, with airport ground access mode choice as a lower level in nest, in order to allow the measure of airport accessibility to reflect the available airport ground access options and their relative attractiveness to a given air party.

Airport Bond Prospectus Documents and Studies

Forecasts of passenger activity and other airport activity measures are also developed for airport bond prospectuses. Anticipated revenues from future passenger activities are one of several metrics that are reported in a prospectus to inform potential investors in an airport's bonds. Our interest in this section is in the types of models and data used by airports and their consultants to produce the passenger activity forecasts that are reported as part of airport bond offerings. The air passenger forecast found in the bond prospectus is customarily performed by an airport consultant, and is reported along with numerous other measures and examples of airport characteristics and performance in a section of the prospectus called *The Report of the Airport Consultant* or some similar title. In addition to the passenger forecasts, the consultant's report typically covers such areas as

- the economic and demographic characteristics and prospects for the population residing in the area served by the airport,
- the regional economic basis for commercial aviation activity, including the regional industrial mix,
- the historical and current patterns of airline service at the airport,
- the types of aviation and non-aviation activity taking place at the airport,
- the airport's facilities and capital programs,
- the financial and governance structure of the airport,
- the contributions of airlines and other airport users to airport revenues, and

- key factors that affect future airline traffic.

Because the purpose of the bond prospectus is to provide information to bond market participants about the magnitude and reliability of the airport's revenue sources and costs, the prospectus documents have similar structures from airport to airport.

Airline Passenger Demand Studies

Airlines undertake a range of air passenger demand studies in support of their operational and strategic planning, although these generally have a relatively near-term focus compared with forecasts produced by airport operators and other planning agencies. In the short-term, airline revenue management systems rely on forecasts of demand for a given flight as a function of the air travel service products⁷ and fare offers in each market, using their system's ability to adjust the availability and pricing of each service product over time. On a longer-term basis, airlines may undertake forecasts of the potential traffic in a given market when deciding whether to initiate or modify service in that market. Even so, these forecasts tend not to project future air passenger demand for more than a few years, since so many changes in the market environment can occur over which the airline has little or no control (e.g., entry or exit of a competitor in a given market, or changes in oil prices or the macroeconomic environment).

Although airlines develop and retain large amounts of detailed disaggregated information about the travel patterns of their customers, the scale of the available data makes it challenging to use for forecasting, particularly since they do not have access to the comparable data for other airlines. Furthermore, unlike the other types of air travel demand studies discussed in this section, any studies undertaken by airlines are generally considered commercially sensitive or proprietary.

Projections of Future Demand for Aircraft or Other Aviation-Supporting Goods and Services

Aircraft manufacturers and the firms in their supply chains have an obvious interest in correctly anticipating the future demand for aircraft. Both Airbus and Boeing produce annual forecasts of the expected long-term demand for air travel and the number of new aircraft that will be required to meet this demand. These forecasts provide projections of future levels of air travel demand by world region, but not at the level of individual airports.

Other organizations producing goods and services supporting the aviation sector also have a strong interest in the likely future growth in the market for air travel. However, rather than generate their own independent projections of this growth, they tend to rely on the forecasts produced by the major aircraft manufacturers and governmental agencies, such as the FAA, which have the resources to assemble and analyze the necessary data and generate updated forecasts on a regular basis.

⁷ We define an airline product as a fare and associated purchase and travel restrictions and amenities. For example, an airline's low-yielding restricted fare product may have a lower fare, but also require that the consumer purchase the ticket 21 days or more in advance of departure and pay a large exchange fee if travel plans change.

c. Assessment of the Current State of Practice of Air Passenger Forecasts

The remainder of this section will examine and summarize the approaches and techniques used in a range of recent examples of air passenger models and forecasts that have been prepared for use by airports or groups of airports for various purposes. Some of the examples are standalone airport forecasts, such as the FAA Terminal Area Forecast (TAF), but most were prepared to inform other airport or airport system requirements, such as airport planning or airport financing.

Approach

We have grouped the numerous air passenger forecast examples according to the type of airport study that contains each example. We will start with the FAA TAF, which includes forecasts for all individual commercial service passenger airports in the country. We then consider the forecasts prepared for regional and state aviation plans, which also take account of multiple airports. We then turn to forecasts prepared for or by individual airports, for use in airport master plans, finance documents and airport marketing purposes. The section concludes with a review of air passenger forecasts prepared by aircraft manufacturers for analyzing air passenger flows between regions of the world.

d. Review of Existing Studies

The following sections review a broad range of existing studies undertaken by the FAA, state aviation agencies, metropolitan planning organizations, airport operators, airlines, aircraft manufacturers, and industry organizations.

FAA Terminal Area Forecast

The FAA prepares forecasts of aviation activity at each active airport in the National Plan of Integrated Airport Systems (NPIAS) on an annual basis and published as the FAA Terminal Area Forecast (TAF). As of the end of 2015, the most recent TAF provides forecasts for the period 2014 to 2040 (FAA, 2016). The TAF provides historical data and forecast activity levels on a Federal fiscal year basis for the following measures of aviation activity for each airport (FAA, 2015b):

- Enplanements (enplaned passengers) by air carriers and regional airlines (separately and total)
- Itinerant aircraft operations by air carriers, commuters and air taxis, general aviation, and military aircraft (separately and total)
- Local aircraft operations by civil (general aviation) and military aircraft (separately and total)
- Total aircraft operations
- Based aircraft

In addition the TAF includes historical data and forecast activity for total aircraft operations under radar control at each Terminal Radar Approach Control (TRACON) facility.

Forecast Methodology

Prior to the 2014 TAF for the period 2013 to 2040 (FAA, 2014) the forecast process was primarily trend-based. Aviation activity forecasts for airports with FAA-operated control towers or Federal contract towers were developed using historical relationships between air passenger demand and other activity measures and local and national factors that influence aviation activity. These relationships were developed using statistical techniques, such as regression analysis or growth rates developed separately from the TAF (FAA, 2013). The TAF also incorporated estimates prepared by local authorities, including recent FAA-approved airport master plan forecasts, when FAA staff concluded that the methods used to develop these forecasts were acceptable.

In addition, a group of 30 larger airports termed the Core airports received a more extensive review by FAA staff economists. These airports comprised the 29 large hub airports in fiscal year (FY) 2011 that each enplaned more than 1 percent of total passenger enplanements plus Memphis International Airport. This review included consideration of the effects of local economic variables such as income and employment, the growth of originating and connecting traffic, and trends in airfares. The forecasts for these airports included assumptions regarding the seating capacity and load factors for commercial aircraft operations at these airports, together with near-term forecasts that utilized future airline schedules to project aircraft departures and seats and trends in enplanements per departure to project enplanements.

Forecasts of military operations were generally held at the current level except where the FAA was aware of a specific change in activity announced by the Department of Defense. Similarly, for airports without an FAA-operated or Federal contract tower, forecasts of general aviation aircraft activity were held constant unless otherwise specified by local or regional FAA officials.

The preliminary forecasts for airports with FAA-operated or Federal contract towers prepared by FAA headquarters staff were submitted to FAA regional and district offices for review. Suggested changes by FAA regional staff were reviewed by FAA headquarters staff economists and incorporated into the forecasts when determined reasonable and if significant increases in projected commercial aviation activity were supported by verifiable evidence of airline commitments to initiate new service.

With effect from the 2014 TAF, a new forecast process was adopted, termed the Terminal Area Forecast Modernization (TAF-M) (Bhadra, 2013; Bhadra, 2014). This is based on a set of formal, bottom-up models of air travel demand and aircraft operations (LeBoff, 2016). For airports with more than 100,000 enplanements in the most recent fiscal year for which activity data is available, the forecasts of domestic passenger enplanements and commercial operations are based on a regression model of air passenger travel in origin and destination (O&D) markets on a metropolitan regional basis, using airfares, regional demographics, and regional economic factors. The forecasts of O&D passenger travel are then allocated to airport pairs where a region is served by more than one airport and then to nonstop flight segments using historic flight segment data reported by the airlines to the U.S. DOT on Schedule T-100 of Form 41. The air passenger O&D demand model is described in more detail below. The nonstop flight segment passenger forecasts are then assigned to aircraft equipment types in order to generate forecasts of

aircraft operations by flight segment. The forecasts of domestic passenger enplanements and aircraft operations at the flight segment level are then aggregated to the airport level.

Forecasts of international passenger enplanements are generated using time series analysis at the nonstop flight segment level based on Schedule T-100 data. The flight segment passenger forecasts are used to generate forecasts of aircraft operations, based on trends in average aircraft size and average load factor. Forecasts of cargo aircraft operations at the nonstop flight segment level are also prepared using time series analysis of Schedule T-100 data. The forecasts of international passenger enplanements and aircraft operations and cargo operations at the flight segment level are then aggregated to the airport level.

The forecasts of passenger enplanements at airports with an FAA-operated or FAA contract control tower and less than 100,000 enplanements are based on an analysis of past trends. The corresponding forecasts of commercial operations are based on the enplanement forecast and an analysis of the trend in enplanements per operation.

Forecasts of itinerant and local general aviation operations at each airport with an FAA-operated or FAA contract control tower are based on a time series analysis, while itinerant and local military aircraft operations are assumed to remain constant unless the FAA has information about a specific change in activity that has been announced by the Department of Defense.

For airports without an FAA-operated or FAA contract control tower and less than 100,000 enplanements, passenger enplanements and aircraft operations are assumed to remain constant unless information from local or regional FAA offices indicates otherwise.

The overall structure of the analysis for domestic air passenger flows and commercial aircraft operations is illustrated in Figure B-4.

Although the overall TAF-M modeling process involves a number of different discrete components, from the perspective of the current ACRP project, the primary component of interest is the model of domestic passenger O&D flow.

Passenger Origin-Destination Model

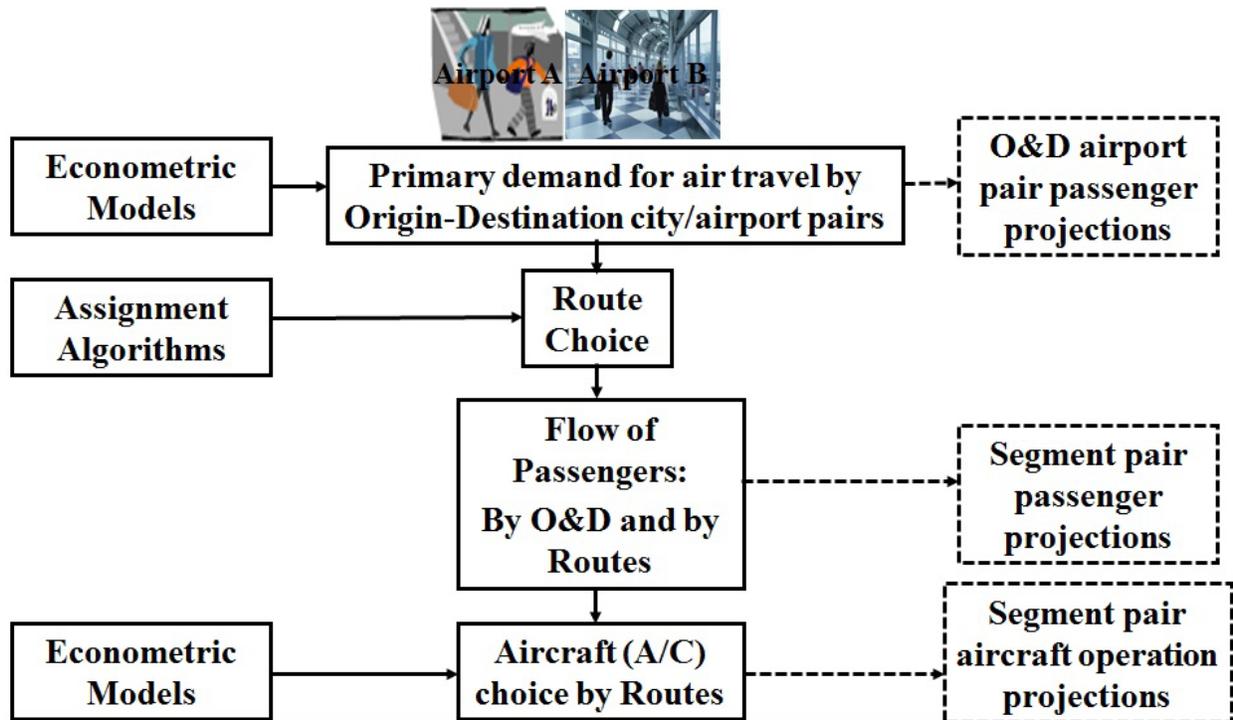
The domestic passenger O&D flow model forms the basis of the TAF-M forecast process. The model represents the directional passenger O&D flow between airport pairs serving geographic regions represented by Core Based Statistical Areas (CBSA) defined by the U.S. Office of Management and Budget, comprising 369 metropolitan areas and 582 micropolitan areas (Bhadra, 2013). The model structure takes the form of a log-log (multiplicative) relationship between the quarterly passengers flying between an airport pair and explanatory socioeconomic and air service variables.

The form of the model is given by:

$$\log(Passenger_{it}) = \beta_0 + \beta_1 \log(Fare_{it}) + \beta_2 \log(Route_{it}) + \beta_3 \log(Distance_{it}) + \beta_4 \log(IncomeOrigin_{it}) + \beta_5 \log(IncomeDest_{it}) + a_i + u_{it}$$

where $Passenger_{it}$ = Sum of O&D passengers flying on airport-pair i at time t

- $Fare_{it}$ = Average market fares paid by the passengers flying on airport-pair i at time t (in 2000\$)
- $Route_{it}$ = Total number of unique routes provided by airlines flying on airport-pair i at time t
- $Distance_{it}$ = Nonstop market distance (miles) for airport-pair i
- $IncomeOrigin_{it}$ = Total real personal income (in million 2000\$) for the CBSA for the origin airport of the airport-pair i at time t
- $IncomeDest_{it}$ = Total real personal income (in million 2000\$) for the CBSA for the destination airport of the airport-pair i at time t
- a_i and u_{it} = Market constant and random error terms



Source: Dipasis Bhadra, 2014 *Aerospace Forecast and Terminal Area Forecast: New Capabilities of Terminal Area Forecast (TAF)*, Powerpoint presentation, Federal Aviation Administration, April 1, 2014.

Figure B-4. TAF-M Analysis Structure for Domestic Passenger Flows and Commercial Aircraft Operations

As of the end of 2015, the most recent version of the model was estimated in June 2015 using a correlated random effects (CRE) procedure.⁸ The CRE procedure was chosen to improve the estimation accuracy on variables that stay constant over time, such as distance, or variables such as personal income that have very little variation over time compared to their variation across airport-pair markets. This procedure was implemented by including the average

⁸ Dipasis Bhadra, personal communication, July 28, 2015.

values of the *Fare* and *Route* variables over time in the model in addition to their value in a given quarter. The model was estimated on quarterly data from the first quarter of 2000 to the fourth quarter of 2014. Separate models were estimated for each quarter and for “thick” and “thin” markets, where thick markets refer to airport pairs with more than 500 quarterly O&D passengers, giving eight different models.

Where large metropolitan regions comprise several CBSAs, the personal income variables were summed for the metropolitan region. In cases where large metropolitan regions are served by multiple airports, the relationship between O&D passengers flying on individual airport-pairs with one end in the region and the total personal income of the region will be distorted by airport choice decisions and differences in air service at the airports serving the region. Therefore the passenger, fare, route, and distance variables were aggregated for the region.

Since the model form is expressed in logarithms, the estimated coefficients can be interpreted as demand elasticities. The estimated coefficients for the 2015 model estimation are shown in Table B-9.⁹ The model estimation did not include an overall constant term in addition to the market constants (a_i terms).

Table B-9. Estimated Passenger O&D Model Coefficients

Variable	Thick Markets (Over 500 pax/quarter)				Thin Markets (500 pax/quarter or less)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fare	-0.592	-0.608	-0.633	-0.607	-0.023	-0.022	-0.028	-0.021
No. of Routes	0.226	0.241	0.234	0.238	0.733	0.715	0.718	0.720
Distance	-0.106	-0.212	-0.204	-0.210	-0.406	-0.420	-0.416	-0.434
Origin Income	0.360	0.401	0.440	0.444	0.088	0.095	0.102	0.099
Dest. Income	0.361	0.391	0.441	0.444	0.092	0.099	0.106	0.103

Although the differences in the estimated coefficients across the four quarters for either the thick or thin markets are not large, the differences in a given coefficient between the thick and thin markets are considerable. The fare elasticity for thick markets is within the range found in other air travel demand models, although on the low side. However, the fare elasticity for thin markets is surprisingly low, implying that demand is essentially inelastic. If this were really the case, fares in these markets would be much higher than typically observed, since airlines would increase fares to maximize profits. Conversely, the demand elasticities of the number of routes and market distance in the thin market models are much greater than for thick markets.

The inclusion of market distance in the demand model raises potential issues of correlation between airfares and distance. Generally, fares are higher for longer distance trips, although the effect is far from proportional. Nonetheless, the distance elasticities may partly (or entirely) reflect the effect of distance on airfares rather than a direct effect on demand. Although it is common in intercity travel demand analysis to assume that demand for travel between two communities decreases with increasing distance, other things being equal, reflecting the growing number of intervening opportunities to satisfy the need for travel as the distance increases, in the

⁹ *Ibid.*

case of air travel this effect is likely to be distorted by two considerations. The first is that a high proportion of shorter-distance trips are made by automobile, rather than flying. The second is that the time and cost of making an air trip, when considering all the time and cost elements involved and not just the airfare and flight time, does not increase very much for a trip distance above about a thousand miles. However, an important difference between thick and thin markets is that thin markets do not have enough passenger traffic, by definition, to support nonstop service. Therefore passengers in such markets generally need to make one or more connections, which add significantly to the travel time involved.

Similarly, there is likely to be strong correlation between passenger demand and the number of airline routes available in a given market. The greater the passenger demand in a market, the more airlines will be able to provide viable service in that market, resulting in a greater number of routes available. While air travelers may benefit from the competition offered by different airlines and to a lesser extent from the greater choice of routes that this implies, there is likely to be rapidly diminishing utility from an increase in the availability of many alternative routes. Furthermore, much of the benefit to the traveler of the competition from having multiple airlines serving a market would be reflected in lower fares. Thus airline competition, as measured by the number of available routes serving a market, could be expected to have an inverse effect on fares. It is possible that this effect may explain the low fare elasticities and relatively high elasticities for the number of routes in thin markets.

Including both the total personal income of the region served by the origin airport and the region served by the destination airport in the model is likely to result in double-counting of the effect of income on air travel demand, reducing the value of the demand elasticity for income at each end of the market. If personal income levels rise generally, as is usually the case, it can be expected that air travel demand in all markets will increase according to the income elasticity, with some local differences in air travel demand growth due to differences in income growth in different communities as well as local differences in income elasticity. Having both variables in the model, with their effect multiplied together, effectively results in the income elasticity given by the coefficient for each variable to be approximately half the overall income elasticity. Thus in the case of the thick markets the overall income elasticity estimates vary between 0.72 and 0.89. This is somewhat lower than found in several other recent air travel demand studies for U.S. domestic O&D passenger travel, which found income elasticity values in the range from 0.74 to 1.81, although the measures of income in those studies varied, so the estimated TAF-M income elasticity measures may be broadly consistent. However, the estimates of overall income elasticity for thin markets vary between 0.18 and 0.21, which appear implausibly low and well outside the range of values found in other studies. This would appear to be deserving of further examination. One possible explanation may be the way that thin markets are defined. A large number of such markets necessarily have fairly small communities at one or both ends of the market. Differences in O&D passengers in many such markets may be due more to the level of air service available at the airports serving these smaller communities than differences in the population and per-capita income in these communities, since there may be a considerable amount of leakage of air travel demand from these communities to nearby larger airports. The air service variable in the models only reflects the number of alternative routes, which in many cases may only be one, not the frequency of service.

Summary

The TAF-M represents an ambitious attempt to develop a comprehensive air travel and aircraft activity forecasting process for the U.S. at a national level. Among the many attractive aspects of the process is the use of a consistent forecasting approach for all airports in the U.S. that is based on an underlying model of air travel demand that reflects the influence of socioeconomic factors (currently limited to total personal income) as well as differences in air service in each O&D market (currently incorporated as average airfares in the market and the number of available routes serving the market). An important benefit of the bottom-up approach to modeling O&D passenger demand is that the resulting forecasts of enplaned passengers and commercial aircraft operations can be made on a flight segment basis, rather than simply on the basis of total activity at a given airport. This has enormous benefits for use of the resulting forecasts in a wide range of planning activities, from aircraft noise analysis at airports to airspace and air traffic management planning, and is a significant improvement over the use of what was essentially trend analysis of airport activity.

However, as with the development of any complex, new process, there are many aspects that appear deserving of continued research and improvement. Because the TAF has to cover a very large number of airports (essentially all those in the NPIAS) and needs to be updated on an annual basis, a considerable effort has been devoted to the extensive data management issues involved. Now that the data management challenges have been largely overcome, the FAA staff economists can devote more attention to ensuring that the underlying air travel demand models appropriately reflect the influence of different socioeconomic factors and air service measures, and how the influence of these factors may vary in different markets. Although of less interest to the current ACRP project, further development of the TAF-M process should include more rigorous modeling of the various components of aviation activity that are currently still represented through trend analysis or the use of existing market shares, including international passenger and aircraft operations, the allocation of regional passenger demand to airports in multi-airport regions, the allocation of air passenger demand in each O&D market to alternative routes and flight segments and the projection of the associated aircraft operations by equipment type, and projections of general aviation activity.

As the details of the TAF-M process become more widely known and understood in the airport planning community and within the regional and local offices of the FAA, a continuous process of model improvement will be needed to build confidence in the resulting forecasts and facilitate their integration into airport master planning and other airport planning and development studies.

State Aviation System Plans

State aviation system plans generally include an aviation demand forecast element. In some cases these forecasts only or primarily address activity at general aviation (GA) airports, reflecting the greater focus of many state aviation agencies on GA airports. However, some state aviation system plans do address future air travel demand at air carrier airports within the state. The following sections summarize the forecast approach for air passenger demand in a representative selection of five recent state aviation system plans.

Alabama

The Alabama Statewide Airport System Plan (Garver Engineers, 2005) includes a forecast for air carrier enplanements at the state's six commercial service airports from a base year of 2000 for 2005, 2010 and 2020. It also includes forecasts of based aircraft and total GA operations at the six commercial service airports and 66 GA airports for the three forecast years, as well as a forecast of based aircraft fleet mix by aircraft category for 2020. The forecasts of enplaned passengers at each commercial service airport were developed by taking the FAA Terminal Area Forecast (TAF) projections through 2015 and extrapolating them to 2020.

The System Plan report contains a chapter that discusses economic development and demographic factors in the state. This discussion includes the findings of a survey of the 12 Alabama Regional Councils that explored the strategies being followed to promote economic development in each region. The chapter also contains an analysis of population change in each region and the most rapidly growing counties from 1990 to 2000, together with projections of future population growth in each region to 2020, based on data from Woods and Poole Economics, Inc. and the U.S. Census Bureau. A similar analysis of total employment and per-capita income trends and projections to 2020 is presented, based on data from Woods and Poole Economics, Inc., the U.S. Bureau of Economic Analysis, and the U.S. Bureau of Labor Statistics. There is no attempt to relate these trends in population, employment, and per-capita income to changes in air carrier enplanements.

Florida

The Florida Aviation System Plan (FASP) 2025 was initially prepared in 2005, then updated beginning in 2010 (CDM Smith, 2012a). The update included an analysis of the economic impact of airports on local communities and of airport projects on local economies. The FASP updates have been prepared as part of the Continuing Florida Aviation System Planning Process (CFASSP), which is guided by nine Regional CFASSP Steering Committees and an Executive Statewide Committee. As of February 2016, the FASP is undergoing a strategic update which is updating the goals and objectives from the previous plan. To support this update, the State has divided the state into nine centers of aviation activity: five aviation regions and four metropolitan areas.

The FASP report provides little detail on the forecasts of enplaned passengers beyond a bar chart showing projected passenger enplanements in five-year intervals from 2012 to 2022, as well as historical data for 2002 and 2007. The website of the Florida Department of Transportation Aviation and Spaceports Office includes a table of historical and forecast enplaned passengers by year from 1994 to 2033 for each commercial service airport in the state, but this appears to have been downloaded from the FAA TAF database as of early 2015.

The FASP update report makes brief reference to Florida's growing and aging population, but presents limited data and it is unclear how this has been reflected in the enplaned passenger forecasts. The report also notes that population and employment growth differ regionally within the state, but again presents limited data or discussion of how this will affect the future growth in enplaned passengers. A second report that provides a Statewide Overview (CDM Smith, 2012b) provides more detail on forecast future demographics in Florida, including

the projected growth of population by age range and regional differences in the proportion of population growth due to in-migration. Population data were obtained from the U.S. Census Bureau, as reported in the Florida Statistical Abstract, as well as population forecasts by the Bureau of Economic and Business Research at the University of Florida at Gainesville. However, there was no apparent attempt to develop quantitative relationships between these demographic data and future air passenger demand levels.

Kansas

The 2009 update of the Kansas Airport System Plan includes forecasts for air passenger enplanements at each of the state's nine airports with commercial air service in 2007, as well as forecasts of based aircraft and total aircraft operations at each of the commercial service airports and 132 general aviation airports in the state (Wilbur Smith Associates, 2009). The air passenger enplanement forecasts were taken from the master plans for each airport, using the forecast average annual growth rates to extrapolate to a consistent horizon year (2027) where necessary. In cases where the master plan was in the process of being updated or was out of date, the growth rates in the most recent forecast were applied to the actual enplanements in 2007. In one case, Salina Municipal Airport, the growth rate in the most recent FAA TAF was applied to the 2007 actual enplanements. It should be noted that there is a significant size disparity between the nine commercial service airports. The largest airport, Wichita Mid-Continent Airport, enplaned 769,124 passengers in 2007. The second largest airport in terms of commercial service, Topeka Forbes Field, enplaned only 24,319 passengers in 2007, while the smallest, Great Bend Municipal Airport, enplaned only 844 passengers in 2007. The System Plan technical report justified using the master plan forecasts on the grounds that these forecasts involved more in-depth research and analysis of the future needs of each airport and these forecasts had been reviewed and approved by the FAA.

The System Plan technical report contains a discussion of the population growth from 1970 to 2008 in the three Kansas metropolitan statistical areas, as well as the rest of the state, including population growth rates from 1985 to 2008 by county. There is also a discussion of employment growth for each area or county over the corresponding periods. However, these data were not used in preparing the forecasts of enplanements, given the approach adopted. The population and employment data were obtained from Woods and Poole Economics, Inc.

Minnesota

The latest update of the Minnesota State Aviation System Plan was prepared by the HNTB Corporation for the Minnesota Department of Transportation Office of Aeronautics and published in 2013 (HNTB, 2013). The System Plan report includes an extensive discussion of the development of aviation activity forecasts for the state, supported by a technical appendix. The statewide forecast of passenger enplanements by commercial air carriers was developed by defining catchment areas for each commercial service airport in the state and then estimating an econometric model to relate historical enplanements at each airport to socioeconomic factors for each catchment area, defined on the basis on driving time to each airport. The model development explored various socioeconomic variables, including population, total personal income, per-capita personal income, and employment, but total income was found to provide the best correlation with historical traffic. The explanatory variables in the chosen model also

included the number of scheduled air passenger aircraft departures as a measure of air service, together with dummy variables for five of the eight airports with scheduled airline service in the state. The discussion of the model in the report also mentions dummy variables for the attacks of September 11, 2001 and the Northwest Airlines bankruptcy in 2005, although these are not shown in the model equation given in the report. Since they would certainly have had a measurable impact on enplaned passenger traffic, and thus would have had statistically significant estimated coefficients, presumably they were included in the model estimation but not reported.

There are obvious problems of correlation between the two continuous explanatory variables, since the more passenger traffic that at an airport handles the more flights are needed to carry the traffic. This was acknowledged in the discussion of the model in the report, which describes an iterative process of applying the model, in which the forecast number of flights is projected by assuming an average aircraft size and load factor, then the passenger traffic is recalculated and the process continues until the passenger demand forecast converges. However, the report does not explain how this issue was addressed when the model was estimated in the first place.

The report includes a fairly extensive discussion of past trends and forecasts of population, personal income, and employment, although only the projected future growth in personal income was finally used in the forecast. The population, employment, and income data were obtained from Woods and Poole Economics, Inc., the U.S. Bureau of Economic Analysis, and the Minnesota State Demographer's Office. There is also a discussion of airfares and jet fuel prices although no cost variables were included in the final model.

Washington

The Washington State Department of Transportation (WSDOT) Aviation Division commenced an update of the Washington Aviation System Plan (WASP) in June 2015 (WSDOT Aviation, 2015). The update is scheduled to be completed by early 2017. The previous update of the WASP was completed in 2009 as part of the Washington State Long-Term Air Transportation Study (LATS) that was developed as a joint effort between WSDOT Aviation Division and a consultant team led by Simat, Helliesen & Eichner, Inc. (SH&E). The forecasts used in the 2009 WASP were prepared as part of Phase II of the LATS (SH&E, 2009). These forecasts were prepared using several different approaches for subsets of the 20 airports in the state that had commercial air service in 2006 (SH&E, 2007). In each case, the forecasts projected enplaned passengers and aircraft operations, separately for air carrier aircraft and commuter/air taxi aircraft (which were defined as having less than 70 seats for the purpose of the study). Total enplaned passengers were initially forecast then these were allocated to either air carrier or commuter/air taxi operators. Finally, the number of aircraft operations in each category was projected based on trends in average aircraft size and load factor.

Four different approaches were used to forecast total enplaned passengers. In the case of three airports, Seattle-Tacoma International (Sea-Tac), Grant County International/Moses Lake, and Friday Harbor, the study team adopted forecasts used in recent airport planning studies at those airports that had been approved by the FAA. In the case of Sea-Tac, which accounted for 87 percent of total enplanements statewide in 2006, the study team adopted the forecasts from

the 2005 FAA TAF. Where necessary, the forecasts for these three airports were extrapolated to 2030 using the growth rate for the later years of the forecasts.

For the second group of airports, which comprised the next eight airports (excluding seaplane bases) with the highest passenger enplanements in 2006, forecasts were prepared by the study team using three methods. The first method estimated a time-series model that effectively assumed that historic growth rates in enplaned passengers would continue in the future. The second method estimated the correlation between the annual change in passenger enplanements and the annual change in total income in each airport's service area, defined on a county basis. This correlation was then used to project future enplanements from forecasts of future total income in the relevant counties. The third method compared historic trends in enplanement and income growth at each airport and its catchment area with the corresponding data for the U.S. as a whole. These relationships were then applied to national forecasts of enplaned passengers and income to derive enplanement forecasts for each airport. The final forecast for each airport was then obtained by averaging the forecasts from the three methods. The details of each of these three methods are not reported in the technical report. Appendix D of the technical report lists the LATS Phase II technical memoranda, which include a technical memorandum on commercial service passenger traffic and operations forecasts. However, this memorandum is not included in the technical memorandum document on the LATS Technical Reports and Resources page on the WSDOT website.

The third group of airports, comprising William R. Fairchild International in Port Angeles, Eastsound/Orcas Island, and Anacortes, had each experienced a decline in traffic since the mid 1990's although this was not expected to continue in the future. It was assumed that enplaned passenger traffic would return to a level approximating the average level over the previous 10-15 years by the end of the forecast period.

Finally, for the fourth group of airports, which comprised the four commercial seaplane bases in the state and two airports in the San Juan Islands, Wes Lupien and Lopez Island, the forecasts were based on discussions with the air taxi operators serving those airports as well as the airport management.

Neither the LATS Phase II technical report nor the WASP contains a formal summary of socioeconomic data for the state or regions within the state, although reference is made in various places in the text of both documents to changes in population and income in specific regions or airport catchment areas. It appears from footnotes in the LATS Phase II technical report that some socioeconomic data was obtained from NPA Data Services, Inc.

Summary

Of the five state system plans reviewed, two used the TAF forecasts directly and one primarily adopted airport master plan forecasts, supplemented with the TAF forecast for one airport that presumably did not have a master plan forecast that could be used. Only one system plan, for Minnesota, developed forecasts for all the commercial service airports in the state. These forecasts were generated using an econometric demand model with only one socioeconomic variable, the aggregate total personal income in the catchment area of each airport. The fifth system plan, for Washington State, used a combination of approaches for

forecasts for different airports in the state. For the principal airport, Seattle-Tacoma International Airport, which as of the date of the system plan accounted for about 87 percent of the total enplanements in the state, the forecast was adopted from the TAF. For the next eight largest airports in terms of passenger enplanements, which together account for a further 13 percent of total enplanements in the state, forecasts were prepared using three different methods and the average of the forecasts generated by each method was used for each airport, although the details of the three methods are not described in the technical report documenting the forecasts. The forecasts for the remaining airports, which together account for less than 1 percent of the enplanements in the state, were basically assumptions, either by the study team or based on discussions with the air taxi operators serving the airports or the airport management.

Four of the five system plans included a discussion of socioeconomic trends in the state, typically including population, employment and personal income, although only one of the system plans actually used these data in developing the forecasts. Although the socioeconomic data was often presented at the county or regional level, it was generally not disaggregated in any way other than geographically with the exception of the Florida Aviation System Plan, which presented data on historic trends and projections of population by age range and regional differences in the growth rate of population due to in-migration versus natural increase., although these data were not apparently used in developing the forecast.

Regional Airport System Plans

Large metropolitan regions served by multiple commercial service airports generally prepare regional airport system plans to supplement and integrate the planning undertaken for each individual airport through its master planning or airport development planning process. These regional airport system plans are typically prepared by regional agencies, such as metropolitan planning organizations.

Although some of the larger metropolitan regions include parts of several states, airport system planning studies may address even larger multi-state regions, particularly where air service in a multi-state region such as New England is dominated by a single large hub airport.

The following sections provide a discussion of one such a multi-state regional airport system plan and examples of four recent system plans for large metropolitan regions, two involving parts of multiple states and two entirely within one state.

New England

The New England region comprises six states with 11 commercial service airports, although over half of the passenger enplanements in the region take place at the largest airport, Boston Logan International Airport (BOS). Increasing levels of air traffic and congestion at BOS from the 1980's led to a series of state and regional system planning studies from 1989 to 1998 that initially explored opportunities to develop a second major airport to serve the Boston region and subsequently ways to reduce the demand on BOS by expanding air service at other airports in New England (Louis Berger Group, 2006b). Starting in 2002, the Massachusetts Port Authority, the operator of BOS, and the Massachusetts Aeronautics Commission, working with a consortium of airport authorities and state aviation agencies in all six New England states,

together with the FAA and the New England Council, termed the New England Airport Coalition, undertook the *New England Regional Airport System Plan* (NERASP), a comprehensive study of alternative options for meeting the air service and commercial airport capacity needs for the entire New England region (Louis Berger Group, 2006b).

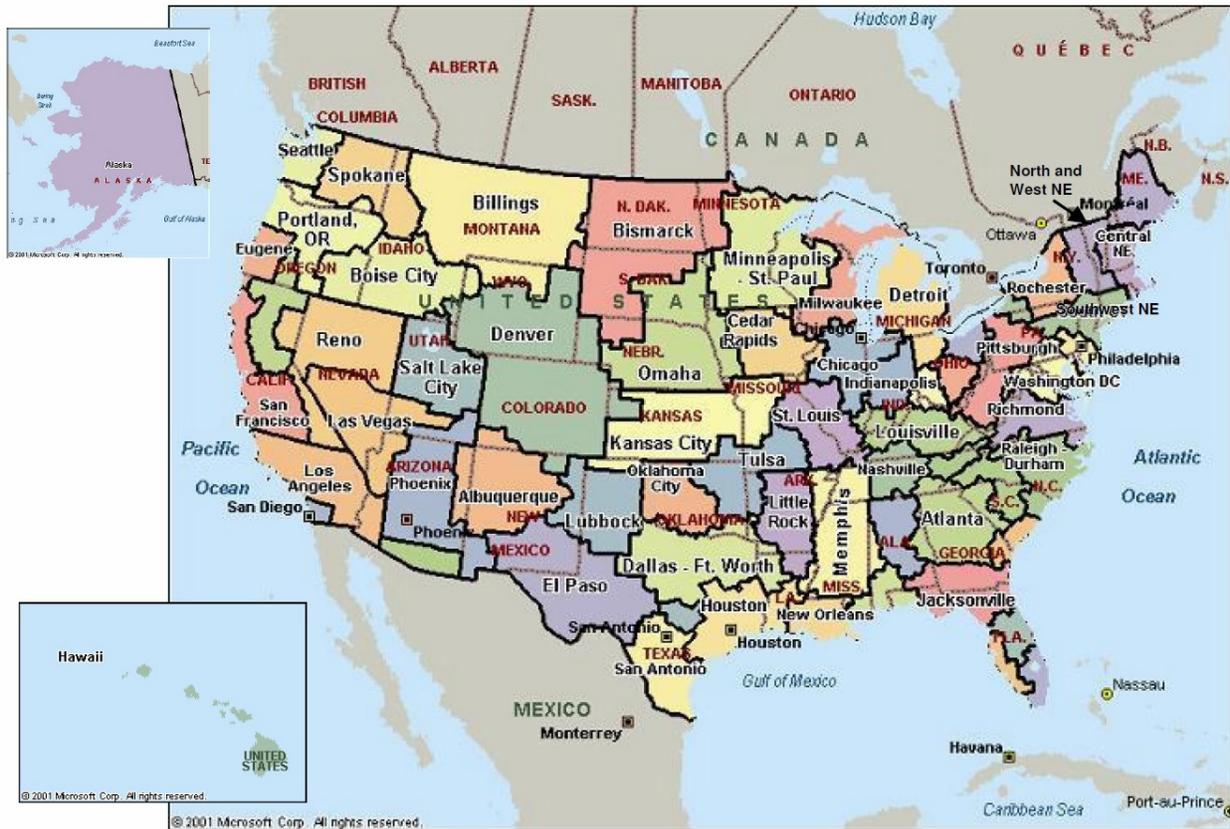
The NERASP was undertaken in two phases. Phase I ran from 2002 to 2004. Phase II ran from 2004 to 2006, culminating in the publication of the NERASP final report in October. The majority of the work on developing forecasts of air passenger activity at each of the 11 commercial service airports in the region occurred during Phase I. In Phase II, these forecasts were updated to reflect recent trends in regional air traffic and lower expectations for air passenger growth in the period from 2010 to 2020 (Louis Berger Group, 2006a).

The forecasts developed in Phase I of the study used different methods for three broad air travel markets: domestic air trips between New England and a trip origin or destination outside New England, international air trips to and from New England, including those connecting at a domestic gateway airport outside New England, and intra-New England air trips that did not involve a trip origin or destination beyond New England.

Domestic O&D air trips between New England and the remainder of the U.S. were forecast by developing a set of air passenger demand models that predicted the number of air trips in different geographic markets based on dividing the U.S. into a system of 62 Air Service Areas (ASAs), defined on the basis of Economic Areas defined by the U.S. Bureau of Economic Analysis (Louis Berger Group, 2006b). New England was divided into three ASAs: one covering the central area of region, including the Boston metropolitan area; one covering the north and west of the region, including the Albany-Schenectady-Troy Economic Area in New York State; and one covering the southwest of the region, including the New York-Northern New Jersey-Long Island Economic Area, which also included parts of western Connecticut and Massachusetts, and the southwest corner of Vermont. This definition of the New England ASAs reflected the fact that many air trips to and from the western parts of New England used Albany International Airport or the New York region airports. Separate demand models were estimated for each of the three New England ASAs, although the models all had the same variables and structural form. The geographical areas covered by each ASA are shown in Figure B-5.

For each New England ASA, separate demand models were estimated for markets in three distance ranges, based on the nonstop distance between the largest airports in each ASA: less than 750 miles, 750 to 1,500 miles, and over 1,500 miles. The models were estimated using annual 10% O&D survey data for the period 1981 to 2000 and corresponding data for the other variables. The continuous variables in the models were expressed in logarithms, giving a multiplicative structure, and included the following variables:

- Y Average real yield in the market (1981 dollars)
- PCIP Product of per-capita income in the ASAs at each end of the market
- PP Product of population in the ASAs at each end of the market
- LFC Dummy variable for years in which low-fare carrier entry in a market stimulated additional traffic
- REC Dummy variable for years in which the economy was in recession



Source: The Louis Berger Group, Inc., et al., *The New England Regional Airport System Plan – Technical Paper #5: Macro Forecast Model Description and Baseline Forecasts for 2010 and 2020*, Prepared for the New England Airport Consortium, October 2003, Exhibit A-2.

Figure B-5. NERASP Air Service Areas for Domestic U.S. O&D Demand

The yield variable was defined as the average fare per mile in the market, including taxes and fees. Separate market-specific constants were estimated for each ASA-pair. The estimated models generally had a good fit to the data (R^2 values of 0.97 or better) with generally high levels of statistical significance for the t-statistics for the yield, population and income coefficients. Since models were linear in logarithms of the continuous variables, the estimated coefficients of these variables can be interpreted as demand elasticities, and are summarized in Table B-10.

The yield elasticity values span a fairly wide range from -0.50 to -1.10 and do not appear to have a consistent relationship with distance. The per-capita income elasticity values are generally within the range found by other studies, although values of 0.71 and 0.73 are lower than might be expected, since income elasticity is commonly found to be around 1.0 or higher. The population elasticities also span a very wide range, even leaving aside the value for markets over 1,500 miles from north and west New England (which had very low statistical significance), from 0.42 to 1.00. However, interpretation of the elasticity values for the socioeconomic variables is complicated by the use of the product of the values at either end of each market.

Thus the estimated values reflect both cross-sectional and time-series effects, which could lead to significant distortions in the estimated coefficients.

Table B-9. NERASP Domestic Market O&D Demand Elasticity Values

	Market Distance		
	< 750 miles	750 – 1,500 miles	Over 1,500 miles
Central New England			
Yield	-0.81	-0.57	-0.54
Per-capita income	0.71	0.99	0.82
Population	0.94	0.45	0.89
North and West New England			
Yield	-0.90	-0.88	-1.10
Per-capita income	0.90	1.00	1.18
Population	0.29	0.35	0.09
Southwest New England			
Yield	-0.67	-0.50	-0.67
Per-capita income	0.73	0.97	0.85
Population	1.00	0.42	0.54

The models were used to generate the forecasts by applying forecast values of yield and the socioeconomic variables. The low-fare carrier and recession dummy variables were not used, implying that there would be no further stimulation by low-fare carrier entry in any of the markets during the forecast period and no recessions. The forecast values of the socioeconomic variables were obtained from Moody’s Analytics, Inc. In general the future values of the real yield in each market were assumed to decline by 1.2% per year after 2000, reflecting the most recent forecast of future yields by the FAA in the *FAA Aerospace Forecasts*. However, the real yield in some markets that were judged to have below-average yields was held constant for the forecasts. The traffic in five markets, including the markets between all three New England ASAs and Hawaii, were found to be outliers to the model predictions and the forecasts for these markets were made using a linear extrapolation of historic trends.

These forecasts were termed the base forecasts. However, they projected future traffic from a base year of 2000 and did not take account of the subsequent recession and effects of the terrorist attacks of September 11, 2001. Therefore an alternative set of forecasts were generated that shifted the forecast levels of traffic by four years, in effect assuming that traffic growth would return to 2000 levels by 2004 and would continue to grow thereafter by the amounts projected by the base forecast for each successive year.

The forecasts for international air trips were based on an analysis of the pattern of international O&D air travel in 2000 and an estimate of the growth that had occurred in international travel between New England and seven world regional markets between 1990 and 2000 (Louis Berger Group, 2003a). Estimates of future growth in each market were made based on industry forecasts of future growth in international travel between the U.S. and each world region, with adjustments for the historical growth for international air travel to and from New England. The analysis of international O&D trip patterns was based on data from the U.S. DOT 10% O&D survey, with adjustments for travel on foreign flag carriers that is not reported in the

O&D survey and for trips that use ground transportation to access international flights at the New York airports. The estimate of travel on foreign flag carriers was based on the T-100 data that those carriers report, with adjustments for passengers connecting at foreign hubs to or from flights to their ultimate destination or from their initial trip origin, while the estimate of international trips using ground transportation between New England and the New York airports was based on data from an air passenger survey undertaken by the Port Authority of New York and New Jersey in 1998.

The analysis of domestic O&D markets did not consider intra-New England air travel. This was forecast using a different approach. This was based on historic passenger and air service trends, together with judgement about future air carrier strategies, rather than using a formal model based on underlying socioeconomic factors and air fares. This was because the distances involved and the relatively high air fares in short-haul intra-New England markets meant that a high proportion of the trips between any two New England communities uses ground transportation, although there is a lack of equivalent data to the 10% O&D survey for travel by surface modes. For the purposes of the analysis, New England was divided into four air service areas, together with two partly external air service areas, one comprising the area served by the New York airports, Hartford-Bradley International Airport, and Tweed-New Haven Regional Airport, and one representing the area served by Albany International Airport (ALB). The New York and Albany regions were excluded from the analysis of domestic O&D markets, since they are close enough to large parts of New England that a high proportion of trips between New England and either region use ground transportation. For each airport-pair market, with the New York airports and Boston area airports treated as two groups, the number of passengers in 2000 from the 10% O&D survey was assumed to grow at a constant rate through the forecast period. The growth rate for each market was based initially on the growth rate for U.S. domestic enplanements forecast in the 2002 *FAA Aerospace Forecasts*, with adjustments to reflect the actual growth or decline experienced in the market between 1995 and 2000. Markets that experienced a decline in air passengers from 1995 to 2000 were generally project to remain at their 2000 traffic level through the forecast period. Markets that experienced a growth rate from 1995 to 2000 below the national forecast growth rate in the FAA forecast were generally assumed to continue to increase at that rate, while markets that experienced a growth rate from 1995 to 2000 significantly higher than the national forecast growth rate were assumed to increase at twice the national forecast growth rate. Markets between New England and the New York region were assumed to increase at the national forecast growth rate.

A set of assumptions for future growth in the independent variables in the domestic O&D air passenger demand models was defined for a base case scenario. These assumptions were varied to define a high and low growth scenario, termed “enhanced” and “depressed” in the final report. Assumed growth in population was held constant for all three scenarios, but assumptions for growth in per-capita income and air fares (yield) were varied, together with some air service assumptions. The NERASP technical documentation does not discuss whether the forecasts of international and intra-New England passengers were adjusted in the enhanced and depressed scenarios.

The revisions to the air passenger forecasts in Phase II did not involve any additional modeling of air passenger demand for the base case. Instead, the average annual growth rates for air passenger activity for the forecast years from 2010 to 2020 given by the assumptions and

modeling in Phase I were reduced to reflect a reduced expectation of longer-term growth in air passenger demand (Louis Berger Group, 2006a). Generally the revised growth assumptions resulted in considerably lower assumed average annual growth rates during the period from 2010 to 2020 compared to the period from 2004 to 2010, particularly for BOS, where the average annual growth rate for total airport passengers for 2010 to 2020 in the base case scenario was assumed to be only 2.1% per year, compared to 5.4% per year for the period from 2004 to 2010. Overall for New England in total, the average annual growth rate for total airport passengers for 2010 to 2020 in the base case scenario was assumed to be 2.3 % per year, compared to 5.4% per year for the period from 2004 to 2010. The Technical Paper on the revised forecasts (Louis Berger Group, 2006a) provides limited discussion of the rationale behind the reduced growth assumptions beyond noting that they resulted in a more linear growth in air passenger activity and air passenger trends since the year 2000 (which of course included the drop in air traffic throughout the U.S. following the terrorist attacks of September 11, 2001 and the impact of the 2001-2002 recession). The Phase II final report (Louis Berger Group, 2006b) provided a little more justification, noting that the historical period used for model estimation in Phase I comprised a period of declining price of air travel and an expansion of services, which caused the models to project average growth rates which exceeded longer-term historical experience and that this level of growth was not sustainable in the future period covered by the study. The report is unclear in what way the forecast level of growth in Phase I was considered unsustainable, but presumably this referred to airport capacity limitations at BOS, since there were effectively no airport capacity limitations at any of the other airports.

However, the whole point of developing an airport system plan is to project the level of demand that is expected to occur in the absence of airport capacity constraints in order to determine the need for future airport capacity. While it is of course true that it may not prove politically possible to provide that capacity, one of the purposes of a system plan is to identify the consequences of not doing so, so that those engaged in the political debate over how to meet the future airport capacity needs of the region can understand the trade-offs involved. Making arbitrary adjustments to forecast growth rates in demand to better conform to expectations about the level of growth that will occur significantly reduces the value of preparing forecasts of future demand. However, there is another important aspect to the concern that the models and analysis in Phase I gave projected growth rates that were unreasonably high. This concern suggests that while these models may have explained the historical data fairly well, they may not have done as good a job at predicting future demand due to limitations of the models themselves, perhaps because they omitted important variables or incorporated causal variables in a way that exaggerated the effect of future changes in the values of those variables. While these concerns may be moot at this point as far as the NERASP is concerned, they speak directly to the motivation for the current ACRP project.

In addition to the changes to the overall forecast of air passenger demand, Phase II of the study included several significant other data collection and modeling activities. An air passenger survey was performed in 2004 at ten commercial air service airports in New England (Louis Berger Group, 2004). Worcester Regional Airport had no scheduled service at the time the survey was performed. The survey was performed at the four largest airports in May 2004 and at the six smaller airports in June. The larger airports were generally surveyed over a two-week period, while the smaller airports were surveyed on three days each, generally over a one-week period. The survey obtained 5,487 responses at BOS, between 2,710 and 3,721 responses at each

of the other largest airports, and between 83 and 1,154 responses at each of the smaller airports, with a total of 18,527 responses overall.

The survey results were used for two subsequent analyses. The first consisted of the development of a trip generation model that predicted the number of annual air trips with a ground trip origin in a given zone comprising one of 743 New England towns or counties. Separate models were estimated for resident business trips, resident non-business trips, non-resident business trips and non-resident non-business trips. The explanatory variables varied across the four market sectors, and included population, employment, per-capita income, and driving time to BOS or the nearest airport, as well as dummy variables for five cities.

The second analysis consisted of the development of an airport choice model that was used to allocate forecast air trips by origin zone to airports, based on assumed changes in air service at each airport. Details of this model are discussed in the section on Airport Choice Models and Airport Demand Allocation Studies below.

Baltimore/Washington Region

The Baltimore/Washington region is served by three air carrier airports: Baltimore/Washington Thurgood Marshall International Airport (BWI), Ronald Reagan Washington National Airport (DCA), and Washington Dulles International Airport (IAD). BWI is operated by the Maryland Aviation Administration (MAA), while DCA and IAD are operated by the Metropolitan Washington Airports Authority (MWAA). The Metropolitan Washington Council of Governments (MWCOG) provides staff to support the National Capital Region Transportation Planning Board (TPB), the federally-designated Metropolitan Planning Organization for the region. The TPB has conducted a Continuous Airport System Planning (CASP) program since 1978 and both the MAA and MWAA are represented on the TRB (MWCOG, 2016b).

The CASP comprises a number of elements although there has not been a comprehensive Regional Airport System Plan (RASP) update covering the commercial service airports since 1988. Rather, the focus of the CASP has been on developing forecasts of the distribution of air passenger ground origins and destinations in the region and airport ground access planning, addressing both passenger trips and air cargo activity. For many years there has been a regular planning cycle that commences with an air passenger survey at the three commercial service airports, followed by updates to a *Regional Air Passenger Origin/Destination Forecast* (MWCOG, 2013a), an *Air Passenger Ground Access Forecast* (MWCOG, 2013b), and the *Ground Access Element* of the RASP. Periodically, other studies have assembled data on airport ground access travel times and updated the *Air Cargo Element* of the RASP.

The Regional Air Passenger Origin/Destination Forecast (MWCOG, 2013a) does not develop a forecast of total enplanements at each airport. Instead, the FAA TAF forecasts are used. Based on the data from the latest air passenger survey, the enplanements at each airport in the base year are divided into connecting passengers, originating passengers with trip origins within the Washington-Baltimore Air System Planning Region, a 21-county region, and originating passengers with trip origins outside the planning region. The Air System Planning Region is divided into 161 Aviation Analysis Zones (AAZs). The air passenger survey responses are weighted to correspond to the annual air passenger enplanements at each airport in the base

year, and the annual passenger trips originating within each AAZ are calculated separately for passenger trips starting at a residence and those starting at some other trip origin. Ratios are calculated for each AAZ of the home origin trips (including visitor trips starting at a residence) to households in the AAZ and the non-home origin trips to employment in the AAZ.

Forecasts of trip origins by AAZ in future years are made by applying these ratios to the forecast number of households and employment in each AAZ developed as part of the TPB regional planning process. These forecasts are then adjusted to ensure that the forecast total air passenger originations at each airport corresponds to the forecast enplanements in the FAA TAF, assuming that the proportion of connecting passengers and external trip origins remain constant. There is no attempt to use an airport choice model to predict how air passengers from a given AAZ might change their airport use in response to changes in air service at each airport. This implies that if the FAA TAF predicted higher a growth rate at one airport compared to another (as it did), this is assumed to result from a higher growth in air passenger trip origins from each AAZ in proportion to the distribution of trip origins for that airport in the base year.

The Air Passenger Ground Access Forecast (MWCOCG, 2013b) largely follows the same process as the Origin/Destination Forecast, with one difference and some additional analysis. The difference is that the data from the air passenger survey is used to select air passengers departing on a weekday in allocating air party trips to AAZs. These are then converted to average weekday trips by dividing by 260. The air passenger survey data is also used to calculate the proportion of air party trips from each AAZ by ground access mode and in three time of day periods. For forecast years, adjustments were made to ground access mode use to IAD from some AAZs to reflect future extension of the Metrorail system to the airport using professional judgement

New York/New Jersey Region

The New York/New Jersey metropolitan region comprises New York City, Long Island, suburban counties in southern New York State, a large area of northern New Jersey, and parts of western Connecticut. The area is primarily served by three major commercial service airports: LaGuardia Airport (LGA) and John F. Kennedy International Airport (JFK) in New York and Newark International Airport (EWR) in New Jersey. There is also some commercial air service at Long Island MacArthur Airport (ISP) near Islip on Long Island, at Stewart International Airport (SWF) in Orange County, New York, some 60 miles north of Manhattan, and at Westchester County Airport (HPN) in southwestern Connecticut. The three major airports and SWF are operated by the Port Authority of New York and New Jersey (PANYNJ). Each of the three major airports and the surrounding airspace have been experiencing increasing levels of congestion for many years and the provision of adequate airport and airspace capacity to meet the future needs of the region has been an ongoing policy concern.

In 2007 the FAA completed a *Regional Air Service Demand Study* in cooperation with the PANYNJ, the New York State Department of Transportation, and the Delaware Valley Regional Planning Commission (PB Americas, 2007a). This study included the preparation of air travel demand forecasts for the nine airports in New York State, New Jersey, and Pennsylvania included in the study (PB Americas, 2007c-h). The forecasts were undertaken in two stages. In the first stage forecasts were prepared for the total passenger traffic at each airport, subdivided

into domestic O&D passengers, international O&D passengers (at those airports with international service), and connecting passengers. In the second stage, forecasts of O&D passenger trip originations by county were prepared for each airport and then combined to give total passenger trip originations by county. These total forecast passenger trip originations were then allocated to airports under different airport development scenarios using an airport demand allocation model described later in this appendix. This section describes the forecasts of future passenger traffic by airport in the first stage analysis and the forecasts of O&D passenger trip originations by county in the second stage analysis.

The first stage in the forecasting process used time-series data to project future air passenger traffic levels at each airport, although the approach varied by airport. For the three major PANYNJ airports, several econometric models were developed using 21 years of historical data from 1985 to 2005 (PB Americas, 2007c). Separate models were estimated for domestic originating enplanements for each airport and for the three airports combined, together with a model for international originating enplanements at JFK. A separate model was estimated for international originating enplanements at JFK and EWR combined and a different approach was followed for international originating passengers at LGA, for the reasons discussed further below. Using the responses to an air passenger survey undertaken as part of the study (PB Americas, 2007b) catchment areas were defined for each airport comprising those counties which generated at least 0.05 survey responses per thousand population in the county. Historical and projected data for four socioeconomic variables, population, real personal income, per-capita personal income, and total employment, were assembled for each county for each year from 1985 to 2025. In addition, annual data were obtained for the Gross Regional Product, the U.S. Gross Domestic Product (GDP), and the World GDP, and average domestic airline yield at each airport and the three airports combined. Dummy variables were defined to account for specific events in particular years that were believed to have impacted enplaned passenger traffic. The variables that were found to give the best fit to the historical data varied by airport, as shown in Figure B-6.

Domestic			
<u>JFK</u>	<u>LGA</u>	<u>EWR</u>	<u>3-Airport Region</u>
Yield	Employment	Yield	Yield
Population	Personal Income	PCPI	Employment
Personal Income	Dummy Variable	Dummy Variable	Personal Income
Dummy Variable			Dummy Variable
International			
<u>JFK</u>	<u>JFK + EWR</u>		
Personal Income	Personal Income		
U.S. GDP	U.S. GDP		
Dummy Variable	Dummy Variable		

Source: PB Americas, Inc., et al., *FAA Regional Air Service Demand Study: Task B – Forecast of Passengers, Operations, and Other Activities*, Port Authority of New York and New Jersey Airports, May 2007, Table V-1.

Figure B-6. Independent Variables Used in Final O&D Forecasts for PANYNJ Airports

However, the details of the regression models, including the structural form, the estimated coefficient values, and statistical tests, are not given in the report. The table shown in Figure B-6 refers to a “Dummy Variable,” although the report mentions several different events that affected air traffic and that were accounted for using the “dummy variable.” Presumably this should have referred to dummy variables, since by definition a dummy variable can only account for the effect of one event.

The report presents charts showing differences in the socioeconomic data by county, including population density and PCPI in 2005, population and PCPI growth from 1995 to 2005, forecast population and PCPI growth from 2005 to 2015, and employment density in 2005. However, apart from being used to generate the socioeconomic variables for each catchment area, these differences in county socioeconomic data were apparently not used in the forecast modeling.

The regression models were used to develop a base case forecast for domestic and international originating passengers at each airport, using the forecast values of the socioeconomic variables and average airline yields, with two exceptions for international passengers. The model initially estimated for international originating passengers at EWR gave forecast values that were felt to be too high. Therefore the model estimated on international originating passengers at JFK and EWR combined was used to forecast the international passengers at both airports, then the forecast for international passengers at JFK given by the model estimated for JFK alone was subtracted from the combined forecast to give the forecast for EWR. It did not prove possible to estimate a satisfactory regression model for international originating passengers at LGA, so the forecast was based on a trend analysis of historical international originating passengers at LGA.

Optimistic and pessimistic forecast scenarios were defined by assuming an increase in originating low-cost airline traffic over the base case for the optimistic forecast, while the pessimistic forecast assumes that the growth in the underlying socioeconomic variables would only be 75 percent of the growth in the base case. The report offers no rationale for either set of assumptions.

Connecting passengers were forecast by analyzing historical trends in connecting passengers as a percentage of O&D passengers and extrapolating these trends into the future. Total passenger enplanements were then forecast by combining the projected O&D and connecting passenger enplanements.

The forecasts for the other six airports were developed using generally simpler approaches. The forecast for ISP was developed using a similar regression model to the three major PANYNJ airports (PB Americas, 2007f) that used the following variables:

- Yield
- Personal income
- Dummy variable(s)

As with the PANYNJ airports, further details of the model are not given in the report. An optimistic forecast scenario was defined by assuming an expansion of Southwest Airlines service at the airport, while a pessimistic scenario assumed a slightly slower growth of personal income

than assumed in the base case. The report offers no rationale for the assumptions used in either scenario. The forecasts for HPN and SWF (PB Americas, 2007d,e) did not use a regression modeling approach. In the case of HPN, the enplaned passengers were projected to grow at the growth rate of the catchment area population and employment, with some adjustments for market stimulation from the introduction of service by AirTran Airways in April 2006. The details of this adjustment, nor how the growth rates of the catchment area population and employment were combined, are not given in the report. The details of the forecast approach for SWF are even less clear from the forecast report for that airport. The report discusses the introduction of service by AirTran Airways and JetBlue Airways in December 2006 and January 2007, but how was reflected in the forecasts is not clear, particularly for the later years of the forecast.

Forecast were also prepared for three airports to the south of the region, Lehigh Valley International Airport (ABE) in Pennsylvania, Atlantic City International Airport (ACY), and Trenton Mercer Airport (TTN), both in New Jersey (PB Americas, 2007g). All the airports are located between EWR to the north and Philadelphia International Airport to the south, so a large proportion of the passenger trips that originate within their catchment areas are attracted to the larger airports. Partly for this reason, none of the forecasts used a regression modeling approach. In the case of ABE, a base case enplaned passenger growth rate was assumed based on the average past passenger traffic growth at the airport and optimistic and pessimistic scenarios defined using different assumed growth rates. In the case of ACY, the base case forecast adopted the projected growth in enplaned passengers given by the 2006 FAA TAF. An optimistic scenario added to this an assumed expansion of low-cost airline service, with an initial level of 11 daily flights and an assumed annual growth rate somewhat higher than that projected by the TAF. A pessimistic scenario assumed a somewhat lower growth rate corresponding to the historical traffic growth over the period 1990 to 2005. In the case of TTN, a pessimistic scenario was defined that assumed a continuation of the air service in effect in 2006 with a 2 percent annual growth rate in the future. The base case forecast assumed that the 19-seat aircraft in use in 2006 would be replaced with 50-seat regional jets, with the same departure frequency, load factor, and annual growth rate in enplaned passengers. An optimistic scenario assumed the addition of new low-cost airline service similar to that assumed in the optimistic scenarios for ABE and ACY.

The second stage in the forecasting process used the air passenger survey data collected as part of the study (PB Americas, 2007b) to develop models of trip generation by county for ten different market sectors, distinguishing between residents and non-residents of the region, business and non-business trips, and the type of trip origin (residence, business location, or hotel). This was essentially a cross-sectional analysis, since it was based on survey data for one point in time. This cross-sectional analysis was then extrapolated to future years using the forecast growth at each airport predicted in the first stage of the forecasting process and the effect of changing socioeconomic factors over time.

For each of the ten market sectors, the average daily number of air passenger originations in each county was expressed in terms of the ratio to an appropriate metric for each type of trip origin: population for residences, employment for business locations, and hotel rooms for hotel origins. This allowed the forecast levels of trip generation to reflect projected changes in population and employment in each county. In addition, an adjustment was made to the weighting used for each air passenger survey response to reflect changes in the distribution of

households by income as real PCPI increases. Survey respondents were classified into three household income ranges: less than \$50,000, \$50,000 to \$100,000, and greater than \$100,000 in 2006. Using data from the 2000 U.S. census relationships were defined that gave the percentage of households in each income range as a function of the ratio of the average PCPI in the county to the average PCPI for the region as a whole in 2005. As projected real incomes increased for forecast years, these relationships were used to adjust the proportion of households in each income range and hence the weights applied to each resident survey response to reflect the increase in trip propensity due to increased income.

A second ancillary analysis was performed to estimate a model of the number of hotel rooms in each county as a function of employment, population, household income, and travel time to the nearest major airport. This model was used to estimate the number of hotel rooms for counties for which hotel room data was not available and to project the number of hotel rooms in each county in forecast years.

A subsequent study of regional airport capacity needs and potential strategies and options to address those needs was undertaken by the Regional Plan Association (RPA) with support from Landrum & Brown, Inc. (Zupan, Barone and Lee, 2011). The study examined the current levels of congestion at the region's three major airports, the potential future growth in demand, and a range of alternative ways to meet that demand, including deployment of advanced air traffic management technology, greater use of outlying airports or development of a new airport, improved intercity rail services, demand management, and capacity expansion at the existing airports. The study prepared forecasts of total passenger traffic at the three major airports using several different methods and compared the resulting forecasts of future air passengers to those given by four other forecasting studies: the *Regional Air Service Demand Study* described above, forecasts prepared by the PANYNJ in 2009 and 2010, and the FAA 2010 TAF. The PANYNJ 2010 forecast projected future traffic growth for three scenarios, termed optimistic, moderate, and pessimistic (with the optimistic scenario projecting higher growth than the moderate scenario and the pessimistic scenario projecting lower growth). The level of air passenger traffic in 2030 at all three airports projected in the FAA TAF was considerably higher than the optimistic scenario in the PANYNJ 2010 forecast and implied a greater increase in air passengers over the 21-year period from 2009 to 2030 than had occurred in any previous 21-year period from 1969 to 2009. This was deemed implausible and not given further consideration.

The forecasts prepared as part of the study were all based on an analysis of the historical data on annual air passenger traffic at all three airports from 1990 to 2009. Two forecasts were based on fitting a linear time-series models to the passenger data, one to a weighted moving average of total passengers and one estimating separate time-series models for annual domestic and international passengers. A second set of forecasts were based on estimating relationships between total annual passengers at all three airports and regional personal income in constant 1984 dollars. One model estimated the relationship between total air passenger trips and total personal income, while a second model estimated the relationship between air passenger trips per capita and per capita personal income. Expressing the income variable in logarithms was found to give the best fit for both relationships. However, it should be noted that these relationships were expressed in terms of the population and income of the New York region, while the air passenger traffic numbers included trips by visitors to the region and passengers connecting at the three airports.

The four forecasts prepared as part of the study gave projected levels of air passenger traffic in 2030 that lay between the traffic levels projected by the pessimistic and optimistic scenarios of the PANYNJ 2010 forecast. Based on a comparison of the growth rates implied by the various forecasts, the study adopted high, medium and low growth forecasts scenarios, with assumed annual average growth rates from 2009 to 2030 for the high and medium growth scenarios similar to the optimistic and moderate forecasts by the PANYNJ and the assumed average annual growth rate for the low growth scenario between the pessimistic forecast by the PANYNJ and the lowest of the forecasts prepared as part of the study. However, rather than assuming the same growth rate in each year of the forecast, it was assumed that air passenger traffic would increase by the same number of air passengers each year, giving a linear projection of future traffic levels.

The air passenger demand analyses undertaken in the RPA study used highly aggregate data, both for the air passenger traffic and the socioeconomic variables. Only two of the four analyses used any socioeconomic data at all. One of these used the total regional personal income for each year and the other also used the total regional population for each year (to calculate the per-capita personal income and air passenger trips). None of the four analyses considered the impact of potential changes in the cost of air travel, thus implicitly assuming that past trends in the real cost of air travel would continue largely unchanged during the forecast period.

San Francisco Bay Area

The San Francisco Bay Area is served by three airports with significant levels of commercial air service and a fourth airport with more limited air service. San Francisco International Airport (SFO) is the primary airport serving the region with extensive international air service. It is also a hub for United Airlines and the home base for Virgin America. In 2015, the airport handed just over 50.0 million passengers. Oakland International Airport (OAK) and Mineta San José International Airport (SJC) also have substantial levels of air service, dominated by Southwest Airlines and Alaska Airlines, with additional service by other legacy and low-cost airlines. OAK handled 11.2 million passengers in 2015, while SJC handled almost 9.8 million passengers. Both airports have a small amount of international traffic. The fourth airport, Charles M. Schulz Sonoma County Airport (STS) near Santa Rosa in the north of the region, has a small amount of service by Alaska Airlines in major West Coast markets. The airport handled just over 263,000 passengers in 2015.

Regional airport system planning in the San Francisco Bay Area is guided by the Regional Airport Planning Committee (RAPC), a joint standing committee of the Metropolitan Transportation Commission, the Bay Conservation and Development Commission, and the Association of Bay Area Governments (ABAG). RAPC membership comprises elected officials from the region appointed by the three agencies, and representatives of the region's airports, the FAA, the California Department of Transportation, other regional agencies, and surrounding counties. The most recent update of the Regional Airport System Plan, termed the Regional Airport System Planning Analysis (RASPA), was completed in 2011 (RAPC and SH&E, 2011a).

The forecasts of air passenger demand developed for the RASPA were prepared in conjunction with a Forecast Working Group comprised of invited aviation forecasting experts

and relevant airport staff, in addition to members of the consultant team and regional agency staff. Three forecast scenarios of total regional air passenger demand were prepared, comprising a base case that reflected the best estimate of the growth that was expected to occur in the future based on current trends and conditions, together with a low and high growth case based on changes in the assumptions on future changes in the factors driving air passenger travel growth. Separate forecasts were prepared for domestic local (originating or terminating) passengers, international gateway passengers, and connecting passengers (SH&E, 2009). The international gateway passengers include both international local passengers and international passengers connecting to or from domestic flights, although these two components were forecast separately.

The forecast for domestic local passengers was based on a time-series regression model estimated on annual data for the years 1990 to 2007. The model used a log-linear structure (a linear model with the continuous variables expressed in logarithms) with three explanatory variables: the real total personal income for the Bay Area, the average airline yield for the Bay Area's 50 largest domestic O&D markets in 2006, and a dummy variable for the years from 2001 to 2007, to reflect the changes in the airline industry from 2001 on. The average airline yield variable weighted the average yield in each market by the proportion of total domestic Bay Area O&D air passenger trips in that market in 2006 to avoid distorting the yield trend over time from changes in the proportions of trips by destination. The estimated demand elasticity (model coefficient) for real personal income was 0.76, while that for average airline yield was -0.50. The technical report on the forecast development (SH&E, 2009) notes that the estimated personal income elasticity is low compared to other mature domestic air travel markets, but suggested that this might have resulted from the combination of two factors. The first factor was the strong growth in traffic at Sacramento International Airport to the northeast of the region during the period 1990 to 2007, which could have attracted passengers who might otherwise have used the Bay Area airports. The second factor was the faster growth of higher income households in the Bay Area over the same period compared to the U.S. as a whole, which could have resulted in travel propensity growing slower than would have been expected from the growth in average income if those higher income households did not increase the number of air trips they made as much as their growth in total income would suggest. However, no analysis was done to pursue either hypothesis any further.

The base case forecast of domestic local passengers used a forecast of future growth in real personal income for the Bay Area prepared by ABAG as part of its regional planning activities. A forecast of future changes in airline yields was made using the baseline forecast of future oil prices made by the U.S. Energy Information Administration (EIA) in December 2008 and relating the change in oil prices to the change in overall airline expenses. The dummy variable was also included in the forecast for future domestic local passengers under the assumption that the post-2001 changes in the airline industry would continue to affect air travel demand to the same extent.

The low and high growth forecast scenarios for domestic local passengers were made by varying the assumed annual growth in real personal income and the assumed personal income elasticity from the value estimated in the regression model, and using the high and low oil price forecast in the EIA forecast, as shown in Table B-11.

Table B-10. Bay Area Domestic Local Passenger Forecast Assumptions

Variable	Scenario		
	Base	Low	High
Personal income (annual change 2007-2035)	1.8%	1.8%	2.2%
Personal income elasticity	0.88	0.76	1.00
Price of oil (2035) (1)	\$135	\$207	\$50
Airline yield (annual change 2007-2035)	0.4%	1.0%	-0.3%
Post 2001 structural changes	Yes	Yes	Yes

Note: 1) Price per barrel in constant 2007dollars.

In addition, a forecast of domestic local passengers in each of the top 50 Bay Area O&D markets in 2007 was made by comparing the historic average annual growth rate in each market from 1990 to the end of fiscal year (FY) 2008 with the average annual growth rate in total passenger traffic in each destination market from FY 2007 to FY 2025 forecast in the most recent FAA TAF published at the time. Average annual growth rates for each market were then assumed such that markets that had grown faster (or slower) than the average for the region would continue to do so, while over the forecast period the growth rates in each market would tend to move toward the average for the region.

A different approach was followed for the forecast of international gateway passengers. This was based on an analysis of the Bay Area's share of U.S. international passengers by world region and recent trends in those shares. For Asia, Canada, Europe/Middle East/Africa, and Latin America except for Mexico, the recent shares had been relatively stable and the 2007 share was assumed to continue through the forecast period. However, the share for Australia/Oceania had been growing rapidly and that for Mexico had been slowly declining. For Australia/Oceania, the share was assumed to remain constant in the low growth scenario, but continue to increase in base case and high growth scenarios. For Mexico, the share was assumed to remain constant in the base case scenario, continue to decline in the low growth scenario, but increase in the high growth scenario to reach the same share as Canada by 2035. The most current forecasts of average annual growth rates for U.S. international passenger traffic by world region prepared by IATA, Boeing, and the FAA were reviewed, together with recent traffic statistics, advanced airline schedules, and independent industry analysis, and a set of annual growth rate assumptions for passenger traffic between the U.S. and each world region developed. The total passenger traffic in each market was projected using these growth rates and the Bay Area market share assumptions were then applied to this traffic to generate the forecasts of Bay Area international gateway passengers.

The forecasts of Bay Area connecting passengers were made by analyzing the past trend in connecting passengers as a percent of local passengers over the period from 1990 to 2007, separately for domestic and international passengers. These percentages had shown a declining trend with some fluctuations from the early 1990s to around 2001, but had remained relatively stable since 2002. The average percentages from 2002 to 2007 were assumed to continue through the forecast period and these were applied to the forecasts of local domestic and international gateway passengers to project the future levels of connecting passengers.

The forecasts of total Bay Area passengers were then allocated to airports under several scenarios reflecting alternative potential strategies for serving future Bay Area demand. Initially seven separate scenarios were defined:

1. A base case scenario reflecting the expected traffic at each airport under the base forecast scenario without consideration of runway capacity constraints.
2. A traffic redistribution scenario reflecting a shift of some domestic flights from SFO to OAK and SJC, and some new transborder services at OAK and SJC, in response to increasing delays at SFO. The extent of the assumed shift was envisaged as returning the shares of the regional traffic handled by those two secondary airports to their historic shares.
3. An alternative internal airports scenario that assumed some air passenger demand would be served by three smaller secondary airports in the Bay Area, including an expansion of service at STS and the introduction of air service at a current military airfield under a joint use agreement and a general aviation airport that had received very limited air service for a short period in the past.
4. An alternative external airports scenario that assumed expansion of air service at three existing commercial service airports in adjacent counties to the Bay Area that would attract some passengers who would otherwise use the Bay Area airports.
5. A high-speed rail scenario that assumed some future air passenger demand in California Corridor markets would be attracted to the planned California High-Speed Rail system between the Bay Area and Southern California.
6. A demand management scenario that envisaged the use of administrative or regulatory measures at SFO to reduce aircraft delays by limiting the number or scheduling of flights.
7. A new air traffic control (ATC) technologies scenario that assumed the deployment of ATC technologies being developed under the FAA Next Generation Air Transportation System (NextGen) program.

Each of these scenarios was analyzed individually to forecast the passenger demand at each airport and the resulting change in aircraft operations at each airport relative to the base case scenario. Based on the results of this analysis, three combined scenarios were defined for further analysis:

- Combined Scenario A comprised the traffic redistribution scenario with elements of the new ATC technologies and demand management scenarios. Passenger traffic at each airport was based on the traffic redistribution scenario, with elements of the other two scenarios contributing to enhanced capacity and reduction of aircraft delays. A variant of this scenario was analyzed assuming that high-speed rail service was available in the California Corridor by 2035.
- Combined Scenario B was similar to Scenario A, but assumed a greater redistribution of demand to OAK and SJC, expanded service at STS as assumed in the alternative internal airports scenario, and additional elements added to the demand management measures assumed in Scenario A. A variant of this scenario

was analyzed assuming that high-speed rail service was available in the California Corridor by 2035.

- Combined Scenario C assumed the level of regional air passenger demand projected under the high growth forecast and a wider range of strategies to handle the additional traffic. These strategies included even greater redistribution of demand to OAK, SJC, and STS compared to Scenario B, full deployment of new ATC technologies at all three primary airports, high-speed rail service in the California Corridor, and expanded air service at the three external airports.

The redistribution of air passengers from SFO to other airports in the various scenarios for meeting forecast future demand was not performed using a formal airport demand allocation model, but instead was based on assessments of markets that could be served with viable levels of expanded or new air service at each airport. In the case of the traffic redistribution scenario, the share of regional local domestic passengers handled by OAK and SJC was assumed to return to their historic shares. In the case of the alternative internal airports scenario, this assessment identified five West Coast or Nevada markets that were projected to have enough passenger demand from the region that viable levels of air service could be supported by those passengers with ground trip ends within the catchments area of each airport. In addition, it was assumed that these airports could also support service to two airline hubs. In the case of the alternative external airports scenario, an assessment was made of the number of passengers from the external counties served by those airports who were using Bay Area airports, based on the findings of air passenger surveys performed at the Bay Area airport, and who could potentially be attracted to the external airports by expanded air service at those airports. The assessment of air passengers diverted to high-speed rail in the high-speed rail scenario was based on the results of demand modeling previously undertaken for the California High-Speed Rail Authority (RAPC and SH&E, 2011b). The demand management and new ATC technologies scenarios did not involve any redistribution of air passenger traffic.

Although the RASPA update did not involve any formal modeling of airport choice, it did include a demand allocation methodology that distributed the forecast air passenger demand by airport to regional travel analysis zones for each scenario (RAPC and SH&E, 2011b). This allowed an analysis to be performed of the airport ground access trips and resulting vehicle-miles of travel (VMT) and emissions for each alternative scenario for serving forecast Bay Area air passenger demand. Using data from recent air passenger surveys at the three primary airports, separate distributions of air passenger ground trip ends were made for four types of trip: resident trips from home trip origins, resident trips from non-home trip origins (e.g., their place of employment), visitor trips from home trip origins (homes of residents they were visiting), and visitor trips from non-home trip origins (hotels, businesses, etc.). Since the air passenger surveys interviewed departing passengers, the data covered airport access trips and ground trip origins. It was assumed that air passenger travel in the reverse direction was symmetrical.

The demand allocation process was performed in two steps. In the first step, the total regional passenger trips were assigned to analysis zones using the air passenger survey data. Trip generation models were then estimated for resident home-origin trips separately for domestic and international trips that projected the number of annual passenger trips from each zone as a function of the zonal population and average household income. These relationships allowed the

distribution of trip ends to be forecast for future years in response to the changing geographic distribution of population and household income projected by ABAG. The distribution of visitor home-origin trips was assumed to be proportional to resident home-origin trips. The proportional distribution of non-home-origin trips was assumed to remain constant.

In the second step, the projected air passenger trips from each analysis zone were allocated among the regional airports under each scenario. For the base case scenario, this reflected the choice of airport for trips from each zone in the air passenger survey data. For the traffic redistribution scenario, the air passenger trips redistributed from SFO to OAK and SJC were allocated among the analysis zones in proportion to the trips using OAK or SJC in the base case scenario and the trips to SFO from each zone reduced accordingly. This effectively assumed that trips from zones with a higher use of OAK or SJC in the base case would have a higher likelihood of being redistributed from SFO, which seemed intuitively reasonable. In the case of the alternative internal and external airports scenarios a catchment area was defined for each airport for which the driving time to the alternative airport was less than the driving time to any other airport. The proportion of the passenger trip ends within each catchment area that would need to be attracted to the alternative airport to generate the forecast passenger traffic was calculated, and this proportion was applied to the passenger trips from each analysis zone in the catchment area, with the balance of trips from the zone distributed among the other airports in proportion to the airport shares in the base case.

Southern California

The Southern California region comprises six counties in the Los Angeles basin and surrounding area and is geographically the largest metropolitan area in the U.S. It also is the metropolitan region with the largest number of commercial service airports in the world. In addition to Los Angeles International Airport (LAX), the primary airport serving the region, there are significant levels of air carrier air service at Burbank Bob Hope Airport (BUR), John Wayne Orange County Airport (SNA), Long Beach Airport (LGB), Ontario International Airport (ONT), and Palm Springs International Airport (PSP). There is also currently regional airline service at Imperial County Airport (IPL) and in the past there has also been regional airline service at Oxnard Airport (OXR). In addition, there are several commercial airports at former or current military air bases that handle some non-scheduled flights and could potentially attract scheduled air service in the future. One of these, Palmdale Regional Airport, has had scheduled commercial air service in the past.

The Southern California Association of Governments (SCAG) is the Metropolitan Planning Organization for the region and maintains an ongoing regional airport system planning program. Rather than prepare a stand-alone Regional Airport System Plan, SCAG includes an Aviation and Airport Ground Access Element in its *Regional Transportation Plan/Sustainable Communities Strategy* (RTP/SCS), which is updated every four years (SCAG, 2016a). The Aviation and Airport Ground Access Element contains a forecast of air passenger demand in the region and a process to allocate the forecast regional demand to each commercial service airport under different demand growth and airport development scenarios. The development of the Aviation and Airport Ground Access Element of the RTP/SCS is guided by a standing Aviation Technical Advisory Committee, which includes representatives of each of the commercial service airports in the region as well as other aviation stakeholders.

The air passenger demand forecast for the Aviation Element of the draft 2016-2040 RTP/SCS (SCAG, 2016b) was developed using a set of econometric models that were estimated on historical air passenger, socioeconomic, and air service data. Separate models have been estimated for O&D passengers in three domestic market segments: intra-California traffic, domestic short-haul traffic, and domestic medium-to-long-haul traffic. A further set of models have been estimated for O&D passengers in five international markets: the Asia/Oceania market, the Canada/Greenland market (although there is negligible traffic to Greenland), the Mexico/Central America/Caribbean market, the South America market, and the Trans-Atlantic market. Each model was estimated on annual time-series data for the period 1990 to 2013, with the exception of the intra-California market, which was estimated on data from 1990 to 2000, and the trans-Atlantic market, which was estimated on data from 2002 to 2013. The models all took the same structural form with the continuous variables in logarithms, giving a multiplicative relationship and allowing the estimated coefficients of the continuous explanatory variables to be interpreted as demand elasticities.

Domestic short-haul traffic was defined as travel to destinations or from origins in ten states in the Western and Southwestern U.S. outside California: Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming (InterVISTAS and AECOM, 2015). Because a significant number of air passengers with trip ends in San Diego County to the south of the SCAG region or Santa Barbara County to the north use airports within the SCAG region, primarily LAX, the air passenger traffic in models included traffic using San Diego International Airport, McClellan-Palomar Airport in Carlsbad, San Diego County, and Santa Barbara Municipal Airport. Scheduled air service at McClellan-Palomar Airport ended in 2015, but existed during the period used for model estimation.

Due to the limited level of direct air service to South America, it did not prove possible to estimate a separate model for that market. Traffic in the Mexico/Central America/Caribbean market was added to traffic to and from South America and a combined model for the Latin America market estimated. The forecast growth rate predicted by this model was then applied to the actual South America traffic to forecast future traffic in the South America market.

Each model included an aggregate real GDP variable for the relevant market region and a real average airfare variable for each market. The region for which the GDP variable was defined is shown in Table B-11. In addition the models included a number of dummy variables for specific years, as shown in Table B-11. The regional share of connecting passengers was assumed to remain constant in the future at the current level of 17% of the total passenger traffic.

The estimated demand elasticities for the GDP and airfare variables are also shown in Table B-11. Some of the airfare elasticities are surprisingly low, particularly for medium-to-long-haul domestic traffic and for trans-Atlantic traffic. All the GDP elasticities are surprisingly low, particularly for short-haul domestic traffic, with the exception of the GDP elasticity for trans-Atlantic traffic, which is both extremely high for what is a very mature market and significantly different from the estimated values for all the other markets.

Table B-11. Southern California O&D Demand Models

Market	GDP Variable	Dummy Variables				Demand Elasticity	
		Gulf War	9/11	Global Financial Crisis	SARS (1)	GDP	Airfare
Domestic							
Intra-California	California					0.54	-0.56
Short-haul	Region	x	x	x		0.20	-0.70
Medium-long-haul	Region		x	x		0.65	-0.25
International							
Asia/Oceania	Region		x	x	x	0.38	-0.96
Canada/Greenland	Region		x	x		0.54	-0.91
Mex/Cent Am/Carib	California		x	x		0.48	-0.64
Latin America	Region		x	x		0.46	-0.54
Trans-Atlantic	Europe					2.28	-0.20

Note: 1) Severe Acute Respiratory Syndrome.

There is little discussion in the draft RTP/SCS Appendix about the reasonableness of these elasticity values. The discussion notes that previous studies of air travel demand have found elasticities of demand with respect to GDP typically between 1 and 2, with the GDP elasticity in mature markets, such as the U.S. domestic market, at the lower end of the range. There is no discussion of the finding that the estimated values for all markets except the trans-Atlantic market are well below this range. The discussion notes that previous studies of air travel demand have found elasticities of demand with respect to airfare in the range -0.2 to -2.0 and that the estimated values found in the models for the SCAG RTP/SCS lie within this range. Although it is true that some prior studies have found values of airfare elasticity as low as -0.2 (or even lower), such values have generally been found for particular market segments, such as long-haul business travel. The empirical analysis presented in the previous InterVISTAS study cited in the discussion (InterVISTAS, 2007) found airfare elasticity values for the U.S. domestic market between -0.83 and -1.46 and airfare elasticity values for the trans-Atlantic market between -1.06 and -1.42, significantly greater (more elastic) than the values found in the modeling for the RTP/SCS.

The econometric models were used to forecast regional air passenger traffic, based on assumptions regarding future growth in real airfares and GDP. In the case of the trans-Atlantic market, the elasticity with respect to GDP was assumed to decline over the forecast period. The resulting growth rates were compared to other industry forecasts and adjusted as deemed necessary.

The resulting regional forecasts of air passenger traffic were allocated to airport in the region using an Air Traffic Allocation Model. This model is based on dividing the region into a set of sub-regions. The regional forecast passenger traffic was first allocated to each sub-region in proportion to the income-weighted population, in which the population in each sub-region was weighted by the ratio of the average household income of the sub-region to the average household income of the entire region. The number of passenger trips generated by each sub-region was then allocated to each airport in the region using a scoring approach to reflect the influence of driving time to the airport, the air service available at each airport, and passenger

preferences and past experience. The score for driving time for each airport was calculated by determining the population living within 30-minute, 60-minute, and 90-minute driving times of the airport, with the population living more than 30 minutes or more than 60 minutes from the airport discounted to reflect the fact that the attractiveness of an airport declines with increased access time. Each airport was assigned a score reflecting the size of the discounted population within a 90-minute catchment area. The score for air service at each airport was based on the airlines serving the airport, the destinations served from each airport, and the flight frequencies offered, although the details of how this score was constructed are not given in the draft RTP/SCS Appendix. Finally a score was assigned to each airport to reflect passenger preference, although the details of how this score was determined are not given. The three scores were then combined and adjusted until the allocated traffic levels for 2012 corresponded to the actual passenger traffic at each airport, although the details of how the scores were combined and adjusted are also not given. The model description in the draft RTP/SCS Appendix states that the model was validated by comparing the results to air passenger surveys that were available, but no details of this validation are reported.

Summary

The forecast approach followed in each of the regional system planning studies varied in the both the approach to modeling air travel demand and the level of detail with which the modeling was performed. Two different studies were reviewed for the New York/New Jersey region which used different approaches. The study for the Baltimore/Washington region did not develop an independent forecast of future demand but adopted the FAA TAF forecast for each airport. The earlier study for the New York/New Jersey region developed separate demand models for each airport for domestic and international O&D passengers, although the variables included in the models varied by airport and market sector. The later study for the same region compared the projected traffic given by several different approaches to forecasts of future traffic prepared independently by the Port Authority of New York & New Jersey and the forecast passenger traffic given by the earlier study. These alternate approaches included time series models of total regional passengers, one for total passengers and one that distinguished between domestic and international passengers. A second approach developed econometric relationships between the total regional traffic and regional personal income.

The system planning studies for New England and Southern California estimated demand models for domestic passenger demand on a destination zonal basis, although the number of destination zones considered was considerably more detailed in the New England models. The New England models included the population and per-capita income in both the origin (New England) and destination (other domestic) zones, whereas the Southern California models used the total regional GDP for the destination regions (California in the case of the intra-California market). The models for both studies included average airline yield in each market as a variable. The Southern California study also estimated demand models for international passenger demand by world regions using variables for GDP and average yield. The forecasts of international passenger demand in the New England study were made by applying growth rates from forecasts by the FAA and industry firms or associations to the distribution of international passenger traffic to and from New England in the base year.

The Bay Area Regional Airport System Planning Analysis study developed an econometric model based on annual data for total regional domestic O&D passenger demand and using real total personal income for the Bay Area and average airline yield for the Bay Area's 50 largest domestic O&D markets as explanatory variables. A more disaggregated forecast of domestic local passengers in each of the top 50 Bay Area O&D domestic markets was made by comparing the historic average annual growth rate in each market with the average annual forecast growth rate in total passenger traffic in each destination market in the FAA TAF and assuming growth rates in each market using judgement. A forecast of international gateway passengers was based on an analysis of the Bay Area's share of U.S. international passengers by world region and recent trends in those shares, together with forecasts of the total international travel between the U.S. and each world region based on a review of the most recent forecasts by the FAA and industry firms or associations.

The studies for all five regions (only the earlier study in the case of the New York/New Jersey region) developed models or procedures to allocate regional or airport O&D demand to regional analysis zones. The resulting distribution of ground trip ends was then used in most studies to assign forecast demand to airports under different air service scenarios or to forecast airport ground access trip patterns. Two studies, the earlier study for the New York/New Jersey region and the study for the San Francisco Bay Area, estimated trip generation models, while the other studies used a demand allocation procedure based on population, households, employment, and/or income.

In conclusion, there appears to be no consistent approach to preparing air passenger forecasts for regional airport system planning studies, although generally some form of econometric model is used, at least for domestic O&D passengers. These models typically use one or two aggregate socioeconomic variables as well as average airline yields. There is no consistency in whether the models predict passenger traffic at the market, airport, or regional level, or how the ground origins or destinations of the air trips given by the resulting regional forecasts are allocated to travel analysis zones in the region.

Airport Master Plans

A review of 47 master plans, demand studies, and environmental and noise assessments revealed that a majority of these studies acknowledge the role of socioeconomic data in determining air passenger activity, although with less frequency do they use socioeconomic factors in their air passenger demand forecasting models. Three of the documents did not include enough detail to clearly determine the airport's usage of socioeconomic data or methodology, so the following discussion pertains to the 44 that mentioned socioeconomic data. Although 39 of the 44 documents that included some mention of socioeconomic variables also contained information about forecasting approaches used, only 21 of these reported using socioeconomic data in their forecasting calculations.

Some of the airports use the forecasts from the FAA's TAF to project their passenger demand, but many others develop their own analyses and forecasts based on the specific conditions at their airport, including socioeconomic factors. For these forecasts, airports tend to use one of three broad types of analysis. Time series, or trend analysis, reviews the history of an airport's passenger activity and creates a forecast under the assumption that, barring any major

industry changes, observed trends will continue into the future. A second approach, market share analysis, reviews forecasts for the aviation industry as a whole across the U.S. or in the region containing the airport, and creates predictions assuming that a given airport's share of the overall aviation market will remain the same or will change in a well-defined way. These two analysis types differ in that time series analysis extrapolates past trends, whereas market share analysis may include expectations of the effect of changes in the aviation industry, such as mergers, creation of new flight services, or a move towards certain types of flights, on a given airport's share of the overall aviation market. The third type of analysis, econometric or regression modeling, statistically evaluates the historical relationship between local or regional socioeconomic variables such as population, economic activity (GDP), or income and the level of an airport's passenger traffic measured in enplanements, typically using linear or logarithmic regressions. Whereas the first two methods may indirectly take into account socioeconomic changes (e.g., an increased preference for low-cost carriers nationwide would increase flight forecasts for those carriers across the country, which would be reflected in market share analyses at airports used by these low-cost carriers), econometric models provide more direct insights into the significance of each socioeconomic variable on an airport's overall passenger demand as represented in passenger enplanements.

Of the airports that indicated that they used socioeconomic variables, the majority noted that population, income, and/or employment are relevant for understanding and forecasting air passenger traffic. Forecasts of these independent variables must be used to calculate air passenger forecasts from models based on estimations of historical relationships among the variables. Such projections for socioeconomic variables are prepared by the firm Woods & Poole Economics, Inc., as part of the data products they produce for airports and many others concerned with socioeconomic relationships. Population and income are commonly used independent variables and in statistical estimates often appeared to be more statistically significant than employment levels for individual airports, although airports created models using different geographical areas (using city-, MSA-, and state-level socioeconomic data and projections, for example) and often defined variables differently. Other socioeconomic variables mentioned or used in some of the airport master plan forecasts included cost of living, employment by sector, and, for areas with economies that were particularly reliant on tourism, variables such as "de facto" population due to tourism or the prevalence of second homes in the region served by an airport.

Four Examples of Airport Master Plan Forecasts

This section highlights four airports that used socioeconomic data in their demand forecasts in different ways and outlines their respective methodologies to provide examples of the different approaches used by airports in preparing airport master plan forecasts. The following discussion describes the forecasts contained in the master plans of two large hub airports, Minneapolis–St. Paul International Airport and Portland International Airport, the medium hub General Mitchell International Airport, and the small hub Birmingham-Shuttlesworth International Airport.

Minneapolis–St. Paul International Airport

Among large hub airports, the 2010 update to the Minneapolis–St. Paul International Airport (MSP) 2030 Long Term Comprehensive Plan includes a detailed study of passenger originations using socioeconomic data for the seven–county metropolitan region served by the airport. The MSP report indicates that the analysis included regressions using a number of variables, including population, employment, total regional income, and per-capita income within the region. The best fit for passenger enplanements was a logarithmic regression in which the number of people who flew out of MSP each year was a function of total income (as opposed to per-capita income) and average airfares, with some adjustments for a 1998 pilot strike and the events of September 11.

Not only did this forecast fit well statistically, but it also made sense that passenger traffic would be influenced by pricing and income. MSP’s Comprehensive Plan update is noteworthy as it is one of only a few master plans that were reviewed that included the details of any regression modeling within the study documentation, such as the regression equation, global F-statistic and t-statistics of the coefficients.

Portland International Airport

Between 2007 and 2010 the Port of Portland completed an update of the Airport Master Plan for Portland International Airport (PDX). This update was conducted in conjunction with the City of Portland as part of the *PDX Airport Futures* project (City of Portland and Port of Portland, 2011). An important issue for the airport and the city that was addressed in this collaboration was whether to plan for a third parallel runway for the airport. An critical factor in this decision was the likely scale of future passenger demand at the airport, and as part of the Master Plan Update a probabilistic range of passenger forecasts was developed. These probabilistic forecasts were derived from an econometric model of air passenger enplanements at PDX and assumed distributions of future values of the independent variables in this econometric model. The independent variables included two socioeconomic variables, regional population and regional per capita income. This approach to forecasting passenger activity at PDX, which is described in greater detail in Attachment B-2 to this appendix, permitted the calculation of the probability of the future passenger activity level in a given year exceeding a particular level.

General Mitchell International Airport

General Mitchell International Airport (MKE), a medium hub airport in Milwaukee, used socioeconomic data in its 2003 Master Plan Update. Using Woods & Poole Economics data for the airport’s catchment area of southeast Wisconsin and far northern Illinois, the master plan update study evaluated the impact of population, personal income, per-capita income, and employment on passenger traffic using linear and logarithmic regressions. The best fit for MKE’s historical data was a regression in which the logarithm of the number of enplaned passengers was a function of logarithms of both the population of the catchment area and of airline yield. The master plan report states that “the historical data were adjusted to take into account events and trends such as the Gulf War, the September 11 attacks, and the increasing popularity of certain airlines in the Midwest” (which respectively reduced and increased

subsequent passenger demand above estimated trends), although the details of how this was done are not explained.

MKE's 2003 update is noteworthy in its presentation of the regression formulae used: whereas a number of airport master plans list the models used to determine passenger traffic, this particular update gives not only the specific regression equations, but also interprets those results, explaining the difference between linear and logarithmic equations for readers without a statistical background. As an example of the contrasts and differences that appear between models for air passenger demand forecasts used at different airports, it is noteworthy that in contrast to the best fit relationship for MSP's passenger traffic reported in the 2010 update to the 2030 MSP Comprehensive Plan, which was based on total income and average airfares, the best fit relationship for MKE's passenger traffic, as reported in its Master Plan Update, was based on population and airline yields.

Birmingham-Shuttlesworth International Airport

Like many airports in the group of airport master plan studies under review, as part of an ongoing update of the Airport Master Plan initiated in 2014 by small hub Birmingham-Shuttlesworth International Airport (BHM), the airport developed more than one forecast of total enplaned passengers. BHM then compared these forecasts – in BHM's case, two – to one another and to the FAA TAF forecast for BHM. A “preferred forecast” was then selected, from which a subsequent forecast of passenger aircraft operations was derived.

The BHM master plan update included three applications of one regression model with different growth rates applied to inputs (moderate, optimistic, and aggressive economic growth in the region) and two market share models (market share within Alabama and within the U.S. as a whole). The first step in this forecasting process developed a regression model based on historical data from 2000 to 2013. The explanatory variables used in the regression model included airline yield, Birmingham-Hoover MSA nonfarm employment, and MSA real GDP.

The master plan then describes a process in which forecast data were used as inputs to another set of three regression models. The forecast socioeconomic data was based on projections from Woods & Poole Economics. The forecast annual growth rates for the airline passenger yields were based on FAA Aerospace forecast FY2014-2034 and extrapolated to 2035. The three regression models were based on three different scenarios for economic growth in the region: moderate, optimistic, and aggressive.

The preferred forecast used in the Master Plan Update, however, was not based on one of these three regression models and was instead taken directly from the FAA TAF forecast for the airport.

Review of Airport Master Plan Forecasts

Table B-12 summarizes the 47 airport master plans reviewed and notes their treatment and use of socioeconomic data.

Table B-12. Summary of Airport Master Plan and Master Plan Update Passenger Demand Forecasts

Airport Code	Airport Name	Hub size	Mentions population?	Mentions income?	Mentions employment?	Uses population?	Uses income?	Uses employment?	Year of Study	Models Used
ATL	Hartsfield-Jackson Atlanta Int'l	Large	Yes	Yes	Yes	Yes	Yes	Yes	2012	Linear regression, with GDP
BOS	Logan Int'l	Large	No	Yes	No	No	Unknown	No	2011	Not Specified/Unknown
DEN	Denver Int'l	Large	Yes	Yes	Yes	Yes	Yes	Yes	2011	Market share, socioecon reg
DTW	Detroit Metropolitan Wayne County	Large	Yes	Yes	Yes	Yes	Yes	Yes	2004	Reg, Mkt Share, Time Series
FLL	Fort Lauderdale/ Hollywood Int'l	Large	No	No	No	No	No	No	2010	TAF
IAH	George Bush Intercontinental	Large	Yes	Yes	Yes	No	No	No	2011	Market Share
LAS	McCarran Int'l	Large	Yes	Yes	No	Yes	Yes	No	2011	Log Regression (gravity)
MCO	Orlando Int'l	Large	Yes	Yes	Yes	Unknown	Unknown	Unknown	2013	TAF
MIA	Miami Int'l	Large	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	2008	TAF
MSP	Minneapolis- St. Paul Int'l	Large	Yes	Yes	Yes	No	Yes	No	2010	Logarithmic regression
PDX	Portland Int'l	Large	Yes	Yes	No	Yes	Yes	No	2008	Regression
SEA	Seattle-Tacoma Int'l	Large	Yes	Yes	Yes	No	Yes	No	2013	Regression
SFO	San Francisco Int'l	Large	Yes	Yes	Yes	No	Yes	No	2015	Regression
SLC	Salt Lake City Int'l	Large	Yes	Yes	Yes	Unknown	Unknown	Unknown	2010	Regression
TPA	Tampa Int'l	Large	Yes	Yes	Yes	Yes	Yes	No	2013	TAF, Reg, Mkt Share, Trend
BNA	Nashville Int'l	Medium	Yes	Yes	Yes	Yes	Yes	Yes	2013	Mkt Share, Regression, Trend
BUF	Buffalo Niagara Int'l	Medium	Yes	Yes	Yes	Yes	Yes	Yes	2013	Mkt Share, Regression, Trend
BUR	Bob Hope	Medium	Yes	Yes	No	No	Yes	No	2009	Market Share
CVG	Cincinnati/ Northern Kentucky Int'l	Medium	Yes	Yes	Yes	No	No	No	2013	Econometric modeling
IND	Indianapolis Int'l	Medium	Yes	Yes	Yes	Unknown	Unknown	Unknown	2011	TAF, Regression
MCI	Kansas City Int'l	Medium	Yes	Yes	Yes	No	No	No	2009	TAF
MKE	General Mitchell Int'l	Medium	Yes	Yes	Yes	Yes	Yes	Yes	2003	Log-log regression
PBI	Palm Beach Int'l	Medium	Yes	Yes	Yes	No	No	No	2005	Market share
SJC	Norman Y Mineta San Jose Int'l	Medium	Yes	Yes	Yes	Yes	Yes	Yes	2009	Regression
SMF	Sacramento Int'l	Medium	Yes	Yes	Yes	No	Yes	No	2001	Regression
BHM	Birmingham-Shuttlesworth Int'l	Small	Yes	Yes	Yes	Yes	Yes	Yes	2015	Multiple regression, with GDP
BIL	Billings Logan Int'l	Small	Yes	Yes	Yes	Yes	No	No	2010	TAF, Market Share, Trend
BLI	Bellingham Int'l	Small	Yes	Yes	Yes	No	No	No	2004	time series, market share
BTR	Baton Rouge Metropolitan	Small	Yes	Yes	Yes	No	No	No	2007	TAF, Market Share
CID	The Eastern Iowa	Small	Yes	Yes	No	No	No	No	2014	Market share
FSD	Sioux Falls Regional	Small	Yes	Yes	Yes	No	No	No	2014	Market share
GEG	Spokane Int'l	Small	Yes	Yes	Yes	Yes	Yes	Yes	2014	TAF
GSO	Piedmont Triad Int'l	Small	Yes	Yes	Yes	Unknown	Unknown	Unknown	2010	Not Specified/Unknown
HPN	Westchester County	Small	Yes	Yes	Yes	Yes	Yes	Yes	2007	Multi-linear regression
ILM	Wilmington Int'l	Small	No	No	No	No	No	No	2005	Not Specified/Unknown
KOA	Kona Int'l	Small	Yes	Yes	Yes	Yes	No	No	2010	Regression
RIC	Richmond Int'l	Small	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	2010	Not Specified/Unknown
BGM	Greater Binghamton	Non-hub	Yes	Yes	Yes	No	No	No	2009	Market Share, Trend
DLH	Duluth Int'l	Non-hub	Yes	Yes	Yes	No	No	No	2015	TAF
EKO	Elko Regional	Non-hub	Yes	Yes	No	No	No	No	2004	Time series
ERI	Erie Int'l	Non-hub	Yes	Yes	Yes	Yes	No	Yes	2005	Regression
GON	Groton-New London	Non-hub	Unknown	Yes	Unknown	Unknown	Unknown	Unknown	2013	Not Specified/Unknown
ITH	Ithaca Tompkins Regional	Non-hub	Yes	Yes	Yes	No	No	No	2005	Market Share
LNK	Lincoln	Non-hub	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	2009	Not Specified/Unknown
MFE	McAllen Miller Int'l	Non-hub	Yes	Yes	Yes	No	No	No	2005	Simple growth rate formula
RDD	Redding Municipal	Non-hub	No	No	No	No	No	No	2004	Time series
STS	Charles M Schulz- Sonoma County	Non-hub	Yes	Yes	No	No	No	No	2011	TAF

Large Hubs

Of the 15 large hub studies available for review, 14 identified the model or type of model that was used to create passenger forecasts. Four airports (FLL, MCO, MIA and SFO) used the FAA Terminal Area Forecasts, one airport (IAH) relied primarily on a market share approach, and the other nine large hubs (ATL, MSP, PDX, SEA, SLC, TPA) each used a regression model of some form (linear or logarithmic). Four of these regression models used income as an independent variable, two used population levels, and two used employment.

The studies also approached variable selection differently. The PDX and ATL studies determined which variables to use in passenger demand forecasts by determining which variables increased the R^2 value for the model, whereas the MSP, SEA, SLC, and TPA studies considered the estimated coefficient and t -statistic for each variable in order to determine its significance.¹⁰

With respect to model choice, three of the six studies (ATL, SEA, and SLC) explained their choice to use a regression model for what can be called theoretical reasons. In these studies there was expressed a belief that regression is the most accurate and appropriate model for using data to develop passenger forecasts. In some cases the choice not to use market or time series models was justified with an explanation of the inherent flaws in those types of model, either for airport-specific reasons or because of a more general flaw in such approaches. The ATL plan, for example, explained that market share models don't make sense because they rely on the assumption that a given airport will take up the same share of industry traffic over time, which may or may not be a reasonable assumption for ATL.

In contrast, the MSP, PDX, and TPA studies presented results from a number of different models before explaining the choice of model based on the accuracy of the fit to historical data: both presented information on historical passenger yields and found regression models to be the most accurate. These approaches to model selection are labelled "statistical." It is important to note that none of the six airports chose its model on purely "theoretical" or "statistical" reasons. Each of the documents that discussed different models did explain why their chosen model would be most accurate numerically, and all checked to ensure that their model choices made sense. The difference is in the stated rationale for choosing one model over the other, but the reliance on one approach or the other by the six airports is not as distinct as the table might suggest.

Medium Hubs

Master planning studies for medium hubs contained more variation in types of models used than did the master planning studies for large hubs. Of the ten medium hub studies examined, four used regressions, two used averages of an assortment of models, one used its own form of econometric modeling, two used market share models, and one used the TAF. Of the six medium hub studies that included regressions or other econometric models and explained model choice, five viewed the highest R^2 value as the preferred determinant of factors and relationships impacting passenger enplanements. Only the study for MKE discussed t -statistics as a justification for model variable choice. Because the hybrid models also incorporated regression modelling, five different medium hubs used socioeconomic variables within the preferred forecasts.

Two of the medium hub studies explained their model choice in theoretical terms, two gave a statistical explanation, and two relied on averages of multiple models. The use of averages in this way represents an interesting case: of the 48 total airports included in this study, only the studies for BUF and SJC described using an average to determine passenger forecasts. The model for BUF is termed a "hybrid projection," arrived at after examining seven other

¹⁰ The second method is typically preferred to simply looking at the value of R^2 , as the addition of any variable will always increase the R^2 value, while t -statistics indicate whether or not a given variable actually has a significant impact on the model's fit to passenger demand.

models of all three types (time series, market, and regression as described previously). The model results were averaged in order to balance out the impact of outliers at any specific point in the forecast. In the case of SJC, the forecast used was an average of the two models that were seen as most accurate. These were a regression model and a market model that assumed accelerated recovery from the 2008 financial crisis. Both of these incorporated all three types of socioeconomic variables within their regressions. CVG also created its own model after establishing that other methods were not fitting to its catchment area. All three are termed “hybrid projections” for the purposes of this report.

Small Hubs

All but two of the 13 small hub studies examined discussed socioeconomic variables, but only three used some combination of these in their preferred models. Studies for three small hubs used the TAF as their preferred passenger forecast (BHX, GEG, and TUS), whereas the studies for the other ten small hubs reported models that included regression models, market share models and growth rate models. Small airports saw a disproportionately high share of reports using market share models, possibly because small hubs often have very specific market and as such provide a consistent share of the passenger service within a given region. Only the TUS study stated it used coefficients in selecting a particular set of socioeconomic variables; BHM and BLI used R^2 whereas the other nine did not provide an explanation as to variable choice.

Three of the small hub studies explained model choice in theoretical terms, four gave a statistical explanation, and the rest did not provide an explanation.

Non-Hubs

Of the ten non-hub airport master planning studies reviewed, nine mentioned socioeconomic variables. However, despite mentioning income, population and employment, none used these in their forecast models. The non-hubs were also the only hub group for which no studies used a regression model as a preferred forecast methodology. The analysts for four different non-hub reports did estimate and report regression models for passenger demand, but chose not to use them for various reasons. It is interesting to note that all five of the models included in this study that chose time series models for their preferred forecasts were non-hubs.

The two time series forecast were justified in theoretical terms whereas the growth rate formula was given a statistical explanation. No non-hub document included any variable selection rationale.

Summary and Critique

The general use of airport forecast modeling techniques are summarized below in Table B-13. For the purposes of this summary, “trend analysis” has been termed “time series” and all types of linear and logarithmic regressions are categorized together as regressions. A few airports created forecasts by predicting a future annual growth rate in passengers: this is similar to the time series method, but as these airports sometimes used other information to determine the predicted growth rate, they have been categorized separately.

Table B-13. Passenger Air Travel Demand Models Used in Sample of Airport Forecasts

Preferred Model	Large	Medium	Small	Non-Hub	Total
Growth Rate	-	-	-	1	1
Market Share	1	2	2	1	6
Regression	7	4	3	1	15
TAF	3	1	1	2	7
Time Series	-	-	-	2	2
Multiple Models	3	3	3	1	10
Not Specified/Unknown	1	-	3	2	6
Total	15	10	12	10	47

Airport usage of population, income, and employment projections in their forecast modeling is divided into five categories: used, discussed, mentioned, not used, and unknown. For a master plan or other document to have “used” a given variable, that variable must be included in its final forecast as an independent variable (the hybrid projections present an exception, described below). A document that has “discussed” a variable has presented information about the predicted future of the variable and the ways in which it may impact passenger traffic, sometimes even running regressions incorporating it, but the variable was not ultimately used in the final forecast. “Mentioned” variables may be listed in a brief overview of socioeconomic variables or presented in a table without any detailed discussion. Variables that are listed as “not used” for a given airport are not mentioned specifically, although in some cases documents included a brief note about socioeconomic variables or economic growth as a whole without reference to any of the three specific variables and these are also listed as “not used”. “Unknown” use of socioeconomic variables comprise cases where the documents reviewed did not provide technical details of the forecast methodology, and therefore it is possible that more detailed technical documentation for the master plans for these airports included information about the variables or even incorporated them into models, but they were not mentioned within the documents that were reviewed. These airport usages of each of the three categories of socioeconomic variable (population, income and employment) are summarized in Table B-14 below. The table reports this usage by airport hub size, and also includes a tabulation of airport use of at least one of the socioeconomic variable categories.

Table B-14 indicates that use of each (and any) of the socioeconomic variables is least common among non-hub airports, although a sizeable number of reports from large hub airports make no mention of any of the socioeconomic variables.

The Research Team identified several airport master plan forecasts in the review that were based on regression models that contained methodological errors in model selection and interpretation. Although the focus of this review is not to assess the quality of the models and forecasts developed, it is important to note that incorrect use of modeling techniques may hinder airports when they are choosing the best model for their preferred forecasts or from using models that include the most appropriate socioeconomic data.

Table B-14. Use of Socioeconomic Variables in Airport Passenger Demand Forecasts

Treatment of at Least One Socioeconomic Variable	Large	Medium	Small	Non-Hub	Total
Used	9	6	5	1	21
Mentioned but not used	3	3	4	6	16
Mentioned but usage unknown	2	1	1	1	5
No mention or unknown	1	0	2	2	5
Treatment of <i>Population</i>	Large	Medium	Small	Non-Hub	Total
Used	6	4	5	1	16
Mentioned but not used	4	5	4	6	19
Mentioned but usage unknown	2	1	1	0	4
No mention or unknown	3	0	2	3	8
Treatment of <i>Income</i>	Large	Medium	Small	Non-Hub	Total
Used	7	6	3	0	16
Mentioned but not used	3	3	6	7	19
Mentioned but usage unknown	3	1	1	1	6
No mention or unknown	2	0	2	2	6
Treatment of <i>Employment</i>	Large	Medium	Small	Non-Hub	Total
Used	3	4	3	1	11
Mentioned but not used	5	4	5	4	18
Mentioned but usage unknown	2	1	1	0	4
No mention or unknown	5	1	3	5	14

One common issue seen in the review of airport master plan forecasts was what appeared to be a sole focus on R^2 values. Examining R^2 values alone is not an appropriate method for selecting which variables to include in a multiple regression model. The R^2 value only reveals the percentage of the variation in the dependent variable that is explained by the independent variables and their estimated coefficients in the model. It does not provide information on whether the estimated coefficients of the independent variables are statistically significant. That is, R^2 does not explicitly indicate whether or not the independent variables have any predictive ability.

Furthermore, R^2 should be used with extreme caution in a multiple regression model. Simply, R^2 never decreases when explanatory variables are added to a multiple regression model. Every time another independent variable is added to a model, the R^2 value will often increase, whether or not this reflects an improvement in the causal explanation of the model. This property can give the analyst an inaccurate picture of the model fit if many variables are used in a model. A modified statistic, the adjusted R^2 value, is included in the output of nearly all statistical

software packages and should be used instead to judge model fit. Adjusted R^2 values will only increase if the addition of a new independent variable improves the model.

Additionally, other statistics (such as the model mean-square error, global F -test, or t -statistics for the individual variables) are needed to help assess whether or not a regression model adequately reflects the factors that influence demand. Very few of the technical reports on the 48 master plan or other forecasts in the review included any model diagnostics in their forecast documentation.

As noted above, many airports developed forecasts in addition to the TAF and then selected a preferred forecast to use in their planning. Sometimes the preferred forecasts included socioeconomic variables, but many times they did not. The issues with many master plan forecasts presented here may prevent airports from selecting the best forecast. By improving the regression modeling techniques used in master plan and other studies, airports may discover that the preferred model includes additional or different socioeconomic variables.

Metropolitan Regions and Major Airports Outside the U.S.

In order to compare the current state of practice in developing air travel demand forecasts for U.S. airport master plans and regional airport system plans with forecasting approaches used in airport planning studies outside the U.S., the following sections summarize the approach used for air travel demand forecasts in metropolitan regions or at major airports in other countries. The first two sections describe the forecast process in large multi-airport regions, one a metropolitan region within a single country and the other a region spanning parts of three European countries, while the following sections describe the forecast process for four individual airports. However, two of these six studies, one for a multi-airport region and one for an individual airport, utilized forecasts that were originally prepared at a national level for all major airports in the respective countries.

London, England

In July 2015, the United Kingdom (UK) Airports Commission released its Final Report on a multi-year study to examine strategic options for expanding airport capacity in the London region (UK Airports Commission, 2015a). Developing forecasts of air travel demand under the various airport development options being considered by the Commission (as well as the option of no provision of additional runway capacity at the airports serving the region) was central to the recommendation that additional runway capacity is needed in the region, as well as the evaluation of the various options to provide that capacity considered by the Commission. The Final Report recommended construction of a third parallel runway at Heathrow Airport, located to the northwest of the existing runways.

The work of the Commission represents one of the most extensive and thorough regional airport planning studies of how to meet the future airport capacity needs of a major metropolitan region ever undertaken, and certainly the most extensive undertaken in recent years. Two key aspects of the approach followed by the Commission involved an extensive stakeholder consultation process and independent reviews of the forecasting and demand allocation process

adopted by the Commission as well as of alternative forecasts and demand allocation modeling submitted in response to the stakeholder consultation.

Although the forecasts of future demand were only one of many issues addressed by the Commission, the discussion in this appendix only considers the forecasting approach used. The Commission based their forecasts on an expanded and updated version of the suite of aviation demand models developed by the UK Department for Transport (DfT) over several years and most recently used to prepare forecasts for UK air travel in January 2013 (DfT, 2013). This modeling suite was used to produce forecasts of air passengers and airline aircraft operations, termed air transport movements (ATM), for each of the 31 largest commercial airports in the UK, and was described in the literature review undertaken as part of the current project and documented in Appendix A to the final report. These forecasts were prepared using two linked models: the National Air Passenger Demand Model (NAPDM), which predicts the number of air passengers beginning or ending their air trip in each of 455 analysis zones (termed districts) into which the UK is divided, and the National Air Passenger Allocation Model (NAPAM), which allocates the air passenger trips to and from each analysis zone to one (or two in the case of domestic air trips or domestic connections to or from an international trip) of the airports included in the model.

For the forecasts prepared for the Airports Commission, the DfT enhanced the modeling suite in a number of ways (UK Airports Commission, 2014; UK Airports Commission, 2015b). The most significant change was to include four major overseas hubs (Amsterdam Schiphol, Paris Charles de Gaulle, Frankfurt, and Dubai) in the airport choice modeling in NAPAM. This was done to better reflect the effect of capacity constraints at the major London airports (principally Heathrow) on the level of international connecting passengers (those connecting between international flights) using Heathrow and the use of the overseas hubs for travel between the UK and international destinations. This required the development of forecasts of air travel demand between European countries and other European or longer-haul international destinations. Other enhancements included the use of Monte Carlo simulation techniques to model uncertainty, although this was only applied in the case of two variants of a scenario termed assessment of need, one of which assumed no capacity constraints at any airports and the other assumed no change from the existing capacities at each airport.

In order to explore the potential effect of changes in airline industry structure and global economic relationships, forecasts were prepared for five different scenarios, termed:

- assessment of need
- global growth
- relative decline of Europe
- low-cost is king
- global fragmentation

The assessment of need scenario was considered the baseline scenario and the input assumptions for the demand modeling for this scenario were selected based on current projections by the UK Office for Budgetary Responsibility, the Organisation for Economic Co-operation and Development (OECD), and the International Monetary Fund. The input assumptions for the other scenarios were varied from the assessment of need scenario based on

an assessment of how those factors might be expected to change in response to the conditions described in the scenario. In addition, forecasts were prepared for each scenario assuming two different sets of assumptions for the future price of carbon, termed the carbon-traded and carbon-capped cases. The carbon-traded case assumed that the aviation sector is able to purchase carbon credits that allows the carbon emissions of aircraft departing the U.K. to exceed the target limit of the 2005 CO₂ emission levels established by the UK Committee on Climate Change, while the carbon-capped case assumes that the sector is required to reduce its emissions to this level by 2050. The carbon-traded case was modeled using the projected future traded values of carbon recommended by the UK Department for Energy and Climate Change for policy appraisals. The carbon-capped case was modeled by raising the price of carbon credits (and hence airfares) until emissions were reduced to meet the cap in 2050.

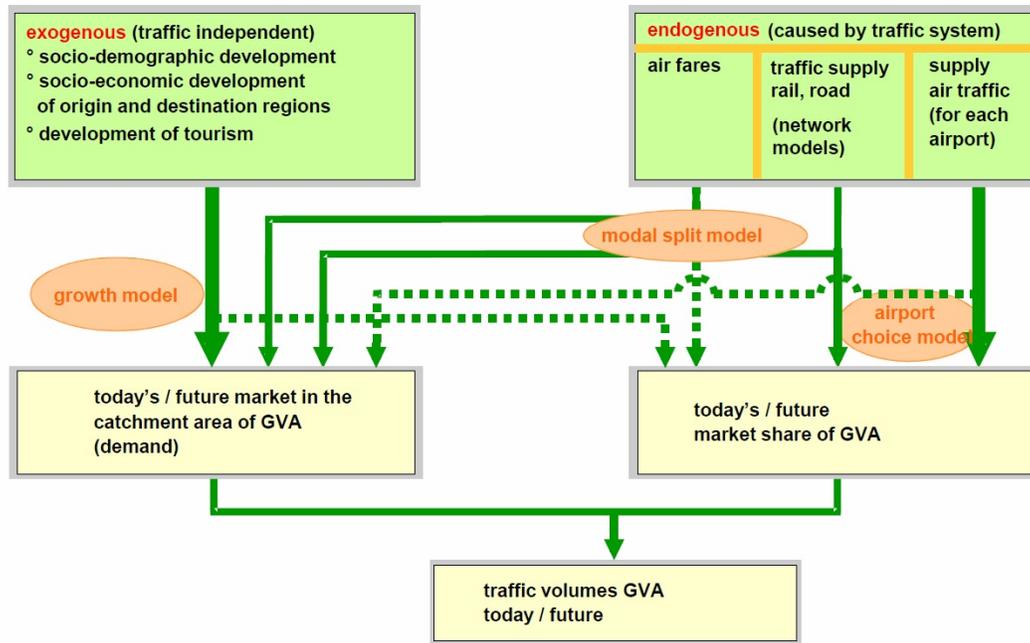
Details of the NAPDM, the variables included, and the elasticity values that were obtained are described in Attachment B-3 to this appendix, together with a discussion of the approach used to allocate the national demand to analysis zones and the peer review process of the forecast methodology that was undertaken by the UK Airports Commission.

Geneva, Switzerland

In 2014 the Swiss Federal Office of Civil Aviation (Office fédéral de l'aviation civile) commissioned Intraplan Consult of Munich to prepare an air traffic forecast for Geneva Airport (GVA). The airport had been experiencing steady growth in passenger traffic due to expansion of service by low-cost airlines, principally EasyJet, and the introduction of long-haul flights by Middle East carriers (Emirates, Qatar, and Etihad) to their hubs in the Persian Gulf. At the same time, Zurich Airport, the primary airport serving Switzerland, is starting to face capacity constraints. GVA is located adjacent to the border between Switzerland and France (the border runs down one side of the airport) at the west end of Lac Léman (Lake Geneva), the north shore of which forms the Swiss Riviera while a large stretch of the south shore is in France, with the border running down the middle of the lake. In consequence, GVA draws traffic from a large area of Switzerland, eastern France, and even northern Italy, although this catchment area is also served by a number of other airports in France and Switzerland, including Zurich Airport. In addition, at the time of the study there were (and still are) plans for significant expansion of the high-speed rail network linking GVA to other communities in Switzerland, France and Italy. It was recognized that improved rail connections could have two opposite effect on air traffic at GVA. By improving rail links to GVA, they could attract air passengers to GVA who might otherwise use other airports serving the region that are located closer to their trip origins or destinations. On the other hand, they might encourage air passengers with trip origins or destinations in the region surrounding GVA to use rail to access larger, more distant hubs, such as Frankfurt or Paris, or even travel by rail for their entire trip.

Therefore the approach adopted in the forecast was to first forecast the air travel demand from this larger region, then apply an airport demand allocation model to predict how the demand would distribute itself among the airports serving the region, as well as diversion if trips from air to high-speed rail (Intraplan Consult, 2014). The general framework for the analysis is illustrated in Figure B-7. The forecast of total regional passenger demand from the three-country catchment area used a fairly simple linear demand model with two explanatory variables: the GDP of the region and the average yield of the Association of European Airlines (AEA) member

airlines as a surrogate for the actual airfares at the airports serving the region. The model was estimated using annual total local (O&D) air passenger traffic at all airports in Switzerland and the adjacent Rhône-Alpes, Franche-Comté, and Alsace regions of France for the period 1995 to 2013. Although the description of the model in the report does not mention the use of dummy variables, from the reported statistical fit of the model it would seem likely that dummy variables were used to account for the disruptions in passenger traffic due to the terrorist attacks of September 11, 2001 in the U.S., the grounding of Swissair the following month and its subsequent restructuring, and the global financial crisis of 2009.



Source: Intraplan Consult, GmbH, *Air Traffic Forecast – Aéroport International de Genève*, Final Report, December 2014, Figure 2-1.

Figure B-7. Geneva Airport Forecast Model Structure

The passenger demand model as stated in the report was:

$$y = -22,344 + 0.117 x_1 - 826.1 x_2$$

where

- y = Total local passengers (000)
- x₁ = Regional GDP (millions of 2005 euros)
- x₂ = Average yield of AEA airlines (1991 U.S. cents per passenger-km)

One consequence of the use of a linear demand model (as distinct from a log-linear model) is that the demand elasticity with respect to GDP or airfare (yield) varies with the values of the dependent variable (passengers) and respective independent variable. Therefore the demand elasticities were calculated for 2013. These demand elasticities were then apparently used to project future passenger traffic by sub-area (Swiss cantons, French departments, and Italian regions) within the overall catchment area of GVA based on projections of future growth

in GDP for each subarea and future changes in yield. There is no discussion in the report about adjusting the future elasticity values to account for changes in the dependent and independent variables. There is also no discussion in the report about other well-known limitations of a linear demand model.

The report discusses past trends in GDP and population for each of the sub-areas in the catchment area and presents forecasts for future growth in GDP in each sub-area. It is not clear from the report whether the forecasts of GDP growth in each sub-area were obtained from external sources or were developed by the report authors from forecasts at a national level. The report mentions the use of “past trends” in defining GDP growth by sub-area, which suggest that these growth rates may have been developed by the report authors. However, if so, there are no details in the report on how this was done.

The report presents estimates of the total local passenger traffic by sub-area, but does not explain how these were derived. The report includes a discussion of population trends and projections of future population growth in each sub-area, but does not explain how these data were used in the forecast, if indeed they were.

The assignment of forecast passenger demand by sub-area to the airports serving the region or diversion to high-speed rail was performed using a two-step approach. In the first step an extensive network model was constructed of all the air and rail links between each sub-area and destination regions or countries in the case of international trips (considering outbound trips). This network model included ground travel links between each sub-area and each airport or closest station on the high-speed rail network. The time and cost on each link was converted to a generalized travel cost using assumed values of travel time. The report states that different values of travel time were assumed for business and leisure trips, but does not explain how the trip purpose split of the total travel demand was obtained or the source of the assumed values of travel time. The report references earlier studies by the same company (in German) that prepared forecasts for other airports in Switzerland using a similar methodology, so perhaps those reports provide more detailed explanation. From the large number of possible paths through the network between any given sub-area and destination region, a subset is defined and weighted on the basis of the generalized cost.

Travel O&D matrices were developed between each of the sub-areas in the catchment area and destination regions. The source of these matrices is rather vague in the report and simply specified as “developed among others in the context of overall air traffic studies in Switzerland, Germany and France.” In the second step of the process the passenger demand on each given origin-destination pair is assigned among the weighted set of possible routes using a Box-Cox logit model, the details of which are not stated.

The initial route network includes assumptions about flight frequency and fleet mix on each link, which are used to calculate the schedule delay (waiting time for a flight) for a given route and capacity on each link. After assigning the passenger demand to routes, the load factors on each link are calculated. The flight frequency or fleet mix on each link is adjusted where necessary to given a reasonable load factor and the passenger demand reassigned to routes. The process then iterates until a stable and reasonable load factor is achieved on all links. The details of the process by which flight frequency and fleet mix are adjusted are not given in the report.

Dublin, Ireland

A forecast of passenger and aircraft movement demand for Dublin Airport (DUB) was prepared in 2006 by the Dublin Airport Authority (DAA) and submitted to the Irish Commission for Aviation Regulation as part of regulatory proceedings for the 2005 determination of approval of airport charges at Dublin Airport (Dublin Airport Authority, 2006). The forecast report stated that passenger demand and aircraft movement forecasts for DUB are prepared by DAA on an annual basis. The report documents the methodology and assumptions used by the DAA in 2005/2006 to prepare the forecast, which covered the period from 2005 to 2015. The discussion of the forecast process in the report is extensive and detailed, the report presents the values of the parameters used in the forecast model, and unusually for reports of this type even identifies the staff responsible for preparing the report by name.

The passenger forecast model used by the DAA projects future traffic by routes and route-groups (such as transatlantic routes), using a demand elasticity approach based on assumed future growth in the GDP of the foreign country and the change in average airfares. From the description in the report it appears that the model uses a pivot-point approach based on the actual traffic on the route in the base year and projected growth in the traffic from applying the demand elasticities for GDP and airfare to the assumed changes in GDP and airfares. The form of the underlying demand model is not described, but presumably it is multiplicative (i.e., effectively a log-linear relationship) so that the percent change due to the change in GDP is multiplied by the percent change due to the change in airfare. The demand elasticities are not estimated statistically from historical data, but rather are assumed based on values found in other studies and validated by comparing past changes in traffic with the corresponding changes in GDP and airfares for different routes. Since it is believed that demand elasticities for GDP tend to decline as air travel markets mature, the assumed elasticity values were gradually reduced over the forecast period, as shown in Table B-15. However, the demand elasticities for airfare were kept constant over the forecast period, although they varied somewhat by route group, being higher in the route groups that generally had higher average fares, as shown in The assumptions for future changes in GDP were based on forecasts by the Economic and Social Research Institute in Dublin for the Irish GDP and the National Institute of Economic and Social Research in London for the GDP of other countries. Assumptions for future changes in airfares were based on recent trends in average airfare by market for near-term changes and expectations for future airline price competition and the potential impact of oil prices in the longer term. For the 2006 forecasts, it was assumed that real average airfares would remain constant after 2006 in the UK and European markets and after 2010 in the domestic and long-haul international markets, due to airline efforts to increase yields and potential increases in oil prices offsetting downward pressure on airfares from competition.

Table B-16

Table B-15. DAA Passenger Forecast Model - Assumed GDP Elasticity by Route Group

Route Group	Period	GDP Elasticity
Dublin – London / UK Provinces	2006 - 2010	1.1 / 1.4
	2011 - 2015	0.9 / 1.3
Dublin - Europe	2006 - 2010	1.4 to 1.8
	2011 - 2015	1.2 to 1.5
Dublin - Transatlantic	2006 - 2010	1.6
	2011 - 2015	1.5
Dublin – Other Long Haul	2006 - 2010	2.0
	2011 - 2015	1.7

The assumptions for future changes in GDP were based on forecasts by the Economic and Social Research Institute in Dublin for the Irish GDP and the National Institute of Economic and Social Research in London for the GDP of other countries. Assumptions for future changes in airfares were based on recent trends in average airfare by market for near-term changes and expectations for future airline price competition and the potential impact of oil prices in the longer term. For the 2006 forecasts, it was assumed that real average airfares would remain constant after 2006 in the UK and European markets and after 2010 in the domestic and long-haul international markets, due to airline efforts to increase yields and potential increases in oil prices offsetting downward pressure on airfares from competition.

Table B-16. DAA Passenger Forecast Model - Assumed Airfare Elasticity by Route Group

Route Group	Airfare Elasticity 2005 - 2015
Dublin – London	-0.777
Dublin – UK Provinces	-0.870
Dublin - Domestic	-0.768
Dublin – Europe Scheduled	-0.833
Dublin – Long Haul	-0.944

After projecting future passenger traffic growth by route using the demand elasticities, adjustments were then made using judgement on a route by route basis to take account of other factors that could affect demand on a given route, including:

- Airline plans to add frequency to existing routes, commence new routes, begin serving seasonal routes year-round, or abandon routes
- Exchange rates
- Fuel prices
- Population and demographic changes
- Tourism
- Modal competition
- Market fragmentation
- Airline route mix, fleet changes, and strategies
- Airport capacity constraints.

The report contains a discussion of the factors that were considered in general terms, although it does not document the adjustments that were made. There is a fairly detailed discussion of immigration and emigration trends and a discussion of the trip purpose composition of travelers using DUB by route group. However, it is not clear how this information was used in the forecast.

The forecast growth in passenger traffic was compared with forecast growth rates in air passenger travel by Airbus and Boeing and with forecasts of foreign visitor spending in the Irish economy by the World Travel and Tourism Council.

Hong Kong, China

The Airport Authority Hong Kong (AAHK) pursues a three-tier planning process for Hong Kong International Airport (HKG) that comprises an annual budget, a rolling five-year plan, and a 20-year master plan that is updated on five-year basis (AAHK, 2011a). As of early 2016, the most recent update of the HKG master plan was published in June 2011 (AAHK, 2011b). As part of the master plan update, an air passenger demand forecast was prepared by IATA Consulting. This forecast was based on a model that related total annual air passenger traffic at the airport to the real GDP of the Hong Kong Special Administrative Region (HKSAR). This model used a standard log-linear specification and was estimated on data from 1993 to 2008. The model included a dummy variable for 2003 to account for the drop in traffic from the outbreak of Severe Acute Respiratory Syndrome. The model gave an estimated demand elasticity with respect to GDP of 1.03 (AAHK, 2011a), which corresponds to typical values found in other studies for relatively mature markets.

As part of the modeling for the master plan forecast, IATA Consultancy estimated air passenger demand models for Mainland China and three other regions of China: the Greater Pearl River Delta (excluding Hong Kong), the Yellow River Delta (which includes Shanghai), and the Bohai Bay rim economic zone (which includes Beijing). These models followed the same structure as the model for the HKSAR but were estimated on data for 1997 to 2008 (IATA Consulting, 2010). The estimated demand elasticities with respect to the real GDP of each region were higher than for the HKSAR. The estimated demand elasticity for Mainland China was 1.31, while those for the other three regions varied from 1.29 to 1.63. These values are consistent with typical values found in other studies of rapidly developing markets.

The models do not contain any variable for airfare or other measures of the cost of air travel, which obviously have to be a factor in determining the future demand for air travel to and through Hong Kong. The Final Report on the development of the forecasts noted the omission of a variable for airfares, but stated that airfare data were not available prior to 2005 and an attempt to model the period from 2005 to 2008 using quarterly data and including an airfare variable produced counter-intuitive estimates of airfare elasticity (IATA Consulting, 2010). It also commented that a prior study for IATA had found a fairly low demand elasticity of airfare for the broader Asia region (in the range -0.4 to -0.5), which combined with the relative small expected change in real airfares over the forecast period (perhaps 1 percent per year) and the much larger expected growth in real GDP would limit the role that changes in airfare would have on future traffic levels.

The Master Plan Technical Report (AAHK, 2011a) included an extensive discussion of the economic structure and past trends in GDP growth in Mainland China and its more rapidly developing economic regions, as well as such potential influences on future air passenger demand at HKG as changes in cross-Strait travel and trade opportunities between Mainland China and Taiwan and development of high-speed rail services that could compete with air travel to and from Hong Kong. However, the report concluded that most of these factors represented a continuation of trends that were already occurring and thus their effects were accounted for in the demand relations to GDP. Some minor adjustments were made to the forecast of air passenger demand at HKG given by the model to account for some reduction of traffic from expanded future direct air links between Taiwan and Mainland China. The report noted that two planned major projects, the Hong Kong-Zhuhai-Macao Bridge and the Guangzhou-Shenzhen-Hong Kong Express Rail Link could potentially shift some passenger demand to HKG from other airports in the Greater Pearl River Delta region by improving surface travel times to Hong Kong from the rest of the region, but the extent of any such shift could not be determined until the pricing and economic effects of these projects became clearer.

Since the air passenger demand forecast for HKG was almost entirely driven by the projected future growth in HKSAR GDP, IATA Consulting gave particular attention to forecasts of future GDP growth. Two such forecasts were used, one prepared by the Economist Intelligence Unit (EIU) and one prepared by IHS Global Insight. IATA Consulting prepared an assumed forecast that combined the short-term forecast from the EIU with the long-term forecast from Global Insight, both released in July 2009. In 2010 both firms revised their forecasts upward leaving the IATA Consulting assumed GDP forecast lower than both forecasts for the period to 2020 and approximately mid-way between the two forecasts for 2030 (IATA Consulting, 2010), although the assumed GDP forecast used for the air passenger demand forecasts was left unchanged.

Sydney, Australia

In December 2013 Sydney Airport submitted a draft update to the master plan for the airport covering the period 2013 to 2033 to the Australian Government, which approved the updated master plan on February 17, 2014. The Master Plan 2033 (Sydney Airport, 2014) included a discussion of the economic and regional significance of the airport, a review of the prior evolution of air traffic at the airport, and forecasts of the expected growth in air passenger traffic, air cargo activity, and aircraft movements over the next 20 years. The forecasts were prepared by Tourism Futures International, a company specializing in the future of aviation, travel, and tourism, and involved extensive consultations with airline representatives, including both representatives of individual airlines as well as meetings with the Board of Airline Representatives of Australia and the Regional Airlines Association of Australia. The draft forecasts were also peer-reviewed by the CAPA Centre for Aviation (formerly the Center for Asia-Pacific Aviation).

The air passenger demand forecasts were prepared using a combination of top-down econometric modeling and segment-based forecast models for individual country-pair markets and domestic routes. The econometric model variables included the GDP of Australia and foreign countries with significant visitor travel to Australia, the gross state product for New South Wales, the Australian trade weighted index (of exchange rates), and specific exchange

rates. The econometric modeling also apparently included consideration of demographic factors, such as population, that might impose constraints on demand in the long term. However, the details of the econometric models or how the demographic constraints were applied were not given in the Master Plan report. The segment models apparently involved trend assessment, but again the details were not given in the report. The Master Plan report makes no mention of including the cost of air travel in the econometric or segment models.

The Master Plan report included a comparison of the forecast growth in activity levels at the airport with a number of prior forecasts prepared for Sydney Airport, including the prior master plan, as well as several industry forecasts for future growth in air passenger traffic at a global level.

Toronto, Canada

In December 2007, the Greater Toronto Airport Authority (GTAA) completed a master plan update for Toronto Lester B. Pearson International Airport (YYZ) for the period 2008 to 2030 (GTAA, 2007). The forecast of air passenger demand included in the master plan update was based on a forecast prepared for the airport by Transport Canada as part of the *General Forecast Update 2006/07*, an annual update of forecasts of aviation demand at the largest 77 Canadian airports that at the time was prepared by Transport Canada (this function has since been discontinued). For the master plan forecast, the forecast prepared by Transport Canada was reviewed by GTAA staff and adjusted to account for non-revenue passengers, that were not included in the Transport Canada forecasts, and to adjust market sector definitions to provide additional detail required for facility planning. The details of these adjustments were not described in the master plan report.

Transport Canada Forecast Process

Since the Transport Canada national forecasts formed the basis of the master plan forecast of air passenger demand for YYZ, this section provides a brief summary of the Transport Canada forecast process at the time. This process was based in the use of two models: the Passenger Origin-Destination Model (PODM) and the Passenger Traffic Allocation Model (PTAM). As the names of the two models suggest, PODM projects origin-destination flows of air passenger traffic while PTAM allocates those O&D passenger flows to specific routes, including routes involving intermediate connections. This in turn allows the estimation of connecting passenger flows at each airport and hence total enplaned and deplaned passengers at each airport.

PODM is an econometric model that projects the annual O&D passenger demand between a system of 36 Canadian domestic zones and 20 U.S. zones (Tecsult, 2003). Airports within a zone were grouped together and the zones were defined using a procedure that tested whether grouping particular airports together significantly changed the estimated model coefficients. The Canadian domestic zones comprised one or more census divisions that were generally smaller than a province. The U.S. zones comprised states or combinations of states. The model was estimated using directional O&D air passenger data between Canadian domestic zones or between Canadian zones and U.S. zones (transborder traffic). In the absence of reliable data on trip purpose, separate models were estimated for passengers traveling on full-fare

economy tickets and those traveling on discounted economy tickets. The former were considered to be mostly making business trips while the latter were considered to be mostly making non-business trips. Separate models were estimated for domestic and transborder markets, giving four market sector models. As of 2003, the most recent estimation of the four models used data for the period 1995 to 2001 (Tecsult, 2003).

The model structure took the form of a linear model with a Box-Cox transform on the dependent variable and some of the continuous independent variables. This allowed the elasticities of demand to vary across different markets. A Box-Cox transform expresses a variable in following form:

$$\begin{aligned} f(X) &= (X^\lambda - 1) / \lambda && \text{if } \lambda \neq 0 \\ &= \ln(X) && \text{if } \lambda = 0 \end{aligned}$$

The estimated value of the parameter λ determines the shape of the functional form. If λ equals 1 the functional form is linear and when λ equals 0 the functional form is logarithmic. For values of λ between 0 and 1, the functional form lies between linear and logarithmic. It can be shown that in cases where the values of λ for either the dependent variable or a given independent variable are non-zero, the demand elasticity with respect to the independent variable depends on the estimated coefficient of the independent variable and the values of the dependent and independent variables each raised to the power of their respective λ parameter (if λ equals 0, that term drops out). Thus non-zero λ values result in a demand elasticity that varies across markets, depending on the estimated values of λ and the values of either or both the independent and dependent variables.

A Box-Cox transform parameter was estimated for each continuous independent variable, but for several variables the estimated value of the parameter was not statistically different from zero, implying that the variable was included in the model as the logarithm of its value. A non-zero Box-Cox transform parameter was estimated for each dependent variable. Hence all demand elasticities vary across the markets. Each of the models for the four markets included the same three air service variables: the average standard economy fare, the average discounted economy fare, and a dummy variable for the availability of direct flights in the market that took the value one if there were at least five daily direct flights in domestic markets and three daily direct flights in transborder markets. Each model also included a variable for the highway travel time in the market in order to reflect the effect of competition from surface modes. Some models included a variable for linguistic similarity between the origin and destination zones, defined as:

$$\text{LingSim}_{od} = 1 - |L_o - L_d|$$

where L_o, L_d = Proportion of population in zone o or d whose mother tongue is English

This variable was introduced to account for the observed tendency for English-speaking Canadians to have a higher propensity to travel to predominantly English-speaking provinces and for French-speaking Canadians to have a higher propensity to travel to other zones in Quebec than to predominantly English-speaking provinces. This may simply reflect the distribution of family and friends, as well as business relationships, rather than any difficulty with the other language. In addition, several dummy variables were defined for different Canadian and U.S.

regions. These variables took the value 1 for zone-pair markets with at least one end in the region in question. Dummy variables were also defined for the years 2000 and 2001. In the case of transborder markets a dummy variable was defined if the origin zone was Canadian. This allowed the models to reflect different travel propensities for Canadians traveling to the U.S. from U.S. residents traveling to Canada. The independent variables included in each of the four models are shown in Adult population was defined as 20 years and older. The zonal GDP and per capita Personal Disposable Income (PDI) were expressed in constant 1996 Canadian dollars. The GDP for Canadian zones was calculated from the provincial GDP by the ratio of the real PDI for the zone to the real PDI for the province.

The forecast demand for international traffic other than transborder markets was estimated using a separate set of time series models for three markets: trans-Atlantic (termed Europe); Caribbean, Mexico, and Central and South America (termed South); and trans-Pacific (termed Asia). These models used a fairly conventional log-linear structure with two explanatory variables: average real airline yield in the market and real GDP, both expressed in 1981 Canadian dollars. As of 2003, the most recent model estimation used annual data from 1980 to 2000. The average airline yield variable was based on yield data reported by Canadian carriers serving each market. The GDP variable for the Europe and Asia markets consisted of the sum of the GDP for Canada and selected countries in each market (France, Germany, Italy, the Netherlands, Switzerland, and the United Kingdom for the Europe market and Hong Kong, Japan and Taiwan for the Asia market). For the South market, only the GDP for Canada was used. The models projected total air passenger traffic to and from Canada in each market. The allocation of forecast traffic to Canadian airports and routes was made using PTAM, as discussed in the following paragraphs.

Table B-17.

Adult population was defined as 20 years and older. The zonal GDP and per capita Personal Disposable Income (PDI) were expressed in constant 1996 Canadian dollars. The GDP for Canadian zones was calculated from the provincial GDP by the ratio of the real PDI for the zone to the real PDI for the province.

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Table B-17. Independent Variables in PODM Market Sector Models

Variable	Market Sector			
	Domestic Economy Fare	Domestic Discounted Fare	Transborder Economy Fare	Transborder Discounted Fare
Standard Economy Fare	X	X	X	X
Discounted Economy Fare	X	X	X	X
Availability of Direct Flights	X	X	X	X
Highway Travel Time	X	X	X	X
Linguistic Similarity	X	X		
GDP of Origin Zone	X		X	
GDP of Destination Zone	X	X	X	X
Adult Population of Origin Zone		X		X
Per Capita Personal Disposable Income (Origin Zone)		X		X
<i>Dummy variables</i>				
Maritimes		X		
Ontario			X	
Alberta/Manitoba/Saskatchewan		X		X
BC/Northern Territories/Yukon			X	
Canadian Origin Zone			X	X
U.S. Northeast (1)			X	
U.S. Southwest (2)			X	
U.S. Sunspot (3)			X	X
Year 2000	X	X		X
Year 2001	X	X		

- Notes: 1) New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia
 2) Arizona, California, Nevada, New Mexico, Utah
 3) Florida, Hawaii

The function of PTAM is to assign predicted future O&D passenger flows to routes in order to calculate connecting and transit passengers (those traveling through an intermediate airport in the same aircraft) at each airport in the system. This allows the calculation of enplaned and deplaned passengers at each airport as well as passenger loads in each non-stop flight segment. It also generates commercial aircraft movement forecasts at each airport. The use of PTAM proceeds in two basic steps (Supply and Services Canada, 1988). In the first step, a projected set of aircraft routes for a future year are generated by aircraft equipment type. In the second step, the forecast O&D passenger flows are assigned to passenger routes (a sequence of non-stop flight segments).

The first step starts with a base year set of aircraft routes by equipment type that is obtained from published airline schedules. PTAM acts a decision-support system that allows the analyst to modify this for a future year, using heuristics and judgement while taking account of projected changes in aircraft fleets and forecast O&D passenger flows. The analyst can add capacity to particular routes by assuming changes in flight frequencies or aircraft types in order to ensure that there is enough non-stop capacity in major O&D markets to meet the forecast demand. Once the future aircraft routes and associated capacities have been established, a set of potential air passenger routes are defined between each airport pair, comprising, non-stop, same-

plane multi-stop, and connecting routes, primarily using heuristics to select a reasonable number of likely routes for a given airport pair from the vast number of all possible routes through the network. In the second basic step in the process, PTAM uses a linear program to optimally assign the O&D passenger flows to the available air passenger routes, while respecting aircraft capacity constraints.

Summary

The six international demand forecasting studies reviewed in this section of the appendix used a variety of analysis methodologies and the extent to which the details of the methodology were described in the published reports that were available also varied. As best can be determined from the documentation for each study, all but one used a multiplicative (log-linear) model structure, although two studies (for the London region and Canada) used a more complex variation on a traditional log-linear formulation. The study for the London region used lagged and difference terms (described as an unrestricted error correction model) while that for Canada used a Box-Cox model structure.

All but one of the studies (that for Hong Kong) developed forecasts of passenger demand in different markets but the way in which these markets were defined varied widely, as did the approach to forecasting traffic in each market. For two of the studies (Geneva Airport and Sydney Airport), key details of the forecasting process were unclear. Two of the studies (for Geneva Airport and Canada) included competition from surface modes, high-speed rail in the case of Geneva and driving in the case of Canada, in the demand modeling, although the possible impact of high-speed rail on the forecasts was discussed in the forecast for Hong Kong.

Interesting, two of the studies (for Hong Kong and Sydney Airports) do not appear to have included future changes in the cost of air travel in the demand modeling (at least this was not mentioned in the respective reports). The study for Geneva Airport used changes in average airline yield on an industry basis in lieu of more detailed information on airfares in the markets in question. The model for Dublin Airport avoided the difficulty of obtaining airfare data by market by applying an assumed value of airfare elasticity to projected changes in airfare on a percentage basis using a pivot-point approach.

All six studies used aggregated values of GDP as the primary (or only) socioeconomic variable. The forecasting model for the UK (which formed the basis for the forecasts for the London region) also used consumption, imports and exports as socioeconomic variables in different market sectors, for some market sectors in conjunction with GDP and for other market sectors in place of GDP. However, the decision of which variables to use for a given sector appears to have been based on which variables gave the best statistical fit rather than any underlying causal logic. Each of the studies included some discussion of other socioeconomic factors that were thought to influence air travel demand, in some cases quite a detailed discussion which included projections of future values of those factors, but none appeared to use that information in the formal modeling of future demand. However, the study for Dublin Airport did make judgmental adjustments to the forecasts as a later step based on a consideration of a number of other socioeconomic factors as well as several air service factors.

Two of the studies (for the UK and Geneva Airport) included an explicit allocation of national or regional demand to airports serving the region, while the study for Canada used a model of air passenger demand on an origin-destination market-pair basis, which was then assigned to routes using a separate model in order to forecast traffic at individual airports. The study for Geneva Airport also included an assignment of demand to routes, although the forecast of demand was developed as a regional total and then subsequently assigned to markets and routes, rather than explicitly forecasting the demand on a market-pair basis.

Air Service Development Studies and Airport Demand Leakage Studies

Airport air service development studies and the factors customarily considered in them have been described in detail in ACRP Report 18 *Passenger Air Service Development Techniques* (ACRP, 2009b). Along with many financial, marketing, and route structure considerations that may be included in an airport's efforts to develop new passenger services with airlines, the study stresses the value of passenger demand projections and regional demographic and economic factors in influencing decision makers at potential airline service providers. "Such information could include local economic and demographic data, details about local businesses and their travel habits, information about local civilian and military government facilities, and local tourist attractions that drive inbound leisure traffic. Airline planners reported that they most needed local economic and demographic data, as well as information on actual or potential market demand. Air carriers are particularly interested in the strength of local businesses together with their travel habits because business travelers are their preferred type of customer." The report identifies the types of socioeconomic data that could inform these studies, but does not propose specific modeling approaches or formulations for use in preparing passenger demand projections.

The importance of demographic data for air service development analyses was recently assessed for an audience of airport practitioners (Dietz, 2014). Demographic data about the characteristics of the population served by an airport provides airlines with important information about the likelihood that airline service could be successful. Important factors affecting air service development assessments in these data are the size and characteristics of the airport region's overall population, the characteristics of the region's business community, and the characteristics of the region's potential leisure travel and travelers. For example, the goals of an airport's reporting of its region's population demographics include informing an airline about the region's population base, the population's income profile, its ancestry (which may be of particular importance for international travel demand), the region's rate of employment and the population's educational level. Similarly, information about a region's business community might include information about the region's types and sizes of business, about the region's major employers, and about the region's economic development agencies and other corporate infrastructure. All of these will better inform airlines about the propensity of the region's population and business community to choose to travel by air. It is important to note that these descriptions of ways in which regional demographic data could be informative for an airport's potential airport users do not involve the development of formal models of the air travel demand at the airport in question in order to demonstrate a level of demand available to be served. Rather, the intent is to draw parallels between the region's population and business community characteristics and the factors that airlines would regard as favorable for a region's likely demand for air travel.

ACRP Report 18 also identifies the principal cause of passenger leakage from a given airport as the competitive challenges that are posed by larger airports within driving distance. Such airports are likely to be able to provide business travelers with a wider range of destinations, often at lower fare levels. Such lower fare levels will also be attractive for leisure travelers, who are more price sensitive than business travelers in most instances.

Air service development studies and passenger leakage studies are customarily products prepared for airports by aviation consulting firms. Air service development studies may be used by airports for marketing efforts about individual travel markets (rather than an airport's overall passenger demand), which are directed at airlines, often specific airlines. In contrast, passenger leakage studies are generally informational studies for airport stakeholders, with the potential to be used as background for subsequent air service development efforts. For these reasons these studies are often regarded and treated by consultants and their airport clients as proprietary products rather than public documents. In addition, the time horizons that are relevant for these studies tend to be short term rather than directed at medium or longer term growth in an airport's passenger demand.

Airport Demand Allocation and Ground Access Mode Choice Studies

Although airport demand allocation and airport ground access models are not air travel demand models in the sense of predicting how the overall demand for air travel is influenced by changes in socioeconomic and air service factors, they typically make use of disaggregated socioeconomic data and by predicting how air travel demand in a region distributes itself among the airports serving the region, they can shed light on the level of air travel activity that occurs at a given airport. While airport ground access mode choice models are designed to predict the use of different access modes at a given airport, and do not directly attempt to model the level of air travel activity at that airport, they can form an important component of airport demand allocation models. Since air travelers' choice of airport in a region served by multiple airports is influenced in part by the relative accessibility of each airport (ACRP, 2013), which in turn depends on the different ground transportation models that are available for travel to each airport and the relative level of service of each mode, including travel times, frequency, costs, reliability, and number of changes of mode or line required, airport ground access mode choice models can be used to help define the overall accessibility of a given airport from a given location. As such, they often form a lower-level nest in a nested model of air traveler airport choice.

Both airport choice and ground access mode choice models are inherently disaggregate in approach, generally modeling the airport choice or mode choice decisions of individual air parties. This allows the models to reflect the different circumstances faced by each air party, including trip ground origin, air trip destination, time of day of travel, and travel party characteristics, all of which influence each air party's decisions. Typically these studies use data from an air passenger survey to define the travel and air party characteristics of a reasonably large sample of air travelers to estimate disaggregate behavioral choice models, which can then be applied to develop forecasts of future airport use patterns or ground access travel. The extent to which these models include demographic or socioeconomic factors varies, often depending on the data available from the air passenger survey from which they are estimated.

Airport Choice Models and Airport Demand Allocation Studies

There has been a substantial academic literature addressing airport choice in multi-airport regions. While many of these studies have focused on multi-airport metropolitan regions, such as the Baltimore/Washington region, the New York/New Jersey region, the San Francisco Bay Area, or Southern California (the Los Angeles region), studies of airport choice have also addressed airport choice decisions over longer distances, where air travelers choose to use surface modes to access more distant airports in order to take advantage of better air service or lower costs at those airports. Most of these studies have developed disaggregate choice models that predict the probability of an air party with a given trip origin and travel characteristics choosing each of the alternative airports serving the region. These models typically include variables measuring the accessibility of each airport from the trip origin as well as the air service available at each airport to the air party's travel destination. Some of the more recent studies have also included variables for socioeconomic characteristics of the members of the air party, such as household income.

Incorporating socioeconomic variables into disaggregate choice models requires some thought. The variables cannot simply be included in a linear utility function for each variable, since they have the same value for each choice alternative for a given air party, so they will not change the relative utilities of the different alternatives and in general will have no effect in the application of the model. One approach is to include them for some alternatives but not others. This will have the effect of giving different values of the alternative-specific constants for each alternative that vary with the values of the socioeconomic variables. Another approach is to define interaction variables that consist of the product of the socioeconomic variable and an air service or access variable that assumes different values for the different alternatives. This will have the effect of modifying the value of the coefficient of that variable for different values of the socioeconomic variable. An example of the second approach is to divide airfare and access cost variables by a function of the household income, which makes the sensitivity of the choice between the alternatives to differences in cost vary with household income, such that higher income travelers are less sensitive to cost differences than lower-income travelers.

Suzuki, Crum and Audino (2003) developed a multinomial logit (MNL) choice model to study air travel leakage from Des Moines International Airport (DSM), Iowa, to three nearby larger airports: Kansas City International, Minneapolis-St. Paul International, and Omaha Eppley International Airports for air trips made by residents of the Des Moines area. The model was estimated from survey data obtained from 317 respondents who had made an air trips in the past year, collected by a combination of a mailed survey to a sample of households in the area and intercept surveys performed at DSM. In addition to air service and ground access variables, the authors attempted to include variables for respondent age, income, and air travel frequency, but these variables were dropped from the model because the estimated coefficients had counter-intuitive signs or were not statistically significant. The income variable was only included in the model if the most recent trip was for leisure. Variables retained in the model included the respondent's frequent flier membership, whether the respondent had prior experience using the airport in question, and a composite airport rating score that each respondent was asked to provide for airports that they had used that rated the airport on seven criteria. The frequent flier membership variable was defined by determining which frequent flier programs the respondent was an active member of, defined as having flown on that airline in the past two years, and then

defining a dummy variable for each airport if that airport had flights to the traveler's destination by one of the airlines with a frequent flier program in which the traveler was an active member. The paper does not explain how the age, income, and travel frequency variables were defined or present estimated values of the coefficients prior to the variables being dropped.

Başar and Bhat (2004) used a probabilistic choice set multinomial logit (PCMNL) model to study airport choice in the San Francisco Bay Area, a metropolitan region served by three airports with significant levels of airline service: Oakland International, San Francisco International, and San José International Airports (a fourth airport, Sonoma County Airport, had very limited air service at the time analyzed in the study). The PCMNL model consists of two stages. The first stage comprised a probabilistic model of the choice set of alternative airports considered by each air party. The second stage then modeled the choice among the alternative airports in the choice set for each air party using a MNL model specification. The two-stage model was developed using data from a survey of air passengers at each airport performed by the Bay Area Metropolitan Transportation Commission (MTC) in 1995. The model only considered travelers making business trips and was estimated from a sample of 1,618 survey respondents, with a validation sample of 300 survey respondents held back for use in comparing the results of the PCMNL model to a conventional MNL model. The choice stage of the PCMNL model included variables for ground access time and flight frequency in the market to the air party's travel destination. Additional variables consisted of the product of these variables with dummy variables for whether the respondent was traveling alone, the respondent's gender, and whether the respondent's household income exceeded \$150,000. The estimated coefficient of the product of ground access time and the income dummy variables was not statistically significant and this term was dropped from the model. The first stage of the PCMNL model included a product term for gender and access time, as well as product terms for both access time and flight frequency with a dummy variable for travel on a weekday. The PCMNL model gave a somewhat better fit to the data than the conventional MNL model for both the estimation and validation samples and the elasticities implied by the estimated coefficients of both models were significantly different.

A later study by Hess, Adler and Polak (2007) used stated preference data to estimate an MNL model of air airport and airline choice. The estimation data were obtained from an Internet survey in May 2001 of about 600 respondents who had made a paid U.S. domestic air trip within the previous year. The survey collected data on the most recent such trip made the respondents and then used this information to generate stated preference survey experiments that involved the respondents choosing between the trip they had actually made and a hypothetical alternative trip with different characteristics, such as a different airline, airport, departure time, or airfare. The survey also collected data on selected socioeconomic factors of the respondents and their frequent flier program membership. Separate MNL models were estimated for three different trip purposes: business, vacation, and visiting friends and relatives. The authors performed exploratory model estimations using Box-Cox transforms on the variables for airport access time, airfare, flight time, flight on-time performance, and two schedule delay variables reflecting the amount by which each flight alternative arrived earlier or later than the preferred arrival time. Based on the results of those estimations, which showed a non-linear response to several variables in the models for each trip purpose, those variables were included in the final model using the natural logarithm of their value. Respondent household income was included in the model by multiplying the logarithm of the airfare variable by the ratio of the respondent household income to the average household income of all respondents with that trip purpose

raised to a power that was estimated. These estimated power coefficients were all negative, as would be expected (the effect of airfare differences reducing with higher incomes) although the statistical significance of the estimated coefficients was generally weak, particularly for vacation trips, with estimated values and t-statistics (in parentheses) as follows:

- Business -0.146 (-1.61)
- Vacation -0.043 (-0.75)
- Visiting friends and relatives -0.053 (-1.34)

Nonetheless these results appear to show that airport choice is influenced by household income, as would be expected. It should be noted that the airfare variable was only variable in the model that was expressed in dollars, so this term monetizes all the travel time variables, including airport access time. Since the average household income is constant for all respondents with the same trip purpose, this simply acts as an adjustment to the estimated coefficient of the airfare term and the airfare term can be expressed as the logarithm of the airfare divided by the respondent's household income raised to the above powers (reversing the sign) for the respective trip purpose. Although the effect of household income appears to be fairly weak (estimated power of the ratio to average household income varying between 0.04 and 0.15), the interpretation of the effect is complicated by expressing the airfare in logarithms. In fact, the airfare is raised to the power $(\text{income})^\lambda$ before being expressed as a logarithm, where λ is the estimated (negative) value of the power term. Thus for a respondent making a business trip with a household income of twice the average, the effective airfare is approximately 90 percent of the nominal airfare. However, to the extent that travelers with higher incomes, who are less sensitive to airfare differences, are more likely to select alternatives with a higher fare but more convenient or otherwise attractive characteristics, the non-linear effect represented by the logarithmic transform could be partly a hidden income effect.

A subsequent study by Ishii, Jun and Van Dender (2009) studied airport and airline choice for travelers from the three largest airports in the San Francisco Bay Area to four airports in Southern California: Burbank, Los Angeles International, Ontario International, and Orange County John Wayne Airports. The study, like several others, used data on air party characteristics and travel destination from the 1995 MTC air passenger survey. The authors estimated an MNL model of airport and airline choice using weighted maximum likelihood to account for different sampling rates at the three airports in the survey. The model included variables for average airfare, flight frequency, and average delay at the departure and arrival airports in each airport-pair market, driving time to each Bay Area airport from the trip origin zone, and dummy variables (alternative-specific constants) for the departure and arrival airports and the two dominant airlines in the markets: Southwest Airlines and United Airlines. Dummy variables also indicated if the departure time was within 30 minutes of the first flight of the day or the arrival time was within 30 minutes of the last flight of the day in each market. The model also included two variables consisting of the product of the average airfare and an income dummy variable if the survey respondent's household income was in one of two ranges: \$75,000 to \$149,999 or \$150,000 and above. However, the estimated coefficients for these variables were not statistically significant, although the variables were retained in the model. The authors also estimated a mixed logit model with the same variables as the MNL model. The coefficients for the dummy variables for the departure airport and airlines, as well as airfare, flight frequency, and access time were assumed to follow a normal distribution. The mixed logit model gave a

marginally better fit to the data, but many of the estimated parameters were not statistically significant. The authors concluded that the mixed logit model did not perform any better overall than the MNL model.

Two recent academic studies (Marcucci & Gatta, 2011; de Luca, 2012) developed models of airport choice in two regions of Italy. Marcucci and Gatta studied airport choice in the coastal region of northeast Italy between Bologna and Ancona. This region is served by four airports with commercial service. The authors developed a set of MNL choice models to explain the airport choices made in stated preference experiments administered to a sample of 165 air travelers who were either interviewed in one of the four airports or in a telephone survey of households in the catchment areas of each airport. The authors estimated a reference model that only included air service and ground access variables, a model that included interactions between air service and ground access variables and respondent age and income, and a number of model variations that segmented the sample by different criteria or estimated airport-specific coefficients. The variables for age and income grouped respondents into three age ranges and three income ranges. Many of the estimated coefficients for the model that included all potential interactions between the two socioeconomic variables and the air service and ground access variables were not statistically significant. The model variant that the authors felt gave the best specification included interactions between the age and income variables and the dummy variable for service by a low-cost airline, but not with any of the other air service or airport access variables. The stated preference experiments did not explicitly include airfare differences, so the dummy variable for service by a low-cost airline served as a surrogate for a difference in airfares, although the extent of any such difference is unclear.

De Luca (2012) developed an airport choice model for the Campania region in southern Italy that surrounds Naples. Air travelers in this region can use Naples Capodichino Airport or travel about miles to one of the two airports serving Rome: Ciampino Airport or Fiumicino Airport. A stated preference survey was administered to a sample of 800 respondents in municipalities surrounding Naples. The respondents were presented with alternative choice scenarios for flights from the three airports for a leisure trip of varying duration to Amsterdam, Berlin, London, or Paris. The alternative flight scenarios were generated from services that were actually offered at the three airports and included some connecting flights. The resulting data were used to estimate a MNL choice model. The model included air service and ground access variables and the following socioeconomic variables: age, the number of air trips made in the past year, private automobile availability (measured as the ratio of the number of vehicles owned by the household to the number of household members), and a proxy for household income (defined as the fraction of the household members who were employed). The age variable was defined as a dummy variable if the respondent was under age 23. Various alternative age criteria were tested and using age 23 was found to give the best model fit. Two other socioeconomic variables were investigated, the respondent gender and whether the respondent had ever flown before, but were not found to give statistically significant coefficients and were dropped from the model. The socioeconomic variables were included in the linear utility function for Naples Capodichino Airport and thus the estimated coefficients of these variables had the effect of modifying the alternative specific constant for that airport. The study also explored various nesting structures of the alternatives and different model structures, including cross-nested logit and mixed multinomial logit models. These model structures were found to perform slightly better than the MNL but in some cases gave very different estimated values for the coefficients

for the airfare, flight frequency, and ground access time variables, resulting in considerably different elasticities of the market share of each airport in response to changes in those three service variables.

Recent examples of the development and application of airport demand allocation or airport choice models for regional airport system planning studies are more limited. The forecasting process used for the 2006 New England Regional Airport System Plan (NERASP) included both a trip generation and an airport choice model that were used to allocate the forecast air passenger traffic to geographic zones within New England and then project how the forecast trips by zone would be attracted to the commercial service airports in New England in response to changes in air service (Louis Berger Group, 2006a). The airport choice model was estimated from the results of an air passenger survey performed at ten New England airports, although the number of survey responses at some of the smaller airports was quite small. Separate MNL models were estimated for four market sectors: resident business trips, resident other trips, non-resident business trips, and non-resident other trips. Each air passenger was assumed to choose between all airports. Various combinations of potential model variables were explored. The final models included airport-specific constants and three continuous variables:

- Congested driving times from the zone to each airport
- A flight frequency variable, defined as the logarithm of the number of daily non-stop flights each way in the market plus either two or the weighted number of airline hubs served from the airport divided by two, if greater. The weighted number of airline hubs was calculated as the number of hubs served by jet aircraft plus the number of hubs served by non-jet aircraft divided by four.
- The average airfare from each airport to each destination

The models did not include any airport ground access costs nor attempt to predict ground access mode choice. They also did not include any air passenger or trip characteristics other than trip purpose, such as air party size, household income, or trip duration. In some forecast scenarios, the airport-specific constants were adjusted to reflect assumptions about changing relative attractiveness due to expansion of air services.

The Technical Paper that includes details of the airport choice model (Louis Berger Group, 2006a) provides the estimated coefficient values and standard errors, but does not state what units were used for the driving time and airfare variables, and whether the airfares were one-way or round-trip. Therefore it is difficult to assess the reasonableness of the estimated values of the coefficients.

The 2007 Regional Air Service Demand Study prepared for the FAA and the Port Authority of New York and New Jersey, the New York State Department of Transportation, and the Delaware Valley Regional Planning Commission (PB Americas, 2007a) included the development of an airport choice and airport ground access mode choice model covering the nine airports in New York State, New Jersey, and Pennsylvania included in the study (PB Americas, 2007h). The model initially used a nested logit structure with the choice between the nine airports at the top level and the choice between eight access modes at the lower level. However, the nesting coefficient proved to be slightly greater than 1.0, so the model was subsequently changes to a joint MNL model of airport and ground access mode choice, with the available

access modes to each airport as separate choices, giving a rather large number of potential choices. The access modes included in the model were drop-off by private automobile, drive and park, rail, taxi, rental car, chartered bus, shared-ride van or limousine, and local bus. Separate models were estimated for business and non-business travel using data from an air passenger survey performed at the nine airports in 2005 as part of the study. The models addressed differences between residents of the region and visitors through adjustments to the access mode-specific constants by including a dummy variable for residents in the utility functions for each mode other than drop-off, which was treated as the reference mode. Similarly, socioeconomic factors were included in the model through dummy variables in the utility functions for each mode. Socioeconomic variables were included for gender, age and household income. The gender dummy variable was set to one if the respondents to the survey were female. The age of the survey respondents were grouped into three ranges: less than 35, 35 to 55, and more than 55 years old. Dummy variables were used for the youngest and oldest of these three groups. However, the survey provided no information about the gender or ages of other members of a multi-person travel party. Similarly, the household income of the survey respondents were grouped into three ranges: less than \$60,000, between \$60,000 and \$140,000, and more than \$140,000. A significant proportion of the survey respondents (25 percent) refused to answer the household income question. The use of dummy variables for the low and high income ranges means that those who did not provide their income were effectively considered to be in the middle income range.

A later airport choice and ground access mode choice model was developed for the Alternatives Analysis Phase I Screening Report for the West of Hudson Regional Transit Access Study (RSG, 2010). This also made use of a subset of the 2005 air passenger survey data, as well as two additional stated preference surveys performed for the study. A joint airport and ground access mode choice MNL model was estimated for the seven airports considered in the study using a combined stated-preference and revealed-preference data set, although each of the survey respondents in the combined dataset only faced a choice between a subset of the airports, depending on the alternatives that were presented to them in the stated-preference survey experiments or the airports included in the revealed-preference survey dataset. The model included six ground access modes: drive and park, drop-off, taxi or limousine, transit, shared-ride van, and rental car. The drive and park mode was assumed to be only available to residents of the region, while the rental car mode was assumed to be only considered by visitors to the region. Separate models were estimated for resident business travel, resident non-business travel, visitor business travel and visitor non-business travel. The only socioeconomic variable included in the models was the ratio of the average number of automobiles owned by each household in the trip origin analysis zone to the average household size in the zone and this was only included in the utility function for the drive and park mode for the two resident models in the revealed-preference dataset.

A more recent ACRP research study (ACRP, 2015a) developed a model to analyze the potential diversion of air trips to intercity rail from improved rail service. This model included a sub-model of airport choice or station choice. However, the structure and coefficients of the airport (or station) choice sub-model were adopted from the West of Hudson Regional Transit Access Study discussed above.

In summary, there has been limited experience using socioeconomic variables in airport choice models, although household income, gender, and age have all been found to play a role in airport choice. However, there is considerable variation in the way in which these variables have been incorporated into airport choice models and they have often been expressed using dummy variables for particular age or income ranges. There is also no consistency in how these ranges have been defined. In several models where socioeconomic variables were incorporated, the estimated coefficients were not found to be statistically significant.

Airport Ground Access Mode Choice Models

The state of practice of airport ground access mode choice models was reviewed in an early ACRP Synthesis study (ACRP, 2008). This study included a detailed review of nine airport ground access mode choice models. Five of the nine models included household income as an explanatory variable, although the way that this was done varied across the five studies. One study, for Boston Logan International Airport, divided survey respondents who paid their own travel expenses into low and high income categories and estimated separate travel cost coefficients for each income category, as well as for those whose travel expenses were paid by their employer. A second study, that estimated separate models for Chicago O'Hare International Airport and Chicago Midway Airport, also divided survey respondents into high and low income categories and estimated separate travel cost coefficients for each category. Two studies (by the same consultant), for Oakland International Airport and San José International Airport, divided the travel costs for personal trips by the household income to the power 1.5 but did not adjust travel costs for business trips. The fifth study, for Portland International Airport, divided travel costs other than automobile operating costs for drop-off trips by the natural logarithm of the household income. A sixth study, that developed a model for the Southeast of England used a more aggregate approach that modeled total trips for different market segments from each of a system of ground origin zones. The utility functions for each mode included the value of travel time, rather than a direct measure of household income, and assumed the same value of travel time for each market segment. None of the models reviewed considered demographic factors (such as age or gender) or any other socioeconomic factors than household income.

As discussed above, the joint airport choice and ground access mode models developed in the New York Regional Air Service Demand Study (RASDS) and the West of Hudson Regional Transit Access Study (WHRTAS) incorporated a limited number of socioeconomic variables in the access mode utility functions. The RASDS models included gender, age, and income, although age and income were only expressed in three ranges. The WHRTAS models included the average number of automobiles per household member, but only in the utility function for the drive and park mode for trips by residents of the region and used the average value for the analysis zone of the trip origin (presumably because the data on household automobile ownership and household size were not available from the air passenger survey, although this was not explained in the report).

As discussed above, a model to analyze the potential diversion of air trips to intercity rail from improved rail service that was developed as part of a recent ACRP research study on integrating aviation and passenger rail planning (ACRP, 2015a) included a sub-model of airport choice or station choice. This sub-model in turn included an airport or station access mode choice model. The coefficients of the airport access mode choice model were adopted from the

West of Hudson Regional Transit Access Study discussed above. The main mode choice model for the choice between air and intercity rail was derived from an intercity travel choice model developed for the California High-Speed Rail Authority (Cambridge Systematics, 2014). This model included airport and station access mode choice sub-models, although these access sub-models were not used in the ACRP model.

The airport access mode choice sub-model estimated as part of the intercity travel choice modeling framework for the California High-Speed Rail Authority used a disaggregate approach (as did the main mode choice model). Data for the model estimation was derived from a telephone survey of household long-distance automobile travel and air and rail passenger intercept surveys that were used to synthesize an integrated disaggregate travel dataset. Separate models were estimated for airport and station access at the trip origin and airport and station egress at the trip destination. Mode choice sub-model variables included dummy variables for low-income households, single-person households, and households with fewer cars than employed household members. These dummy variables were included in the utility functions for specific modes and had the effect of modifying the alternative-specific constant for those modes. For example, the low-income household variable was included in the access and egress model utility function for drive-and-park mode for business and commute trips, and the access and egress model utility functions for the rental car and pick-up/drop-off modes for recreation and other trips. Household were classified as low-, medium-, or high-income based on their household income in 2010. Low-income households had a household income under \$45,000 and high-income households had a household income of \$90,000 or more. The dummy variable for single-person households was only included in the access model utility functions for pick-up and drop-off trips for all four trip purposes (business, commute, recreation, and other).

In summary, there has been limited experience using socioeconomic variables in airport ground access mode choice models. Where these have been included, they have been limited to gender, age, household income, household size, and automobile ownership (number of automobiles per household). Only one model identified in the review of relevant literature included gender or age, with the age variable based on three age ranges. Only one other model included household size, and this was limited to a dummy variable for single-person households. Two models considered household automobile ownership, with one using the average ratio of automobiles to household members for the analysis zone of the trip origin and the other using a dummy variable for households with fewer automobiles than employed household members. Household income was considered in several models, but the way in which income was incorporated in the models varied widely from dummy variables for incomes in a specified range to continuous functions of income. Thus while it appears from the findings of past studies that household income, and possibly gender and age, influence airport ground access mode choice, there is no consensus yet on how best to incorporate these factors into airport access mode choice models.

Airport Bond Prospectus Documents and Studies

The following sections summarize the air passenger demand analysis contained in six recent airport bond prospectus documents.

Boston Logan International Airport

A *Market Analysis* of airport aviation activity was prepared by ICF SH&E for the Massachusetts Port Authority in 2014 as part of a bond prospectus for Boston Logan International Airport (BOS) (Boston, 2014). The report provides a summary review of economic characteristics of the BOS service area, including a review of economic and socioeconomic trends in the Boston area. This review included the mix of industries contributing to economic activity in the region and recent trends in regional income and per capita income growth. There is a discussion of the airlines operating in the region and other factors contributing to air service at BOS, and of trends in the aviation industry both in the country overall and in the Boston region. The consultant's report does not include a new forecast of passenger activity at the airport, but does review Massport forecasts for the airport. The report notes that Massport uses a planning forecast and a more conservative financial forecast. The planning forecast is used to anticipate future capital investment needs on the airport and to estimate potential environmental impacts of airport activity, while the financial forecast is used for financial planning, including to support bond issuances by Massport.

The Massport planning forecast reviewed in the report links passenger demand to numerous factors, including economic growth at the regional, national and global level, the costs of air travel, and the economic health of the airline industry. The report notes that "air travel demand and airport passenger traffic are strongly linked to the economic characteristics of a region." Regional socioeconomic factors influencing future air travel activity at BOS include growth in regional population, regional real incomes, and regional employment, and data for these factors are taken from sources at the U.S. Bureau of the Census and the Bureau of Labor Statistics. Although socioeconomic data are reported in the report, no details of the methodology used in the Massport planning forecast or other causal relationships between socioeconomic factors and air passenger demand are reported. The Massport financial forecast of air passenger activity is more conservative than the planning forecast, and is described as an extrapolation of recent air passenger demand growth at BOS.

Dallas/Fort Worth International Airport

A *Report of the Airport Consultant* was prepared by LeighFisher for the cities of Dallas and Fort Worth, Texas, as part of a 2014 airport revenue bond issuance for Dallas/Fort Worth International Airport (DFW) (Dallas/Fort Worth 2014). The report states that national airline passenger traffic has historically correlated closely with the state of the U.S. economy and with levels of real disposable income. No models or model results to enumerate these relationships are reported. A base forecast of DFW passenger enplanements through 2020 is reported, and for these forecasts it is assumed that the U.S. economy would grow at an average annual rate of 2.5%, and that the airport's service region would grow at the same average annual rate. Sources for the data of interest include the U.S. Bureau of the Census and the Bureau of Labor Statistics. Other factors assumed to contribute to air passenger growth include the stability of the international political and security environments, continued stability and security within the airline industry, continuity in the patterns of airline service at DFW, among others. These factors are presented as qualitative contributors to the growth of passenger traffic at DFW, and no model is reported. The consultant report also presents a "stress test" forecast for DFW. This alternative forecast represents the impact on air passenger demand at DFW of weaker economic growth in

the U.S. and the resulting effects on airline service at DFW. The stress test forecast includes reductions in both originating passengers and in the number of passengers connecting at DFW, relative to the base case forecast.

Los Angeles International Airport

A Report of the Airport Consultant was prepared in 2012 by Ricondo and Associates as part of a bond prospectus for a 2012 bond issuance by Los Angeles World Airports (LAWA) for Los Angeles International Airport (LAX) (Los Angeles 2012). Several socioeconomic factors are identified as contributors to the economic base for air transportation and air travel demand. These include both aggregate and disaggregated socioeconomic measures. Aggregate variables include regional population, per capita regional product, per capita regional personal income, and employment and labor market trends. These data are attributed to Woods & Poole.

There are also numerous disaggregated socioeconomic variables identified as contributing to the economic base for air transportation. The explanation for their inclusion was in each case the likelihood of differences in propensity for using air transportation among the different subgroups. One of these disaggregated socioeconomic variables was the age distribution of the regional population, which was included because (based on BLS Consumer Expenditure Survey results) individuals between 35 and 54 years of age and those 55 or older account for a significant majority of spending on air travel. The LAX region's ethnic and racial diversity was also identified as a contributor to the region's economic base for air transportation. The white proportion of the region's population is lower than that of California as a whole and significantly lower than the proportion for the U.S. as a whole (54.9%, 57.5%, and 72.4%, respectively). The Consultant's Report argues that the region's high proportions of Hispanic and Asian residents will contribute to air travel demand both through international business connections and through family and cultural connections that engender travel to and from the region.

Because survey data from the BLS Consumer Expenditure Survey indicate that a large majority of airline fares are purchased by travelers with a college degree or who have completed some years of college, the LAX Consultant's Report cites the distribution of the region's population by level of education as another contributor to air travel demand. The region is home to many college educated residents, although the distribution among levels of educational attainment is not much different from the distributions in California and the U.S. overall. The Consultant's Report also identifies the region's distribution of households by income level as a contributor to air travel demand, again using results from the BLS Consumer Expenditure Survey. Households with annual incomes of \$75,000 or more purchase 65% of air fares although they represent less than 40% of U.S. households, and in the LAX region nearly 45% of households have incomes of \$75,000 or more.

The aggregate and disaggregated socioeconomic variables identified above are identified as contributors to the basis for air travel demand in the LAX region, and related factors are identified in the Consultant's Report as influences on future air travel and aviation activity in the region. These include aggregate economic variables such as consumer income, business performance and both national and global GDP. Various factors related to the state of the airline

industry were also cited, including industry structure, industry financial health and airline costs and schedules.

Longer term projections of passenger activity at LAX were made using three distinct methodologies, including:

- Market Share Approach, which is based on informed judgements about the extent to which growth at LAX will resemble or differ from FAA national projections, with the understanding that FAA planning forecasts may not be as conservative as desired for forecasts used for bond financial feasibility and planning purposes.
- Socioeconomic Regression Approach, using statistical linear regression tools to model passenger enplanements as a function of local aggregate socioeconomic factors as independent variables, including such variables as regional population, regional income, per capita income, and regional employment.
- Trend Analysis, in which time series techniques are used to project future enplanement counts using past counts.

The Market Share Approach was selected as the preferred approach, with the other two methodologies used for comparative purposes. The model structure and estimation results from the regression approach are not reported, and the modeling approach as described indicates that only aggregate socioeconomic variables were used in the estimations, although the significance of disaggregated socioeconomic concepts for air travel demand was clearly described in other parts of the Consultant's Report.

Milwaukee General Mitchell International Airport

A Report of the Airport Consultant was prepared by Unison Consulting in 2013 as part of a bond prospectus to support a bond issuance by Milwaukee County for General Mitchell International Airport in Milwaukee, Wisconsin (Milwaukee 2013). The report describes numerous aggregate socioeconomic factors as contributing to the local economic base for air transportation, including regional population, regional per capita income, and regional employment.

The report for Milwaukee includes a forecast of air passenger enplanements based on what is described as a "hybrid modeling framework that considers both supply and demand factors." This includes a near term forecast for 2013 based on published airline schedules and a longer term forecast driven by demand factors through 2018. The "hybrid approach" refers to this sequence of short term and longer term forecasts. The longer term forecasts were developed using a multivariate regression approach. Independent variables in the regression included air fares, national per capita incomes, and industry factors such as the events of 9/11 and the effect of Southwest Airlines on airline activity at the airport (Southwest began service in Milwaukee in 2009). Historical data on incomes were obtained from Moody's Analytics, and forecasts for incomes were taken from contemporary publications by the Congressional Budget Office (CBO). Thus, use of socioeconomic variables in these forecasts for Milwaukee bond documents is limited to a few aggregate variables.

New York Kennedy International Airport

An economic analysis and passenger activity analysis and forecast was prepared as part of the *Report of the Airport Consultant* for the Port Authority of New York and New Jersey (PANYNJ) (New York, 2010) for a bond prospectus accompanying a 2010 bond issuance to finance air terminal projects at John F. Kennedy International Airport (JFK) by the Port Authority was also prepared by Ricondo and Associates. Like the LAX Consultant's Report, its discussion of the economic basis for air transportation in the region served by JFK includes consideration of some disaggregated socioeconomic variables, such as population diversity, the distribution of educational attainment, and income distribution as important factors supporting air travel demand in the service region. Data for these measures came from the U.S. Bureau of the Census, the Bureau of Labor Statistics, and Woods & Poole.

The JFK report also contains a forecast of passenger demand in the relevant JFK market area, which includes JFK and five other airports in the New York City area. The forecasts relied on socioeconomic data and projections obtained from Woods & Poole, and three distinct forecasting approaches were combined to create a "composite forecast" which was justified by referring to the uncertainty inherent to any individual forecast. The three individual forecast approaches that make up the composite forecast are:

- Income Regression, in which annual enplanement counts for the JFK market area were modeled as a function of incomes in the JFK market area, resulting in a forecast of an annual growth rate of 2.4% from 2010 to 2020
- Employment Regression, in which annual enplanement counts for the JFK market area were modeled as a function of employment levels in the JFK market area, resulting in a forecast of an annual growth rate of 2.0% from 2010 to 2020.
- Linear Trend Analysis, in which annual enplanements for the JFK market area were modeled as a simple linear function of time, resulting in a forecast of an annual growth rate of 2.0% from 2010 to 2020.

Model quality for each of these individual approaches was characterized using the R^2 measure of goodness of fit. This measure took values of 0.82 for the income regression, 0.78 for the employment regression, and 0.72 for the linear trend approach. The composite forecast that was used to project JFK enplanements was reported as the average of the three, resulting in a reported annual growth rate of 2.2% for 2010 to 2020.

An identical approach was taken to forecasting passenger enplanements at JFK alone. There is no discussion of whether changes were made to the socioeconomic variables for their use in the JFK-only forecasts. Again, three distinct forecasts were developed, one based on the relationship between JFK enplanement counts and JFK market area incomes, one on JFK market area employment, and a third based on the time based trend analysis approach:

- Income Regression, in which annual enplanement counts for JFK only were modeled as a function of incomes in the JFK market area, resulting in a forecast of an annual growth rate of 2.2% from 2010 to 2020.

- Employment Regression, in which annual enplanement counts for JFK only were modeled as a function of employment levels in the JFK market area, resulting in a forecast of an annual growth rate of 1.9% from 2010 to 2020.
- Linear Trend Analysis, in which annual enplanements for JFK only were modeled as a simple linear function of time, resulting in a forecast of an annual growth rate of 2.1% from 2010 to 2020.

The composite forecast, made up of an average of these three, is the forecast reported in the document and gave an annual growth rate at JFK alone of 2.1% from 2010 to 2020. A check was made on the JFK-only composite forecast by applying a market share approach to the overall JFK market area forecast, and comparing these results. There were only very modest differences in the two, with the “for comparison purposes only” market share approach forecasting an annual enplanement growth rate at JFK alone of 2.2% from 2010 to 2020.

Tampa International Airport

A *Report of the Airport Consultant* was prepared by Ricondo and Associates in support of a 2013 bond issuance by the Hillsborough County Aviation Authority for Tampa International Airport. The report makes use of socioeconomic data from Woods & Poole in its analysis of demographic and economic factors that support the demand for air transportation. Most of these are aggregate socioeconomic variables – regional population, per capita income, household income, regional GDP and employment trends – but others are examples of disaggregated socioeconomic variables. The report makes note of the Tampa region’s population diversity, pointing out that while the Tampa area does not have a foreign born population share that is higher than U.S. averages, a large share of Tampa’s foreign born residents are from Latin America, which may give rise to international travel to and from the Tampa area. The report also notes that households in the higher income categories tend to be the strongest purchasers of air fares, and the Tampa region has a slightly lower than average proportion of higher income households. Data for these measures comes from the U.S. Bureau of the Census, the Bureau of Labor Statistics, and Woods & Poole.

Socioeconomic variables were also used in the forecasts of passenger activity at Tampa. Short term forecasts were provided to the consultant by the airport authority, and long term passenger activity projections were developed by the consultant. Projections were prepared using two methodologies:

- Socioeconomic Regression Approach – Linear regression and multiple regression approaches were used, with local and national socioeconomic and demographic factors used as independent variables for regressions regarding local enplaned passengers. Independent variables considered in the analysis included regional population, regional employment, regional income, gross regional product, and per capita personal income. The report does not state the chosen model specification, nor the model R^2 , which is described in the report as a measure of the quality of a model’s result.
- Market Share Approach – Under this approach, projections of passenger activity at Tampa are developed as shares of the FAA’s projections for national passenger

activity, with the share proportions determined by past passenger activity at Tampa and for the nation as a whole.

The explained passenger projections reported for Tampa are described as reflecting “the lower end of the growth rate range identified in the socioeconomic regression analyses.” No further detail on the model results or estimated model parameters is reported.

Summary

All six bond prospectus documents reviewed include some mention of socioeconomic factors as determinants of air travel demand that can be used to develop forecasts or projections of future air passenger enplanements. While none of the documents provide information on air travel demand model structure or parameter estimates, in several cases the forecasts were made using a regression model that includes some aggregate socioeconomic factors as independent variables. Three of the studies treat region-specific disaggregated socioeconomic factors as contributors to the economic basis for regional air travel demand, but these factors are not included in the air passenger demand modeling portions of the reports. Table B-18 below summarizes the six bond prospectus consultant’s reports in terms of their use of socioeconomic variables for passenger demand analysis.

Table B-18. Uses of Socioeconomic Data for Air Passenger Demand Forecasts in Selected Airport Bond Prospectus Documents

Airport	Year	Socioeconomic Variables		Data Sources	Forecast Methodology	Comments
		Aggregate	Disaggregated			
BOS	2014	GDP, population, real income, employment	none	Bureau of the Census, Bureau of Labor Statistics	Study only reviews existing Massport forecasts for BOS	Socioeconomic variables identified as contributing to economic basis for air travel
DFW	2014	regional GDP, income	none	Bureau of the Census, Bureau of Economic Analysis	Regional economy drives air travel demand, no model described	Socioeconomic variables identified as contributing to economic basis for air travel
JFK	2010	regional population, regional per capita personal income, employment	Population diversity, educational attainment, income distribution (all cited only as contributors to air travel demand, not as model elements)	Woods & Poole, Bureau of the Census, Bureau of Labor Statistics	Composite forecast based on a market share approach, a socioeconomic regression approach and a time series/trend approach. Regression approach included aggregate variables: regional population, regional income, per capita income and regional employment	Regression model structure and parameters not reported
LAX	2012	regional population, per capita regional product, regional per capita personal income, employment	age distribution, ethnic diversity, educational attainment, income cohorts (all cited only as contributors to air travel demand, not as model elements)	Woods & Poole	Market share of national activity, Trend/time series, Linear regression (regional population, regional income, per capita income, regional employment)	Market share approach was preferred forecast, no information provided regarding regression model structure or estimated values. Disaggregated socioeconomic variables mentioned only in context of basis for economic support for regional air transportation

Airport	Year	Socioeconomic Variables		Data Sources	Forecast Methodology	Comments
		Aggregate	Disaggregated			
MKE	2013	national per capita incomes	none	Moody's Analytics, CBO	Multivariate regression using national per capita income, air fare levels, and industry historical factors	Regression model structure and parameters not reported
TPA	2013	regional population, per capita regional product, regional per capita personal income, employment	population diversity and income distribution (both cited only as contributors to air travel demand, not as model elements)	Woods & Poole, BLS, Bureau of the Census	Two approaches used, first a Market Share approach with TPA as a percentage of FAA national forecasts, and second a socioeconomic regression approach using regional population, regional employment, regional income, gross regional product and regional per capita personal income. No details about model specification or estimates are provided.	Selected forecast is "the lower end of the growth range identified in the socioeconomic regression analysis"

Airline Passenger Demand Analysis

An overview of an airline approach to using socioeconomic data to better understand and serve passenger demand was presented at the TRB Annual Meeting in 2014 by Andrew Watterson of Southwest Airlines (Watterson, 2014). The airline objective for using these data was described as "better understand[ing] passengers and best match[ing] [Southwest's] supply to their demand. With regard to these passengers, the airline was interested in the questions:

- Why they fly?
- Where they fly?
- Can they afford to fly?
- Which airport do they prefer?

The presentation identified several sources for socioeconomic data, including federal sources (Census Bureau, BLS, BEA, BTS), survey and research firms providing data that was purchased by the airline, local sources of data such as community and regional Convention and Visitors' Bureaus, research sponsored by airports served by the airline, and internal airline data on passenger behaviors, preferences, and destinations.

Several specific examples of these uses of socioeconomic data were presented, and it is noteworthy that in these examples the data were not used to develop quantitative models of air passenger demand. Instead, the data, much of it disaggregate socioeconomic data, were used to specify and clarify socioeconomic and demographic trends that the airline could respond to in its service offerings. Examples included

- Using Census Bureau data to report that most U.S. population growth between 2000 and 2010 was due to the increase of the Hispanic population, and this growth was concentrated in a few counties in Texas, Florida, and California
- Using Census Bureau data to identify population centers in the U.S. for individual nations of origin such as Salvador or the Dominican Republic, where air passenger demand for travel to visit friends and relatives could be expected to exist
- Using BTS data on U.S./Mexico border crossings (at highway border crossing stations) to understand the extent of the decline in car border crossings due to drug cartel violence and the economic downturn, indicating the potential of some shift to air travel for some Mexico to U.S. travel demand
- Using data from BLS, BEA, BTS and the Census Bureau to understand demographic and economic growth in the Houston Metro Area, an important city in the Southwest network, and the changes in air passenger traffic flow through the Houston area
- Using data from Southwest's airport partner, Northwest Florida Beaches International Airport (ECP) to understand where owners of second homes in the ECP area make their primary residences, for matching to existing Southwest network of airports
- Using research and survey data from private data providers to characterize travel demand between the Los Angeles Basin and destinations in Guadalajara and Mexico City, for potential market development

- Using Census Bureau data to understand differing rates of population growth in individual Florida urban areas, such as Fort Lauderdale, Palm Beach, and Miami, especially growth of Hispanic and Latino populations in these areas, which will affect future demand for Southwest flights at these airports
- Using internal data from Southwest itself to understand the extent of travel by Canadians to Buffalo to fly Southwest out of BUF, rather than fly out of Canada

These examples illustrate the types of airline planning questions that can be addressed with the numerous data sources that are available to airlines or airports for analyzing passenger demand. These regional data include detailed passenger characteristics such as national origin, ethnicity, travel purpose, and home ownership, making them a clear example of the role that disaggregated socioeconomic data can fill in such analysis. At the same time, the uses of these data do not take the form of inputs to a formal model of passenger demand, and are presented instead as evidence used by airline planners for allocating its traffic across a complex and evolving network to serve passenger demand.

Industry Air Travel Demand Projections

A number of aircraft manufacturers, airline industry associations, and other industry organizations prepare forecasts of future growth in air travel demand, primarily in order to project the expected future demand for their products or services. These forecasts are typically updated on an annual basis. The findings discussed below were from the most recent update that was available at the time the analysis discussed in the text was performed. Although these forecasts do not address air travel demand at the level of individual airports, the forecast growth in air travel demand at a world regional level projected in these studies is often cited in forecasts prepared for specific airports or airport systems as a cross-check on the projected growth in demand in those forecasts.

Because of the global or national nature of industry forecasts, they generally forecast air travel demand in terms of revenue passenger-miles (RPM) or revenue passenger-kilometers (RPK) and use aggregate measures of economic activity, such as national GDP. The forecast reports may discuss more disaggregate factors affecting air travel demand but from the limited details on the forecast methodology that are typically reported, it is unclear how these factors are incorporated into the forecasts.

The following sections provide a brief overview of four of the more widely referenced industry forecasts.

Airbus

The annual Airbus Global Market Forecast (Airbus, 2015) projects the future growth in RPKs for air travel between 20 world regions, six of which are countries (Canada, Japan, the People's Republic of China, Russia, South Africa, and the U.S.), as well as intra-regional travel (for multi-country regions) and domestic air travel within each region. Domestic air travel growth for Brazil, India, Mexico and Turkey is forecast separately from domestic air travel growth in the other countries in their respective regions, and air travel growth between Mexico and the U.S. is forecast separately from air travel growth between other countries in Central

America and the U.S. The forecast presents the projected growth in air travel as a compound average growth rate from 2014 to 2034 but does not present the resulting traffic level in RPKs for each of the 229 defined markets. The estimated origin-destination traffic flow in RPKs in 2014 and the projected traffic flow in 2034 for the largest 20 markets is shown graphically, as is the share of global traffic in each of seven world regions for 2004, 2014 and 2034. The historical growth in total worldwide RPKs from 1974 to 2014 and the forecast worldwide traffic level in RPKs is also shown graphically.

The report includes a fairly extensive discussion of socioeconomic and other market drivers, with selected statistics on trends in these drivers over the past 10 to 65 years (depending on the data) and projections of some of the factors to 2034 or 2050. The discussion of the traffic forecast methodology in the report states that econometric relationships were estimated for each of the traffic flows using data on historical traffic levels and various estimates for historical values of socioeconomic variables. These relationships were then used with forecast values of the socioeconomic variables from various sources to project future traffic growth. However, the details of these estimated relationships or the socioeconomic variables used are not provided. The discussion states that the forecast traffic at the region-pair level is then broken down to the country-pair and airport-pair level. Except for the traffic flow growth rates that are expressed at the country-pair level (where the world region is a single country), the resulting forecasts at the country-pair level are not shown in the report and no data is presented at the airport-pair level. A graphic shows the projected increase in the number of what the report terms aviation mega-cities, defined as aviation hubs with more than 10,000 long-haul passengers per day, with circles shown on two maps of the world, for 2014 and 2034, sized to represent the traffic level in each city, although it is unclear how to interpret the scale shown on the graphic. In any case, it would be difficult to get anything other than a very rough approximation from the graphic.

The forecast projects that domestic air travel in the U.S. measured as RPKs will grow at an average rate of 1.7 percent from 2014 to 2034, for an overall growth of about 40 percent, while air travel between the North America and the rest of the world will grow at an average rate of 4.2 percent from 2014 to 2034, for a total growth in RPKs of about 130 percent. Although North America and the U.S. are not the same thing, since the U.S. has by far the largest share of the North American market, the growth rate for international travel is likely to be similar.

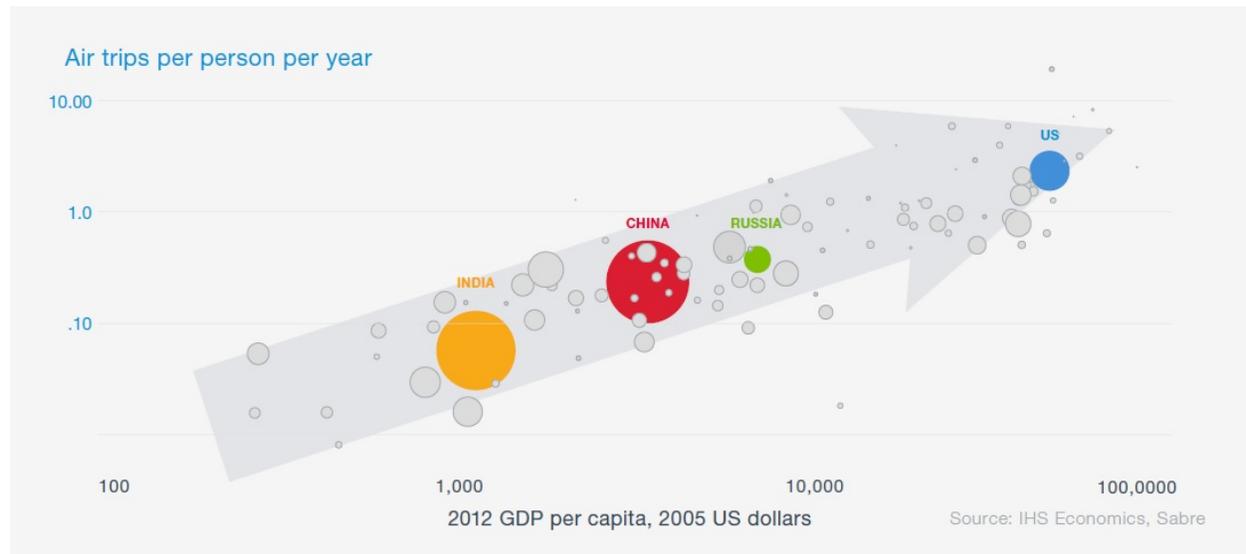
Boeing

The annual Boeing Current Market Outlook (Boeing, 2015) forecasts the future growth in RPKs for air travel within and between 12 world regions, although in addition to the intra-regional flows within the 12 regions, only the 30 largest inter-regional flows are specifically forecast, with the others being grouped as “rest of world.” In the case of the Commonwealth of Independent States region, all the inter-regional flows are grouped as “international.” The forecast report presents the projected traffic growth from 2014 to 2034 for each of these 43 markets as well as the world as a whole. The historic traffic levels in RPKs for each of these markets and the world total is tabulated in the report for each year from 2007 to 2014, as well as the forecast traffic level for 2034.

The report includes a discussion of the business and market environment which includes a chart showing the 2014 GDP and projected GDP growth from 2015 to 2025 for 14 of the

world's largest economies (a mixture of countries and regions) and a chart showing the annual growth rate in real GDP from 2001 to 2014, together with projections to 2020, for the world in total, as well as for advanced economies and emerging markets, although these two groups of countries are not defined. There is also a discussion of volatility in oil prices and exchange rates, with a chart showing oil and jet fuel prices from 2000 to 2015. The discussion of the projected traffic growth and new airplane requirements for each of the world regions, with a discussion of Asia overall and Central and South America together, includes data on the assumed GDP growth rate for the region as well as the forecast traffic growth and charts showing data on a selected market driver for each region or a comparison of air service metrics across regions. In the case of Africa, a chart shows the historical and projected trend in urban and rural population and the percentage of urbanization for the region, in five year increments from 1990 to 2040.

The description of the methodology used to generate the forecasts states that different factors influence the different traffic flows identified in the forecasts and therefore each of these flows is modeled differently, with judgement being used to assess the effect of factors that are not easily quantified. The discussion identifies four socioeconomic factors, namely GDP development, worldwide commerce, population, labor-force composition, and international trade, together with seven other technology, business organization, and air service factors. However, the report does not explain how these factors are incorporated into the forecasts. The discussion presents an interesting chart showing the relationship between air travel and GDP per capita for different countries in 2012, shown as Figure B-8 below.¹¹



Source: Boeing Commercial Airplanes, *Current Market Outlook 2015-2034*, September 2015, p. 22.

Figure B-8. Increase in Air Travel Propensity with Income - 2012

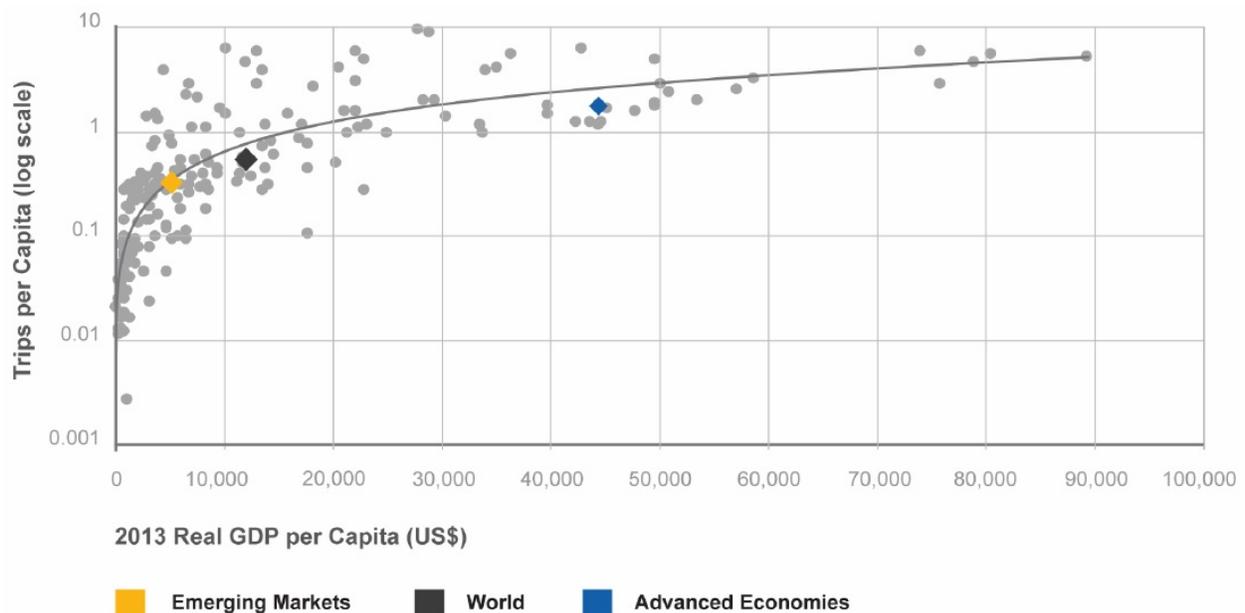
¹¹ The most recent Commercial Market Outlook (Boeing 2018) contains a similar figure showing essentially the same relationship between air travel and national GDP per capita.

The size of circles for each country in Figure B-8 appears to be proportional to population. Since the scales for both axes are logarithmic, the range of air trips per person per year across the different countries shown in the figure varies by more than a hundred times. Although the trip propensity shown in the figure is based on aggregate data (total air trips and average GDP per capita), presumably a similar relationship also exists at a disaggregate level, with the income distribution in each country influencing the air travel propensity at an individual level and hence the average air travel propensity for each country as a whole.

The Boeing forecast predicts that intra-North American traffic, expressed as RPKs, will grow at an average annual rate of 2.4 percent from 2014 to 2034, for a total growth of 61 percent. While intra-North America traffic is not the same as domestic U.S. traffic, presumably the growth rates in the two markets will be similar. The data in the report suggest that international air travel to and from North America will grow by over 120 percent from 2014 to 2034.

Embraer

The annual Embraer Market Outlook (Embraer, 2015) focuses on the market demand for commercial aircraft with 70 to 210 seats, reflecting the Embraer product line. The forecast report contains a discussion of global trends, including a projection of average GDP growth rates for the periods 2015 to 2024 and 2025 to 2034, for the world economy as a whole and for advanced economies and emerging markets, based on forecasts by IHS Global Insight. This also includes two charts on the average propensity for air travel by country, one in terms of the 2013 real GDP per capita, shown as Figure B-9 below, and the other in terms of the share of urban population, shown as Figure B-10 below.

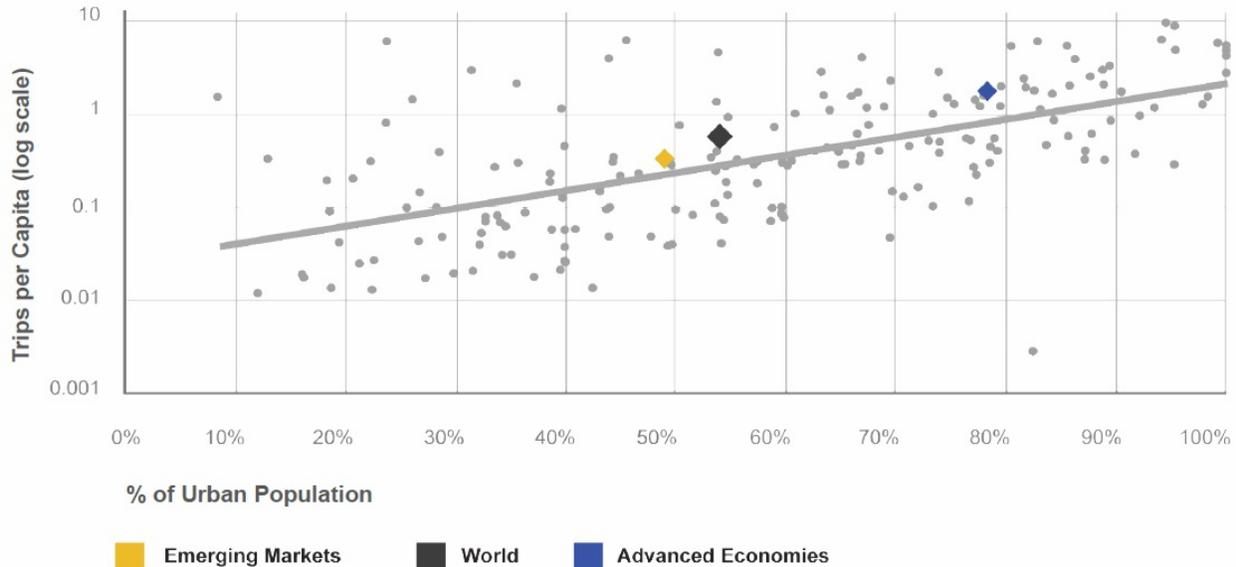


Source: IHS Global Insight, Sabre, Embraer

Source: Embraer Commercial Aviation, *Market Outlook 2015-2034*, June 2015, p. 13.

Figure B-9. Increase in Air Travel Propensity with Income - 2013

The relationship between air travel propensity and real GDP per capita shown on Figure B-9 are effectively the same as the relationship shown on Figure B-8, apart from the different year and the linear scale for GDP per capita. The relationship shown on Figure B-10 indicates that air travel propensity tends to increase with urbanization, although the range of air trip propensity between countries at lower levels of urbanization (below 50 percent urban population) approaches a factor of a thousand.



Source: IHS Global Insight, U.N. Department of Economic and Social Affairs, Embraer

Source: Embraer Commercial Aviation, *Market Outlook 2015-2034*, June 2015, p. 15.

Figure B-10. Increase in Air Travel Propensity with Urbanization

Following the discussion of global trends and drivers of air traffic growth, the report presents forecasts of market demand for aircraft by size range in each of eight world regions. These sections include a projection of the forecast average growth rate in regional GDP and traffic, expressed in RPKs, from 2015 to 2034. Although not clearly stated in the report, these growth rates appear to cover both intra-regional and inter-regional travel. The report states that world air traffic is projected to reach 13.9 trillion RPKs by 2034, somewhat lower than the 16.2 trillion RPKs projected in the Boeing Current Market Outlook.

The discussion of the forecast methodology in the report mentions econometric relationships for projecting intra-regional and inter-regional traffic in RPKs that use a number of socioeconomic inputs, including GDP, tourism, and population dynamics, as well as other economic and air service variables. The report states that the equations and variables are chosen based on which best explain the historical traffic growth for each traffic flow. However, the details of these equations are not given.

International Air Transport Association

The International Air Transport Association (IATA) prepares a set of global *Air Passenger Forecasts* that is updated bi-annually (IATA, 2015a). Prior to 2014, the forecasts provided a five-year projection and were developed using a consensus approach among airline representatives (IATA, 2014a), but starting in October 2014, the forecast provides a 20-year projection that is updated each April and October. The new forecast approach has been undertaken as a joint venture between IATA and Tourism Economics, an Oxford Economics Company. The forecast provides country-pair traffic projections for origin-destination passenger trips between almost 4,000 country pairs. The forecasts are published in a Global Report and a series of reports for 16 individual countries (as of the October 2015 forecast) that are sold separately. The Global Report provides an overview of the forecasts that identifies the ten countries with the largest projected increase in passengers by the horizon year of the forecast (2034 in the two 2015 updates), the ten countries with the largest projected average annual growth rate, the ten country-pair markets (including domestic markets) and the ten international country-pair markets with the largest projected increase in passengers, and the ten country-pair markets with the highest projected growth rate. The October 2015 Global Report update projected an average annual growth rate of U.S. domestic traffic of 3.0 percent from 2014 to 2034, with an overall average annual growth rate for all traffic of 3.1 percent, implying an average growth rate for international traffic of about 3.3 percent per year.

The Global Report includes a discussion of the forecasting framework and the factors considered in developing the forecasts, including the role of living standards, population, and demographics, as well as the price of air travel and other factors.

B.4 Analysis and Critique of Airport Uses of Socioeconomic Data

This section summarizes the findings of the review of current practice documented in the previous section, offers a critique of current practice, and identifies best practices for the use of socioeconomic data in air passenger demand studies. The discussion of current practice addresses such aspects as the relevance and statistical significance of socioeconomic factors in air travel demand, the extent of use of disaggregated socioeconomic data, the ease of availability of socioeconomic data for use in other studies, and the source of forecast values of socioeconomic variables. Based on the current state of practice represented by the studies examined in the previous section, this section concludes with a discussion of the implications for the future conduct of the different types of air passenger demand studies and in particular the potential use of disaggregated socioeconomic data.

a. Socioeconomic Factors Considered in Recent Practice

- There is some variety in the use of aggregate and disaggregated socioeconomic data for analyzing and modeling air passenger demand by airports, airport consultants, and others when conducting air passenger demand studies. In these practices, aggregate socioeconomic data is used for analyzing, explaining and modeling air passenger demand, but disaggregated socioeconomic data is used much less frequent, and disaggregated data is absent when air passenger demand is being statistically modeled. Three ways of categorizing these uses of socioeconomic data in individual studies are:
 - Generally, only aggregate socioeconomic data are used in both discussions of the factors underlying air travel demand and in modeling undertaken in the studies to create forecasts for future air passenger demand at an airport or region
 - While aggregate socioeconomic data are used to populate passenger demand models, a study may also refer to disaggregated socioeconomic factors, such as ranges of household income, strata of educational achievement in households, or other disaggregating criteria, to justify or explain characteristics of the air travel demand for an airport or for a region
 - The most expansive approach would be for the modeling of air passenger demand in a study to be based on both aggregate socioeconomic data and disaggregated socioeconomic data, or even to be based on disaggregated socioeconomic data alone
- The Research Team's review of a wide variety of examples from several types of airport and air travel studies found that most studies fall into the first category, with the study narrative and (if present) any statistical modeling supporting the study relying solely on aggregate forms of regional socioeconomic data, such as regional GDP, regional populations, regional employment, and regional income levels, both in the aggregate and on a per capita basis.

- Air service development studies and airport demand leakage studies typically do not include forecasts of future air travel demand, nor do they consider socioeconomic factors in their analysis. These types of airport analyses generally focus on past patterns and trends in air passenger activity and changes in airline service to inform the analysis of current and near term travel patterns.
- Uses of disaggregated socioeconomic data occurred infrequently, and primarily involved the use of disaggregated factors to model the geographic distribution of air travel demand in a region surrounding one or more airports, rather than for modeling the overall regional demand.

b. Relevance and Statistical Significance of Socioeconomic Factors

- Nearly all of the studies and analyses we examined recognize socioeconomic factors as relevant to air passenger demand. Where studies differ is in the way in which this relevance is incorporated into the analysis of air passenger demand. In some cases the differences reflect the fact that the studies do not report details of model specifications and parameter estimations, which may have been considered appropriate for publicly-released reports that are focused more on communicating an airport's infrastructure or financial plans than they are on reporting the details of the underlying statistical analysis.
- All of the studies and planning exercises that have reported the results of statistical models using a region's socioeconomic data found that the airport or regional air passenger activity was in some way related to those factors. This is true even for studies which concluded that forecasting results from an approach that is not based on socioeconomic factors, such as a time series model or a market share model, was preferable to the results from models driven by socioeconomic factors.
- In of the studies reviewed by the Research Team that involved formal models of air passenger demand, the modeling related the total air passenger demand at an airport or for a region to the socioeconomic characteristics of that region. Some models did not even distinguish between origin and destination (O&D) passengers and connecting passengers (who have no obvious causal relationship to the socioeconomic characteristics of the region where they happen to change flights), but even those models that were estimated using O&D passenger traffic did not distinguish between travel by residents of the region and travel by visitors to the region. Therefore the extent to which air travel by visitors to a region is influenced by different socioeconomic or other factors from air travel by residents of a region, or differences in the relative effect of such factors, appears completely unknown.
- Statistical results were rarely reported for the models leading to passenger forecasts and other study results, and in most of those cases, reporting was limited to model goodness-of-fit measures, such as R^2 statistics. Measures of the statistical significance of parameter estimates, such as t-statistics or p-values, were less commonly reported.

- While acknowledging that the purpose of airport and regional studies is to support airport or regional planning responsibilities and not primarily to document the statistical details of the underlying modeling exercises (in contrast to many of the academic passenger demand modeling efforts reviewed in Appendix A of the final report, which do take pains to document the statistical details of the models that are estimated), the reporting of formal modeling results in greater detail would improve the ability of airport analysts to compare demand models across different airports and regions. It can also be argued that transparency requires that the technical details of the underlying analysis on which the forecasts are based should be disclosed to airport stakeholders and other interested parties.
- A second reason for increased reporting of modeling details, that may be more important than improving the ability of analysts to compare models across airports and regions or allowing stakeholders to better understand the basis on which the forecasts were developed, is that these details would provide both the study sponsor itself and other study users with a greater understanding of the sensitivities in the links between an airport's passenger demand and the underlying socioeconomic factors. Knowledge about such sensitivities, usually categorized as demand elasticities, could help the sponsors and other users of these studies to better understand how changes in socioeconomic or other independent factors could affect air travel demand in the future.

c. Extent of Use of Disaggregated Socioeconomic Data

- The review of airport master plan and other airport planning studies found no use of disaggregated socioeconomic data in the preparation or estimation of models for air travel demand for forecasting or other purposes.
- While disaggregated socioeconomic data was not used for modeling purposes, there was frequent discussion of disaggregated socioeconomic factors in study reports to explain the growth or pattern of air travel demand in a region or in an area served by an individual airport. Analyses of air passenger demand reported in airport bond prospectus documents very often used disaggregated data in this way. These uses of disaggregated socioeconomic data most often took the form of partitioning populations into different strata, such as population or households into distributions by age, income, ethnicity, or educational attainment. These individual strata were then identified as having a greater or lesser propensity to travel by air, relative to the overall population. These relationships were presented in a static fashion, in the sense that the recent distributional characteristics of the population surrounding an airport were used to characterize the current demand for air travel being served by the airport, without being part of a formal model.
- Airports or regional planning organizations making use of disaggregated population characteristics in this way relied on survey-based data about population distributions. In some cases the data were developed from surveys conducted by the Bureau of the Census or, to a lesser extent, other government agencies, and in other cases the data

was developed by the airports or regions themselves through their own surveying efforts.

- There were no examples of airports or regions using data based on digital records from credit card transactions or cell phone activity at airports to inform their total passenger demand modeling and analysis. The development of this type of data and its application for airport uses such as passenger demand modeling is still in the very early stages and is primarily used to identify airport ground access and egress travel patterns for airport ground transportation planning. It may represent an important and informative new source of data for understanding passenger behavior and preferences, especially as customers of airport services.

d. Ease of Availability of Socioeconomic Data for Future Studies

There are two different categories of disaggregated socioeconomic data that have different availability considerations from the perspective of their use in air passenger demand studies. The first category relates to the socioeconomic characteristics of the region served by an airport or airport system. Disaggregated data in this category are generally collected at the household level, although they may be reported at a geographical zonal level for reasons of privacy. The second category relates to the socioeconomic characteristics of the air passengers using an airport or system of airports. Disaggregated data in this category are typically obtained from air passenger surveys and are collected and available for analysis at the air travel party level.

- Aggregate socioeconomic data for a region or sub-regional area (e.g., a county, city, or zip code) are generally easily obtained from both public and commercial sources. Although the public data sources are typically available at no cost, the data may require some manipulation to convert it to a consistent structure and format for use in air travel demand analysis. In addition, projections of future values of socioeconomic variables are typically available from commercial sources on a more consistent basis. The Bureau of the Census does publish population projections, which are available online at no charge.
- Some disaggregated socioeconomic data at the zonal level are also available, although using the public data sources may require some user knowledge of fairly complex data sets, and the data may require a significant amount of manipulation to convert it to an appropriate structure and format for use in air travel demand analysis. In other cases, disaggregated socioeconomic data are not readily available from public sources, and must be acquired through surveys or other direct data collection approaches that must be undertaken by airports themselves.
- Data on disaggregated socioeconomic characteristics of air travelers used by airports and regional planners generally comes from airport and regional surveying efforts. Such data have the advantage of having been gathered with an eye toward its eventual uses by the collecting airport or regional authority, but conducting surveys is a costly and time consuming undertaking, although one that many airports undertake for other reasons anyway.

e. Source of Forecast Values of Socioeconomic Variables

- Many air travel demand forecasts for airport master plans and other studies make use of projected future values of population, income, and/or employment developed and sold by economic data vendors, such as Woods and Poole Economics, Inc. These projections provide aggregate socioeconomic data for relatively large geographic areas, such as counties.
- Population and demographic projections for the United States and for regions within the country are available for download from the Bureau of the Census.
- In some cases forecasts of socioeconomic variables for a particular region or regional subdivisions, such as counties, are prepared by the relevant metropolitan planning organization. In some states, county-level forecasts of population and sometimes other socioeconomic variables are prepared by the state. These data are generally available at no cost.
- These forecasts or projections of socioeconomic variables are generally aggregate measures of the particular variable, aside from disaggregation by geographic area. The research to date has not identified a source of forecast values for disaggregated socioeconomic variables or distributions within individual data categories, such as population by age or household income by income range.

f. Implications for Future Air Passenger Demand Studies

- There is a lack of established standards of good practice for documenting air travel demand forecast models in airport master plan and other airport development studies. At a minimum, technical reports should clearly define the mathematical structure of the model, describe the source of the data for each variable included in the model, give estimated values of the model coefficients together with their statistical significance, and present overall goodness-of-fit statistics for the estimated model. More explicit technical reporting of results would be informative both for airport managers and stakeholders and for the community of analysts from airports and consulting firms. In some cases, it may be necessary to modify some of these reporting expectations due to proprietary concerns from the firms conducting air passenger demand studies for airports and other clients where those studies make use of proprietary models or data sources. This might be an issue for which the Airports Council International-North America (ACI-NA) or other industry organizations could provide insight and guidance.
- There is considerable variety in the socioeconomic variables that are included in air travel demand models developed for individual airport master plan and other airport development studies, suggesting that the choice of variables to include in a given model is determined more by selecting the model specification that gives the best apparent fit to the data used for model estimation than from any theoretical understanding of what socioeconomic factors influence air travel demand. It may be that those who use these studies for planning and other decision making purposes

could benefit from some statements of conceptual or theoretical justification for using one set of variables over another, along with the more typical goodness-of-fit results.

- With this greater transparency and the consequent improvements in the ability to compare studies to one another, it may be possible to clarify how air passenger demand differs from airport to airport and region to region. For example, more informative reporting of model results could make it possible to use other analytic tools, such as elasticities of air travel demand with respect to price or to income. These market characteristics may vary widely from airport to airport and from market to market, but it could be valuable to use more transparently reported demand analysis results at airports to systematically compare elasticity values from one location to another. In particular, use of more disaggregated socioeconomic data in such models may help explain some of the apparent differences in the relationship between air passenger demand and aggregate socioeconomic variables across different markets or regions.

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Attachment B-1

References for Review of Airport Planning Studies

- I. Airport Aviation Demand Forecasts**
 - I.1. Large Hubs**
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Attachment B-2

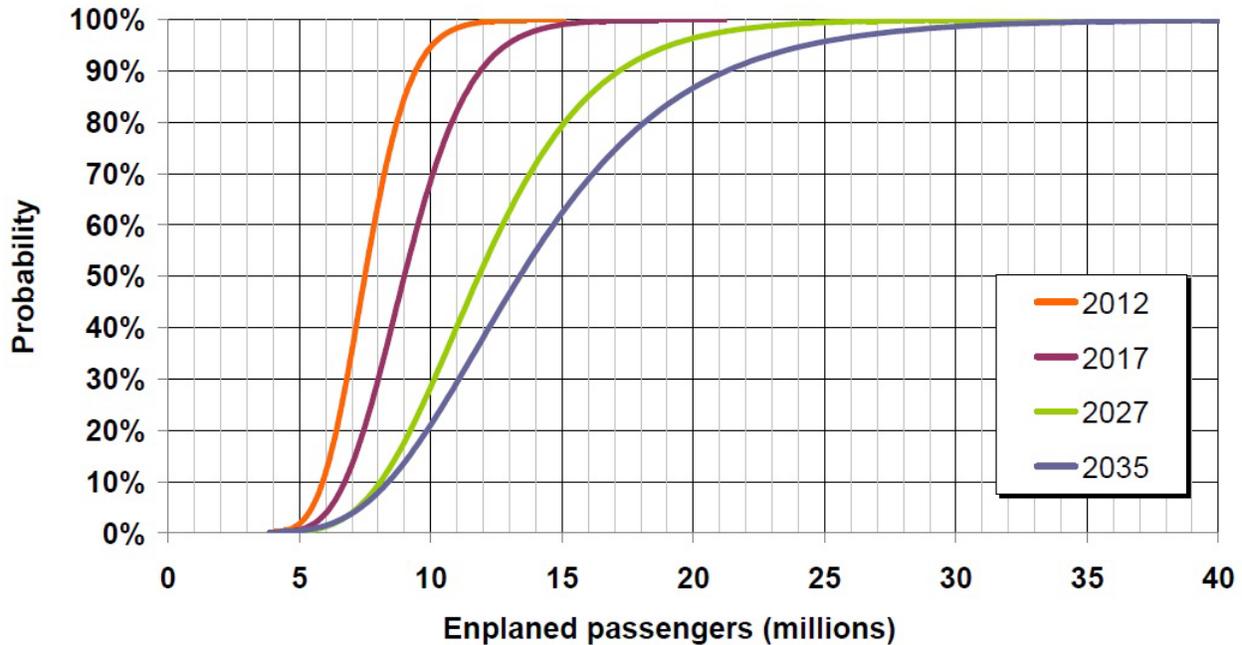
Portland International Airport Master Plan Update Forecast

From fall 2007 to 2010 the Port of Portland, owner and operator of Portland International Airport (PDX), undertook an update of the Airport Master Plan in conjunction with the City of Portland through an extensive collaborative process termed *PDX Airport Futures* (City of Portland & Port of Portland, 2011). The City and Port convened a 30-member Planning Advisory Group that comprised community, government, and business interests to serve as an advisory body for the process and undertook over 130 stakeholder and 13 public meetings during the course of the process. The PDX Master Plan (Jacobs Consultancy et al., 2010; Port of Portland, 2010) was adopted by the Portland Planning Commission, Portland City Council, Vancouver City Council, and the Port of Portland Commission in April 2011.

A critical issue faced in the Master Plan update was whether a third parallel runway would be required during the planning period that extended to 2035 (City of Portland and Port of Portland, 2011). Therefore, a key element of the Master Plan update was the preparation of aviation demand forecasts for the airport (Jacobs Consultancy et al., 2008). These forecasts adopted a risk management approach that developed probabilistic forecasts of future air passenger traffic and air cargo activity. The probabilistic forecasts for a given future year were calculated using a large number of trials (10,000 in the case of the air passenger forecasts), varying the assumed future values of the explanatory variables in an econometric model of total passenger enplanements or total air cargo tonnage respectively, as discussed further below for the air passenger forecasts. Since the current project is only concerned with forecasts of air travel demand, the details of the air cargo forecasts are not discussed, although the general approach to developing the probabilistic forecasts is similar. Although this process could potentially generate a complete distribution of the forecast future value of air passenger traffic for any given future year, the Aviation Demand Forecasts Technical Memorandum (Jacobs Consultancy et al., 2008) only presented the distributions for selected years (2012, 2017, 2027 and 2035), as shown in Figure B.2-1.

Furthermore, once these distributions had been generated, they were used to produce three scenarios: low, median, and high growth forecasts, which were then used for subsequent analysis. The median forecast scenario corresponded to the 50% probability and was used as the baseline forecast. The low growth scenario corresponded to the 10% probability forecast, while the high growth scenario corresponded to the 90% probability forecast. The use of the term “scenario” is a little misleading because these forecast traffic levels are not scenarios in the usual sense of the term (forecast values corresponding to a defined set of assumptions regarding future conditions), but arbitrary points on a forecast distribution of future traffic. Although a 90% probability forecast might be an appropriate upper bound for planning purposes, there is no discussion in the Aviation Demand Forecasts Technical Memorandum as to why that probability was chosen, as distinct from (say) an 85% probability or 95% probability. The lower bound is of course of lesser concern in a master plan study, since if traffic grows more slowly than expected,

construction of planned facilities can always be deferred. However, the lower bound may be of considerable importance if the master plan forecasts are used for financial planning or preparing official statements for issuing revenue bonds, since they reflect the risk that air passenger traffic, and hence airport revenue, may not grow as quickly as expected.



Source: Jacobs Consultancy, et al., *Master Plan Update – Portland International Airport: Technical Memorandum No. 2 – Aviation Demand Forecasts*, March 2008, Figure 17.

Figure B.2-1. Forecast Cumulative Distribution of PDX Enplaned Passengers

It can be seen from Figure B.2-1 that the difference between the median forecast passenger traffic in 2035 and the 90% probability level is considerable: 21.3 million enplaned passengers at the 90% probability level compared to only 13.4 million enplaned passengers at the median probability level (or almost 60% more passengers).

Underlying these forecasts are two critical analyses. The first is an econometric model of air passenger enplanements and the second is the forecast of the future distribution of the explanatory variables in the model, referred to in the Aviation Demand Forecasts Technical Memorandum as independent variables. These were assumed to be independent in two senses. In the first sense they were assumed to be independent of the enplaned passenger traffic (the dependent variable), as is normally assumed in such models. However, they were also assumed to be independent of each other in the statistical sense, so in generating each trial of the forecast distribution, the values for each explanatory variable were chosen randomly from the assumed distribution for that variable and then combined in the econometric model. The details of the air passenger model, given in Appendix B of the Aviation Demand Forecasts Technical Memorandum, noted the possibility that the explanatory variables might in fact be correlated in some way, for example that changes in oil prices might affect economic growth in the Portland

region, but reported that based on historic data for the previous 30 years this correlation was found to be statistically insignificant, lending support to the assumption of independence.

The econometric air passenger demand model used a log-log formulation (linear model with all continuous variables in logarithms) with the following variables:

- Portland/Vancouver regional population
- Portland/Vancouver regional per capita income
- Average airline yield (U.S. domestic prior to 1990 and for PDX thereafter)
- Dummy variables for the years prior to 1990, for 2001, and for the years after 2001, respectively.

The model also included a variable for the product of the dummy variable for years prior to 1990 and the average airline yield. This effectively estimated separate coefficients for the average U.S. domestic yield and the average PDX yield. The model was estimated on annual data for the years 1976 to 2006 (31 observations).

Since the model used a log-log formulation, the estimated coefficients give the elasticity of demand with respect to each variable. These elasticity values are:

- Population 0.89
- Per capita income 1.04
- U.S. domestic yield -0.55
- PDX average yield -1.15

The population and per capita income elasticities are broadly consistent with elasticity values found in other studies, although a population elasticity of 0.89 seems low. *A priori*, one would expect a population elasticity value around 1.0. If population increases by some amount, other things remaining equal, one would expect air passenger traffic to grow proportionately. However, the total enplaned passengers includes visitors to the region as well as connecting passengers, so the population variable may be accounting for other factors not included in the model that change the composition of the traffic. The elasticity value for U.S. domestic yield is implausibly low relative to that for average PDX yield. This appears to be a consequence of the inclusion of the product of the yield and dummy variable in the model. The use of the average U.S. domestic yield for the years prior to 1990 was a consequence of the lack of average yield data for PDX for those years. In 1990 and 1991 the average PDX yield was slightly higher than the average U.S. domestic yield, but from 1992 on it was lower, due in part to the growing presence of low-cost carriers at PDX (principally Southwest Airlines). Assuming that prior to 1990 the average yield at PDX was higher than the average U.S. domestic yield by some constant factor, the adjustment that should have been made to the model was to estimate a different constant term for those years, not a different elasticity. The dummy variable for the years prior to 1990 does this, but including the product of the dummy variable and yield as an additional variable double counts the effect, distorting both the coefficient of the dummy variable and the yield.

The dummy variable coefficients represent factors by which the enplaned passenger traffic calculated from the continuous variables is multiplied for the years in question, as follows:

- Prior to 1990 0.161
- 2001 0.746
- 2002 on 0.679

The adjustment factor for years prior to 1990 is surprisingly low, but this appears to be a result of including a variable with the product of the dummy variable and the yield. The average U.S. domestic yield was around 22 cents in 1989 in constant 2006 dollars (used in the model to express yield and income) and would have been higher in prior years. The coefficient of the logarithm of the product of the dummy variable and the average U.S. domestic yield was 0.60, so the value of this term in 1989 would have increased the modeled enplaned passengers by a factor of 6.4, which would have more than offset the effect of the dummy variable alone.

The value of the 2001 dummy variable, implying a 25% reduction in passenger traffic in 2001 relative to the traffic otherwise predicted by the model, seems plausible, given the combined effect of the September 11 terrorist attacks and a recession. However, the dummy variable for 2002 on is problematical. It seems unlikely that the longer term effects of the events of September 11, 2001 and the subsequent changes in aviation security would result in a 32% reduction in passenger traffic from the level that would otherwise have occurred. In any case, when the model is applied to generate a forecast for future years, it seems unlikely that this reduction in projected traffic would remain constant in subsequent years.

In addition to estimating an econometric model of air passenger enplanements, the forecast process also needed to develop both estimates of the values of the continuous variables for future years and their distribution. The forecast values and distribution for the regional population was obtained from a probabilistic forecast prepared by Portland Metro, the regional metropolitan planning organization, which assumed a normal distribution. The forecast values for the regional per capita income were also obtained from a forecast prepared by Portland Metro, although this only gave a single-value forecast for each year. The difference in annual income growth rates projected in prior forecasts and the growth rates that actually occurred was analyzed and the mean forecast error and its standard deviation calculated. These parameters were then applied to define a triangular distribution for a given year with the most likely value corresponding to the forecast value of per capita income and the lower and upper limit of the distribution were set to give the projected mean and standard deviation for the value for each year based on the analysis of previous forecast errors.

Developing a forecast of future values of average PDX yield was more involved. A regression model was developed to relate average PDX yield to average U.S. domestic yield. A second regression model related average U.S. domestic yield to average break-even yield, defined as the sum of fuel and non-fuel costs per available seat mile (ASM) divided by average load factor. Forecasts of non-fuel costs per ASM and load factor were obtained from trend projections, with the values assuming a triangular distribution based on the forecast error variance from the trend analysis. Forecasts of fuel cost per ASM were based on a third regression that related fuel cost per ASM to the price of oil. Forecast values for the future price of oil were obtained from forecasts prepared by the U.S. Energy Information Administration (EIA) and

adjusted for a potential future carbon tax using estimates of the potential carbon tax per ton of CO₂ emissions developed by the Massachusetts Institute of Technology (MIT) Joint Program on the Science and Policy of Global Change. A triangular distribution was assumed for the future price of oil based on the low, median, and high forecast values given in the EIA and MIT projections.

In summary, the aviation demand forecasts for the PDX Master Plan Update made use of a relatively sophisticated probabilistic forecast approach, although the resulting forecast was then simplified to a conventional three-scenario (baseline, low, and high growth) output for use in subsequent analysis. A fairly conventional econometric model of total enplaned passengers was estimated using regional population, regional per-capita income, and average PDX yield as explanatory variables, together with a number of dummy variables for specific years. This was then used to generate distributions of forecast passenger traffic using a Monte Carlo simulation approach. Considerable effort was devoted to obtaining forecast distributions of the independent variables, although the consultants were able to take advantage of a probabilistic forecast of regional population that had already been prepared by Portland Metro.

Notwithstanding the sophistication of the approach, the analysis involved a number of simplifications, perhaps to keep the level of effort involved manageable. These included combining resident, visitor, and connecting passengers into a single model of total enplaned passengers, the use of simple linear regressions in developing the relationships involved in the approach to forecasting future average PDX airline yield, and assuming triangular distributions for forecast values of several of the intermediate and explanatory variables. The issues surrounding each of these simplifications would benefit from future research to better understand the relationships and factors involved, as well as provide guidance on best practice for addressing them in future forecasting studies using a similar approach.

Attachment B-3

United Kingdom Airports Commission Forecasting Process

Given the mandate of the United Kingdom (UK) Airports Commission to examine strategic options for meeting the future needs for airport capacity in the London region, the development of forecasts of air travel demand were central to the work of the Commission, although they were only one of many issues addressed by the Commission. The Commission based their forecasts on an expanded and updated version of the suite of aviation demand models developed by the UK Department for Transport (DfT) over several years. This modeling suite was used to produce forecasts of air passengers and airline aircraft operations for each of the 31 largest commercial airports in the UK through the use of two linked models. The National Air Passenger Demand Model (NAPDM) predicts the number of air passengers beginning or ending their air trip in each of 455 analysis zones (termed districts) into which the UK is divided. The National Air Passenger Allocation Model (NAPAM) then allocates the air passenger trips to and from each analysis zone to one (or two in the case of domestic air trips or domestic connections to or from an international trip) of the airports included in the model.

Since the focus of ACRP Project 03-36 is on the role of socioeconomic variables in air travel demand analysis, this summary primarily addresses the treatment of socioeconomic variables in the NAPDM with some discussion of the allocation of national demand to analysis zones and the peer review of the forecast methodology and assumptions.

The NAPDM consists of a set of econometric demand models for 19 different market sectors covering trips by UK residents or foreign residents, making business or leisure trips, to a destination in one of four groups of countries (Western Europe, other OECD countries, a group of Newly Industrialized Countries (NIC), and a group of Less Developed Countries (LDC)), together with domestic business trips, domestic leisure trips, and passengers connecting between international flights. The general form of the econometric demand models is log-log (linear with continuous variables in logarithms) structured as unrestricted error correction models (UECM) as follows:

$$\Delta Q_{it} = \alpha_i + \beta_i \Delta Z_{it} + \gamma_i Q_{it-1} + \delta_i Z_{it-1} + D_{it} + \varepsilon_{it}$$

where Q_{it} = log of passenger traffic in market i for year t
 Z_{it} = log of explanatory variables for market i for year t
 D_{it} = dummy variable for market i for year t
 ε_{it} = error in prediction for market i for year t
 $\alpha_i \beta_i \gamma_i \delta_i$ = parameters to be estimated
 Δx_{it} = change in variable x for market i from year $t-1$ to year t

It should be noted that the UECM model structure includes both difference terms of the dependent and continuous explanatory variables (ΔQ_{it} , ΔZ_{it}) and lagged terms for both the

dependent and continuous explanatory variables (Q_{it-1} , Z_{it-1}). The socioeconomic variables used in each of these models vary with the market sector, as shown in the following table:

Table B.3-1. Socioeconomic Variables in UK National Air Passenger Demand Model

Market Sector	Socioeconomic Variable(s)
UK resident, business, Western Europe	UK consumption; UK exports
UK resident, business, other OECD	Foreign GDP; UK imports
UK resident, business, NIC	UK GDP; foreign GDP
UK resident, business, LDC	UK GDP; foreign GDP
UK resident, leisure, Western Europe	UK consumption
UK resident, leisure, other OECD	UK consumption; UK exports
UK resident, leisure, NIC	UK consumption
UK resident, leisure, LDC	UK GDP
Foreign resident, business, Western Europe	UK consumption; UK exports
Foreign resident, business, other OECD	UK exports
Foreign resident, business, NIC	Foreign GDP
Foreign resident, business, LDC	UK imports
Foreign resident, leisure, Western Europe	UK consumption (<i>lagged only</i>)
Foreign resident, leisure, other OECD	Foreign GDP; nominal UK exchange rate
Foreign resident, leisure, NIC	Foreign GDP
Foreign resident, leisure, LDC	Foreign GDP
Domestic, business	UK GDP
Domestic, leisure	UK consumption
International-international connection	Foreign GDP

While the socioeconomic variables for each market sector were those that gave the best fit to the passenger traffic, there appears to be no obvious logic to why specific variables were found to explain the traffic in some market sectors and not others. For example, if both UK gross domestic product (GDP) and foreign GDP explain UK resident business travel to NICs and LDCs, which seems inherently reasonable, why does foreign GDP not appear in the model for UK resident business travel to Western Europe and why does neither UK GDP nor UK consumption appear in the model for UK resident business travel to other OECD countries? In any case, it is clear from the variables listed in Table B.3-1 that the models use aggregated (national level) socioeconomic variables.

The inclusion of difference and lagged variables in the model specification complicates the interpretation of estimated coefficients as elasticities. It can be shown (the derivation is given in the *UK Aviation Forecasts* report (DfT, 2013)) that the long-run demand elasticity for a given variable is given by the negative ratio of the estimated coefficient for the lagged explanatory variable to the estimated coefficient for the lagged traffic. In applying the model to forecasts of future demand, the demand elasticities with respect to the socioeconomic variables in future years were assumed to decline, generally over a 70-year period reflecting market maturity. The initial year in which the assumed decline began varied across the markets, which were divided

into three groups: those considered most mature, those considered fairly mature, and those considered least mature. The assumed decline in the socioeconomic demand elasticities are presented in the *UK Aviation Forecasts* report (DfT, 2013), while the basis for the assumed decline is discussed in an earlier technical note (DfT, 2011).

These elasticities are referred to in the DfT 2013 report as income elasticities, although variables such as imports and exports have no obvious direct connection to household income. While variables such as GDP and consumption will be influenced by changes in household income, they are also influenced by changes in population. Even if household incomes do not change in real terms, real GDP and consumption will increase if population grows. Using aggregate measures also ignores any effects due to changing household income distribution.

For comparison with other studies, the long-run demand elasticities for each of the socioeconomic variables are shown in Table B.3-2.

Table B.3-2. Long-run Demand Elasticities of Socioeconomic Variables in the UK National Air Passenger Demand Model

Market Sector	Socioeconomic Variable(s)	Long-run Elasticity
UK resident, business, Western Europe	UK consumption	0.74
	UK exports	0.54
UK resident, business, other OECD	Foreign GDP	0.45
	UK imports	0.52
UK resident, business, NIC	UK GDP	0.47
	Foreign GDP	0.54
UK resident, business, LDC	UK GDP	0.47 (1)
	Foreign GDP	0.54 (1)
UK resident, leisure, Western Europe	UK consumption	1.33
UK resident, leisure, other OECD	UK consumption	0.76
	UK exports	0.58
UK resident, leisure, NIC	UK consumption	1.59
UK resident, leisure, LDC	UK GDP	1.85
Foreign resident, business, Western Europe	UK consumption	0.62
	UK exports	0.49
Foreign resident, business, other OECD	UK exports	0.55
Foreign resident, business, NIC	Foreign GDP	0.76
Foreign resident, business, LDC	UK imports	0.69
Foreign resident, leisure, Western Europe	UK consumption	1.21
Foreign resident, leisure, other OECD	Foreign GDP	0.55
	nominal UK exchange rate	-2.11
Foreign resident, leisure, NIC	Foreign GDP	0.51
Foreign resident, leisure, LDC	Foreign GDP	0.46
Domestic, business	UK GDP	0.99
Domestic, leisure	UK consumption	2.26 (2)
International-international connection	Foreign GDP	0.47

- Note:
1. It proved impossible to estimate a satisfactory model for this market sector, so the model for UK resident business travel to NIC destinations was assumed to also apply to this market sector.
 2. Assumed to be too high due to absence of airfare variable in final model for the market sector and value set to 1.5 for use in forecast.

As discussed in the summary of the London Region forecast in Section 3 of this appendix, comparing demand elasticities across the market sectors is difficult because of the use of different socioeconomic variables and the presence of two socioeconomic variables in the models for some market sectors but not others. The summary in Section 3 also discusses the demand elasticity values shown in Table B.3-2 for the international markets.

The elasticities of the socioeconomic variables for the domestic market sector are problematical. As noted in Table B.3-2, the unexpectedly high value for leisure trips (2.26) was felt to be a result of the omission of an airfare variable from the model and a lower value was assumed for use in the forecasts. However, the airfare variable was also omitted from the model for domestic business trips, but this elasticity was not adjusted. This appears to be a case of making selective adjustments to the estimated values of the model coefficients to conform to preconceived expectations. Given the small amount of domestic air travel in the UK, this may not make a great deal of difference to the overall UK aviation forecasts, but it does mean that the estimated elasticity values are untrustworthy.

Allocation of National Demand to Analysis Zones

Although the NAPDM predicts air travel from and to the UK in the aggregate for each of the market sectors, this aggregate demand is subsequently allocated to each of the 455 analysis zones in the UK. This allocation is based on data from an ongoing air passenger survey program performed by the UK Civil Aviation Authority (CAA) at the majority of UK airports with commercial air service (DfT, 2003). The surveys are performed with varying frequency at the different airports, annually at the larger airports and less often at the smaller airports. The air trip ground origins (and destinations in the case of domestic air trips) given by the survey responses are weighted to reflect flight sampling and to express the results in a consistent year, using data on enplanements by market sector. These data are then expressed as annual air passenger trips in each market sector with ground origins and destinations in each analysis zone. A process has been developed to adjust the trip ends for air travel generated by the introduction of new service, which would not appear in the survey data for prior years. This was initially developed to account for the expansion of service at smaller airports by so-called “no-frills carriers.”

Initially, the baseline allocation was performed for the year 2000. This was subsequently updated as more recent CAA air passenger survey data became available. A computer routine has been developed to allow the analyst to vary the growth in trip ends in each analysis zone from the overall national growth a-rate for each market sector over time, while ensuring that the total growth conforms to the forecast national growth. This allows the forecast to reflect assumed regional differences in the growth rates of the underlying drivers of air travel demand. The details of how this was done for the latest aviation forecasts (DfT, 2013) are quite vague.

The resulting estimated (or forecast) air passenger trip origins and destination in each analysis zone or larger region can be expressed relative to population as air trips per-person, which DfT refers to as “propensity to fly,” although since this includes air trips by foreign residents, this is not the usual meaning of the term. Table B.3-3 shows the variation in this measure across UK regions for air trips in all market sectors (DfT, 2003, Table 3).

The high number of annual air trip origins and destinations per person in the London region undoubtedly reflects the high level of foreign tourist visits, as well as the effect of higher income levels and the concentration of governmental and economic activities that generate high levels of air travel. The relatively high number of air trips per person in Scotland and to a lesser extent Northern Ireland most likely reflect the distance of both regions from London and the South East, which makes domestic air travel more attractive relative to surface modes for travel between these regions (particularly in the case of Northern Ireland, where surface travel to or from the rest of the UK involves a ferry journey). It would have been interesting to compare the annual air trips per person in each region for each of the 18 market sectors involving UK trip ends, but this level of detail is not provided in the DfT reports.

Table B.3-3. Annual “Propensity to Fly” in 2000 by UK Region

Region	Annual Air Trips per Person in 2000 (each way)
London	5.95
East Midlands	1.47
Eastern	2.93
North	1.39
North West	1.89
South East	2.78
South West	1.45
West Midlands	1.51
Yorkshire and Humberside	1.44
Wales	1.15
Scotland	3.49
Northern Ireland	2.92

Peer Reviews of Forecast Methodology and Assumptions

The development of the DfT forecast methodology and its subsequent application by the UK Airports Commission was subject to an extensive peer review process. Following the close of the consultation process in February 2015, the Commission requested the International Transport Forum (ITF), an independent organization associated with the OECD, to prepare a review of the Commission’s forecasts in the light of the comments received during the consultation (ITF, 2015). This review focused on three aspects of the forecasts: the allocation of traffic between the London airports, the appropriateness and relevance of the scenarios adopted by the Commission, and likely airline response to additional runway capacity in the London region. The review did not address the forecasts of total demand developed using the NAPDM.

The Commission also retained Prof. Andreas Schäfer of University College, London to undertake an expert peer review of the DfT and Commission forecast modeling (Schäfer, 2015). This addressed both the use of the NAPDM and NAPAM. The report noted a number of aspects where it would be helpful for the Commission to provide more technical detail (this was done in the subsequent reports by the Commission). The only technical concern raised with the

econometric modeling in the NAPDM was to note that for four market sectors the estimated coefficient of the lagged $\ln(\text{traffic})$ variable was less than -1, whereas it should have been between -1 and 1 for the variables to be cointegrated, implying that the error correction model specification used is inappropriate. Although the estimated values were not stated in the peer review report, three lay between -1.02 and -1.06, while the fourth was -1.21. The peer review report does not explore what implications this might have for the resulting forecasts. The market sector for which the estimated coefficient of the lagged $\ln(\text{traffic})$ variable was -1.21 was the foreign resident business travel from Western Europe. The model for this market sector used UK consumption and UK exports as the explanatory socioeconomic variables, rather than economic variables for the countries of origin, although this was not mentioned in the peer review.

Prof. Schäfer was also retained to undertake an expert peer review of an alternative forecasting model that was developed by consultants for Gatwick Airport. However, this is not summarized here but will be reviewed separately as part of a review of the alternative forecasting model.

Earlier peer reviews had been undertaken for the DfT during the development of the aviation forecast methodology. These focused on the key drivers for growth in air travel, market maturity issues, estimation of the econometric demand models, the allocation of national demand to airports using the NAPDM, and economic appraisal of aviation projects. These reviews concluded that the models developed by DfT were probably the best that could reasonably be obtained with the data currently available. None of the reviews commented on the apparent inappropriateness of some of the socioeconomic variables used in the models for several market sectors or discussed the potential implications for forecasting future growth in air travel.