Review of Demand Modeling Methodologies for Air-Related Transportation: An Institutional Challenge to Intermodalism

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ABSTRACT

Fundamental to intermodal development is consistent demand modeling across the intermodal system, which coordinates resource allocation. However, different planning organizations are responsible for the development of different components of the intermodal system. In the case of air transportation, air demand modeling is mainly conducted by Federal Aviation Administration and commercial airlines for air traffic control and air flight operations. Airport-related surface demand modeling is undertaken primarily by airport authorities and metropolitan planning organizations for airport design and urban planning. These agencies adopt different methodologies from different perspectives, and there is an institutional gap between the methodologies, which may undermine the well being of the intermodal transportation system. In this paper, methodologies for demand modeling in the airport-related intermodal transportation system are reviewed, and the relevant problems are identified. The authors highlight a great need for a consistent demand modeling in support of intermodalism.

Key words: air demand modeling—intermodal transportation—urban planning

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INTRODUCTION

Air related intermodal transportation has been attracting attention. A major component of this system, air transportation, has grown to be an indispensable part of both the global economy and social interaction among a large number of people around the world. Air transportation has been developing very quickly over the past decades. Further, the number of air travelers is projected to double in this decade (Nettey 2000). Much of the projected growth is expected to concentrate disproportionately at large commercial service airports in major metropolitan population centers, and this growth will generate additional service demands on airports, which are the point of transition between air and surface modes of transportation for both passengers and cargo. As such, Nygard (1999) notes that "airport administrators are faced with implementing a heavy program of improvement and construction to meet the rising demand for facilities and services in an efficient manner."

Growth in air transportation imposes a challenge to urban transportation planning as well. An impact of this growth in air transportation is its contribution to traffic congestion in the areas surrounding the airport. Therefore, much literature has been devoted to how infrastructure is planned to improve access to airports. Khan (1996) envisions a change from conventional airports to intermodal-oriented airports in the future. Coogan (1996) highlights a deep interest in improving the intermodal connection between the aviation and ground transportation systems for passengers. He further points out that, in both Europe and the United States, the problem of improving the quality of ground access to airports is getting attention from policymakers at the highest levels. Improved intermodal connections for passengers in such advanced airports as Charles De Gaulle in Paris and San Francisco International in the United States demonstrate that the airport congestion problem is being tackled on both sides of the World. Roth (1995) discusses incremental high-speed rail issues to relieve airport-related traffic congestion. The author believes that rail has a strong role in the new era of intermodal transportation, prompted by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Clearly, there has been a worldwide effort towards improving the quality of intermodal connections at airports (Coogan 1997).

All the abovementioned efforts towards air-related intermodal transportation focus conceptually on infrastructure improvements only. However, fundamental to infrastructure planning is demand modeling. In our research, we have found that air-related demand modeling methodologies currently in use are not consistent between different planning organizations, which may create dislocated resource allocation activities between the different components of the larger intermodal system. Organizations with different responsibilities develop methods from different perspectives, and therefore a need exists for coordination to overcome this institutional gap. Surprisingly, studies on consistent demand modeling across the intermodal system have never been conducted, according to the published literature. To begin addressing the problem in this paper, we will present a brief review of the methodologies for air-related demand modeling from different organizations, which will highlight the models' different perspectives and the discrepancies among them. Our focus is not to go into detail about each method and its scientific soundness. Instead, we will show the differences in their application and perspectives wherever possible to highlight the need for methods that can help coordinate the development of different components of the intermodal system.

The organization of this paper is as follows. We first cover the methodologies and concepts of air-related surface demand modeling. We then review the application of a four-step method to airport-related demand modeling using two major urban planning organizations in Texas. We also briefly mention the opinions of two metropolitan planning organizations (MPOs) that concurred with our observations. Finally, we will compare the methodologies before highlighting a need for an integrated demand modeling method.

REVIEW OF DEMAND MODLEING METHODOLOGIES AND PRACTICES

In this section, we will discuss airport-related demand modeling and urban transportation planning practices, and we will ultimately make a brief comparison of these practices before proposing a systems approach for computer simulation.

Airport-Related Demand Modeling

In the following, we will briefly review the methodologies that are directly or indirectly related to airport demand modeling.

Directly Related Methodologies

We have identified four main focuses of research, all of which deal directly with air-related travel demand from different perspectives.

Focus I. The first research focus is the problem of airport travel demand estimation inbound to and outbound from a particular metropolitan area. While this has not been directly covered in the literature, the need for air travel demand forecasting in urban areas has long been identified, and small-scale closely related problems have been studied. In Kaemmerle (1991), for example, the research estimated the demand for scheduled commercial passenger services in small communities in the United States. This research was motivated by the change in air travel demand patterns in light of the Airline Deregulation Act. Data were collected describing the social, economic, and geographic characteristics of 260 small communities in the contiguous 48 states, with airports enplaning at least 2,500 passengers in 1985. Small communities were defined as those with service area populations of 200,000 or less. Descriptive data included population, income, labor force characteristics, community economic base, geographic location, departures, airfare per mile, driving distance to an alternative airport, and attractiveness of driving to an alternative airport. A methodology for selecting the most probable alternative airport when choices are present was included in the study. Although this study focused on demand estimation for small communities, it provided insight into the nature of air travel demand generation.

In addition, this research (Kaemmerle 1991) also specified multiple regression models using the collected data to estimate enplanements. Good results were reported. The best model explained 80% of the variation in the data. The model was demonstrated by estimating the demand for air service at 52 small communities in the state of Texas. In addition, this method was designed to be applied easily in the field, and only readily available U.S. Census Bureau and Official Airline Guide data are required.

Along the same lines as Kaemmerle (1991), Flaming (1994) specifically dealt with the economic variables that contribute to regional air travel demand. A model was developed and estimated using data for seven states in the southeastern region of the United States over a period from 1975 to 1987. Interesting results were obtained that suggested that demand is relatively inelastic with respect to manufacturing shipments, tourism expenditures, and statewide flight departures. It is, however, more responsive to changes in the value of manufacturing shipments than to the changes in tourist expenditures. Other things being equal, states with major connecting hubs are likely to experience a significant increase in passenger enplanements.

Focus II. Quite different than the method used in Kaemmerle (1991) and Flaming (1994), another research focus is on capturing the temporal relationship between the upcoming demand and the historical traffic patterns, namely the time series method. This method is adopted in many practices for short-term demand forecasting. In the airline industry, this method is generally for the purposes of revenue management and re-fleeting for recovery from irregular operations. It is also adopted in short-term airport operations planning. The major advantage of this method remains its power to explain periodic effects, including seasonal and weekly phenomena. The general trends that follow economic development are also explainable by this method. As an example of the literature in this area, Sen (1985) uses monthly data on ridership and revenue, one of the most commonly available types of data. A technique was presented based mostly on such data for determining the effects of various factors on ridership and revenue and for forecasting demand under various pricing assumptions. The method in Sen (1985) consisted of first smoothing the data using running medians, and then examining the smoothed data for patterns, using data from Indian Airlines.

As a complement to Sen (1985), Karlaftis et al. (1996) presented a methodological framework for air-travel demand forecasting. In particular, an analytical framework for developing economic models was presented, and post-fact analysis was used to test the accuracy of the models. The models developed were applied to two international airports, Frankfurt and Miami International. Results show that simple models with few independent variables perform as well as more complicated and costly models. Results also show that external factors have a pronounced effect on air travel demand.

Focus III. To our knowledge, the only literature to date explicitly dealing with the fluctuation of demand for airport facility planning is by Odoni and Neufville (1996). The study demonstrates the application of stochastic programming techniques to demand modeling. Though the study had airport planning as its focus, researchers in urban planning can benefit from the general concept as well. As stated in Odoni and Neufville (1996), typical design procedures can be summarized as follows:

1. Forecasting traffic level for peak hours
2. Specification of level of service standards
3. Flow analysis and determination of server and space requirements
4. Configuration of servers and space

Although airport design has a different focus from that of urban transportation planning, both need an accurate forecast of air travel demand, and both need ways to deal with the forecasting errors. Such a forecasting procedure normally first estimates aggregate traffic for the target year for which a new plan or design is developed. This aggregate forecast, in turn, is converted into a further estimate of traffic for the design day, normally taken to be the 30th or 40th busiest day of the year, or something such as the average weekday of the peak month. This is done partly based on historical data.

Note that target year is arbitrary, generally a round number, and that the use of conversion factors assumes that the pattern of traffic over twenty years or so is predictable, contrary to the predominant experience. As indicated by Odoni and Neufville (1996), forecasts are, in any case, demonstrably inaccurate. This has been shown by retrospective analyses comparing forecasts to what actually occurred (U.S. Office of Technology Assessment 1982; Ascher 1978; De Newfville 1976). According to Odoni and Neufville (1996), the 6-year forecasts of the U.S. Federal Aviation Administration (FAA) over the years have been more than 15% to 20% different from reality about half the time. The 11-year forecast for 1981, for example, overestimated the number of flight services by about 119%, and the 7-year forecast miscalculated by 70%. The situation usually gets worse for the more detailed forecasts commonly generated in the standard design process for airport terminal building. In response to the inaccuracy of the forecasts, the authors concluded that it makes more sense to concentrate on professional effort in investigating the implications and effects of uncertainties. Thus, the design effort should create a set of scenarios, with plausible ranges both for the levels of traffic and for key parameters that affect the design. According to Odoni and Neufville (1996), a few airport planning studies do, in fact, already use scenarios with broad estimates of traffic; so far, however, these are exceptional.

Focus IV. Another important method is called unconstrained demand modeling. This is related to an understanding of the difference between demand and traffic. Traffic is a realization of demand subject to network capacity constraints and other constraints. People often take the forecasted demand based on the current travel behavior as the true travel demand. In fact, current travel behavior just reflects a constrained demand. There has been interesting research on untruncation of demand in the airline industry. The reason may be that untruncation of demand is more significant in the airline industry than in any of the other areas, based on the major airlines that are able to study the demand elasticity with respect to air fares across different markets. Demand untruncation is also important to airport planning. One such effort can be seen in King County, WA (2006). The following is the basic concept adopted by King County International Airport, one of the nation's busiest general aviation airports. Unconstrained demand is a projection of what would be predicted as a demand for airport services from a variety of aviation market segments if the airport did nothing to encourage or discourage future demand. After a conceptual plan is identified, the unconstrained demand is adapted to reflect the projections of actual use, based on the proposed conceptual development plan. This projection of actual use is the constrained demand forecast. The constraint is the limitation of the airport to actually serve the entire projected unconstrained demand. As obvious as it is, the task to untruncate the demand is not an easy one. The major challenge is how to infer the concealed preference based on the revealed behavior. Reliability is also questionable. Regarding this front, there has been little published literature to date.

We have summarized research in four representative areas, including airport-related demand forecasting based on social economic characteristics in small communities, demand forecasting by time series, demand forecasting with scenarios (a simple stochastic method), and unconstrained demand forecasting. Though each of the areas is full of theoretical challenges, there is obviously a need to study how inconsistencies in these methods adopted by various organizations adversely affect an effective intermodal transportation system planning.

Other Related Research

Some other research studies and methodologies are indirectly related to air-related demand forecasting. However, these researches may provide insight into the nature of air travel demand. Part of the review that follows is based on the information from Horowitz and Farmer (2000).

Recreational Travel. As early as 1963, recreational trips were considered an important enough travel purpose to warrant separate study (Crevo 1963). In fact, in the late 1960s and early 1970s, the NCHRP (Ungar 1967), Indiana (Matthias and Greco 1968), Kentucky (Deacon et al. 1973), and other states (Gyamfi 1972; Berg et al. 1976) all conducted studies of the special characteristics of recreational travel. Strangely, although Americans seem to have dedicated an increasing amount of time to pursuing recreational activities, the latest of these studies was published several decades ago. Since many state economies depend heavily upon recreational activities, it would seem that this trip type might be important enough to require a closer examination than it has received in the past decades. For example, a Wyoming study (Wilson and Wang 1995) has indicated that peak traffic demand in that state is closely associated with recreational travel. The importance of recreational travel brings into question the appropriateness of using a small set of urban trip purposes in statewide models. In most cities, if not all, airport travel demand is believed to be strongly related to recreational travel to or from an urban area. The special characteristics of recreational travel starting with or ending at the airport, to our knowledge, have yet to be explicitly considered.

Intercity Passenger Demand Models. Intercity travel demand literature is mentioned here because air travel is basically part of intercity travels. Statewide models, in general, have not made effective use of the considerable amount of literature (largely from academic sources) on intercity passenger demand. Intercity models can essentially be divided into four types on the basis of two categories: data and structure. The models can use either aggregate or disaggregate data, and can have a direct demand or sequential structure. Intercity travel demand models can be further classified by whether they encompass only a single mode (mode-specific) or multiple modes (total demand) and by which trip purposes they include. The earliest intercity models were of the direct demand type, which were developed in the 1960s as part of an examination of the Northeast Corridor (Koppelman et al. 1984). The most famous one of these was Quandt and Balmol's (1966) abstract mode model. Readers may also refer to the review by Koppelman et al. (1984) for a more complete historical perspective of significant intercity demand modeling efforts. Particularly interesting contributions to direct demand modeling have been provided by Yu (1970), who introduced regression coefficients that include a time series component; by Cohen et al. (1978), who attempted to eliminate unmeasured effects with a pivot point technique; by Peers and Bevilacqua (1976), who introduced a long list of policy-sensitive variables; and Kaplan et al. (1982), who developed the passenger-oriented intercity network travel simulation (POINTS) model, a multimodal model that explicitly considers accessibility to the transportation system. Disaggregate models typically use a logit formulation to provide a convenient way of including a number of mode-abstract, transportation accessibility, policy-related, and behaviorally based variables in the modeling process. These models were thought to be especially useful in the effort to estimate the shifts in mode share that were expected from deregulation of the air and intercity bus industries, and from the anticipated implementation of high-speed rail transportation (Brand et al. 1992; Buckeye 1992). Again, Koppelman et al. (1984) review many of the earlier disaggregate mode choice models. In addition, Miller (1992), Forinash (1992), and Forinash and Koppelman (1993) provide studies of the various structures (binomial, multinomial, and nested multinomial) available to more realistically represent the cross-elasticities between modes and to eliminate irrelevant alternatives in the logit mode-split formulation.

Intercity Air Travel Elasticity Models for Service Design. This type of research models consumer fare product choices and estimates the elasticity of international business and leisure passengers to fare product attributes. Airline elasticity can be viewed as a summary measure of individual purchasing decisions. By modeling individual choices, different airline elasticity estimates can be developed for groups that share similar characteristics. Through incorporating individual, trip, and fare product attributes, the model can assess an airline's elasticity by different market segments in response to a wide range of marketing strategies. Marketing research and advanced travel demand and forecasting methods are typically integrated. Proussaloglou and Koppelman (1995; 1999) are examples of this effort. A more recent study by You (2001) examined passenger upgrade from a low fare class to a higher fare class when the booking request is rejected, while previous research had assumed that the rejected demand is lost.

Intercity Air Travel Demand Forecasting by Flight. This research develops models of total intercity air travel volume and its allocation to flights based on departure and arrival schedules, routing, fares, market presence, and carrier reputation and performance. This type of model is used to predict future passengers and revenues for different service scenarios. Some of the research in this area can be seen in Morrison and Winston (1985), Koppelman and Hirsch (1991), and Koppelman (1989). Worthy of a note is that almost all major airline companies make significant efforts to improve their ability to forecast itinerary-based air travel demand for the purpose of fleet assignment and revenue management. Much work has been done in this area. A good understanding of the literature in this respect helps with the understanding of the characteristics of air travel demand.

Air transportation is one of the travel modes between city pairs, and it becomes more dominant with longer distances. With large cities such as Houston and Dallas, the amount of peak-hour traffic around the airport that is attributable to tourist activities remains a question. It remains a serious theoretical problem to combine the air travel demand forecasting methodologies in a consistent, coordinated, and reliable framework for airport-related demand modeling that covers urban, airport authority, and aviation planning and that promotes the healthy development of intermodalism.

Airport-Related Ground Transportation Demand Forecasting

Four-step Demand Modeling Method

A four-step method, which includes trip generation, trip distribution, mode choice, and traffic assignment, is primarily designed for long-term urban transportation planning and is generally adopted by metropolitan planning organizations (MPOs). There is no explicit explanation in the literature about how to specifically deal with crucial situations, such as large commercial airports that experience a higher-than-average growth in travel demand. Therefore, in practice, there is a large operational flexibility in dealing with airport-related demand.

As two examples of this method, we examined the practices of the Houston-Galveston Area Council (HGAC) and the North Central Texas Council of Governments (NCTCOG). In both cases, the airport is typically treated as a special trip generator, as seen in the pertinent Texas Transportation Institute report (TTI 1985) and the NCTCOG's website (2007). In the case of the NCTCOG, base-year data is used to adjust the *k*-factor to make the forecasted traffic match the observed patterns. This method virtually raises the trip rates of the local residents (home-based work and home-based nonwork trips) evenly across the zones to compensate for trips made by visitors from outside the region. There is no detailed information about how airport-related travel demand is modeled in the practice of the HGAC. As can be seen, airport-related demand modeling is too coarsely aggregated into the general urban planning process in some practices.

In addition to these passenger concerns, a serious concern in urban transportation planning is regarding airport-related freight traffic. Urban transportation planning typically does not have the capability to explicitly deal with air freight transportation. However, air cargo has been developing quickly in the past years. It is ignored in air travel demand modeling because freight is typically transported in the belly of passenger airplanes and does not increase air traffic. In ground transportation, however, the case is different. The significance of freight transportation to traffic and air pollution should be examined carefully.

Concurrence from Two MPOs

Questionnaires were made to both NCTCOG and HGAC for their opinions on the errors associated with airport-related demand modeling. The former considers the unusual weekday travels by airline pilots and stewardesses an important part of airport traffic while the latter points out that the trips made by people who are not residents or employees of the region are present but difficult to account for. This survey confirms our observation that (1) urban planners do not pay much attention to coordinated demand modeling with other organizations, such as the FAA and airlines, and (2) current urban demand modeling itself needs to be improved to account for the growth of air travel demand in support of the intermodal system.

Remarks

We have reviewed the methods for air and ground travel demand modeling, and inconsistencies have become obvious between the methods adopted by the planning groups. Air transportation planners, including airport authorities, the FAA, and commercial airlines, have as their focus historical data regarding air traffic between regions, while urban transportation planners rely on the social and economic characteristics of the local residents in the planning area. The former emphasizes the temporal relations between regions, while the latter carefully considers the travel preferences per household. Each of the methods shows advantages and disadvantages. Urban transportation planners fall short of the capability to explicitly incorporate the visits by outside travelers and the capability to incorporate air freight transportation; air transportation planners typically do not consider the change of land use and socioeconomic characteristics in the target area at all. Air transportation planners also implicitly assume a relatively stable land use policy and a stable but consistently changing local economy. On the other hand, research on intercity travel offers more opportunity to look at other alternative modes and the dynamics between the modes. In a word, this inconsistency in demand modeling between and within each of the components of the intermodal system is likely to bring about uncoordinated resource allocations and thus undermine the well being of air transportation–related intermodalism.

Proposed Systems Approach for Integrated Demand Modeling

Each component of the intermodal system has different types of demands. For example, the demand for travel to and from the airport, which is typically modeled by MPOs, includes demands by airport employees, airline pilots, and stewardesses, as well as the air passengers, while the aviation system only models the air passenger demand. The demand for air travel shared by each component should be consistent.

As has become evident, coordinating demand modeling across the intermodal system is a fairly complex task. This is justified by the fact that each component of the intermodal system has some extra demand specifically on its own facilities. Because there has been no literature devoted to the coordination of the demand modeling across a large intermodal system, ad hoc analysis could be an option to consider. For this purpose, we propose an integrated microsimulation system that spans the surrounding urban area, airport terminals, and airlines operations, as in Yu et al. (2002), which is beyond the scope of this paper. This system is currently under careful consideration for development. We hope that through this system some insights can be obtained in the near future.

CONCLUSION

With the fast growth of air transportation, air-related demand modeling becomes fundamental to coordinated resource allocation activities between air and ground and between different components of the ground system. In this paper, we have reviewed some methods for air travel demand modeling and airport-related urban travel demand modeling. We have covered disaggregate methods, based on social and economic characteristics designed for small communities; time series methods, based on historical data; stochastic methods, with simple scenarios; and demand untruncation methods. In addition, we have reviewed some indirectly related methods that might shed some light on the characteristics of air travel demand. We further used the NCTCOG and HGAC as examples to examine how the four-step demand forecasting method deals with airport-related urban travel demand in the context of general urban planning practices. Some of the limitations that we have observed in the urban planning methodology in practice have been confirmed by these two MPOs. It is obvious that current urban planning practices do not have the capability to explicitly deal with airport-related ground transportation demand. Finally, we have highlighted the deep institutional gaps between the methodologies.

The gap between the methodologies adopted by the different planning organizations can easily lead to poorly planned resource allocation within a large intermodal transportation system that includes air and ground components. Lack of coordination between the different components could be costly. Research that examines the cost caused by the poor distribution of resources across the intermodal system is needed. Based on the results of our investigation, we specifically propose an integrated demand modeling method based on computer simulation in an effort to develop ways to overcome this institutional gap.

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