Available online at www.sciencedirect.com
SCIENCE DIRECT®
Transportation Research Part A 40 (2006) 841–851
TRANSPORTATION RESEARCH PART A
www.elsevier.com/locate/tra

An aggregate demand model for air passenger traffic in the hub-and-spoke network

Wenbin Wei [a,*], Mark Hansen [b,1]

[a] Department of Aviation and Technology, San Jose State University, One Washington Square, San Jose, CA 95192-0061, United States
[b] Institute of Transportation Studies, National Center of Excellence in Aviation Operations Research, University of California, Berkeley, California, United States

Received 11 August 2004; received in revised form 6 December 2005; accepted 6 December 2005

Abstract

In this paper, we build an aggregate demand model for air passenger traffic in a hub-and-spoke network. This model considers the roles of airline service variables such as service frequency, aircraft size, ticket price, flight distance, and number of spokes in the network. It also takes into account the influence of local passengers and social-economic and demographic conditions in the spoke and hub metropolitan areas. The hub airport capacity, which has a significant impact on service quality in the hub airport and in the whole hub-and-spoke network, is also taken into consideration.

Our demand model reveals that airlines can attract more connecting passengers in a hub-and-spoke network by increasing service frequency than by increasing aircraft size in the same percentage. Our research confirms the importance of local service to connecting passengers, and finds that, interestingly, airlines' services in the first flight leg are more important to attract passengers than those in the second flight segment. Based on data in this study, we also find that a 1% reduction of ticket price will bring about 0.9% more connecting passengers, and a 1% increase of airport acceptance rate can bring about 0.35% more connecting passengers in the network, with all else equal. These findings are helpful for airlines to understand the effects of changing their services, and also useful for us to quantify the benefits of hub airport expansion projects.

At the end of this paper, we give an example as an application to demonstrate how the developed demand model could be used to valuate passengers' direct benefit from airport capacity expansion.

Keywords: Air passenger traffic; Demand; Hub-and-Spoke; Airport capacity expansion

1. Introduction

Since the last decade of the 20th century, when most major airports in the United States were congested and flight delays were a major concern to both passengers and carriers, the US government has spent millions of

* Corresponding author. Tel.: +408 924 3206; fax: +408 924 3198.
E-mail addresses: wenbin.wei@sjsu.edu (W. Wei), hansen@ce.berkeley.edu (M. Hansen).
1 Tel.: +510 642 2880; fax: +510 642 1246.

0965-8564/$ - see front matter
doi:10.1016/j.tra.2005.12.012

dollars each year on airport capacity enhancement projects. These projects involve mostly building new runways or installing more sophisticated air traffic control systems to reduce airport congestion and air travel delays. Due to the large number of connecting passengers, most congested airports in the US are hub airports, which are the central and core airports in airlines' hub-and-spoke service network. Since the congestion and delay at a hub airport will propagate to its downstream and upstream spoke airports, hub airports play a very important role in airport congestion management and delay reduction strategies in the whole air transportation system. Therefore, capacity expansion projects at hub airports are always a priority in government funding allocations. While billions of dollars have been invested on airport capacity expansion projects, surprisingly, there are very few studies in quantifying the benefit of these projects. Recent attempts in this field can be found in Hansen et al. (1998), Hansen and Wei (1998), Hansen et al. (2001), and Jorge and de Rus (2004). One critical reason for the lack of cost-benefit studies of airport capacity expansion projects is the lack of a set of analytical models that can capture the dynamics and interactions in the airport-airline-passenger system. More specifically, a quantitative demand model is needed to understand how improved airport capacity, together with other airline service variables, could affect passenger service quality and travel behavior in air transportation network.

The tragedy on the September 11th of 2001 brought more security concerns to the public and also caused national wide economic slowdown that have significantly changed the airline industry in the United States. Especially, the largest network carriers, such as United Airline, American Airlines and Delta Airlines, are facing more aggressive competition from low cost carriers that mostly apply a point-to-point routing structure in their business. In an effort to avoid eminent business bankruptcy, most network carriers reexamine, and then adjust, their traditional hub-and-spoke routing structure in their "everything-is-on-the-table" reorganization plans. For example, Delta Airline and United Airlines both set up new low-cost subsidiary carriers, "Song" and "Ted", respectively, to provide more direct flights in their high demand markets. American Airlines, which invented the "hub-and-spoke" concept and used to be very proud of this invention, has introduced de-peaking strategies at two of its major hubs: Chicago O'Hare and Dallas – Fort Worth international airports. Comparing with the point-to-point routing structure, the advantages and disadvantages of the hub-and-spoke structure are obvious from both cost and demand perspectives, which have been discussed extensively in literature. But quantitative study on passengers' travel demand in a hub-and-spoke network has seldom been seen either in research literature or in industry practice, and it is urgently called for now when airlines need to make a decision on whether they should and how to adjust their routing structures.

The purpose of this paper is to build an aggregate demand model for air passenger traffic in a hub-and-spoke network that can be used by airlines to evaluate the overall passenger demand in a hub-and-spoke network and to see how demand changes if any of airlines' service variables are adjusted. It can also be used by airport and government to study the impact of airport capacity on passenger service quality and to evaluate the benefit of hub airport expansion projects.

Research work on air travel demand modeling started in the 1970s by Douglas and Miller (1974), Ericsen (1977) and Swan (1979). They build demand models based on the concept of "schedule delay", a function of aircraft size and service frequency. Later on, Viton (1986), Abrahams (1983), and Russon and Hollingshead (1989) build air travel demand models based on a more generic term of "service quality", which is a function of such airline service variables as aircraft size, service frequency, and ticket price. Verleger (1972), Fridstorom and Thune-Larsen (1989), and O'Connor (1995) develop gravity-like demand models, which take social-economic and demographic factors such as local income and population into consideration. Air travel demand models are also built from a more microscopic perspective. Norman and Strandens (1990) build a probabilistic air travel demand model based on the assumption that passengers' desired departure times are uniformly distributed. Nikulainen (1992) assumes that the passenger demand during a specific time period is a function of the distribution of departure times of all flights.

Logit model has been used extensively in the studies of air travel demand. Kanafani and Ghobrial (1985), Hansen and Kanafani (1988), Hansen (1990), Dobson and Lederer (1993), Pels et al. (2000), and Adler (2001) construct demand models or market share models as logit-based functions of service frequency, service quality, ticket price, and etc. Proussaloglou and Koppelman (1995) and Nako (1992) build logit models based on the survey data from individual passenger. Coldren et al. (2003) apply the aggregate multinomial logit methodology and build an itinerary-level market share model. Hsu and Wen (2003) apply a similar model to