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MARKET SHARE MODEL FOR A MULTI-AIRPORT SYSTEM

François Cohas

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by

FRANÇOIS COHAS

Université Paris 1-Panthéon-Sorbonne (1991)
Ecole Centrale Paris (1990)

Submitted to the Department of Aeronautics and Astronautics in Partial Fulfillment of the Requirements for the Degrees of

MASTER OF SCIENCE IN AERONAUTICS AND ASTRONAUTICS
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Signature of Author ______________________________
François Cohas
Technology and Policy Program
May 7, 1993

Certified by ______________________________
Peter P. Belobaba
Assistant Professor, Aeronautics and Astronautics

Accepted by ______________________________
Robert W. Simpson
Director, Flight Transportation Laboratory

Accepted by ______________________________
Richard L. de Neufville
Chairman, MIT Technology and Policy Program

Accepted by ______________________________
Professor Harold Y. Wachman
Chairman, Departmental Graduate Committee

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ABSTRACT

Because capacity at existing airports was limited and/or because the cost of congestion was becoming unacceptable, several large cities around the world have had to build a second or third major commercial airport to keep up with the demand for air transportation. Such groups of competing airports are called *multi-airport systems* (M.A.S.) There is extensive historical evidence suggesting that multi-airport systems have often been poorly understood, resulting in disastrous investments such as the construction of airports that remained underused for very long periods of time. The purpose of this paper is to provide a better understanding of the ways M.A.S.s function.

First, we consider qualitative characteristics of multi-airport systems, showing the importance of market forces. Then, we build an airport market share model that captures the dynamics of the market, where airlines and air passengers select an airport on the basis of a broad range of factors. Case studies are carried out for several origin-destination markets out of three large metropolitan areas: New York, Washington-Baltimore, and the San Francisco Bay Area.

The results show that an airport market share can be well approximated by using few explanatory variables: frequency of service and average fare at the designated airport, and average fare at competing airports. In spite of the relative simplicity of our statistical model, we obtain a good fit between observed and predicted market shares. The explanatory variables are statistically significant and the estimated elasticities (direct price, frequency, and cross-price) are consistent with intuition.

We conclude by highlighting the limitations of the model and by suggesting some implications concerning the construction of new airports in metropolitan areas and the potential for regional airports to alleviate the congestion problems at large metropolitan airports.

<u>Thesis Supervisors</u>

Dr. Robert W. Simpson	Dr. Peter P. Belobaba
Director,	Assistant Professor,
Flight Transportation Laboratory	Aeronautics and Astronautics

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Contents

CHAPTER 1

MULTI-AIRPORT SYSTEMS : BACKGROUND

1.1 INTRODUCTION

The growth in air traffic volume is putting increasing pressure on existing airports in large metropolitan areas. In its 1989 Airport Capacity Enhancement Plan, the Federal Aviation Administration (FAA) noted that the number of U.S. airports exceeding 20,000 hours of annual aircraft delay could nearly double by the end of the century if nothing is found to accommodate the increase in traffic.

By ripple effect, this could have a substantial impact throughout the United States and even the world, because of the increasing reliance on hub and spoke networks domestically, and of the internationalization of the largest American carriers.

This problem is by no means limited to the North American market. In Europe, in 1988, one flight in five was delayed by more than 15 minutes, according to the Association of European Airlines [AEA, 1989] .

As a result, difficult issues have to be addressed concerning the development of many region's airport systems:

- Should infrastructure supply be increased (expansion of existing airports; construction of new airports, ...) ?
- Should traffic management be reconsidered[1] (adoption of new regulations; use of economic incentives to redistribute demand, ...) ?
- Should new technology be introduced (modernization of the Air Traffic Control (ATC) system; improvement of alternative modes of transportation such as high-speed surface transportation in specific areas, ...) ?

Historically, several large cities around the world have had to build new airports to keep up with the demand for air transportation. This is a perfectly natural decision, especially when:

- The capacity of the existing airport is limited.
- The cost of congestion becomes unacceptable.
- The city endorses a "supply-side" approach to the capacity-demand dilemma, i.e. it favors increasing capacity to managing demand. A typical motivation for such a choice is the belief that increased air traffic should have a positive impact on the regional economy.

Understanding the basic principles that govern the potential evolution of commercial air services in a metropolitan area is critical to address these problems adequately. It is well known that airport congestion is very costly, but it is also very true that building a new, large airport will turn out to be a disastrous investment if the airport remains underused.

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1. Several suggestions have often been made regarding traffic management [Hudson, 1989]. For example: privatisation, improved Air Traffic Control System (from both a technical and a managerial standpoint), construction of new "superhubs" or -- along the same line -- development of wayports (remote transfer airports), new landing fee structures, etc.

Forecasting air transportation activity requires more than just correlating the growth in traffic with socio-economic variables such as population and GNP per capita. Indeed, since the deregulation of the U.S. airline industry in 1978, there has been a massive restructuring of the sector, and the major domestic carriers have reshaped their networks so as to fit their best perceived business interests. Most often, they have adopted a hub-and-spoke strategy which dramatically increases the average variability of airports' activity [de Neufville and Barber, 1991].

Multi-airport systems (M.A.S.), as defined in paragraph 1.1.1, raise a particular problem because their dynamics is the result of decisions simultaneously made by airports, airlines and air passengers. As we shall see, understanding how one can forecast the traffic at each airport is of critical importance. This implicitly raises questions such as why should an airline provide a service at one airport instead of another? Why should it bother providing a similar service at two or three airports in the same metropolitan area? and, similarly, why should a passenger select one airport instead of another?

1.1.1 MULTI-AIRPORT SYSTEMS

We can define multi-airport systems as being a group of two or more major commercial airports in a metropolitan region [de Neufville, 3/1986]. Typically, a major commercial airport will be defined as an airport with at least two million passengers per annum.

Interestingly, the M.A.S. solution has been adopted in many highly populated metropolitan areas around the world. Given the high level of air traffic handled by multiple airport regions, there is a strong incentive to understand how M.A.Ss work, and, in particular, to understand how traffic distributes among airports.

1.1.2 A WORLDWIDE PHENOMENON

As mentioned above, multi-airport systems are a feature of a number of metropolitan regions around the world. This assertion is vividly illustrated in table 1.1 by the fact that among the 23 busiest cities worldwide (in terms of air transport passengers), there are ten multi-airport systems, and each of the six busiest cities had two or three major commercial airports in 1990[2].

2. The list in Table 1.1 is not exhaustive. Miami (International/Fort Lauderdale), Sao Paulo (Garulhos/Congonhas), Rio de Janeiro (Galeao/Santos Dumont), Oslo (Fornebu/Gadermoen), and Moscow (Sheremetyevo/Vnukovo/Domodedovo) are other examples of major multi-airport systems.

Table 1.1
THE TOP 23 METROPOLITAN AREAS WORLDWIDE (1990)

Terminal Passengers (000)

NEW YORK	74,796	
. Kennedy		29,787
. La Guardia		22,754
. Newark		22,255
CHICAGO	68,481	
. O'Hare		59,940
. Midway		8,541
LONDON	65,326	
. Heathrow		42,964
. Gatwick		21,185
. Stansted		1,177
TOKYO	61,860	
. Haneda		40,188
. Narita		21,672
DALLAS	54,263	
. Fort Worth		48,515
. Love Field		5,748
LOS ANGELES	51,230	
. International		45,810
. Ontario		5,420
ATLANTA	48,025	

PARIS	46,836	
. Orly		24,330
.Charles de Gaulle		22,506
SAN FRANCISCO	31,060	
FRANKFURT	29,618	
DENVER	27,433	
MIAMI	25,837	
WASHINGTON	25,806	
. National		15,570
. Dulles		10,236
HOUSTON	25,719	
. Intercontinental		17,599
. W.P. Hobby		8,120
OSAKA	23,512	
BOSTON	23,293	
DETROIT	21,942	
PHOENIX	21,718	
TORONTO	21,525	
MINNEAPOLIS	20,381	
LAS VEGAS	18,619	
ROME	18,443	
. Fiumicino		17,836
. Ciampino		607
PITTSBURGH	17,146	

Note : A terminal passenger is either a terminating passenger (i.e. passenger starting or ending its trip at the designated airport) or a transfer passenger (i.e. passenger arriving on an airport and again departing from the same airport on a different, or on the same, aircraft bearing different flight numbers, the sole purpose for using the airport being to effect a transfer).

Source: Aéroports de Paris.

1.1.3 AIR TRAFFIC THRESHOLD

The multi-airport system option has been adopted in every part of the world where air traffic (measured in terms of terminal -- or originating -- passengers)[3]

[3]. What really matters is the number of terminal passengers (or, most conveniently, the number of originating passengers, i.e. half the number of terminal passengers). Indeed, connecting passengers do not

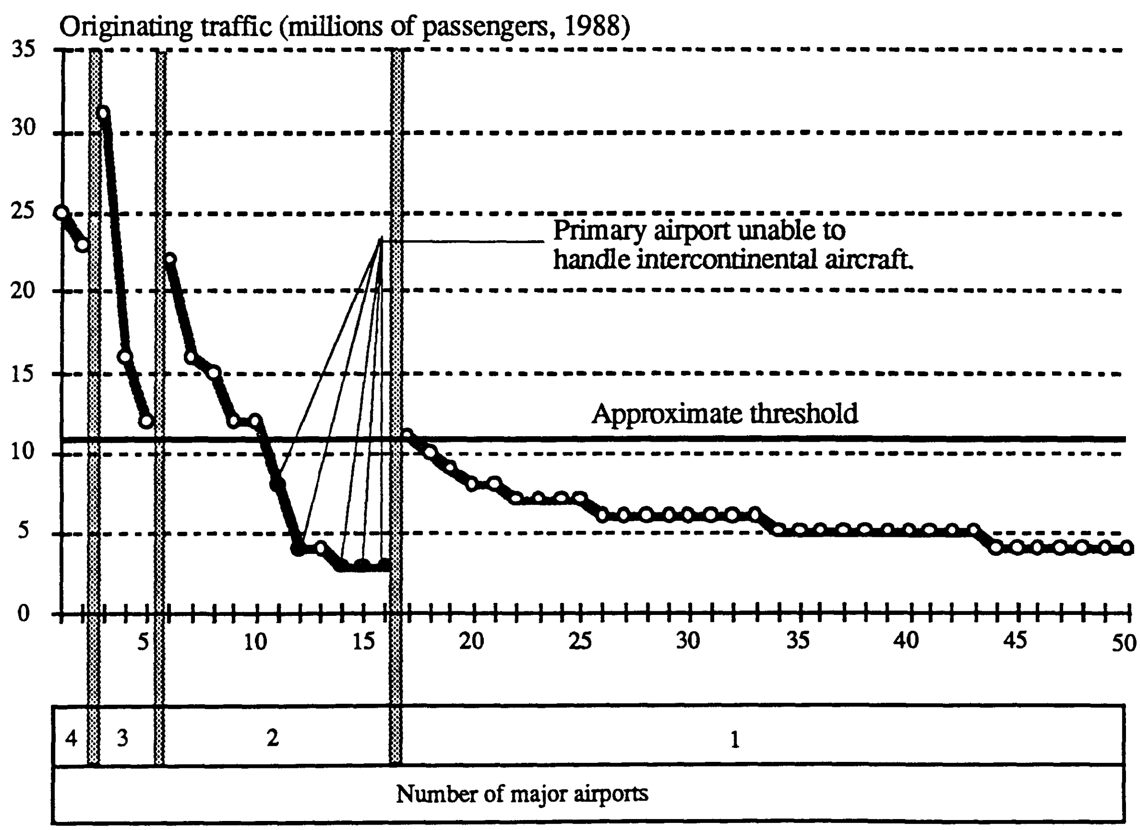
has reached a certain level.

As illustrated in Figure 1.1, which represents originating traffic for 50 major cities (the 50 cities are listed in the legend), worldwide data show that an approximate threshold of about 10 to 12 million originating passengers in a given region should be enough to justify the development of a second major commercial airport [Kinhill Engineers Pty Ltd., 1990 & 1991].

From an airport planning perspective, this means that considering building a second major airport in a region where originating traffic is less than about 10 million is a moot strategy.

Figure 1.1

Major Airports Around the World



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choose the airport within a given multi-airport system, and the question of the distribution of connecting traffic within a MAS is somewhat irrelevant.

Legend :

1 London	18 Boston	35 Pittsburgh
2 Los Angeles	19 Frankfurt	36 Philadelphia
3 New York	20 Denver	37 Amsterdam
4 San Francisco	21 Osaka	38 Sydney
5 Washington-Baltimore	22 Honolulu	39 Madrid
6 Tokyo	23 Minneapolis-St Paul	40 San Diego
7 Paris	24 Las Vegas	41 Tampa
8 Chicago	25 Rome	42 Zurich
9 Dallas-Fort Worth	26 St Louis	43 Dusseldorf
10 Miami	27 Toronto	44 Charlotte
11 Houston	28 Orlando	45 Copenhagen
12 Milan	29 Phoenix	46 Singapore
13 Montreal	30 Hong Kong	47 Athens
14 Rio de Janeiro	31 Seattle	48 Mexico City
15 Sao Paolo	32 Stockholm	49 Bangkok
16 Oslo	33 Palma, Majorca	50 Salt Lake City
17 Atlanta	34 Detroit	

Sources: British Airport Services Limited and BAA Limited.

1.1.4 DO MULTI-AIRPORT SYSTEMS FUNCTION WELL ?

Since there exists a natural tendency for traffic within a multi-airport region to concentrate at one airport, multi-airport systems are most often characterized by a dominant airport. By "natural tendency" we mean that market forces are such that, so far as marginal cost due to increased congestion does not exceed marginal benefit, it is in the interest of an airline to provide service at the dominant airport[4]. Subsequently, air travelers will have a strong incentive to choose the airport which offers the greatest variety of service. Thus, up to a certain point, the process is self-reinforcing. This dynamics is illustrated in Figure 1.2.

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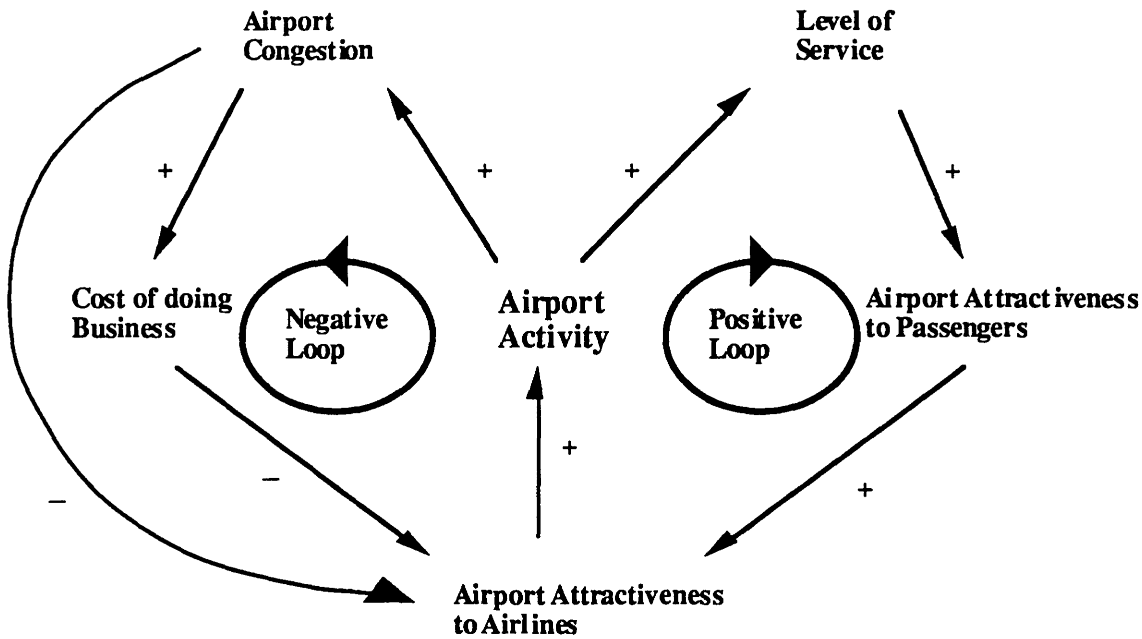
4. A very simple model illustrates this assertion. Suppose that the total demand (d) for a given origin - destination market is a function of fare (p) and the number of flights (n) : d=d(p,n). For an airline maximizing its profit $\pi = pd - nc$, where c -- supposed to be constant -- is the cost per flight, one has to have $\frac{\partial \pi}{\partial p} = 0$ and $\frac{\partial \pi}{\partial n} = 0$. This latter relation is equivalent to $MR = p\frac{\partial d}{\partial n} = c = MC$. In other words, the airline should add flights to the point where the marginal revenue is equal to the marginal cost of operating a flight.

Figure 1.2



Note: A positive arrow between A and B means a positive relationship, i.e. everything else being equal, an increase (decrease) in A leads to an increase (decrease) in B. Conversely, a negative arrow means that if A increases (decreases), B decreases (increases).

Even when the threshold beyond which saturation at the primary airport is reached[5], signaling that a second airport is potentially viable, activity will most often continue to grow at the primary airport. Historically, this has been achieved through increased aircraft size and active traffic management [Kinhill Engineers Pty Ltd, 1990 & 1991].

As a result, there exists a systematic risk that most of the time M.A.Ss will operate unsatisfactorily, with a dominant but congested airport and a second airport[6] operating substantially below capacity. Figure 1.3 illustrates this statement for a sample a 13 major multi-airport systems around the world. A substantial concentration is indeed observed in most cases. Furthermore, an

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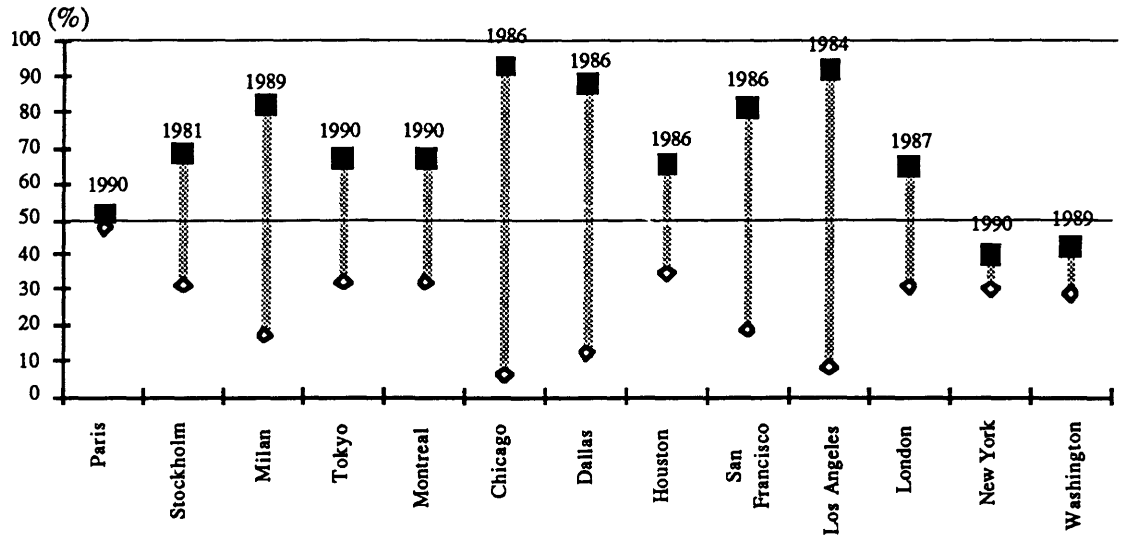
[5]. Here, by saturation we mean that adding new service is becoming either too costly as a result of congestion or useless because of the diminishing returns derived from adding extra flights.

[6]. In the United States, the FAA found that there are at least 20 underused airports located within about 100 miles of a congested airport.

analysis of how traffic distribution evolves over time indicates that even M.A.Ss that apparently function well (such as Paris/Orly and Paris/Charles de Gaulle) have in fact functioned quite inefficiently for long periods of time (Appendix 1).

Figure 1.3
Percentage of terminal passengers at first and second airport



A typical example of failure is Montreal's M.A.S. Opened in 1974, Montreal's second major commercial airport (Mirabel) was expected to become the dominant metropolitan airport. Indeed, the phasing plan for Mirabel was designed *"to increase traffic there and decrease Dorval operations, with Dorval making up for the loss in airline business through greater general aviation and maintenance/overhaul activity"* [Schwartz, 1974]. In the mid-1970s, projections for 1985 were 20 million passengers annually at Mirabel and 3.7 million at Dorval. Eventually, Mirabel was to take over nearly all scheduled Montreal passenger traffic.

However, in spite of substantial government intervention, the market share of Mirabel airport actually declined between 1976 (21% of the total number of terminal passengers) and 1982 (17%). In 1990, Mirabel airport still handled less than half as many terminal passengers as Dorval airport: 2.4 million vs. 5.0 million (Appendix 1).

Although less dramatic an example, the four London airports illustrate how difficult predicting -- and influencing -- traffic distribution can be. According to Arthur Reed[7]:

> *"Although it is saturated with traffic at peak periods, its four passenger terminals sometimes are uncomfortably overcrowded and interlining can be like an obstacle course, the world's airlines continue to stand in line to be allowed to use Heathrow, London's main airport. Space at Gatwick, the second airport, is available, while Stansted, London's No. 3 facility, has a brand-new $640 million terminal building (...) which hardly anybody uses. But despite these alternative accommodations, almost everybody -- from small regionals (...) to the major intercontinentals (...) -- want to buzz around the Heathrow honeypot."*

1.2 CHOICE OF AN AIRPORT

The demand process is the process by which air travelers make their choice among alternative travel opportunities. It is thus important to keep in mind that airports are utilized by both airlines and air travelers.

This process has become much more complicated since deregulation, as a result of the increase in traffic, the multiplicity of air fares, frequent flyer incentives, and other marketing innovations.

The total demand for a given airport depends on the total demand for the region (which depends on economic growth, demographics, ...) and the airport share of total regional demand (which in turn depends on traffic volume, frequency of service, access time,...).

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7. Arthur Reed. "The Unlocking of Heathrow." Air Transport World, 9/91.

1.2.1 CHOICE MADE BY AIRLINES

The supply process is the process by which competing airline managers decide how to utilize the resources of their airline to maximize profitability over all air travel markets open to them.

The supply process is complex in the sense that since the air transportation industry is far from being a perfectly competitive market, there is much room for strategic behavior. Decisions are therefore made on the basis of profitability, but also on the basis of other carriers' actions. Furthermore, in theory at least, the decisions are made in the best interests of each airline over all the markets it serves and not just over each market served from one metropolitan region.

It is usually acknowledged that in a deregulated environment, the relationship between market share and frequency share is not linear. In fact, various empirical studies support the hypothesis according to which the curve is somewhat S-shaped. In other words, high frequency shares gain more than proportional market shares. We shall come back to this assertion later on.

Typically, airlines will tend to increase frequency share so as to capture a targeted market share. As a result, they have an incentive to concentrate their operations at one airport. However, if it appears that an advantage can be gained from providing service at two (or more) airports in the same metropolitan region, it may indeed provide flights at each airport. Such an advantage can be obtained for various reasons: first mover advantage, strong demand at each airport[8], airport specialization, etc.

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8. For example, during the second quarter of 1992, several airlines were providing service at each of the three major airports in New York/New Jersey (American, Delta, TWA, United, USAir), Washington-Baltimore (American, Continental, Delta, Northwest, TWA, United, USAir), and in the San Francisco Bay Area (American, Alaska, Delta, America West, United).

1.2.2 CHOICE MADE BY AIR TRAVELERS

Intuitively, for a given air traveler, the attractiveness of an airport may depend on a variety of factors [Ashford, 1989]:

- Proximity to home
- Proximity to work
- Ease of access/egress
- Quality of airline service (frequency of flights, non-stop flights, cheap fares,...)
- Parking (convenient, cheap,...)
- Past experience (the passenger may be used to a particular airport)
- etc.

Access time and frequency of service can be aggregated in a more general variable, the total travel time. Total travel time is usually defined as [Simpson, 1982]:

$$T = T_a + T_e + T_{ep} + T_{dp} + T_w + T_b$$

where:

T	=	Total time (average time from origin to destination).
T_a	=	Access time (average time from origin to airport).
T_w	=	Wait time (average displacement of the traveler's actual time from his desired departure time).
T_{ep}	=	Enplanement processing time (average time for ticketing, boarding,...).
T_b	=	Block time (flight time per se).
T_{dp}	=	Deplanement processing time (average time for deplaning, customs, baggage,...).
T_e	=	Egress time (average time from airport to final destination).

A good approximation of total time is given by the following formula:

$$T = T_0 + \frac{K}{n} + \frac{d}{V_c}$$

where:

T_0	=	Air and ground maneuver time for aircraft trip.
K	=	Average wait time for service of travelers (assumed constant).
n	=	Frequency of service.
d	=	Trip distance (airport to airport).
V_c	=	Aircraft cruise speed.

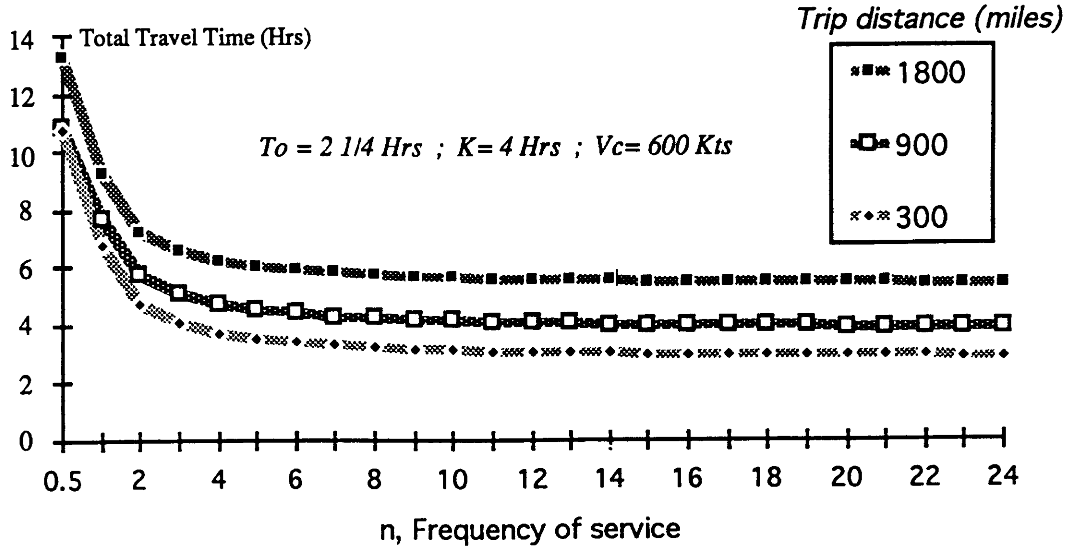
Therefore, an air traveler might not choose the closest airport if frequency of service is insufficient. This point is important since the frequency of service to a given destination is likely to be comparatively low in a newly built airport.

If we believe that air travelers make their decision on the basis of total travel time (this assumes that available prices are similar), then:

- For a given frequency of service and a given trip length, air travelers will choose the closest airport.
- Beyond a certain threshold, additional flights to a specific destination will have almost no impact on the attractiveness of the airport (Figures 1.4 and 1.5).

Figure 1.4

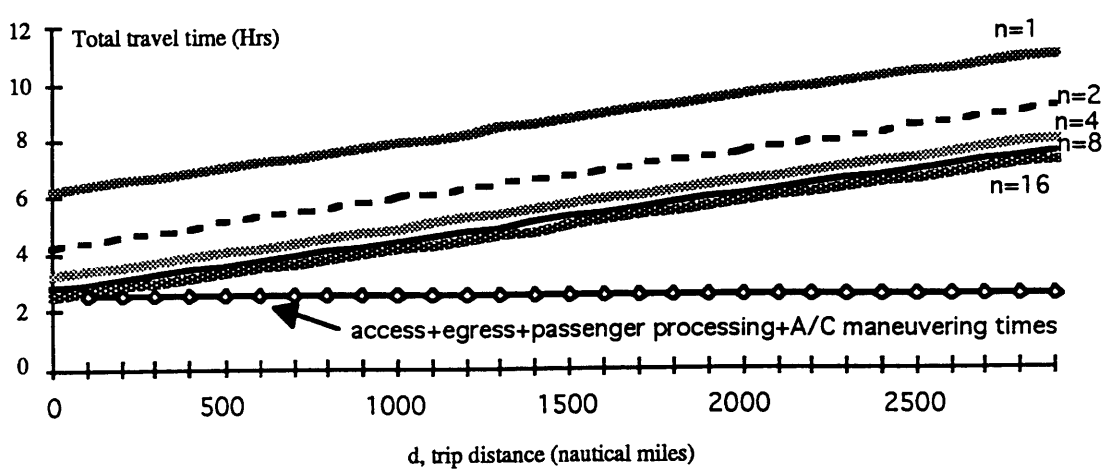
Total Travel Time as Function of Frequency of Service



- Access (and egress) time are more important if the trip distance is small. The same is true regarding the frequency of service.

Figure 1.5

Total Travel Time as a Function of Trip Distance



As a result, everything else being equal, it would make sense to have a majority of long-haul flights located at the airport which has the greatest access time. Conversely, short-haul flights should preferably be handled by the airport closest to the business center.

Tokyo airports provide an example of such a specialization. The two major commercial airports are Narita (New Tokyo International Airport) and Haneda (Tokyo International Airport). All international flights are handled by Narita airport[9] which is located at about 60 km (70 minutes by bus or 100 minutes by train) from Tokyo city center. By contrast, Haneda -- which is located at only 10 km (15 minutes by monorail) south of downtown Tokyo -- is the dominant domestic airport, with more than 400 flights a day arriving from and departing for 35 Japanese destinations.

1.3 SUMMARY AND IMPLICATIONS

Overall, using this understanding of air passenger behavior, and previous modeling studies (a brief overview of the literature is given in chapter 3), it has been shown [e.g. Ashford, 1989] that only three factors have a substantial influence on air travelers' choice of an airport:

- Access travel time
- Flight frequency
- Air fares

In the case of the San Francisco metropolitan region, the multinomial logit model showed that business travelers made their selection of an airport on the basis of access travel time, relative frequency and absolute flight frequency. A similar result -- although less convincing -- has been derived for leisure travelers.

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[9]. With the exception of China Airlines flights.

Everything else being equal, air fares should play only a secondary role in a competitive environment since airlines tend to match prices. This assertion is not always true, as illustrated in paragraph 2.2 where the entry of a low-cost carrier, Southwest Airlines, at Oakland led to dramatic shifts in airline and airport market shares.

Besides the reasons that were mentioned above, understanding how multi-airport systems function is of broader interest in the sense that it would allow us to understand how traffic is likely to distribute between competing airports. This is of critical importance in regions of the world such as Europe where competition between airports is likely to increase as a result of:

- The relatively short distances between metropolitan areas.
- The forthcoming common market (integrating first the EC, then the EFTA[10], and possibly -- in the longer term -- other Eastern European countries).
- The gradual liberalization of the airline industry.
- An extensive, efficient ground transportation system, and
- The general trend towards a global economy.

Within this context, the study of multi-airport systems should be fruitful, and might even be applied to understanding the distribution of traffic between major European hubs, as competition intensifies for the reasons aforementioned.

10. EC: European Community. EFTA: European Free Trade Association.

CHAPTER 2

MOTIVATION FOR THE THESIS

2.1 INTRODUCTION

The supply process by which an airline provides air transportation services in a multiple airport region is complex to model. It is based on decisions that should account for the best interest of the airline over all the markets it serves, and not just the subset of markets served out of the M.A.S. Possibly, an airline will behave in a way dictated by strategic considerations which are not profit-seeking, locally or even globally, at least in the short term. For instance, it might decide to completely abandon an airport or a region to use limited resources more productively in its overall corporate best interest [Simpson, 1992].

In looking at a multi-airport region, the airline managers would prefer to minimize their costs by concentrating all services at one airport, and to use larger capacity, lower unit cost aircraft. By matching the frequency and fares of competitive airlines, the airline attempts to maintain its "fair share" of the demand in all air markets served. (It may not serve all destinations.) But if it appears that an advantage can be gained by initiating new services from a secondary airport, it may make a major initiative to establish a new station at that secondary airport. The decision might be motivated by many reasons such as the prospect of competing against fewer competitors, operating in a less crowded airport, or simply matching the move of a strategic competitor. To ensure that the initiative succeeds, the airline must provide good service and fares which approximately match services and fares by itself and its competitors at the primary airport. Typically, a bold move will be necessary to attract customers to the new airport services and the airline is therefore competing against itself. Furthermore, it should not rely too strongly on the concept of catchment area since air travelers making their decisions of an airport will consider access time, but also -- often more importantly -- fares and frequency of service. If the initiative is not matched by competitors, it may enjoy the advantage of a strong market at the secondary airport offset by a small reduction in traffic at the primary airport.

This chapter is intended to illustrate how dramatic the impact of competition between airlines operating in a multiple airport region can be. With this in mind, we will investigate the dynamics of a particular origin-destination (O-D) market out of the three main San Francisco Bay Area airports from 1988 through 1992.

Then, we will consider the problem of the distribution of traffic within a M.A.S. from another perspective, i.e. by comparing average volatility of traffic at each airport and at the M.A.S. level.

2.2 AIRLINE COMPETITION IN A M.A.S. : AN EXAMPLE

An interesting example can be found at the three San Francisco Bay Area airports: San Francisco (SFO), Oakland (OAK), and San Jose (SJC). More specifically, the San Francisco Bay Area - San Diego (SAN) origin-destination market is of interest because it exemplifies how dramatic the impact of competition on airline and airport market shares can be. It is also fairly simple to study since there is only a small number of major competitors from 1988 through 1992. The following observations are based on our analysis of total O-D passengers, average nominal fares, and weekly frequency of service[11].

2.2.1 MAJOR COMPETITORS (1988-1992)

SFO-SAN	OAK-SAN	SJC-SAN
Southwest	Southwest	American
USAir	USAir	USAir
United		

Note: Southwest (WN), USAir (US), United (UA), American (AA)

2.2.2 AIRLINE MARKET SHARES, FREQUENCY SHARES AND AVERAGE FARES

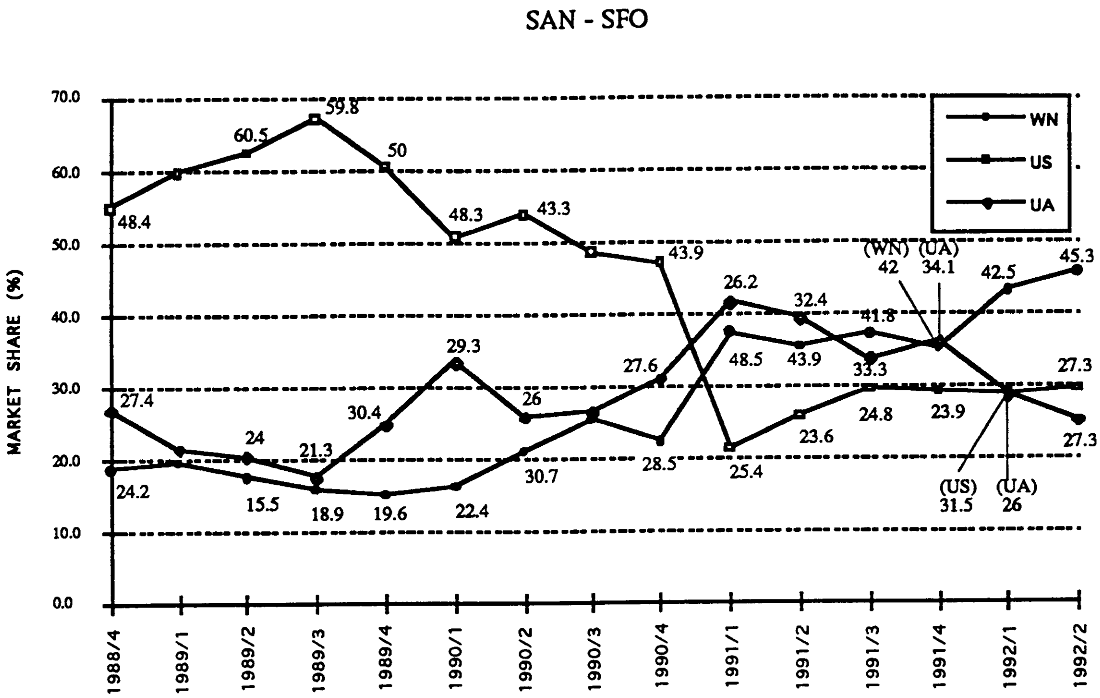
The SAN-SFO market illustrates the competition between USAir, Southwest and United. In late 1988, USAir was the market leader with more than 50% of the traffic, while USAir and Southwest captured slightly less than 30% and 20% of the market respectively. This was reflected by a weekly frequency of service of 76 flights for USAir, and only 43 and 38 for United and Southwest respectively.

Starting in late 1989, USAir started losing market share under pressure from United and Southwest. Southwest increased its frequency of service from about 20 flights a week in 1989 to nearly 70 flights a week in mid-1992, boosting its frequency share from about 20% to 45% (Figure 2.1). Simultaneously, Southwest undercut its competitors with an average fare of about $40 against about $50 for the other two carriers (Figure 2.2). As a result, by the second

[11]. The data regarding average fares and traffic are quarterly data. The weekly frequency of service was calculated using the Official Airline Guide for a particular month for each quarter. This explains some discrepancies in the graphs illustrating airline market share and frequency of service (e.g. the frequency of service may be zero while the market share is greater than zero.)

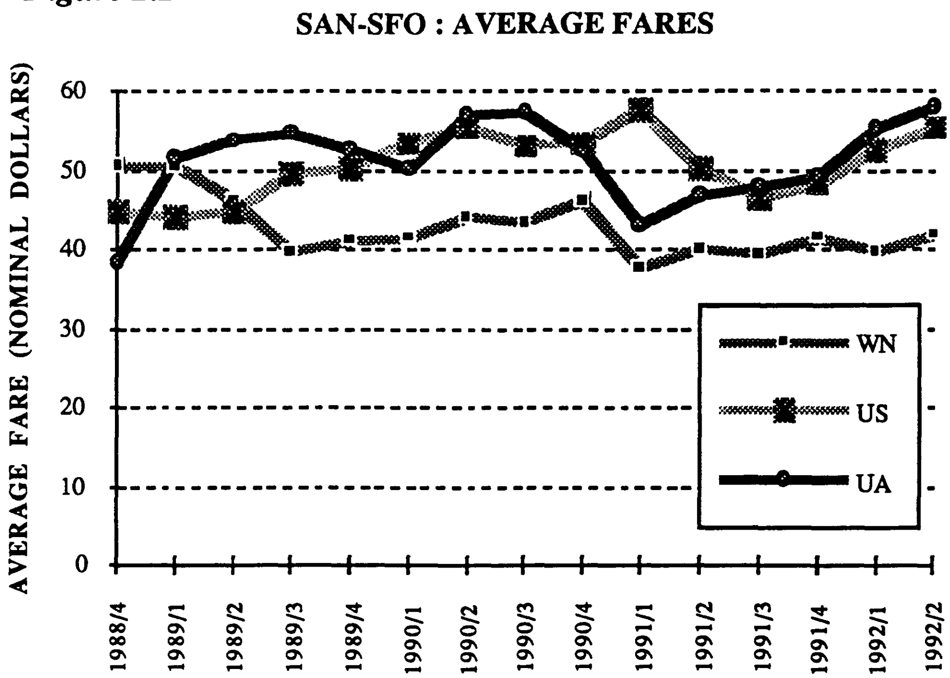
quarter of 1992, Southwest became the market leader with close to 50% of the traffic against only about 25% for USAir and United.

Figure 2.1



Note: Airlines' frequency shares are plotted along their respective market share curve.
Source: Adapted from O&D Plus database; Official Airline Guide.

Figure 2.2

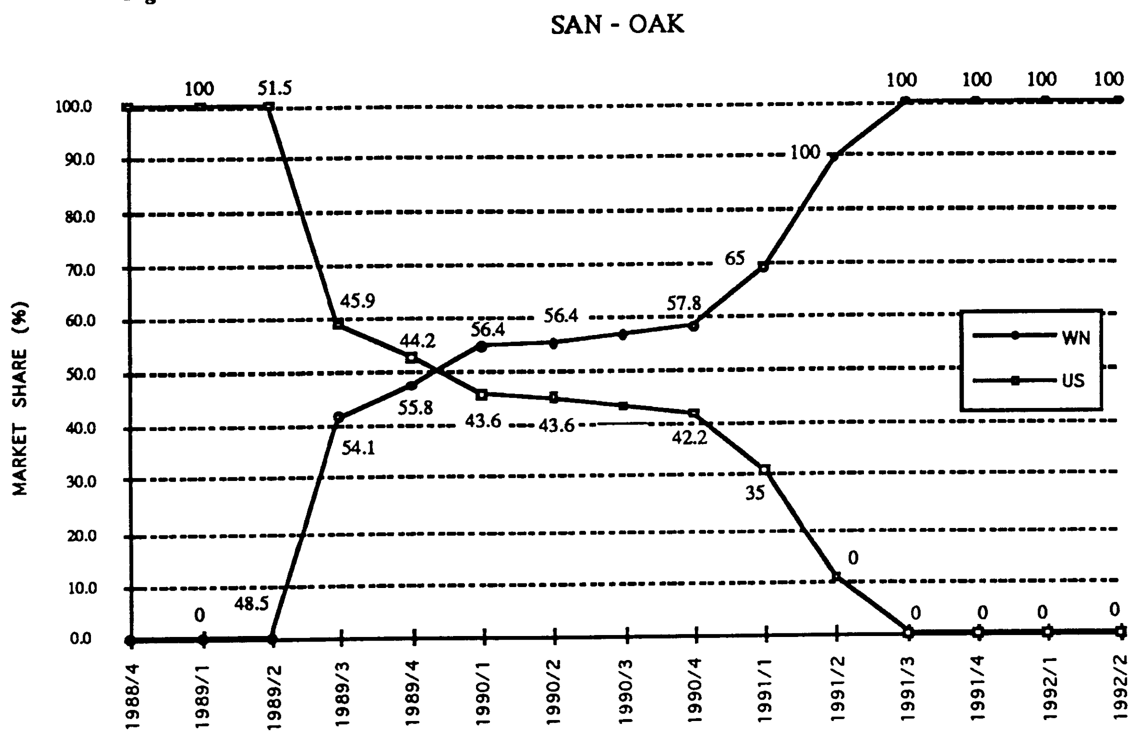


Source: Adapted from O&D Plus database.

The SAN-OAK market illustrates a dramatic change resulting from the entry of Southwest. Initially, USAir dominates with nearly 100% of the market, with a service of just above 30 flights a week and an average fare of $60 to $70. Southwest entered this market in early 1989 and immediately matched USAir's frequency of service while charging only about $40 on average. Southwest kept increasing its service to about 70 flights a week by 1992 while charging an average fare of $40 to $50. During this period, USAir was unable to sustain such a low fare, and its frequency of service did not increase (Figure 2.3 & 2.4).

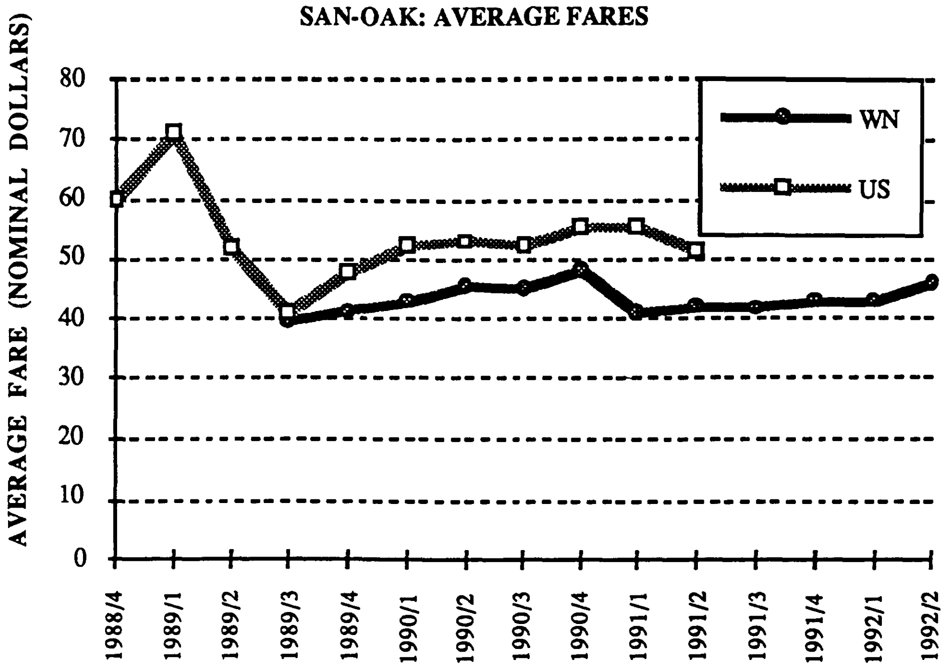
As a result, USAir dropped out of the market, leaving Southwest with nearly 100% of the traffic by the end of 1991, and in a favorable position to capture traffic from SFO.

Figure 2.3



Source: Adapted from O&D Plus database; Official Airline Guide.

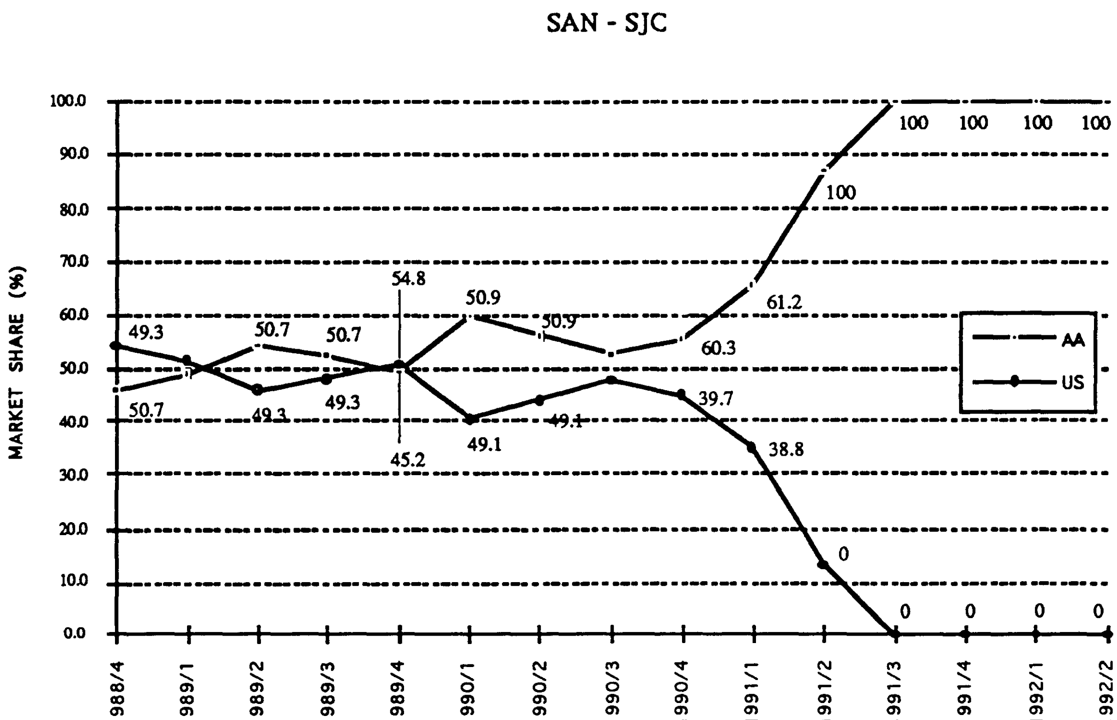
Figure 2.4



Source: Adapted from O&D Plus database.

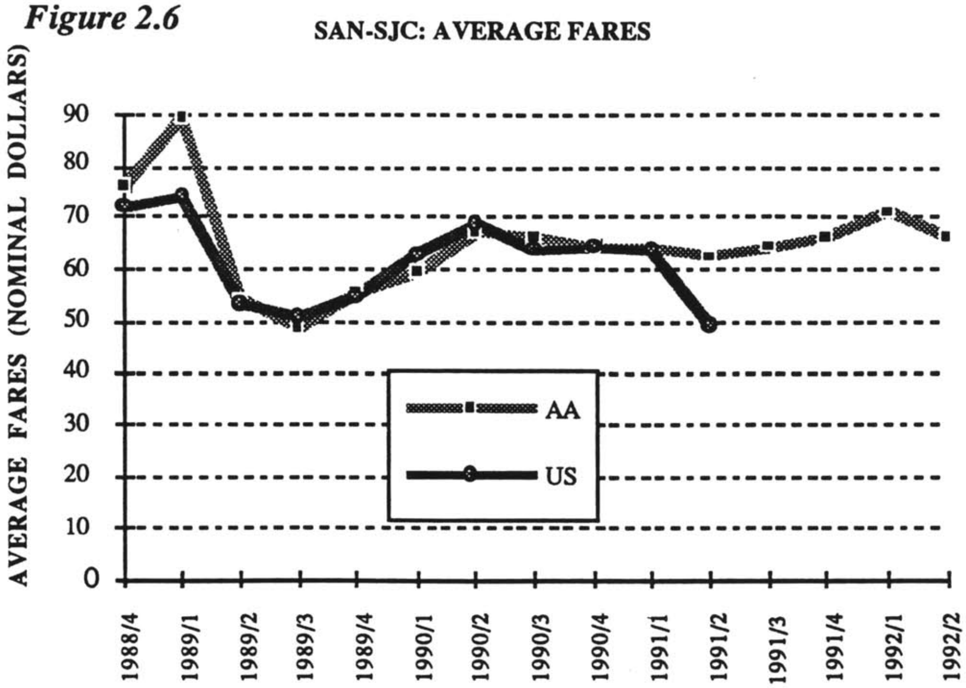
Like the SAN-OAK market, the SAN-SJC origin-destination market is dominated by two airlines: American and USAir. In 1988 and 1989, the two carriers each had about 50% of the market and provided a similar service of about 30 flights a week. However, although the two carriers were initially able to charge as high as about $70 on average, fares dropped sharply in 1989 to about $50. USAir, which was losing market share at each airport, started to reduce its service and eventually withdrew completely from this market by mid-1991 (Figure 2.5 & 2.6).

Figure 2.5



Source: Adapted from O&D Plus database; Official Airline Guide.

Figure 2.6



Source: Adapted from O&D Plus database.

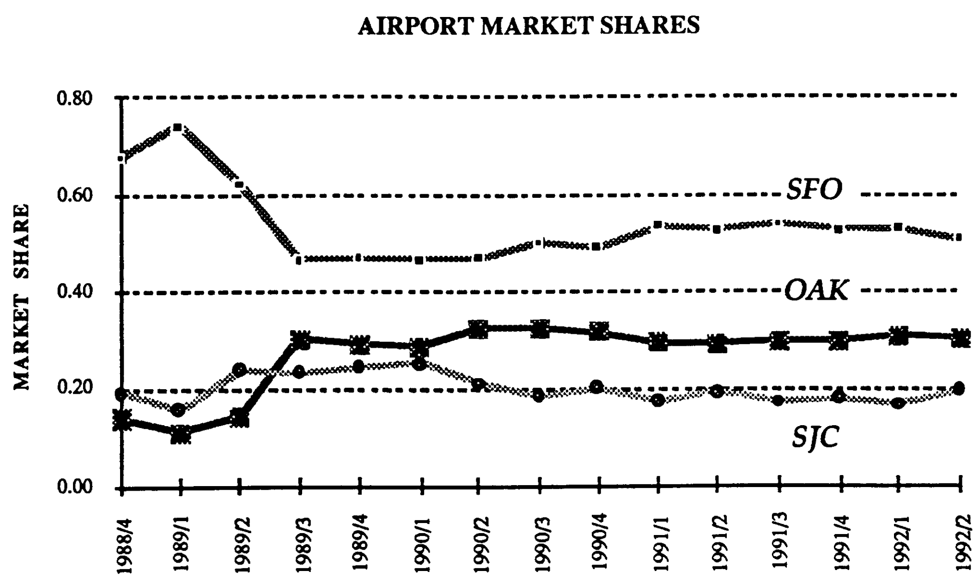
2.2.3 AIRPORT MARKET SHARES

The competition between the four carriers has had a significant impact in terms of distribution of traffic between airports (Figure 2.7). Although the aggregate traffic (SAN-SFO, SAN-OAK, and SAN-SJC, both ways) increased from 435,000 passengers during the fourth quarter of 1988 to 513,000 during the second quarter of 1992, traffic increased significantly only at Oakland (from 60,000 to 154,000) while remaining fairly stable at San Jose (82,000 to 99,000), and decreasing at San Francisco (294,000 to 260,000).

Activity at Oakland undoubtedly benefited from Southwest's strategy of charging very low fares (about $40) and gradually boosting service, a strategy made possible by the relatively low cost structure of the new entrant.

More recently, the competitive pressure exerted by Southwest has continued to have a substantial impact on airport activity. In April 1993, American Airlines announced that it planned to drop 48 flights, or 40 percent of its schedule, from its hub in San Jose, as Southwest announced it would enter the market[12]. American officials acknowledged that low-cost Southwest was in a better position to fly in some markets and that American would shift resources from money-losing routes to concentrate on profitable ones.

Figure 2.7



Source: Adapted from O&D Plus database.

12. The New York Times, Thursday, April 8, 1993.

2.3 VOLATILITY OF TRAFFIC

One of the outcome of deregulation has been an increase in the volatility of airport traffic [de Neufville, 1986; de Neufville and Barber, 1991], resulting mainly from the increased freedom of entry and exit, the creation of hub airports and the profound restructuring of the industry leading to a wave of mergers and acquisitions in the mid-80's [13].

This fact being established, it is interesting to wonder whether there is a relationship, within a metropolitan area, between the volatility of traffic at each airport and the average volatility of traffic for the M.A.S. taken as a whole.

The underlying idea is that part of the volatility of traffic may be explained by mere redistribution of flights within the M.A.S. For example, if -- for a given destination – an airline operates 5 daily flights from both airport A and airport B, and decides to shift 4 flights from A to B, the new distribution will be 1 flight from A and 9 flights from B. Taken separately, each airport will face a very volatile traffic, whereas the M.A.S., taken as a whole, faces a stable traffic. Intuitively, it seems reasonable to suggest that this kind of reallocation of traffic, based on each airline strategy, should tend to lower the volatility of the traffic at the M.A.S. level. Conversely, a lower volatility of traffic at the M.A.S. level relative to the average volatility of traffic at each airport constituting the M.A.S. would suggest, if it tends to be systematic, that airlines do have a strategy which leads them to distribute traffic at the level of the M.A.S.

---

13. The risk induced by this increased volatility of traffic was recently illustrated when Midway airport lost its largest carrier, Midway Airlines. The airline -- which had accounted for more than 70% of the airport's passenger traffic -- stopped operating in November 1991. The immediate, direct result was a drop of $700,000 per month in airport concession revenue as well as a sizable decrease in the airport's concession income. Hopefully, as noted by David C. Suomi, Deputy Commissioner of Aviation for Chicago and manager of Midway Airport, the traffic at Midway is mostly origin and destination, is not slot restricted, and is much closer to the city's business center than is O'Hare. As a result, traffic has started to return to Midway, most notably thanks to the growing presence of Southwest Airlines.
Beyond this example, the whole industry keeps changing rapidly. According to George P. Howard, president, Airports Council International, "Even after 14 years of deregulation, we still haven't seen the ultimate of this industry, by any means."

2.3.1 A MEASURE OF THE VOLATILITY OF TRAFFIC

We define a measure of the volatility of traffic at an airport as in previous studies [de Neufville and Barber, 1991]. Studying the traffic at an airport over a given period of time, one can calculate the trend of traffic, which is a linear function of time. At any given date t, the volatility of traffic is defined as follows :

$$\text{Volatility (t)} = 100 * \left| \frac{\text{Actual Traffic (t) - Trend (t)}}{\text{Trend (t)}} \right|$$

We then simply define a volatility index as the average volatility over time:

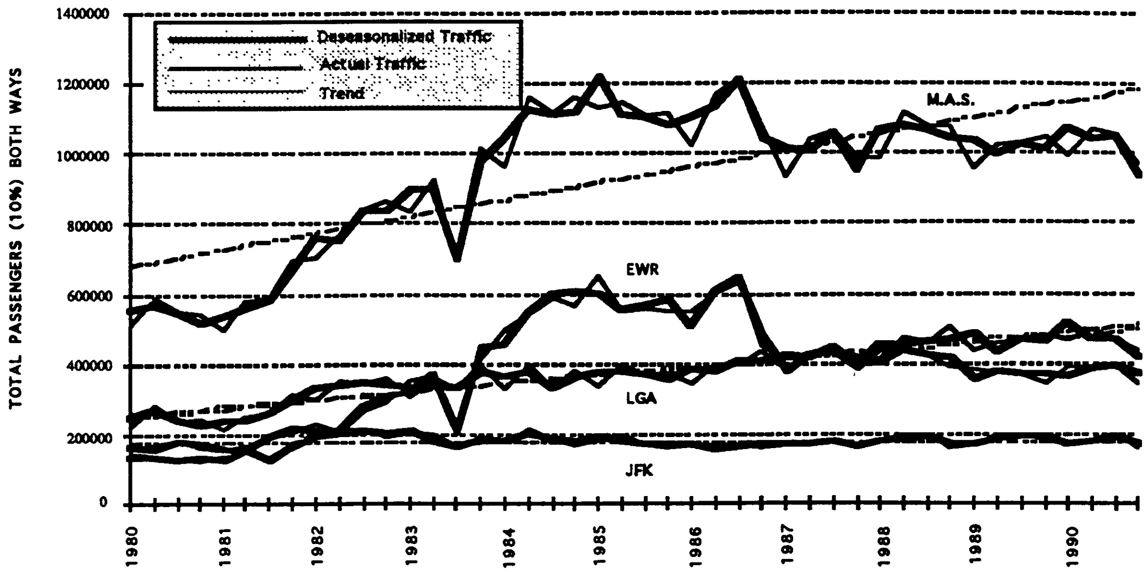
$$\text{Volatility Index} = \frac{\sum_{t=1}^{N} \text{Volatility (t)}}{N}$$

In fact, in our calculations, instead of using the actual traffic[14], we first calculated the deseasonalized traffic, then the trend (Figure 2.8-2.10). We did the calculations using total O-D passenger traffic at three M.A.Ss (New York; San Francisco; Washington) for the period 1980 (1st quarter) through 1990 (4th quarter).

14. By traffic we mean local O-D passengers (both directions, i.e. inbound + outbound). A traveler is considered a local O-D passenger if its entire directional journey, from origin to destination, is on one carrier.

Figure 2.8

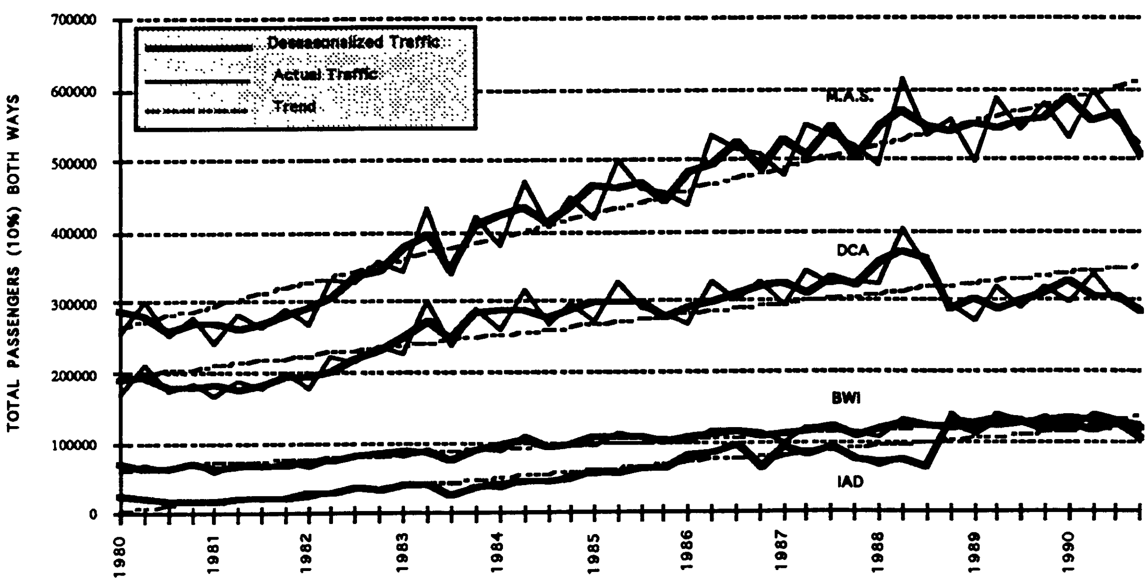
NEW YORK - NEW JERSEY METROPOLITAN AREA



Source: Adapted from O&D Plus database.

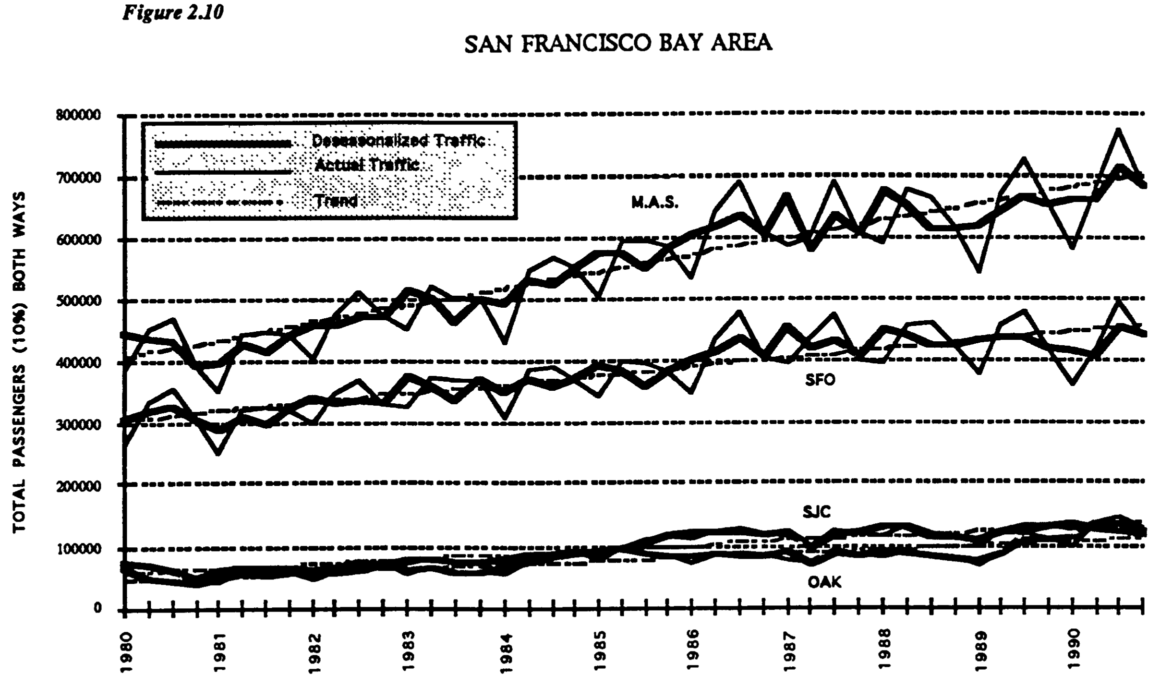
Figure 2.9

WASHINGTON-BALTIMORE METROPOLITAN AREA



Source: Adapted from O&D Plus database.

Figure 2.10



Source: Adapted from O&D Plus database.

2.3.2 RESULTS

The following three graphs (Figure 2.11 - 2.13) illustrate the evolution of:

- The average volatility of traffic at the three airports constituting each M.A.S.[15]
- The volatility of traffic at the M.A.S. level.

15. e.g., Avg. Volatility (EWR, LGA, JFK) = [Volatility(EWR) + Volatility(LGA) + Volatility(JFK)]/3

Figure 2.11

AVERAGE VOLATILITY (EWR, JFK, LGA) v. M.A.S.

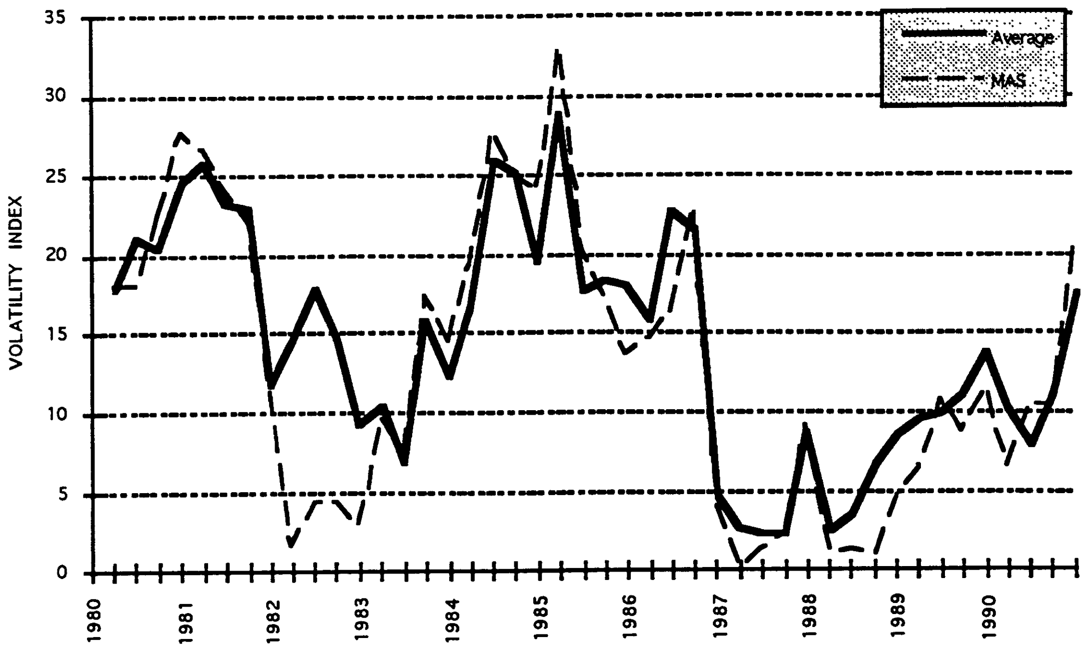


Figure 2.12

AVERAGE VOLATILITY (SFO, OAK, SJC) v. M.A.S.

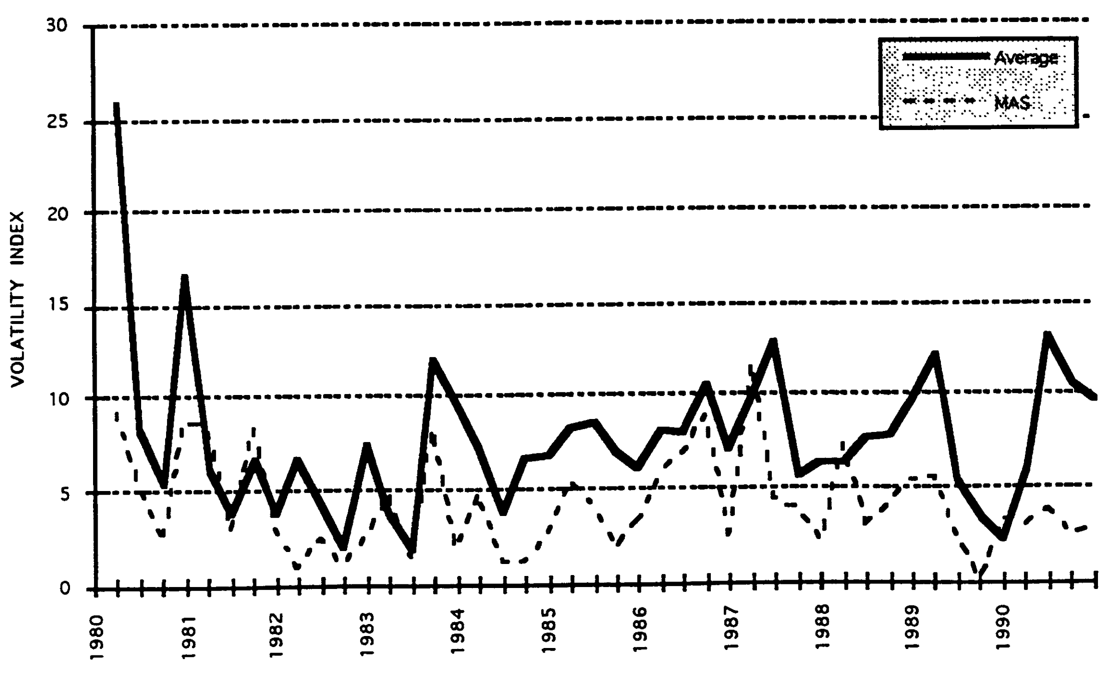
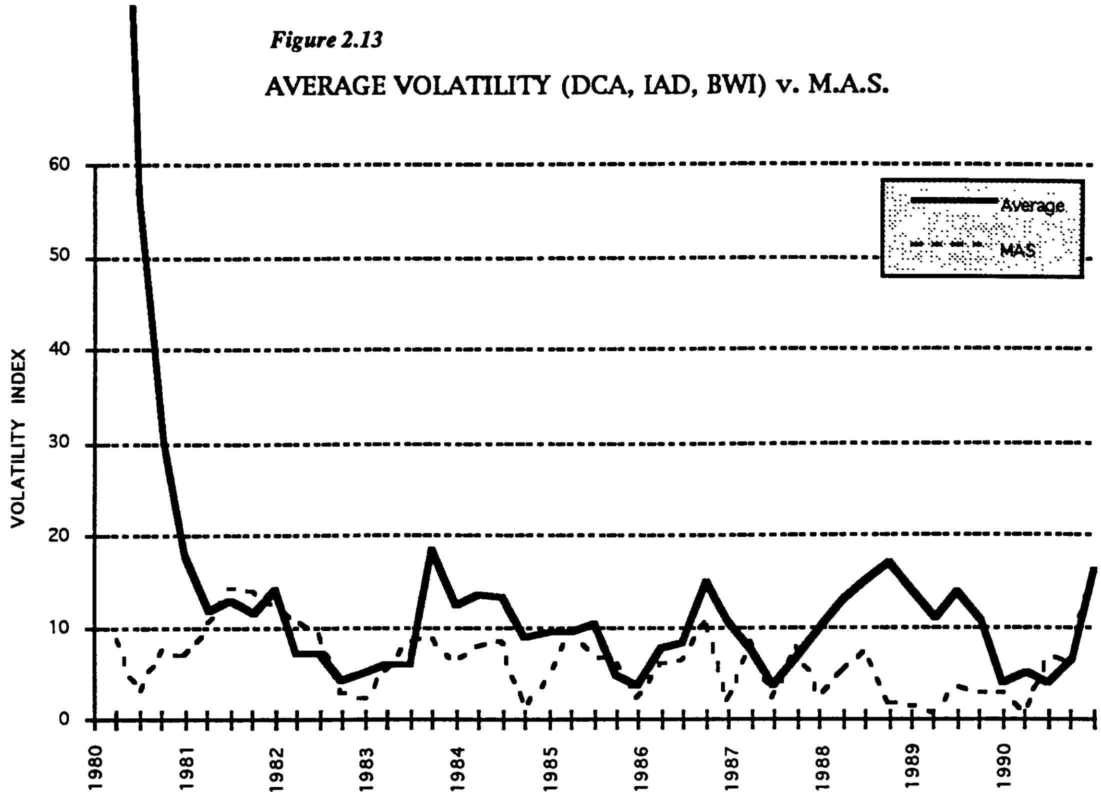


Figure 2.13

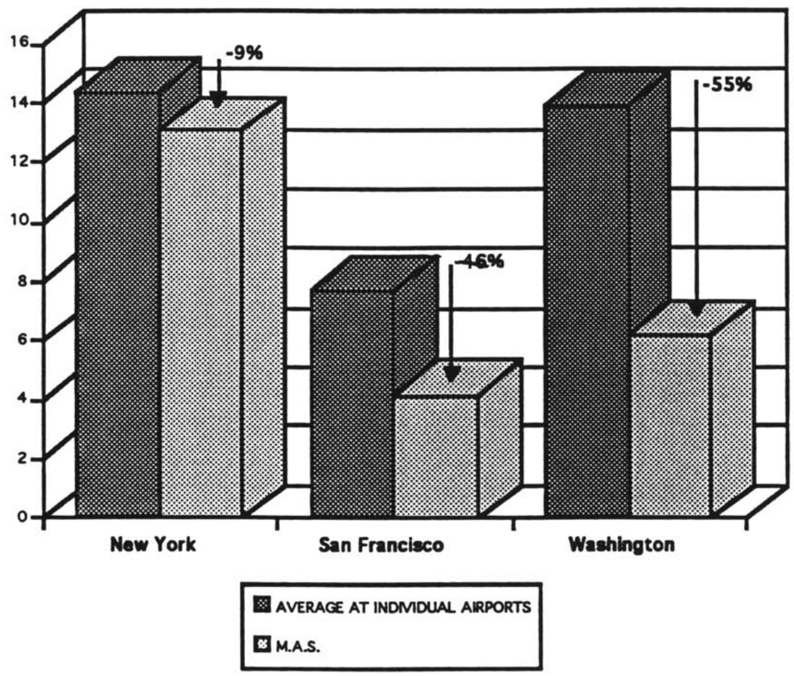
AVERAGE VOLATILITY (DCA, IAD, BWI) v. M.A.S.



It is clear from the above graphs that traffic seems to be -- on average -- less volatile at the M.A.S. level that at the level of the constituting airports. This statement is confirmed by the volatility indices depicted below (Figure 2.14). On the basis of our examples, traffic is 9% less volatile at the M.A.S. level in New York. More dramatically, it is 40% less volatile in San Francisco and 55% less volatile in Washington.

Figure 2.14

VOLATILITY INDEX : INDIVIDUAL AIRPORTS v. M.A.S.



2.4 CONCLUSION

All this suggests that there is a certain degree of interdependency between the airports constituting a multi-airport system. In all likelihood, airlines make strategic decisions in distributing their service at each airport. Simultaneously, air passengers make choices which depend on a variety of criteria including the level of service provided by each airline at each airport.

CHAPTER 3

THE AIRPORT MARKET SHARE MODEL

3.1 REVIEW OF THE PREVAILING METHODOLOGIES

This section briefly summarizes an overview of the literature on multi-airport systems.

3.1.1 OVERVIEW

A first insight, mostly qualitative, of the specific problems raised by multi-airport systems can be found in several papers by Richard de Neufville.

In "Planning for Multiple Airports in a Metropolitan Region" [4/1984], one can find a discussion of the conditions that favor or disfavor a second -- or third -- major commercial airport for a city, with specific comments on London. The author provides indications on :

- The logic of a second airport.

- Common errors in the development of M.A.Ss, and
- The role of airlines and air travelers in the way traffic distributes between airports.

Although no model is constructed, the author suggests that concentration is the end result of the sequence of choice both airlines and passengers make in a M.A.S.

In "Competition Between Airports" [1/1986], the author discusses the impact of deregulation on the U.S. air transportation industry, emphasizing the following outcomes :

- Access to airports and airport facilities becomes an integral part of competition between airlines.
- The airline networks develop into hub-and-spoke patterns.
- Traffic at hub airports becomes more volatile.

In "Multi-Airport Systems in Metropolitan Regions" [3/1986], de Neufville goes further in his analysis of the distribution of traffic in M.A.Ss. The main lessons that can be drawn from the experience of several M.A.Ss worldwide (e.g. New York, San Francisco, Washington, London, and Montreal) are indicated below:

- A system of multiple airports in the same metropolitan area is potentially viable only if the total traffic reaches a minimum threshold of approximately 10 million originating passengers a year.
- Traffic typically distributes by distinctive segments of the market (domestic/international, leisure/business, etc.)
- Market forces -- contrary to other forces, such as political ones -- play a substantial role in shaping the long term distribution of traffic.

A simplified analytical model to capture the process by which air passengers make their choice between airports and between airlines can be found in "Planning for Satellite Airports" by Walter Gelerman and Richard de Neufville [1973]. The authors provide empirical evidence of the relatively low demand for service per unit population nearest each airport for satellite airports compared

to principal airports. Assuming a nonlinear (S-curve) relationship between market share and frequency share, and that frequency of service is the only strategic variable, a payoff matrix is constructed to calculate the airlines' frequency shares.
The study indicates that, in the first order, satellite airports will not, in general, play a substantial role in air transportation because traffic will naturally concentrate at the principal airport.

The actual detailed, quantitative analysis of airport choice in a M.A.S. has been undertaken by several authors, most of whom rely on the multinomial logit model.

Greig Harvey's "Airport Choice in a Multiple Airport Region" [1987] presents the results of an analysis of airport choice within a formal individual choice framework. Data from the San Francisco Bay Area were used to investigate the air traveler choice of a departure airport (1,860 passengers surveyed in 1980.)

Separate models were developed to account for the significant difference in airport choice between business and non business travelers. The basic model structure is multinomial logit with three airport alternatives. Each alternative has a utility function which includes variables for access time and flight frequency. Fares were omitted since nothing was known about the fares actually paid by each traveler. The model was calibrated using a logit estimation computer package.

The analysis shows that:

- A simple logit model based on airport access time and flight frequency to the chosen destination provides a good approximation of airport choice behavior (the impact of congestion at the airport terminals was not taken into account in this study.)
- Beyond a threshold level, additional direct flights to a specific destination do not appear to make an airport more attractive.

- Both connecting and commuter flights appear to be poorly regarded by air travelers who have the option of selecting a departure airport with direct flights.
- No effect of nonstop versus multi-stop direct flights could be discerned.
- The marginal disutility of access time decreases with total time.
- Airport choice does not appear to take place jointly with access mode choice.

A similar choice model is used in Norman Ashford's "Predicting the Passengers' Choice of Airport" [March 1989]. First, the author refutes the concept of catchment area, suggesting that passengers make a rational choice in selecting an airport. The article summarizes a study carried out at Loughborough University using British airports (Manchester, Birmingham, East Midlands, Luton, and London Heathrow) as case studies.

On the basis of data from 1975 and 1978 surveys, four logit models were developed to account for the differences in air travelers' behavior in the business international, leisure international, inclusive tour, and domestic travel markets.
Overall, it was shown that only three variables affect a passenger's choice:

- Access travel time.
- Flight frequency.
- Flight fare.

Finally, the author mentions the application of this approach to third world countries. In Nigeria, for instance, it was shown that only access travel time was significant.
The Nigeria study, by Angus Ifeany Ozoka and Norman Ashford, can be found in "Application of Disaggregate Modeling in Aviation Systems Planning in Nigeria : A Case Study" [1989]. The objectives of the study were:

- Determine the traffic distribution among the 16 major Nigerian airports (with special emphasis on two selected airports that are possible competitors.)
- Give insight into the major determining factors of airport choice by Nigerian domestic travelers.
- Use the model as a predictive tool.

A travel survey was conducted in August 1987 in Nigerian airports to collect disaggregate data in order to calibrate the multinomial logit model. The results of the analysis suggest that access travel time to the airport is the only significant variable.

Along the same line, in "Passengers' Choice of Airline Under Competition : The Use of the Logit Model," Fariba E. Alamdari and Ian G. Black [1992] attempted to understand how factors such as price and frequency of service influence passenger demand. The article summarizes several studies using the logit framework and concludes that :

- In most cases, fares have an influence on the share of passengers.
- The influence of time (either flight time, access to the airports, or access time plus schedule delay plus flight time) varies significantly between studies.
- All the studies find that the relative frequency of flights (either the difference in absolute frequency, the natural logarithm of frequencies between two choices, or the frequency to the power 0.5, depending on the study) along particular routes has an important influence on market share.
- The value of R-square for the studies is on the range of [0.5 - 0.7].
- Only two studies disaggregated the population, and found significant differences between differing classes.

Interestingly, the authors conclude by emphasizing the limits of logit share demand functions for air travel. No great confidence can be placed on the parameters derived from the various studies. Indeed, carriers' competitive behavior is more complex and many factors beyond fare and frequency will impinge on decisions about service attributes. More fundamental research is therefore needed, particularly in the areas of demand prediction and airline pricing behavior.

Other studies combine several choice submodels.

In "Airline Hubbing - Some Implications for Airport Economics" [1985], Adib Kanafani and Atef Ghobrial analyze the impacts of hubbing on airport economics. The nature of traffic generated at the hub airports implies some negative economic impacts which suggest that hub pricing should be taken seriously.

A case study using the Southeastern United States and 1980 data explores the impact of congestion hub pricing. To this end, a network equilibrium model is constructed and includes:

- *A route choice model*: A multinomial route choice model (logit) predicting city-pair traffic. Utility is a function of service, airfare, aircraft size, daily frequency of service, airfare, aircraft size and type of service.
- *An airline operating cost model*: Calculates airline operating costs and flight times for each flight segment.

The results show that hubbing will continue to predominate even with severe penalties: hubbing is inelastic to hub pricing. The authors conclude by suggesting that significant potential benefits to the hub airports could be gained from hub pricing schemes.

The simultaneous use of several choice models can also be found in the work of Mark Hansen and Adib Kanafani, "International Airline Hubbing in a Competitive Environment" [1988]. The purpose of the study is to capture the behavior of passengers with demands between origin and destination city pairs who will select carriers and gateways to use for their international journey (between the United States and Europe.)

In order to understand:

- The selection of gateways for international connection, and
- The provision of domestic feed (connecting) services at these gateways,

the authors opted in favor of a model in which gateway choice occurs first and is followed by airline choice. Passengers first choose between any of the gateways with direct service to their destination, or may select connecting service. Similarly, airlines choose from which gateways to offer what service. Four submodels were constructed :

- *Gateway local share model*: Estimates the proportion of traffic originating in the local area of a gateway that will use direct service.
- *Gateway connecting share model*: Logit model predicting share of connecting passengers that will fly through a particular gateway.
- *Airline local share model*: Model based on the assumed S-curve relationship between market share and frequency share. It predicts airline shares of local traffic between a gateway and a European destination.
- *Airline connecting share model*: Logit model predicting airline shares of connecting traffic between a given U.S. gateway and a European point.

In spite of the numerous deficiencies of the 1985 data used to calibrate the model, the system was used to predict traffic at a specific airport under alternative hubbing strategies of an airline.

3.1.2 SUMMARY

It appears that the prevailing approach to understanding the choice of an airport is the multinomial logit model. This model relies on the assumption that the choice between options is based on the comparison of the utilities of the various options [Ben-Akiva and Lerman, 1985]. Typically, it is assumed -- for practical reasons -- that one can aggregate individual utility functions, although individuals' perception may differ for attributes such as travel time, fares, and frequency of service.

This approach provides a reasonably good approximation of the reality. However, a major problem is the availability of relevant data, and a survey is often the only method to obtain the data that are necessary to the calibration of the model.

We decided not to use the multinomial logit model and focus on a more supply-side oriented approach.

Our literature survey indicates that most studies have tried to understand how passengers make their choice between competing airports and there seems to be agreement on the critical role of the three following variables :

- Fare
- Travel time
- Frequency of service

We have not found substantial literature on the other side of the problem, i.e. the behavior of airlines providing service in multi-airport metropolitan areas. Since the problems are obviously intertwined, there is a need to better understand airlines' strategic behavior.

3.2 DATA COLLECTION

We have relied primarily on quarterly data from 1979/1 through 1992/2[16]. For any origin-destination market in the United States, the following data were available:

- *Passenger traffic*: We consider local O-D passengers (both directions, i.e. inbound and outbound), that is, passengers whose entire directional journey, from origin to destination, is on one carrier.
- *Average fare*: Average fares are derived from the Department of Transportation's Origin-Destination Survey of Airline Passenger Traffic, which results from a continuous survey of ten percent of all passengers (in fact of ticket coupons) traveling on U.S.-certificated air carriers. Fare data compiled by Data Base Products, Inc. integrate the actual fare data (excluding tax). The average is calculated over the ten percent sample.
- *Average number of coupons*: A coupon is valid only between the passenger's point of enplanement and deplanement on a single flight.
- *Average length of haul*: Average air distance between origin and destination.

We chose to concentrate our effort primarily on O-D markets because this is the level at which air travelers and airlines make their decisions. In fact, we started our research by looking directly at the evolution of total traffic (local O-D passengers, aggregated over all O-D markets), and market shares for the following airports: New York (Newark, LaGuardia, Kennedy), Washington (National, Dulles, Washington-Baltimore), San Francisco (San Francisco International, Oakland, San Jose), and Chicago (O'Hare, Midway). It was clear that the results were too general to be really useful. Among other things, we needed data on fares and frequency of service. This could practically be done only at the O-D market level. For these reasons, origin-destination markets are the basis of our investigation.

16. These data are made available by Data Base Products, Inc. on CD-ROM under the name O&D Plus (an Origin & Destination Survey of Airline Passenger Traffic.)

For a given O-D market, the following data were also available for each airline: market share of passengers, total passengers, average fare, average haul, average number of coupons. These terms are defined above.

All the fares were converted into constant 1990 dollars. The Official Airline Guide was used to calculate frequencies of service. In this study, frequency of service is measured in number of non-stop flights per week. We calculated the frequency of service for a given month of each quarter.

3.3 CONSTRUCTION OF THE MODEL

Our objective is to build a model predicting airport market shares (MS) in a multi-airport system.

The model should be able to provide a good approximation of the reality but also should be simple enough to be reasonably easy to use and easy to understand. It should also rely on a limited amount of data, without systematically requiring the use of surveys.

Obviously, the market share of an airport depends on a variety of factors. In the late 1960's, the Boeing company embarked on a long-term study in order to understand passenger behavior [Pina, 1980]. A long list of variables relevant to the determination of airlines market share was established (Table 3.1).

Table 3.1

Range of Possible Determinants of Market Share	
1 Newness of type of airplane	19 Shortness of time to and from the airport
2 Freedom from departure delays	20 Shortness of overall flight time
3 Baggage service	21 Speed
4 Noise suppression	22 In-flight service
5 Adequacy of flight schedule	23 Passenger cabin conveniences
6 Seating comfort	24 Compartmentalization and width
7 Glamour/interesting experience level	25 Interconnecting flight delays
8 freedom from accidents	26 Pre- and post-flight terminal services
9 Seat location and convenience	27 Smoothness of flight
10 Shortness of landing/destination delays	28 Closeness to desired arrival time
11 Fare competitiveness	29 Business versus personal
12 Directness of flight	30 Self versus family
13 Restriction due to fare rate	31 Desire to take trip
14 Physical side effects	32 Departure city population size
15 Family conveniences	33 Arrival city population size
16 Carrier booking reliability	34 Direction of flight
17 Crashworthiness survival devices, etc.	35 Inbound versus outbound
18 Lack of plane and carrier changes	36 Distance to be flown

Source : Boeing Commercial Airplane Company.

We could also include recent marketing innovations such as frequent flyer programs and the ownership of computer reservation systems[17]. Obviously, this list is too broad to be really useful. The determinants of an airline's market share can be categorized in a shorter, more practical, list including:

- Schedule
- Routing
- Equipment
- Service (preflight, inflight, postflight)
- Fares

Ideally, since we are interested in the competition between airports, we should probably take into account other factors influencing a passenger when choosing a particular airport [Ashford, 1989; Ozoka and Ashford, 1989]:

- Ground access time (nearest airport: closest to work, closest to home).
- Airport recommended by travel agents or chosen by the office.
- Convenient and cheap parking.
- Less crowded airport, etc.

As a result of conclusions drawn by previous studies, and also for practical reasons, we shall assume that the market share of an airport is primarily a function of the average price, and the frequency of service. That is :

$$MS_i = fn(Fare_j, Frequency_j)$$

where j can be any airport in the M.A.S. In fact, by using dummy variables, we will also account for other attributes that tend to remain fairly constant over time (distance from the city, average size of the airport, ...)

17. A discussion of the role of these marketing innovations can be found in "Airline Marketing Practices : Travel Agencies, Frequent-Flier Programs, and Computer Reservation Systems." U.S. Department of Transportation, February, 1990.

Total travel time is not used as an explanatory variable in this model for three main reasons:

- First, for a given destination, flight time should be approximately the same for each of the originating airports constituting the M.A.S. As a result, the attractiveness of an airport should essentially depend on ground access time.
- Second, it seems reasonable to assume that in most circumstances ground access time varies slowly over time. This means that even if it has an impact on airport market shares, it does not really influence the quarterly variations of airport market shares.
- Finally, our data do not allow us to know the origin -- and therefore the average ground access time -- of passengers using a designated airport.

3.3.1 FARES

For a given O-D market, the fare used as an explanatory variable is simply the average fare (in constant dollars) at each airport. In other words,

$$\text{Average Fare}_i = \frac{\sum_j \text{Fare}_{j,i} . \text{Passengers}_{j,i}}{\sum_j \text{Passengers}_{j,i}}$$

where $\text{Passengers}_{j,i}$ is the number of passengers flying airline j at airport i.

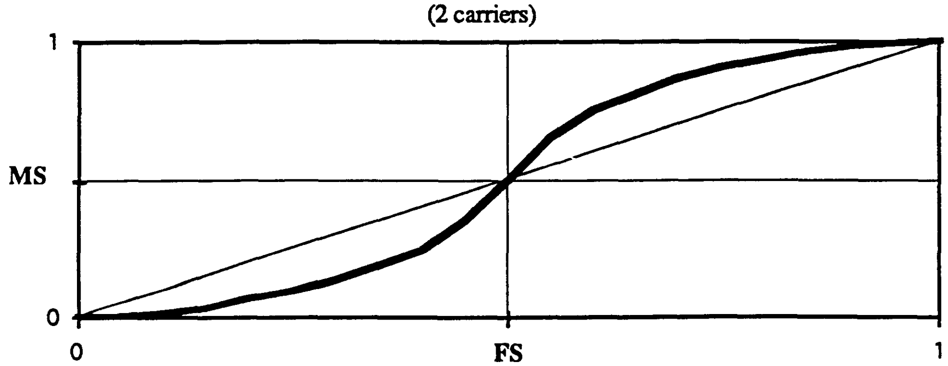
3.3.2 FREQUENCY OF SERVICE

For a long time (prior to 1978) it was assumed that in a regulated environment like the U.S. market, there was avery simple relationship between the frequency of service offered by a carrier and its market share.

In first approximation, it was even assumed that in a given O-D market, "market share = frequency share". In fact, if price is assumed not to be a relevant differentiating factor (e.g. if airlines match their fare structures), several studies have shown that the relationship between frequency share (FS) and market share (MS) is not linear, and is typically adequately described by an S-shaped curve[18]. This means that a comparatively small FS will result in a comparatively smaller MS and, similarly, that a comparatively large FS will result in a comparatively larger MS.

Figure 3.1

MARKET SHARE vs. FREQUENCY SHARE
(2 carriers)



A simple illustration of this phenomenon is based on the idea that market shares will be derived from the proportions of round-trip services [Simpson, 1982] :

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18. See, for instance, Airline Market Share Modeling in Originating City Markets, James E. Davis, MIT, Department of Aeronautics & Astronautics, Flight Transportation Laboratory, Report R89-5, August 1989.

"... If we assume passengers select outbound and inbound trips together, and prefer to travel on one airline (...), then the number of outbound-inbound combinations depends on the square of the frequency share. For example, airline A has 3 trips/day compared to 7 trips/day by airline B. Instead of sharing the market 30/70, they might be expected to share it in proportion to the roundtrip opportunities. Airline A offers 9 roundtrips versus 49 for airline B, so that we might expect 9/(9+49)=16% for A, and 49/(9+49)=84% for airline B. Of course, it would depend on how many passengers insisted on travelling both ways with one carrier."

As a result, there is a strong incentive for competitive airlines to match one another in terms of frequency of service.

Along the same line of thought, Taneja [1968] developed and tested several models to predict the market share that an airline gets when operating in a given market and competing with other airlines. The author found that :

- The dominant explanatory variables are the frequency share and the number of competitors operating in the market.
- S-shaped curves represent well the relationship between market share and frequency share.

A simple model can be derived as follows. Assume that n airlines are competing in a given market, and that MS is a function of FS only:

$$MS = fn\ (FS)$$

Intuitively, we impose that :

$$MS(0) = 0$$
$$MS(1) = 1$$
$$MS\left(\frac{1}{n}\right) = \frac{1}{n}$$

Now, we assume that MS is a polynomial function of FS :

$$MS = a\,FS^3 + b\,FS^2 + c\,FS + d$$

where a, b, c, and d are four parameters to be estimated[19]. Note that defined as such, the S-curve is not constrained to be between 0 and 1.

These equations give the following relationship, where MS depends on FS and a parameter (e.g. c) :

$$MS = n(c-1)\,FS^3 + (n+1)(1-c)\,FS^2 + c\,FS$$

<u>Note</u> :

Indeed, the three conditions give:

$$d=0\,; \quad 1 = a+b+c\,; \quad \frac{1}{n} = a\left(\frac{1}{n}\right)^3 + b\left(\frac{1}{n}\right)^2 + c\left(\frac{1}{n}\right).$$

This can be reformulated as follows:

$$a + bn = n^2(1-c)\,; \quad a + b = (1-c)$$

Or:

$$a = n(c-1)\,; \quad b = (n+1)(1-c); \quad c; \quad d=0$$

By combining this model and actual (observed) data, we are able to estimate c so as to provide the best fit for a certain criterion. In this case we choose to minimize the sum of the square of the errors:

$$\text{Min} \sum_i \left(MS_{i,\text{Observed}} - MS_{i,\text{Predicted}} \right)^2$$

It is easily shown that this criterion leads to :

19. Another possible approach would consist in assuming that $MS = \alpha.\,FS^{\beta}$ and to perform a regression analysis to calculate the two parameters, using the relationship $in(MS) = \ln(\alpha) + \beta.\ln(FS)$.

$$c = \frac{\sum_i A_i.(MS_{i,Observed} - B_i)}{\sum_i A_i^2}$$

where :

$$A = FS - (n+1)\ FS^2 + n\ FS^3$$
$$B = (n+1)\ FS^2 - n\ FS^3$$

What follows is an empirical test of this model. We first test the model over a sample of O-D markets[20] with 2, 3, and 4 or 5 carriers. We then use this model to see whether airport market shares within a multi-airport system can also be represented by a S-shaped curve.

3.3.2.1 MS vs. FS : COMPETITION BETWEEN AIRLINES

Table 3.2

2 CARRIERS		3 CARRIERS		4+ CARRIERS	
OD Market	*Carrier*	*OD Market*	*Carrier*	*OD Market*	*Carrier*
DFW-BOS	AA,DL	PHX-DEN	CO,UA,HP	MCO-BOS	DL,UA,US,NW
LAS-BUR	WN,HP	ORD-BWI	US,UA,AA	DEN-COS	CO,UA,YV,TW
DEN-SNA	CO,UA	ORD-PHL	US,UA,AA	MIA-MCO	DL,US,UA,AA,NW
DFW-LAX	DL,AA	DEN-DTW	NW,UA,CO	ORD-MIA	AA,UA,DL,BE
ATL-MIA	DL,AA	DFW-PHX	HP,AA,DL		
DFW-BWI	DL,AA	DEN-ABQ	CO,UA,US		
ATL-CLE	CO,DL				
SAN-LAS	WN,HP				
SEA-DEN	CO,UA				
ABQ-PHX	WN,HP				

Source: Official Airline Guide.

20. 1992 data from the Official Airline Guide.

where airports and airlines are defined as follows:

Table 3.3

Airports				Carriers	
ABQ	Albuquerque	MCO	Orlando	AA	American
ATL	Atlanta	MIA	Miami	BE	Centennial Airlines
BOS	Boston	SAN	San Diego	CO	Continental
BUR	Burbank	SNA	Orange County	DL	Delta
BWI	Baltimore	PHX	Phoenix	HP	America West
CLE	Cleveland			NW	Northwest
DEN	Denvers			UA	United
DFW	Dallas-Ft Worth			US	USAir
LAS	Las Vegas			WN	Southwest
LAX	Los Angeles			YV	Mesa Air

Figure 3.2

MS v. FS (2 CARRIERS) : S-SHAPED CURVE

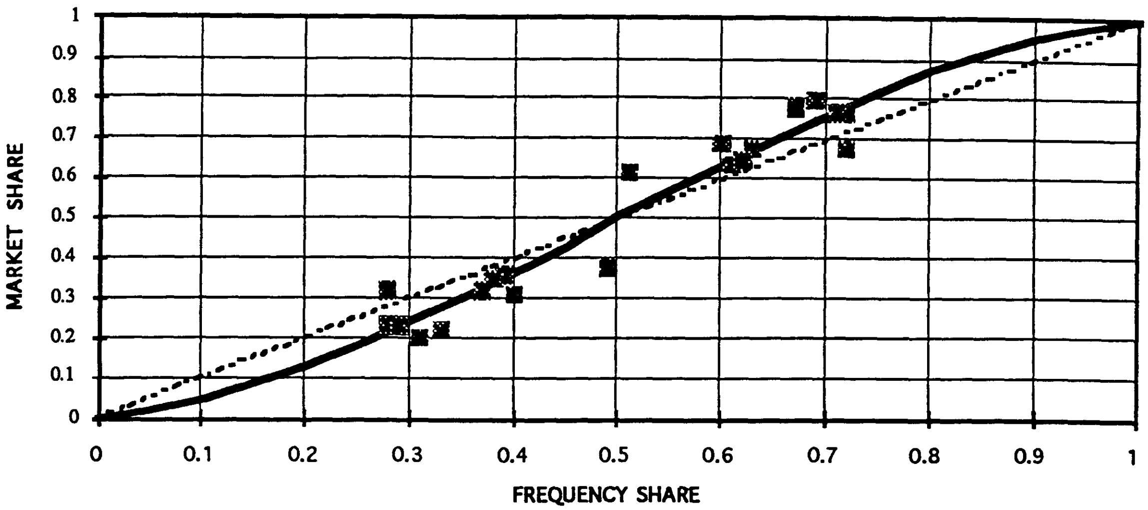


Figure 3.3

MS v. FS (3 CARRIERS) : S-SHAPED CURVE

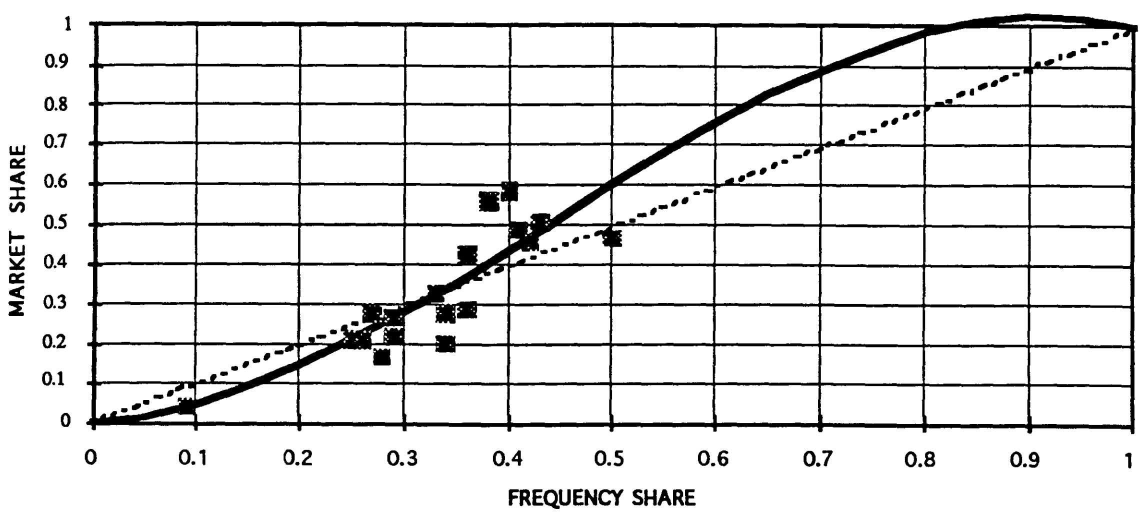
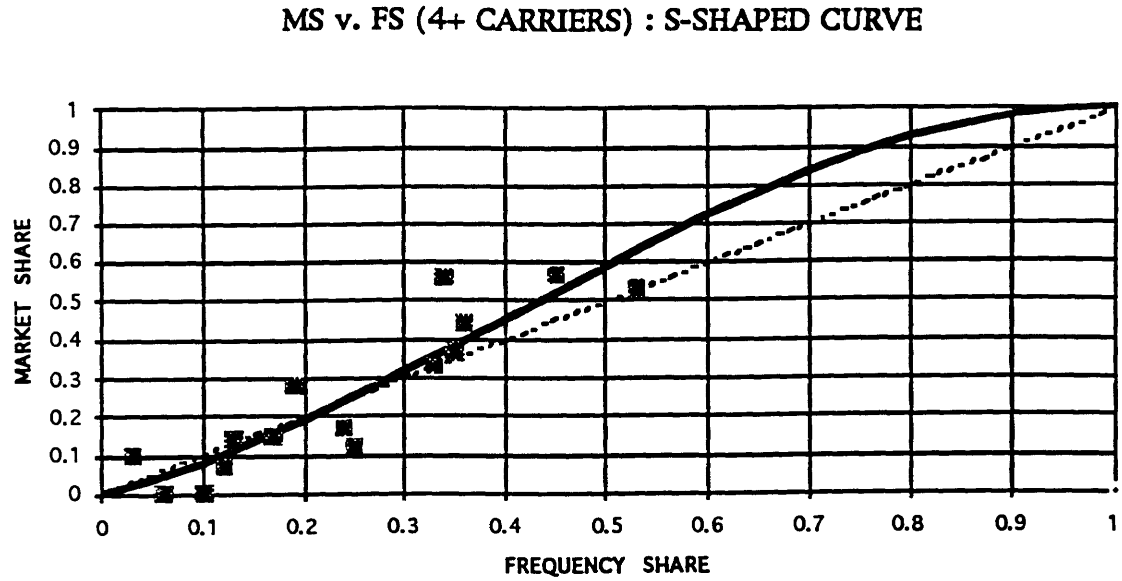


Figure 3.4



These results confirm that at the O-D market level frequency of service is an important factor in determining MS between airlines. In spite of the limitations of the model presented above, it confirms that the relationship between an airline market share and its frequency share is not linear and is well approximated by an S-curve. With our model, we showed that the shape of this S-curve depends (among other things) on the number of competitors.

3.3.2.2 MS vs. FS : COMPETITION BETWEEN AIRPORTS

We adopt a similar approach to evaluate the relationship between frequency of service offered at an airport and its aggregate market share of passengers (Figure 3.5-3.7). As early as 1976, de Neufville showed that this airline market share relationship could also be represented by an S-shaped curve by looking at a few metropolitan and satellite airports (e.g. Baltimore compared to Washington National, and Gatwick compared to London Heathrow).

What follows is based on the data gathered for the case studies[21] presented in Chapter 4. The frequency of service at an airport is the *equivalent frequency of service* at this airport. The concept of equivalent frequency of service will be introduced later on in this chapter. It simply means the aggregate frequency of service as perceived by air travelers, and it is used to generalize the notion of average frequency, and to account for the different scheduling practices across airlines. Finally, it should be indicated that in each case, a few quarterly frequencies of service were not available.

Origin	Destination	Quarterly Data
SFO, OAK, SJC	SAN	From 1988/4 Through 1992/2
DCA, IAD, BWI	ORD	From 1988/1 Through 1992/2
EWR, LGA, JFK	PIT	From 1983/1 Through 1990/4

21. Three metropolitan areas were studied : New York/New Jersey (Newark: EWR, LaGuardia: LGA, Kennedy: JFK), Washington/Baltimore (National: DCA, Dulles: IAD, Baltimore: BWI) and San Francisco Bay Area (San Francisco: SFO, Oakland: OAK, San Jose: SJC).

Figure 3.5

MS v. FS : S-CURVE (BALTIMORE/WASHINGTON AIRPORTS)

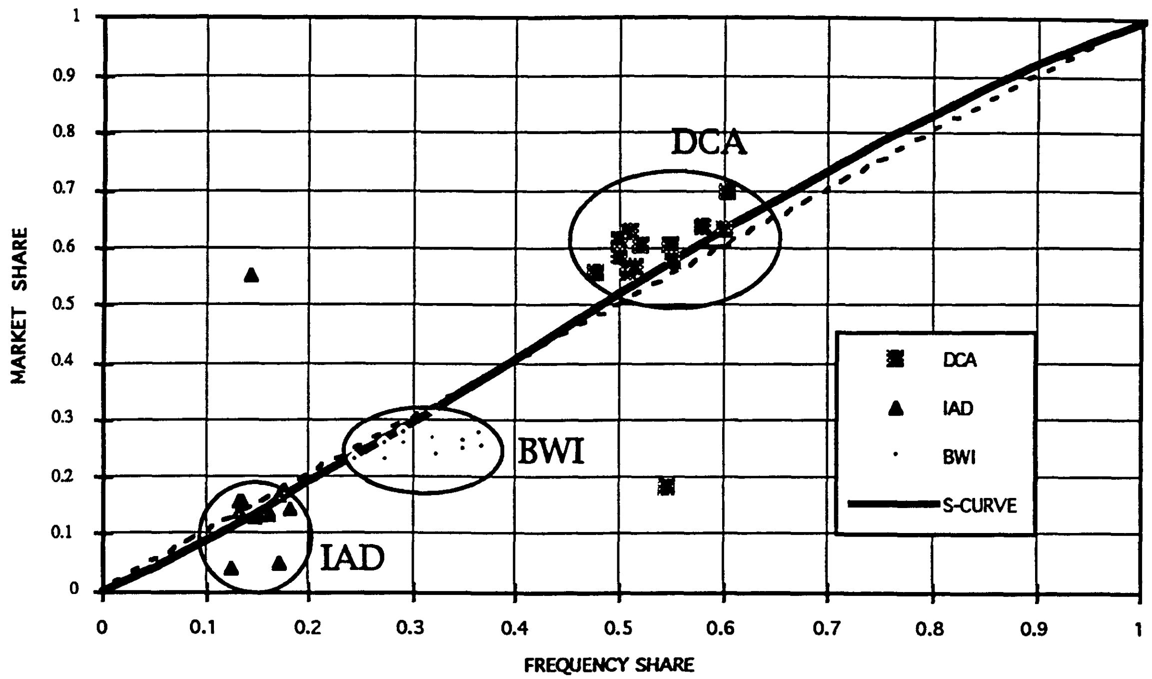


Figure 3.6

MS v. FS : S-CURVE (NEW YORK /NEW JERSEY AIRPORTS)

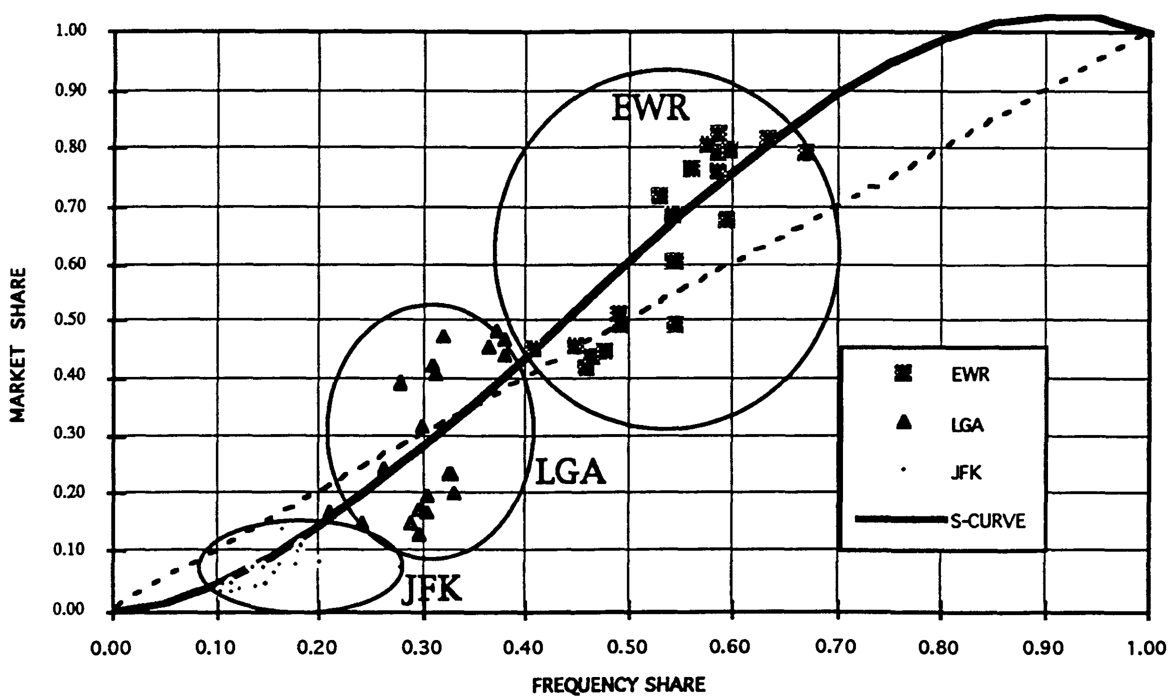
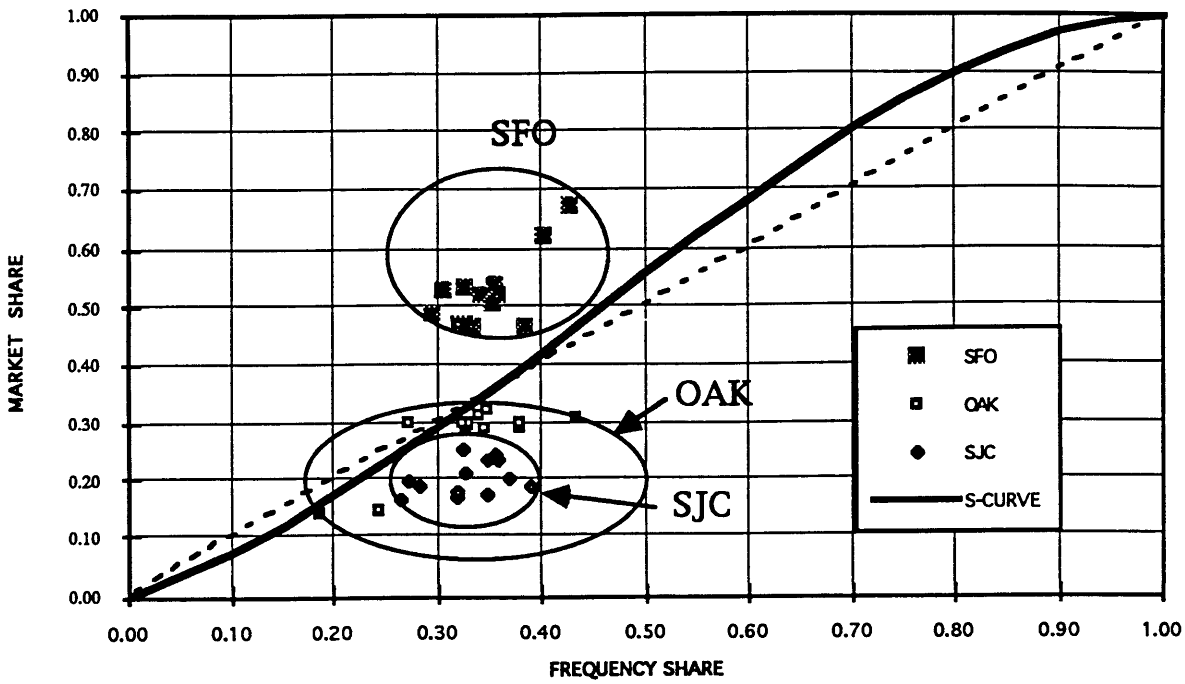


Figure 3.7

MS v. FS : S-CURVE (SAN FRANCISCO BAY AREA AIRPORTS)



As in the case of airlines competing in a given market, there is a non-linear relationship between an airport average frequency of service and its aggregate market share of passengers.

As a result, we shall assume that an airport market share is proportional to the average frequency share at this airport, raised to a certain exponent:

$$MS_i \approx FS_i^{\alpha}$$

3.4 THE MODEL

We know that the market share depends not only on the frequency share but also on fare. The attractiveness of a given airport will depend on the average fare at this airport but also on the average fare at competing airports. To keep the model simple, we found useful to introduce the variable "Other fare" which represents the average fare at all the other competing airports. In each of our case studies, three airports are in direct competition, which means that airport i's market share is a function of its average fare and the average of the fares at airports j and k.

From the above discussion and the previous paragraphs, we derive our statistical model which can be formulated, for an origin-destination market:

$$MS_i = K_i \times FS_i^{\alpha} \times Fare_i^{\beta} \times \text{Other Fare}_i^{\gamma}$$

where :

- MS_i is airport i's market share.
- K_i is a parameter (different for each airport). This is airport i's market share everything else being equal.
- FS_i is airport i's equivalent frequency share (explained below).
- $Fare_i$ is the average fare (in constant dollars), weighted by traffic, at airport i.
- Other Fare_i is the average fare (in constant dollars) at airports j, for all $j \neq i$.

and where the parameters α, β and γ are estimated by regression analysis. Note that given the multiplicative form of our model, α, β and γ have a very simple interpretation. Indeed, assuming that the market share is a function of FS, Fare, and Other Fare, we have:

$$\frac{dMS}{MS} = \alpha \frac{dFS}{FS} + \beta \frac{dFare}{Fare} + \gamma \frac{dOther\ Fare}{Other\ Fare}$$

and:

$$\alpha = \frac{\left(\frac{\Delta MS}{MS}\right)}{\left(\frac{\Delta FS}{FS}\right)} \qquad \beta = \frac{\left(\frac{\Delta MS}{MS}\right)}{\left(\frac{\Delta Fare}{Fare}\right)} \qquad \gamma = \frac{\left(\frac{\Delta MS}{MS}\right)}{\left(\frac{\Delta Other\ Fare}{Other\ Fare}\right)}$$

The three parameters α, β and γ are the *elasticity of the variable market share* with respect to the three explanatory variables: frequency share, direct fare, and the average fare at competing airports ("other fare"). The practical interpretation is simple. For example, everything else being equal, an increase in frequency share of P percent at an airport would result in a $\alpha \times P$ percent increase in its market share. Intuitively, we would therefore expect α and γ to be positive, and β to be negative.

3.5 EQUIVALENT FREQUENCY OF SERVICE

Aggregating data across carriers at each airport within a M.A.S. does not raise any particular problem for the total number of passengers and the average fare. However, the calculation of the average (or, equivalent) frequency of service at a given airport cannot be done that easily. Indeed, just assume that two airlines provide n daily flights at an airport. Suppose also that they perfectly match their schedule. In such a case, the equivalent frequency of service will be n, and not 2n. In fact, we only know for sure that the equivalent frequency of service is larger than (or equal to) n, and less than (or equal to) 2n, the actual value depending on the extent to which the airlines match their departure times.

More generally, and everything else being equal, the question is to know what should be the frequency n offered by only one ("equivalent") airline, which would make the airport as attractive as when there are p airlines providing respectively n1, n2, ..., np flights a week (np>...>n2>n1):

Airline 1, n1 flights/week
Airline 2, n2 flights/week
.
. *equivalent to* 1 Airline, n flights/week
.
Airline p, np flights/week

It is clear that n should be larger than n1 but smaller than n1+n2+...+np. To solve this problem, we will be using a very simplistic model but which has the merit to make intuitive sense. We assume that when p airlines are providing the same frequency n, the equivalent frequency is :

$$n.p^{\alpha}\ ,\quad 0 \leq \alpha \leq 1$$

If the p airlines match perfectly their schedule, $\alpha=0$ and the equivalent frequency of service is n, whereas $\alpha=1$ if the n.p flights are uniformly distributed. By accounting for the fact that airlines do not provide the same number of flights, we obtain the following formulations for p=2 and p=3:

- 2 airlines (n1<n2) $n = 2^{\alpha}.n_1 + (n_2\text{-}n_1)$
- 3 airlines (n1<n2<n3) $n = 3^{\alpha}.n_1 + 2^{\alpha}.(n_2\text{-}n_1) + (n_3\text{-}n_2)$

These formulations are directly derived from the fact that:

- When p=2, two airlines are directly competing on n1 flights, only one airline is providing the extra (n2-n1) flights.
- When p=3, three airlines are competing on n1 flights, two airlines are in competition on (n2-n1) flights, and only one airline is providing the extra (n3-n2) flights.

The three airline example is illustrated below (Figure 3.8 & 3.9):

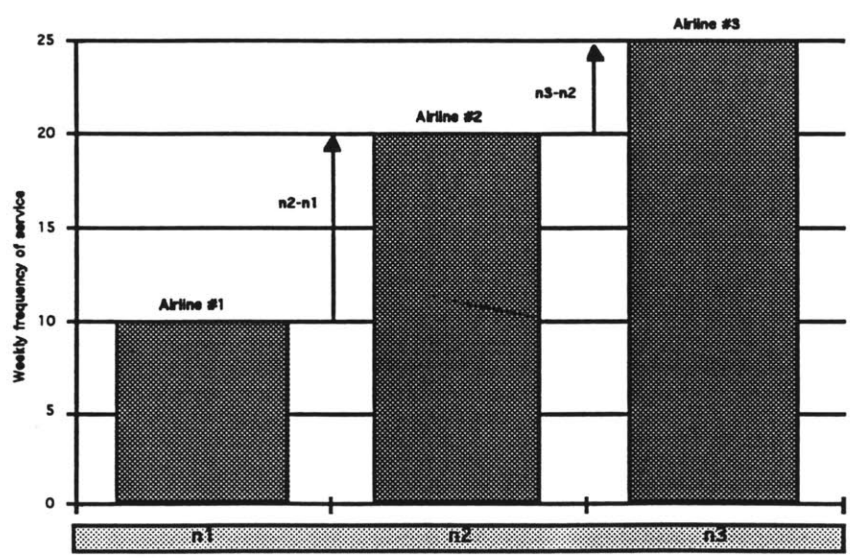
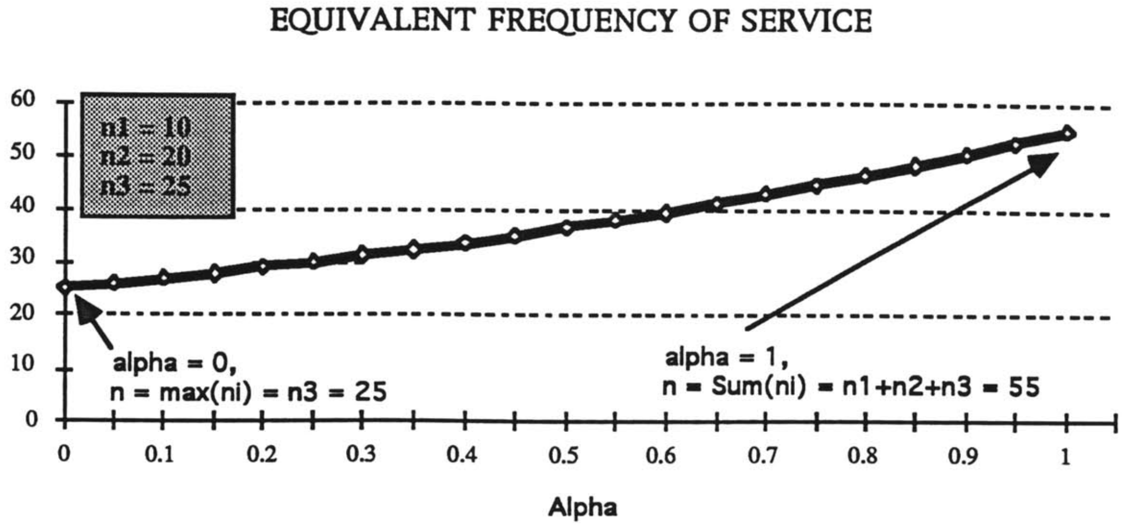


Figure 3.8

Figure 3.9



A problem with this approach is that the equivalent frequency of service is not endogenous. In other words, the parameter α has to be calculated for each airport[22] so as to make our model as good as possible. In fact, there is no obvious way to know the actual equivalent frequency of service, i.e. the aggregate frequency of service at an airport as perceived by air travelers. Thus, there is no direct method allowing us to check the validity of our estimated equivalent frequency.

Another potential problem is that we do not explicitly take into account the saturation effect according to which, beyond a certain threshold, there is a diminishing value in adding extra flights.

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22. In the case studies, we consider M.A.Ss with three airports. We use the terminology alpha, beta, and gamma to identify the parameter "α" on which depends the equivalent frequency at the three airports.

CHAPTER 4

CASE STUDIES

In this chapter, we present the results of case studies involving three major multi-airport systems: New York/New Jersey, San Francisco Bay Area, and Washington/Baltimore. Each M.A.S. is composed of three large commercial airports, as indicated below :

MULTIPLE AIRPORT REGION	AIRPORTS		
New York/New Jersey airports	E : EWR	L : LGA	J : JFK
San Francisco Bay Area airports	S : SFO	O : OAK	J : SJC
Washington/Baltimore airports	D : DCA	I : IAD	B : BWI

For each M.A.S., we studied three O-D markets :

- **New York/New Jersey**
  - Minneapolis/St Paul
  - Pittsburgh
  - Raleigh Durham
- **San Francisco Bay Area**
  - Las Vegas

- Phoenix
- San Diego

- **Washington/Baltimore**
    - Atlanta
    - Chicago O'hare
    - Raleigh Durham

These O-D markets were chosen making sure that the level of traffic was high enough and that the number of competitors was not too high. For practical reasons, collecting data was much easier when the number of competitors is limited (e.g. three or four). Given the fairly concentrated structure of the U.S. market, this should not be a severe limitation.

The detailed statistical results as well as the graphs illustrating the fit between predicted and observed data are presented in Appendix 2. The results are summarized in table 4.1 through 4.4.

Although a more detailed analysis is given in the next chapter, we can summarize the results by remarking that, at the O-D market level:

- **Cross effects have to be taken into account**

  In all the cases studied, an airport's market share depends on fare and frequency of service at the designated airport, but also on fares and frequencies at the other airports within the M.A.S. This simply illustrates the effect of competition between airports.

- **Qualitative relationships are consistent with intuition**

  In all the cases studied, we found that the sign of price and time elasticities are consistent with intuition:

- The elasticity of MS with respect to frequency of service (α) is positive.

- The direct elasticity of MS with respect to price (β) is negative.

- The cross elasticity of MS with respect to price (γ) is positive.

- **Numerical values of price and time elasticities make sense**

In absolute value, elasticities range from 0.29 to 1.85, which seems to be a reasonable range reflecting both inelastic and elastic relationships.

- **A reasonable statistical fit between the model and observed data**

Adjusted R-square values range from 0.85 to 0.98. In seven out of nine case studies, adjusted R-square is greater than 0.92.

The F-statistic ranges from 78 to 393 an d is therefore very significant[23].

The t-test for each of the explanatory variables is also significant[24]. More details are given in the next chapter.

23. The F-statistic is the ratio (Explained Mean Square/Unexplained Mean Square). Typically, given the degrees of freedom in our case studies, the critical value of F at 1% is less than 5. This means that only 1% of the area under the F distribution lies to the right of this critical value. Since the computed Fs are in the [78-393] range, the model is highly significant, in the sense that the variance of the errors is relatively small. See, for instance, Makridakis, Wheelwright, and McGee (1983).

24. In this case, we used this statistical test to test whether coefficients calculated are significantly different from zero. For this purpose, it is simply defined as the ratio of the coefficient to the standard error of this coefficient.

Note: The following tables include many equations similar to $MS = K\times\left(\frac{FS^{\alpha}}{F^{\beta}}\right)\times\bar{F}^{\gamma}$. This relation gives the market share (MS) of each airport in the MAS as a function of the equivalent frequency share (FS) at the airport, the average fare (F – expressed in constant dollars in our calculations) at the airport, and the average fare at the competing airports ($\bar{F}$). The parameter K is different for each airport.

Table 4.1

MAS : NEW YORK / NEW JERSEY AIRPORTS
• **MSP** (R^2 = 0.97)[25] $$MS = K\times\left(\frac{FS^{0.75}}{F^{0.89}}\right)\times\bar{F}^{1.26}$$ • **PIT** (R^2 = 0.96) $$MS = K\times\left(\frac{FS^{0.65}}{F^{0.69}}\right)\times\bar{F}^{0.87}$$ • **RDU** (R^2 = 0.98) $$MS = K\times\left(\frac{FS^{0.30}}{F^{0.92}}\right)\times\bar{F}^{0.91}$$

Note : MSP : Minneapolis/ St Paul ; PIT : Pittsburgh; RDU : Raleigh-Durham

25. In this occasion, R^2 means the adjusted R square and not the simple R square which does not account for the degrees of freedom for either the sum of squares (SS) of deviations due to the regression or the SS of deviations in the original data. The adjusted R square is the proportion of variance in our data that is explained by the explanatory variables (the regressors). The adjusted R square is always less than the simple (not corrected) R square.

Table 4.2

MAS : SAN FRANCISCO BAY AREA

- **LAS** (R^2 = 0.85)

$$MS = K\times\left(\frac{FS^{0.52}}{F^{0.29}}\right)\times\bar{F}^{0.63}$$

- **PHX** (R^2 = 0.95)

$$MS = K\times\left(\frac{FS^{0.58}}{F^{0.98}}\right)\times\bar{F}^{0.87}$$

- **SAN** (R^2 = 0.94)

$$MS = K\times\left(\frac{FS^{0.67}}{F^{0.81}}\right)\times\bar{F}^{0.42}$$

Note : LAS : Las Vegas ; PHX : Phoenix ; SAN : San Diego

Table 4.3

MAS : WASHINGTON / BALTIMORE

- **ATL** (R^2 = 0.96)

$$MS = K\times\left(\frac{FS^{0.52}}{F^{1.20}}\right)\times\bar{F}^{1.40}$$

- **ORD** (R^2 = 0.92)

$$MS = K\times\left(\frac{FS^{0.44}}{F^{0.98}}\right)\times\bar{F}^{1.08}$$

- **RDU** (R^2 = 0.89)

$$MS = K\times FS^{1.85}\times\bar{F}^{1.14}$$

Note : ATL : Atlanta ; ORD : Chicago O'hare ; RDU : Raleigh-Durham

We also used the model to predict an airport aggregate market share for several O-D markets. For instance, table 4.4 gives the equation of the market share for the three New York airports; these equations can be used to predict the market shares on each of the three O-D markets out of the MAS to Minneapolis-St Paul (MSP), Pittsburgh (PIT), and Raleigh-Durham (RDU).

Table 4.4

AGGREGATE MARKET SHARE MODEL FOR EACH M.A.S.

- **NEW YORK / NEW JERSEY** (R^2 = 0.96)

$$MS = K \times \left(\frac{FS^{0.61}}{F^{0.83}} \right) \times \overline{F}^{0.86}$$

- **SAN FRANCISCO BAY AREA** (R^2 = 0.83)

$$MS = K \times \left(\frac{FS^{0.59}}{F^{0.37}} \right) \times \overline{F}^{0.41}$$

- **WASHINGTON / BALTIMORE** (R^2 = 0.78)

$$MS = K \times \left(\frac{1}{F^{0.72}} \right) \times \overline{F}^{1.74}$$

Note : *For each M.A.S., the model was calibrated using data from all the relevant OD-markets (three OD-markets for each M.A.S.)*

In this last case, the fit between observed and predicted data is not as good as when we used the model at the O-D market level. However, it is interesting to notice that we did our regression using dummy variables for each O-D market out of a given airport (e.g. EWR) and that these dummy variables proved not to be statistically significant. In other words, the parameter K in the table above does not depend on which O-D market we are looking at (e.g. EWR-MSP, EWR-PIT, or EWR-RDU).

This suggests that our model, which was initially intended to predict market shares for a given O-D market, seems to remain useful when looking at a more aggregate level (i.e. several O-D markets out of the same M.A.S.)

CHAPTER 5

ANALYSIS AND RECOMMENDATIONS

5.1 ANALYSIS

5.1.1 INFLUENCE OF SEASONAL PATTERNS

We looked at the possible influence of seasonal patterns as an explanatory variable by introducing dummy variables for each quarters[26]. In Table 5.1, the t-test was used to assess the statistical significance of these dummy variables (Q1, Q2, and Q3 for each of the first three quarters).

---

26. Since there are four quarters in a year, we need only three dummy variables Q1, Q2, and Q3 with Qi = 1 during the i-th quarter, and Qi = 0 otherwise.

Table 5.1

t-test

	Quarter 1	Quarter 2	Quarter 3
NYC-PIT	-0.61	-0.33	1.38
NYC-MSP	-0.28	0.22	0.96
NYC-RDU	-1.16	0.53	0.76
SFO-LAS	-1.17	-0.79	-0.23
SFO-PHX	-0.45	-0.24	0.08
SFO-SAN	-0.32	-0.71	-0.81
WASH-ATL	0.61	-0.70	-1.28
WASH-ORD	-0.59	0.13	-0.19
WASH-RDU	-0.72	0.10	-0.47

These results indicate that accounting for seasonal patterns in our model is not necessary. This should not be a surprise since we are dealing with a market share model and not a demand model. Although there is hardly any doubt that seasonal patterns may explain some changes in terms of volume of traffic, the airports that we studied were probably affected somewhat similarly by the seasonal variations, and therefore, everything else being equal, their market shares remain unchanged.

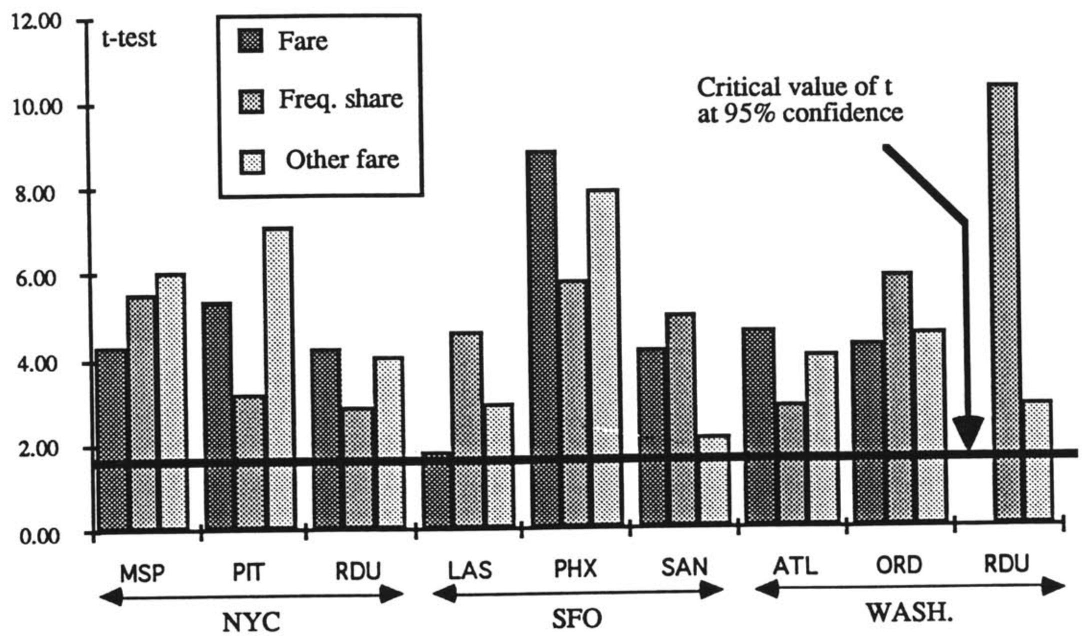
Such a result may be quite general in the U.S. domestic market, but may not hold if we consider multi-airport systems where one airport specializes in very seasonal routes. In other words, in a multi-airport system with no airport highly specialized in a very seasonal business, accounting for seasonal patterns is not justified in the airport market share model.

5.1.2 ELASTICITIES

The elasticities of market share with respect to time (frequency), fare (price), and fare at competing airports are illustrated and commented in the following paragraphs.

First, their statistical significance is illustrated in Figure 5.1 by using the t-test. Given the number of observations for each case studies (between 35 and 55) and the number of explanatory variables (from 3 to 5), the critical value of t with 95% confidence is approximately 1.70. In each case, we obtained higher values indicating statistical significance.

Figure 5.1

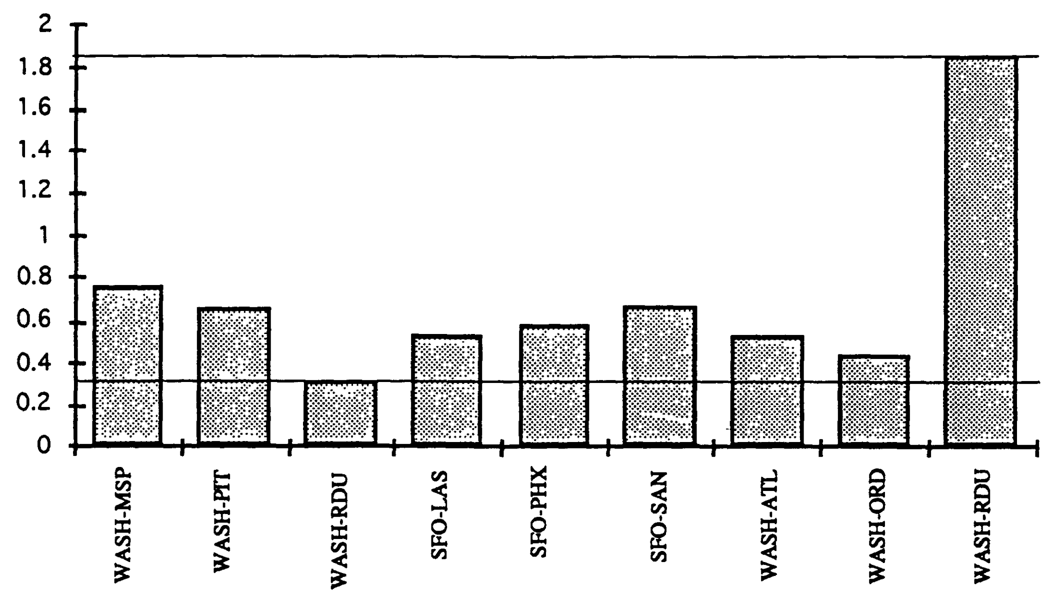


It is interesting to note that fare is not a statistically significant variable in the Washington-Baltimore/Raleigh-Durham market, whereas market share elasticity with respect to frequency share is relatively high: 1.85 (see Figure 5.2 & 5.3). A possible explanation may be that American Airlines opened up its hub in Raleigh-Durham in 1989, which increased the importance of frequency of service. In fact, American did boost its service but this was substantial only out of Baltimore, where its service jumped from nothing until 1990 to 21 flights a week in 1992. This increase in service was matched by United out of Dulles.

5.1.2.1 TIME (FREQUENCY) ELASTICITY

The time-elasticity varies between about 0.3 and 1.85. In most cases however, time sensitivity is inelastic (Figure 5.2).

Figure 5.2



These findings can be compared to an airport choice study carried out in the United Kingdom[27] [Ashford, 1989], according to which the direct elasticity of the frequency of service ranges from 0.07 to 0.13 (except for London Heathrow where the elasticity is 2.89) for leisure travel, and from 0.24 to 1.79 for business travel (Table 5.2).

Table 5.2

Direct Elasticity
FREQUENCY

	Manchester	*Birmingham*	*East Midlands*	*London Heathrow*
Leisure travel	0.07	0.08	0.13	2.89
Business travel	0.31	0.26	0.24	1.79

Source: N. Ashford, 1989.

27. Detailed results are given for the following airports: Manchester, Birmingham, East Midlands, and London Heathrow.

5.1.2.2 DIRECT FARE ELASTICITY

Depending on the case study, the direct fare elasticity ranges from about -0.98 to -0.29 (Figure 5.3). This means that in each case the relationship between airport market share and average fare at that airport is inelastic. As mentioned above, in one case, WASH-RDU, direct fare is not statistically significant.

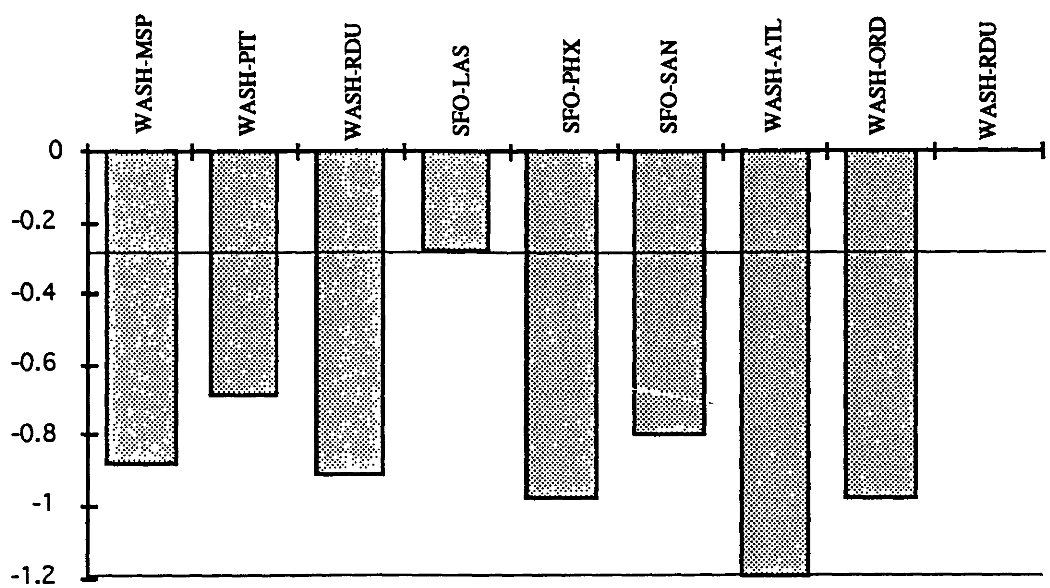


Figure 5.3

This should be compared to the findings of the British study mentioned above, according to which fare is not a significant attribute for business travelers, whereas fare elasticity ranges from -6.74 to -0.97 for leisure travel. Our results lie in between, suggesting a mix of business and leisure activity (Table 5.3).

Table 5.3

Direct Elasticity
FARE

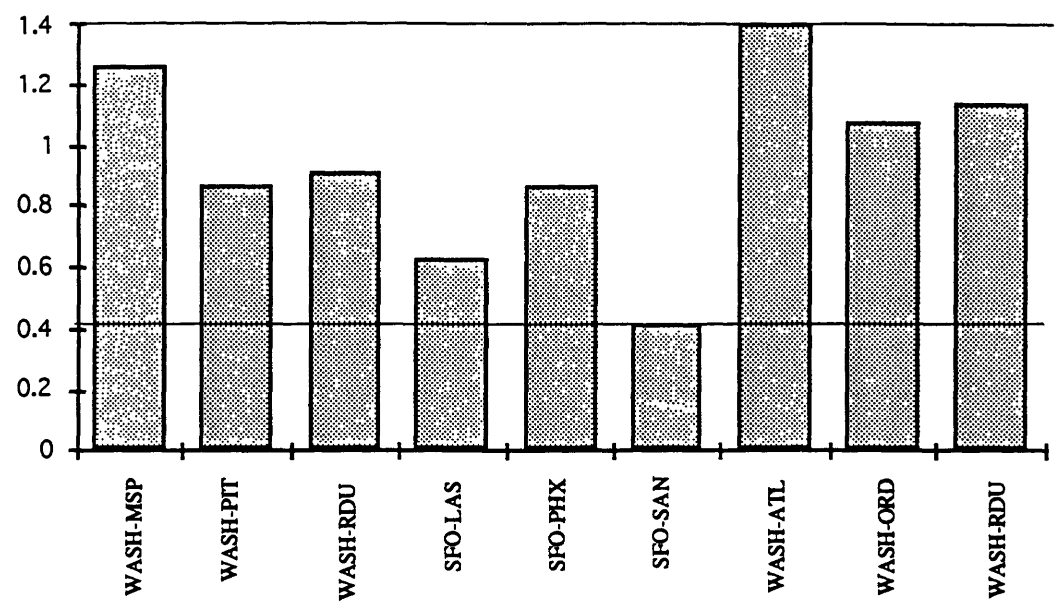
	Manchester	*Birmingham*	*East Midlands*	*London Heathrow*
Leisure travel	-0.97	-1.26	-4.25	-6.74

Source: N. Ashford, 1989.

5.1.2.3 CROSS FARE ELASTICITY

As illustrated in Figure 5.4, cross-price elasticities tend to be less than one although a few markets exhibit elasticities larger than one, which is somewhat surprising because corresponding direct fare elasticities tend to be smaller.

Figure 5.4



One explanation may be the following: Since we are considering M.A.Ss with three airports, cross price elasticities are a measure of the change in market share of passengers at one airport given a change in average fare at the other two airports. Assume for instance that the traffic is initially the same at the three airports (say n=1,000 passengers a day), and that the average fare at airport 1 and airport 2 increases by 10%. Assume also that 10% of the passengers using airports 1 and 2 decide to use airport 3 which now offers lower fares. Traffic at airports 1 and 2 decreases to 900 passengers a day, while traffic at airport 3 increases by 20% to reach 1,200. In terms of market share, we have now MS1 = MS2 = 30%, and MS3 = 40%. This means that the 10% increase in average fare at airports 1 and 2 leads to a 20% increase in airport 3's market share. From airport 3's perspective, the cross price elasticity is equal to 2, although the direct price elasticity at the other two airports was only equal to one. This may be an explanation for the relatively high cross price elasticities.

5.1.3 LIMITATIONS

Although the results generated by our model seem to provide a fairly good approximation of the reality at the O-D market level, we should be aware of some of its limitations. In its present formulation, the model is very simple[28], relies on very aggregated data, deals with frequency of service in a way that is not totally satisfactory, and seems to exhibit problems when we want to aggregate data across too many O-D markets.

First, the data that we used were not extremely disaggregated[29]. For instance, air travel patterns vary substantially between business travelers and leisure travelers. The predictive value of the model would probably gain from distinguishing between such passenger groups. As far as the model is concerned, using fare and traffic data for different groups of passengers would pose no particular difficulty. However, in general, data are simply not available.

Second, the model depends directly on fares and frequencies only. Clearly, this is a very simplistic description of the reality and many other variables have an influence on airport market shares. Access time to airport -- which influences passengers' decisions differently depending on their originating point and their assessment of the value of time -- was not explicitly accounted for. Ideally, we would like to use passenger data (e.g. at the county level) and estimate, for each market, the number of passengers originating from any county, as well as the

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[28]. This is not, in itself, a limitation of the model.

[29]. In general -- and this is not specific of the airline industry -- the availability of consistent, reliable, relatively disaggregated historical data turns out to be a real problem that has the potential to cast a doubt on the validity of some studies.

average access time from each county. Once again, this cannot be done systematically and depends on the availability of data on a case by case basis. In the case of a specific study of a multi-airport system, decision-makers should carefully assess the cost and value of collecting new data that are not readily available. Undertaking a survey should provide them with useful information but is also costly in both time and money, and a careful trade off will be required.

Third, although statistical results were fairly good for each of our case studies, the model seems to work well when the number of competitors is small (typically 3 or 4). One of the possible explanation for this phenomenon is that the explanatory value of the equivalent frequency decreases with the number of airlines. However, this is probably not a critical flaw given the concentration of the US domestic market.

Fourth, the way our model deals with frequency is not entirely satisfactory. The equivalent frequency of service (e.f.s) is computed by using a model which is difficult to validate. Furthermore, e.f.s. is not endogenous and depends on parameters that must be calculated on the basis of a somewhat arbitrary criterion (i.e. improving the explanatory value of the model) and the saturation effect is not explicitly incorporated.

Finally, the predictive value of the model diminishes as we aggregate O-D markets. This is hardly a surprise for a variety of reasons, the most obvious of which being that each O-D market should be considered as a different market. This means for example that passenger behavior may change from one market to another (since passengers are different). A market such as New York-Boston is dominated by business travelers for whom frequency of service is the most important criterion, whereas a market such as New York-Orlando may be dominated by more price sensitive leisure travelers. Also, the length of haul should be accounted for since total travel time, and air travelers' sensitivity to frequency of service depend on it.

To improve the statistical predictive value of the model, accounting for these differences across markets would probably be required. A possible improvement could be achieved by differentiating markets such as business and leisure markets by using different price and time elasticities.

5.2 IMPLICATIONS

5.2.1 GENERAL CONSIDERATIONS

Although individual decision makers attach different weight to different attributes [Alamdari and Black, 1992], our model indicates that fare and frequency of service have a high statistical significance in explaining the attractiveness of an airport in a multi-airport system at the O-D market level.

Other studies found that ground access is also an important reason for airport selection [Harvey, 1987]. However, being relatively stable over short periods of time, this attribute is not, by itself, critical in explaining the dynamics of airport market shares.

This suggests that the dynamics of airport market shares is more likely to be influenced by market forces than by a mere distribution of traffic according to each airport's catchment area [de Neufville, 1984]. As a direct result, it makes economic sense for smaller ("secondary") airports to specialize. Indeed, most often, they cannot expect to compete head-to-head with their larger counterparts on attributes such as frequency of service and a substantial price advantage is by no means guaranteed[30]. Differentiation provides smaller airports with a way to avoid direct competition and take advantage of their competitive advantages.

[30]. This is all the more true that "...the more congested, crowded and uncomfortable an airport the more likely it is to be highly profitable." [Doganis, 1992]. Airports -- more than airlines -- benefit from economies of scale, one reason being that unit cost per passenger decreases when the annual number of passengers increases.

Examples of such strategies are illustrated in Table 5.4.

Table 5.4

EXAMPLES OF AIRPORT DIFFERENTIATION

Metropolitan Region	Airports	Ratio (terminal passengers)(*)	Specialization
New York	Kennedy	100	Transcontinental; bulk cargo
	La Guardia	77	Medium-short haul
	Newark	75	cheap fares; express cargo
Los Angeles	International	100	Domestic, international business
	Ontario	12	California; express cargo
	Burbank	n.a.	California
London	Heathrow	100	Domestic, international business
	Gatwick	49	Charters
	Luton	6	Charters
Tokyo	Haneda	100	Domestic
	Narita	48	International
Paris	Orly	100	Southern; cheap fares
	Charles de Gaulle	93	Northern; East-West
Miami	International	100	Business; International; cargo
	Fort Lauderdale	n.a.	Holiday
San Francisco	International	100	Business; international
	San Jose	22	California; commuter
	Oakland	n.a.	Cheap fares
Washington	National	100	Short-haul, cheap fares
	Baltimore	65	Long-haul, cheap fares
	Dulles	65	Long-haul
Dallas	Dallas-Ft Worth	100	Hub operations (American)
	Love Field	12	Short-haul
Houston	Intercontinental	100	Hub operations (American)
	Hobby	46	Short-haul

(*). 1990 data, except San Francisco (1989)

n.a. : not available

Source: Aéroports de Paris (traffic); de Neufville, 1986 (Specialization).

5.2.2 IMPLICATIONS FOR THE CONSTRUCTION OF NEW AIRPORTS IN METROPOLITAN AREAS

In 1990, an expert committee assembled by the Transportation Research Board (TRB) at the request of FAA formulated various strategies with respect to long-term capacity needs [TRB, 1990]. One strategy envisaged consists in adding new airports in metropolitan areas with high traffic volume.

This option deserves consideration since:

- Most airports with severe congestion are in large metropolitan areas which constitute major economic centers.
- Airlines tend to favor hubs in these large cities because they constitute the origins and destinations of most air travelers.
- The impact of adding new facilities in such metropolitan areas would depend on how well the new multi-airport systems function.

A 1988 survey by the TRB Airport Network Study Panel identified 13 locations with high potential for major expansion of an existing site or conversion of a secondary site, and 27 others with medium potential. Assuming the construction of major airports capable of handling 900,000 operations annually, the capacity available in the ten major population centers[31] would almost double.

This strategy is attractive in the sense that it would provide, at least in theory, large capacity gains at precisely the points of highest traffic concentration. However, as recognized by TRB, the workability of this option is questionable because new airports might remain underused for long periods of time. Moreover, this option presents strong disadvantages with respect to several

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31. Chicago (ORD, MDW), Atlanta (ATL), Los Angeles (LAX, SNA, LGB), Dallas-Ft Worth (DFW), Denver (DVX), New York (JFK, LGA, EWR), San Francisco (SFO, OAK, SJC), Miami (MIA), Phoenix-Tucson (PHX, TUS), and Boston (BOS).

criteria such as capital cost, environmental effects, funding and financing, and implementation.

A related option would be to develop new hubs at presently underused airports. This options is motivated by the fact that 28 airports have been identified by FAA as having both underused capacity and the potential to relieve some of the congested airports [TRB, 1990]. Once again, there is substantial uncertainty concerning how effective this option would be. Ultimately, this would depend on the strategic assessment made by each airline regarding the decision to "re-hub".

5.2.3 IMPLICATIONS FOR REGIONAL AIRPORTS

Regional airports have been considered as a possible source of relief to reduce airways and airport congestion. It seems very tempting indeed to increase the activity of underused regional airports ("satellite" airports) located within reasonable distance of larger, congested facilities. According to FAA forecasts, each of the major airports that are predicted to be congested by 1997 are surrounded by at least one -- sometimes two or more -- airport within 50 miles that is underused[32]. Although some investments would be required, these satellite airports have adequate runways for commercial air services.

For regional airports to increase their share of the total market, they will have to gain the support of several constituencies.

Air travelers

First, regional airports must persuade passengers and carriers to change their travel and network patterns. To this end, the role of fares and frequency of service should be emphasized. We know that reducing fares and/or increasing frequency of service (relative to competing service at the main metropolitan airport) should increase an airport market share. By nature, regional airports tend to be at a disadvantage with respect to their ability to provide high frequencies. However, they should persuade airlines to offer flights at convenient times (at least an early morning departure and an evening return.) Regional airports should also be extremely competitive in terms of fares and rates. This competitive advantage should be aggressively advertised.

Other measures include the improvement (if necessary) of the ground access, the parking space, and the links to the business center of the region.

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32. See Transportation Research Board (1991).

Regional airports should also differentiate themselves by advertising to both carriers and travelers the relative absence of congestion and delays. Often, *"satellite airports (...) lack the lounges, food concessions, and modern architecture of world-class airports, and may offer non-stop service to only a few points. But savvy travelers are using them with growing frequency to sidestep the ground traffic, flight delays, and hassle of sprawling megaterminals."* (Ellis, 1990).

For travelers, convenience and time gain advantage can make satellite airports attractive. For example, small terminals mean shorter walks from the parking lot to the ticket counter, and to the gate. At Bristol, England, the long-term car park offers no more than a five-minute walk back to the terminal. As noted by Frank Barrett (1990), *"the terminals are usually very quiet and uncrowded. The aircraft used are relatively small, so after a plane has landed, passenger baggage is speedily taken to the arrivals hall, where it quickly appears to the carousel."*

As a result, and as illustrated in the table below, business travelers may find it wise to choose a satellite airport, especially in metropolitan regions as large as New York, Chicago, Los Angeles and San Francisco (Table 5.5).

Table 5.5

WHEN A 'SATELLITE' AIRPORT MAY BE JUST THE TICKET

Use ...	On ...	... To be near
FOR NEW YORK		
• Westchester/White Plains	Northwest,United, USAir	IBM, PepsiCo, TWA, GTE, Xerox
• Macarthur/Islip	American, USAir, United	Grumman, the Hamptons
• Stewart/Newburgh	American	West Point; Danbury, Conn.
FOR CHICAGO		
• Midway	TWA, United, Midway, USAir, Northwest, Southwest	Downton Chicago, Northern Indiana, U. of Chicago
FOR SAN FRANCISCO		
• Oakland International	Alaska, America West, USAir, American, Delta, Southwest, United	Safeway Stores, Cetus, Kaiser Aluminum&Chemical
• San Jose International	Alaska, America West, USAir, American, Delta, Northwest, Cont'l, TWA, United	Apple, Hewlett-Packard, Intel, Silicon Valley
FOR LOS ANGELES		
• Burbank/Glendale/Pasadena	Alaska, America West, Delta, Southwest, TWA, United, USAir	Lockheed, movie companies
• Ontario International	Alaska, America W., American, Continental, Northwest, Delta, TWA, United, USAir	Eastern L.A. suburbs, Palm Spring
• Orange County	same as above	Irvine Co., AST Research, Fluor, Disneyland, Newport Bch.

Source: Business Week/July 16, 1990

Carriers

Satellite airports need to persuade airlines that increasing their flights make economic sense. They should be ready to provide traffic analyses, economic development plans for the service area, and attractive rates and an lease offer[33].

33. See "The Regional Airports: Their Emerging Role in Relation to the Capacity Shortage at Logan and the Prospect of a Second Major Airport" Second Draft. Report to The Regional Airports Sub-Committee of the New England Council. January, 1991.

Local community

More often than not, the local community may not support an increase in airport activity. This is quite understandable for people leaving in the neighborhood of an airport to fight what is perceived as a potential increase in the level of noise and pollution. For the airport management, this means that economic and environmental impact studies showing the benefit of a more active airport should be prepared. New jobs would be created, and noise abatement procedures making airports quieter and growth more acceptable should be implemented and advertised.

By adopting an appropriate strategy, we believe that airport can significantly increase their activity. However, market forces tend to concentrate traffic activity at a limited number of points (hubs) and do not distribute traffic evenly across regions. As already suggested in previous studies [Gelerman and de Neufville, 1973], there is a doubt that regional airports will be able to play a significant role in air transportation. More likely is a scenario in which most of the growth at regional airports will come from created traffic, and not from traffic diversion relieving the primary airport.

APPENDIX 1

TRAFFIC AT DIFFERENT MULTI-AIRPORT SYSTEMS WORLDWIDE

TERMINAL PASSENGERS (in million)

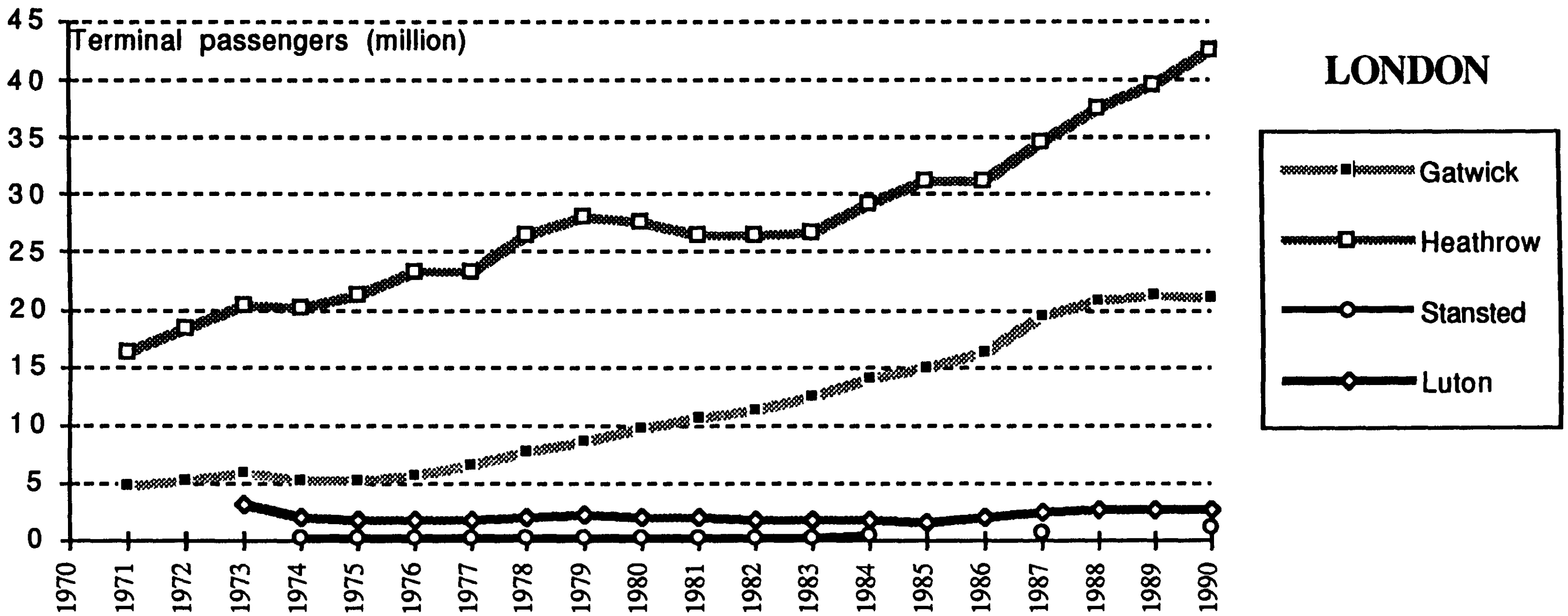
	• PARIS			• STOCKHOLM		• LONDON				• MILAN		• TOKYO		• MONTREAL		• CHICAGO	
	Le Bourget	Orly	CDG	Arlanda	Broma	Gatwick	Heathrow	Stansted	Luton	Linate	Malpensa	Haneda	Narita	Dorval	Mirabel	O'Hare	Midway
1970																	
1971	2.4	10.9		2.9	0.8	4.7	16.2			3.4	0.6	10.8		4.9		29.8	1.9
1972	2.5	13.1		3.2	0.8	5.3	18.3			3.4	0.7	12.2		5.5		33.1	1.7
1973	2.7	13.9		3.3	0.8	5.8	20.3		3.2	3.8	0.9	15.5		6.5		35.5	1.6
1974	1.7	12.7	2.5	3.4	0.9	5.1	20.1	0.2	2.0	4.1	0.8	17.2		7.0		37.9	0.8
1975	1.5	10.6	6.0	3.7	0.8	5.3	21.3	0.2	1.9	4.0	0.8			6.7	0.1	37.0	0.6
1976	1.5	10.7	7.5	3.8	1.0	5.7	23.2	0.3	1.8	4.2	0.8	19.4		5.5	1.5	41.4	0.5
1977	0.5	12.6	8.4	4.0	1.0	6.6	23.4	0.3	1.9	4.8	0.9			5.6	1.5	43.6	
1978	0.3	13.7	9.0	4.4	1.2	7.8	26.5	0.3	2.1	4.8	0.9			5.8	1.5	47.4	0.7
1979	0.2	14.5	9.8	4.7	1.8	8.7	28.0	0.3	2.2	4.9	1.0	20.5	8.1	6.4	1.6	47.8	0.9
1980	0.3	15.7	10.1	4.3	1.9	9.7	27.5	0.3	2.1	5.3	1.0	20.7	8.2	6.6	1.5	43.7	1.3
1981	0.0	17.0	10.9	4.6	2.1	10.7	26.4	0.3	2.0	5.6	0.9	22.1	7.4	6.5	1.3	38.0	
1982	0.0	16.1	12.9	4.9		11.2	26.4	0.3	1.8	4.9	1.8	21.8	7.7	5.7	1.2	37.7	2.1
1983	0.0	16.3	13.4	5.7		12.5	26.7	0.3	1.7	6.0	1.1	22.9	8.2	5.4	1.3	42.9	2.3
1984	0.0	17.2	13.6	8.6		14.0	29.1	0.5	1.8	6.2	1.2	26.4	8.9	5.8	1.5	45.7	2.7
1985	0.0	17.7	14.6	9.1		14.9	31.3		1.6	6.6	1.3	27.2	11.7	5.7	1.7	48.5	
1986		18.5	14.4	10.6		16.3	31.3		2.0	7.4	1.2	27.2	10.0	5.7	1.9	53.3	3.7
1987		20.4	16.0	11.9		19.4	34.7	0.7	2.6	8.4	1.3		12.0	5.8	2.0	56.3	
1988		22.2	17.9	13.1		20.7	37.5		2.8	8.6	1.6	32.2	14.7	5.7	2.1	56.8	
1989		24.1	20.3	14.1		21.2	39.6		2.8	8.5	1.8	36.6	17.0	5.2	2.3	59.1	
1990		24.3	22.5	14.8		21.0	42.6	1.2	2.7			40.2	19.3	5.0	2.4	59.9	8.5

Sources: Aéroports de Paris; Port Authority of New York and New Jersey; ICAO; Airport Forum (various issues)
Note: Several data (usually concerning secondary airports) were non available.

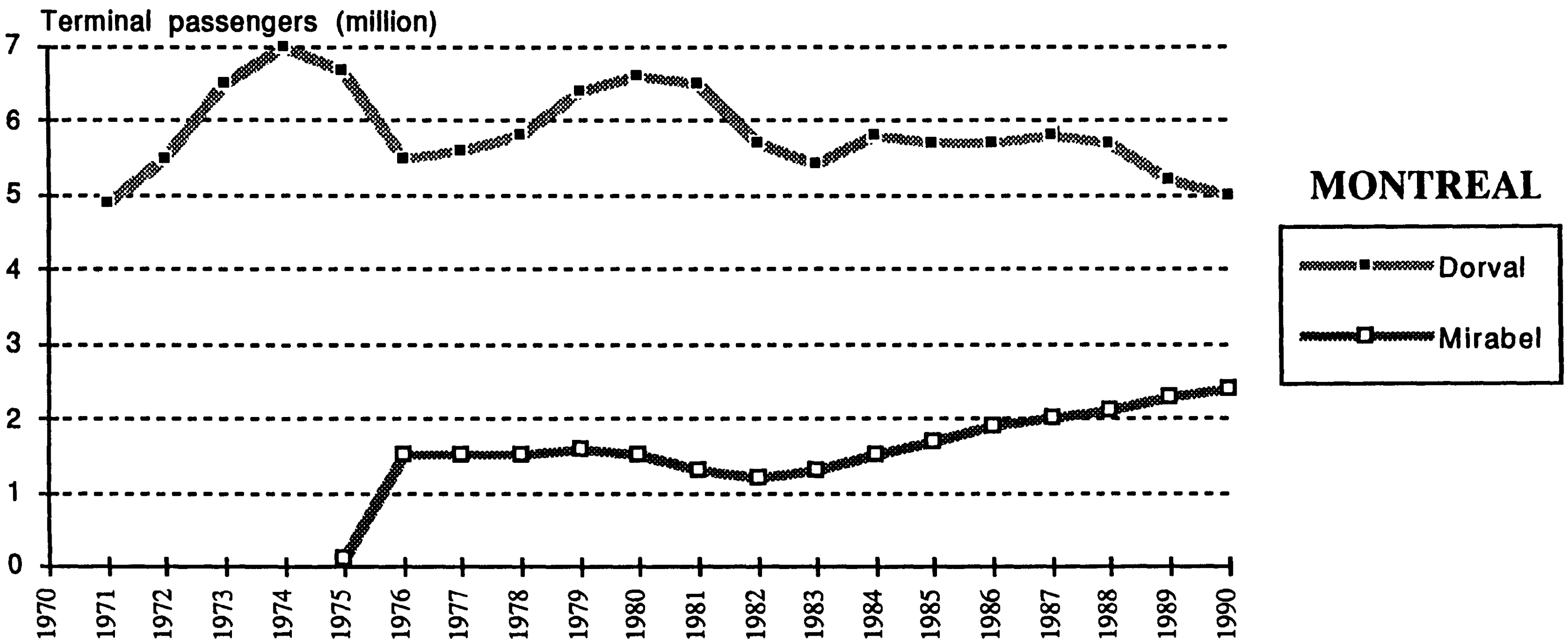
TERMINAL PASSENGERS (in million)

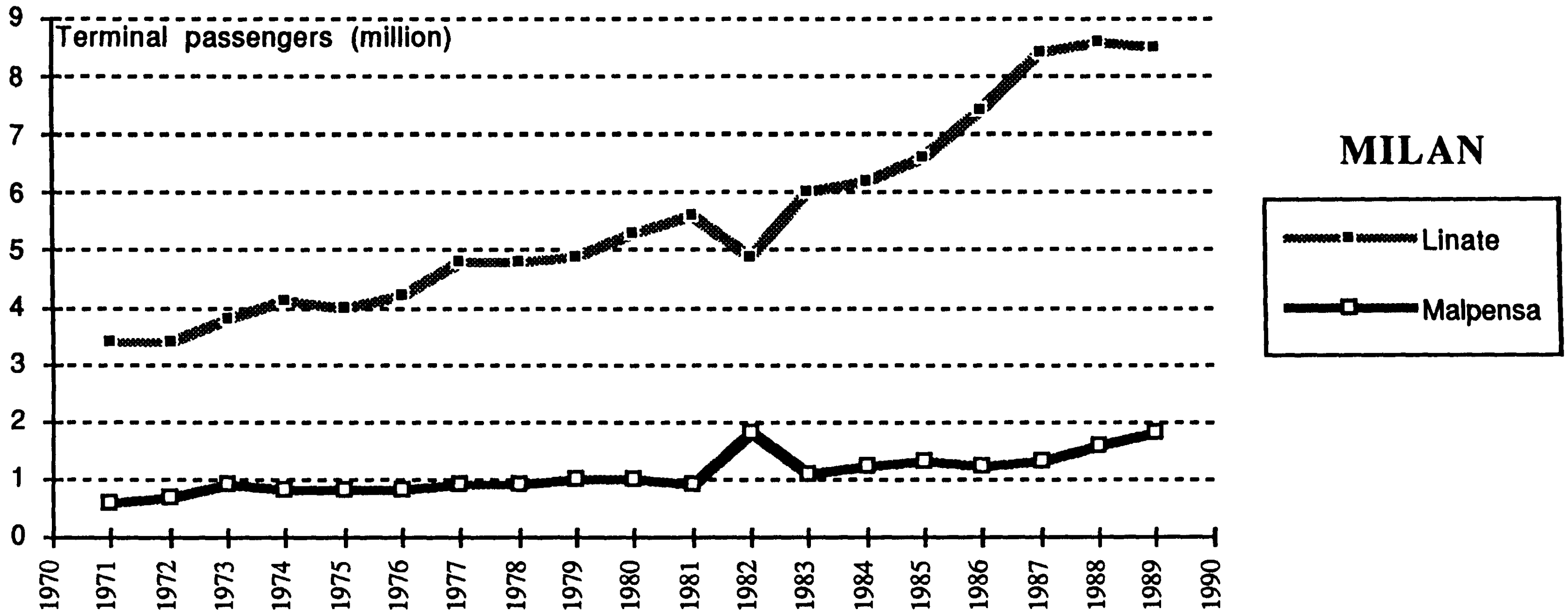
	• DALLAS		• HOUSTON		• NEW YORK			• WASHINGTON			• SAN FRANCISCO			• LOS ANGELES	
	L. Field	DFW	Hobby	Intercont'l	LGA	JFK	Newark	Dulles	National	Baltimore	Int'l	San Jose	Oakland	Int'l	Ontario
1970					11.8	19.1	6.5								
1971	5.2		0.0	4.8	12.7	19.2	6.1	2.0	10.0	2.8	14.1		2.1	20.3	
1972	5.8		0.3	5.2	14.2	20.7	6.8	2.3	10.7	2.9	15.5		2.1	22.1	
1973	6.7		0.6	5.4	14.0	21.4	6.8	2.5	11.2	3.0	16.6	2.0	2.2	23.5	
1974	1.4	6.8	0.7	5.9	13.7	20.2	6.5	2.4	11.2	2.8	17.4	2.1	2.3	23.6	
1975	0.9	14.7	0.8	6.1	13.2	19.5	6.3	2.4	10.8	2.8	16.4	2.3		23.7	1.1
1976	1.2	16.0	1.1	6.8	14.1	20.0	6.8	2.7	11.7	3.0	17.6	2.7		26.0	1.3
1977	1.7	17.3	1.6	8.0	15.1	22.5	7.3	2.7	12.6	3.2	20.2	3.1		28.4	1.7
1978	2.5	19.8	1.9	9.7	17.1	24.8	8.5	3.0	13.5	3.6	21.5	3.4		32.9	2.0
1979	3.5	22.6	2.7	10.9	18.4	27.0	9.3	3.3	14.9	3.8	23.1	3.6		34.9	2.4
1980		21.6	3.3	10.7	17.5	26.8	9.2	2.5	14.3	3.8	21.3	2.9		33.0	2.0
1981	4.4	23.6	4.0	11.6	18.1	25.8	10.2	2.2	13.9	3.8	19.8	2.8		32.7	1.8
1982	5.2	24.8	4.7	12.5	18.5	26.5	11.7	2.6	13.3	4.6	21.0	3.1		32.4	2.0
1983	6.4	26.9	5.1	13.0	18.8	27.9	17.4	3.0	14.5	5.2	23.2	3.6		33.4	2.5
1984		32.3	7.1	12.8	20.3	29.9	23.7	3.6	14.8	6.7	24.2	3.9		34.4	3.1
1985		37.1			20.5	28.9	28.6	5.1		8.2	24.9			37.6	
1986	5.5	39.9	7.5	14.0	22.2	27.2	29.4	8.8	14.3	8.7	27.8	5.7		41.4	
1987		41.9			24.2	30.2	23.4	10.8		9.1	29.8			44.9	
1988		44.2			24.2	31.2	22.5	9.5		9.9	30.5	5.7		44.4	
1989		47.6		16.1	23.2	30.3	20.9	10.2	15.1	10.4	29.9	6.7		45.0	
1990	5.7	48.5	8.1	17.6	22.8	29.8	22.3	10.2	15.6	10.2	31.1			45.8	5.4

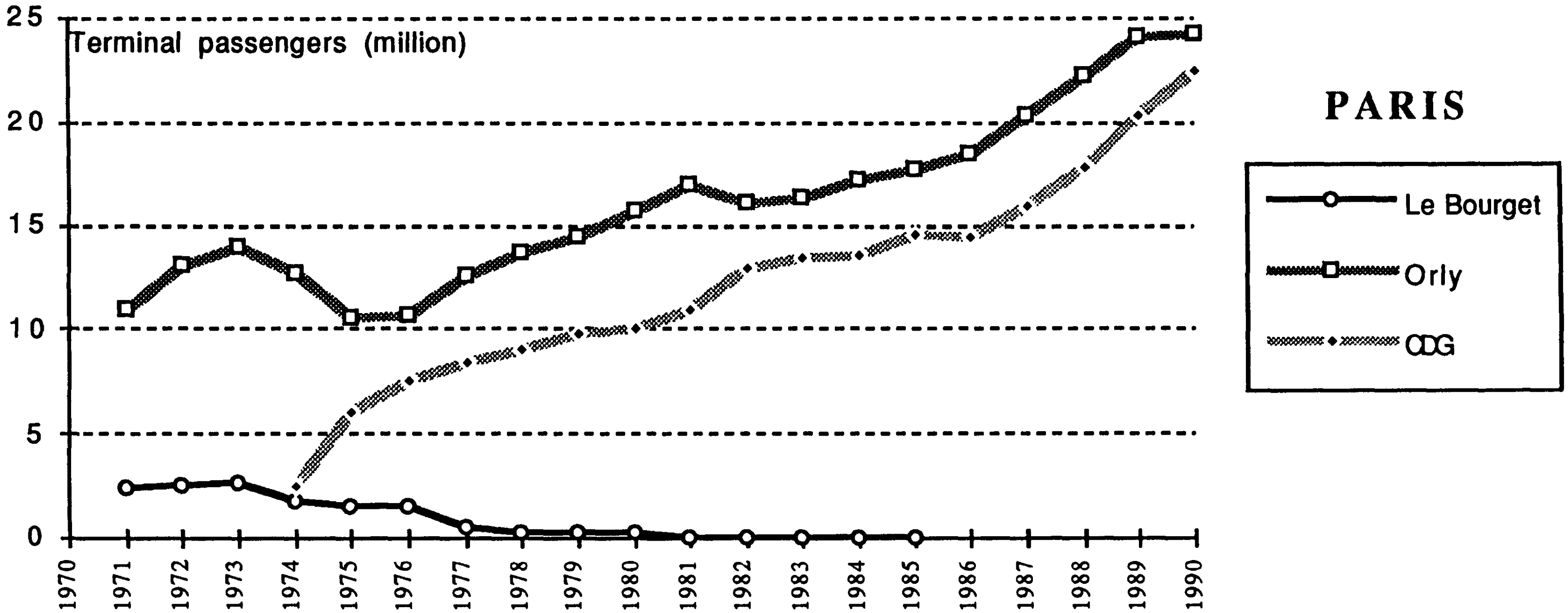
Sources: Aéroports de Paris; Port Authority of New York and New Jersey; ICAO; Airport Forum (various issues)
Note: Several data (usually concerning secondary airports) were non available.



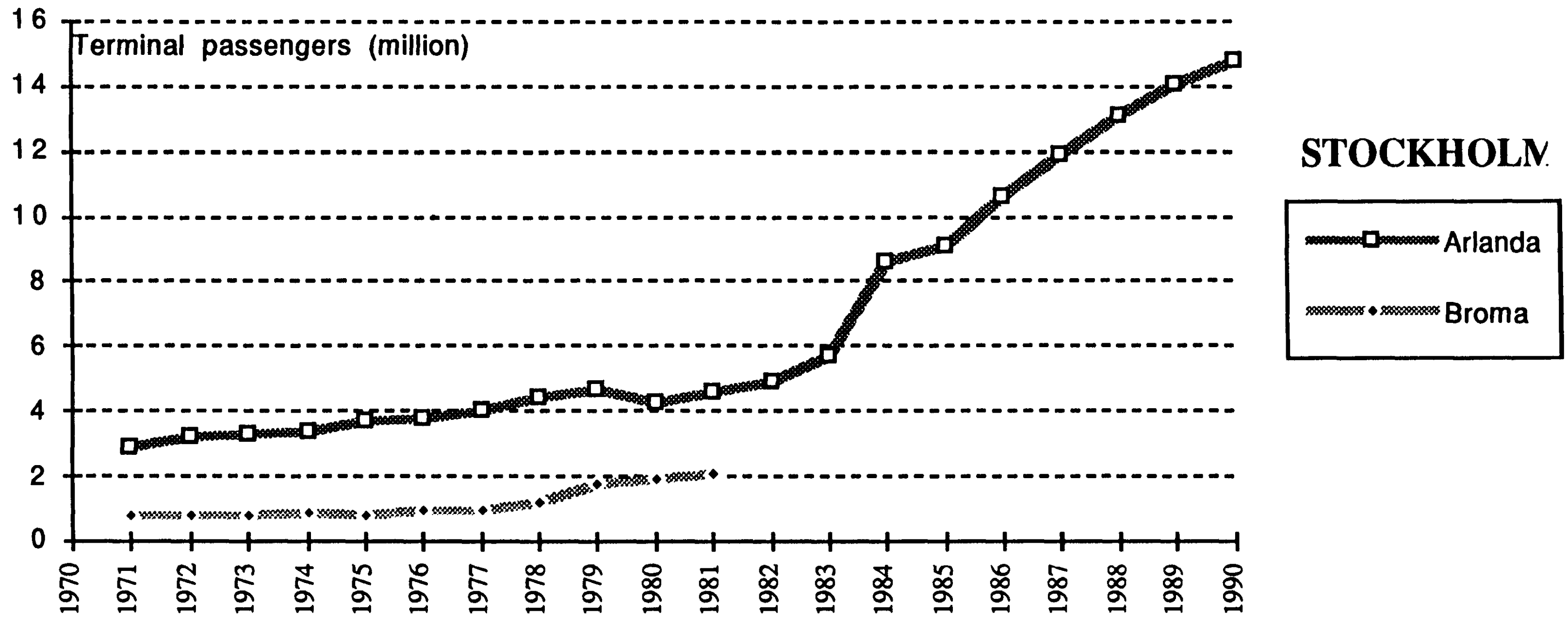
Terminal passengers (million)
LONDON
Gatwick
Heathrow
Stansted
Luton
45
40
35
30
25
20
15
10
5
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

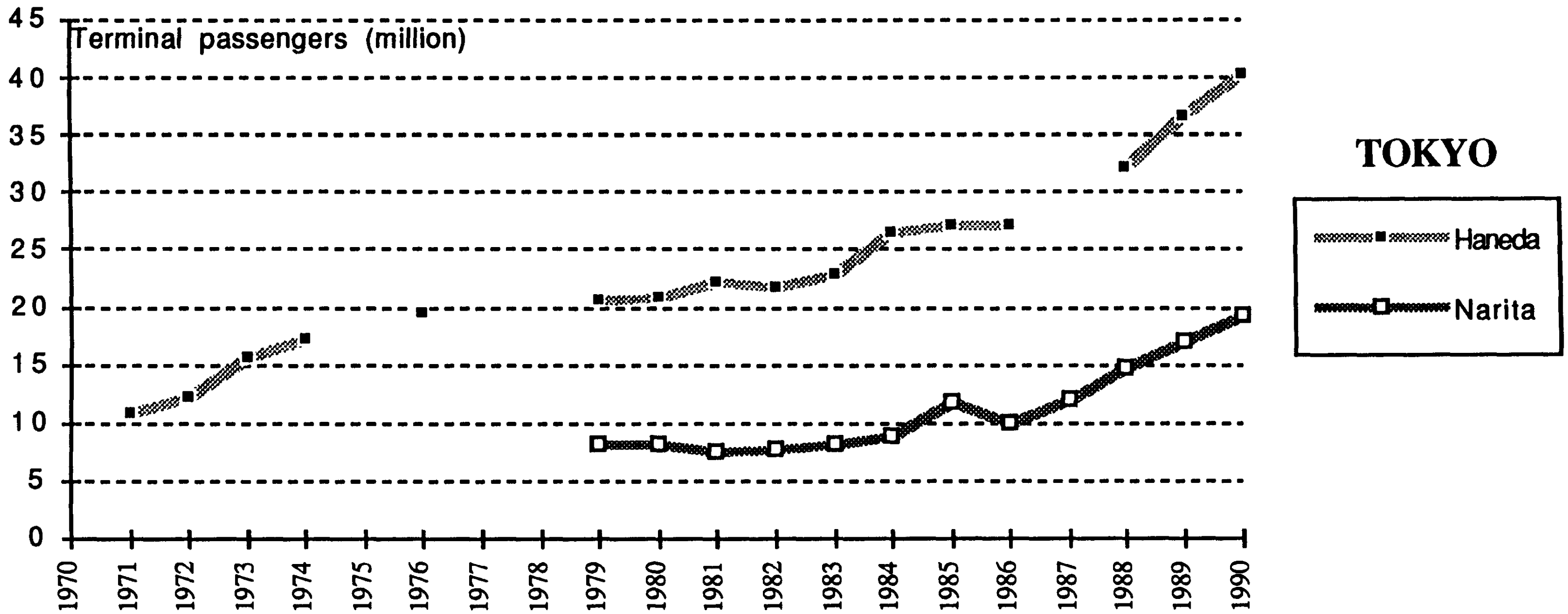

Terminal passengers (million)
7
6
5
4
3
2
1
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
MONTREAL
Dorval
Mirabel

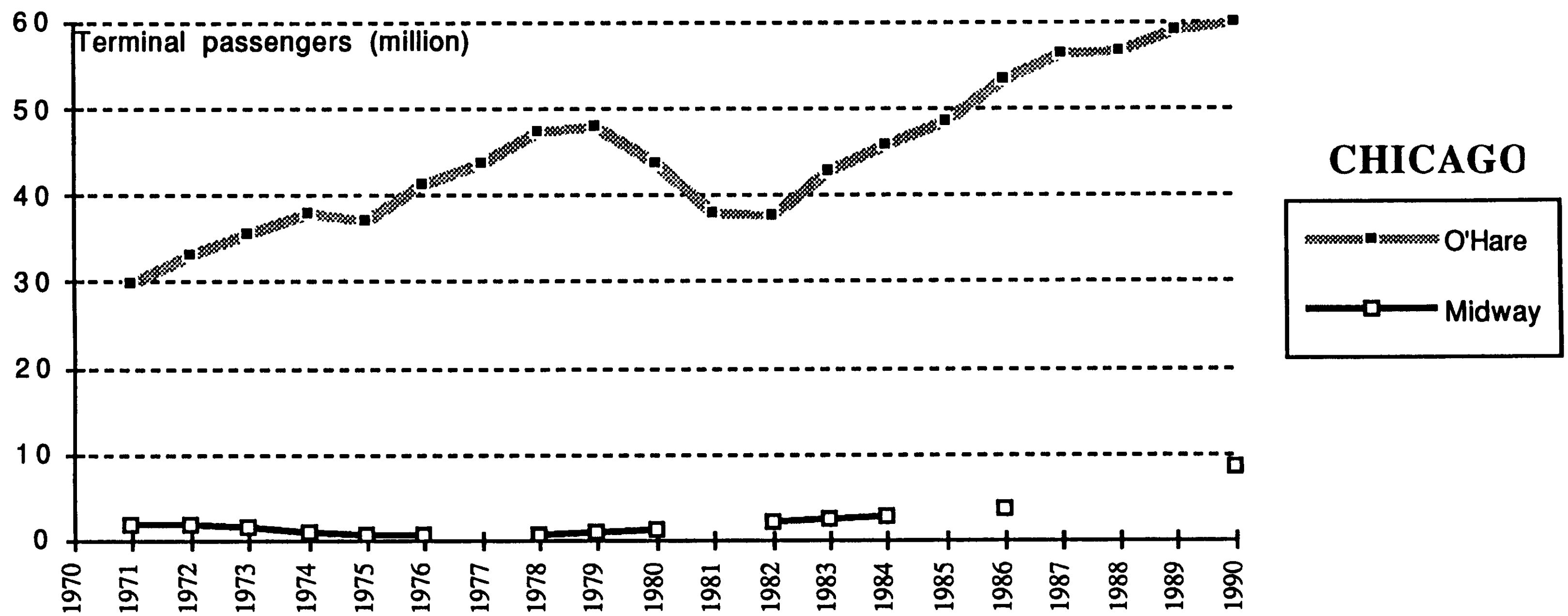

MILAN
Terminal passengers (million)
0
1
2
3
4
5
6
7
8
9
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Linate
Malpensa

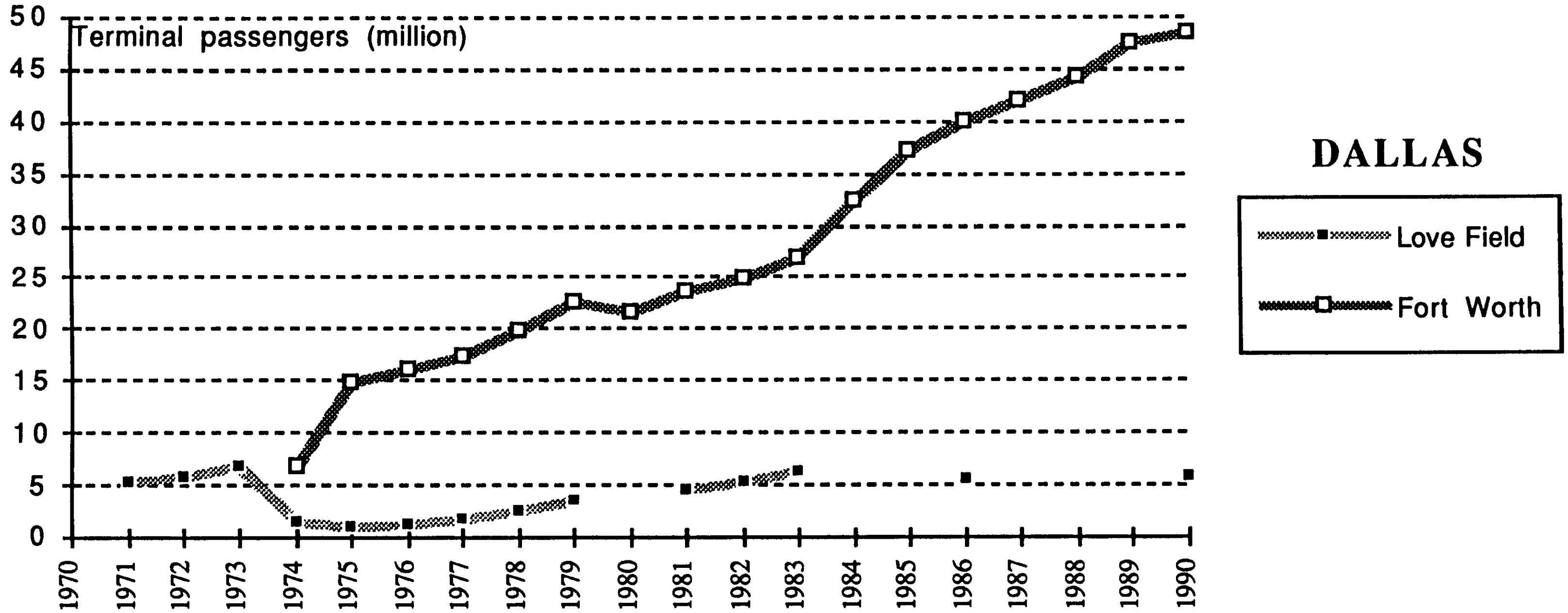


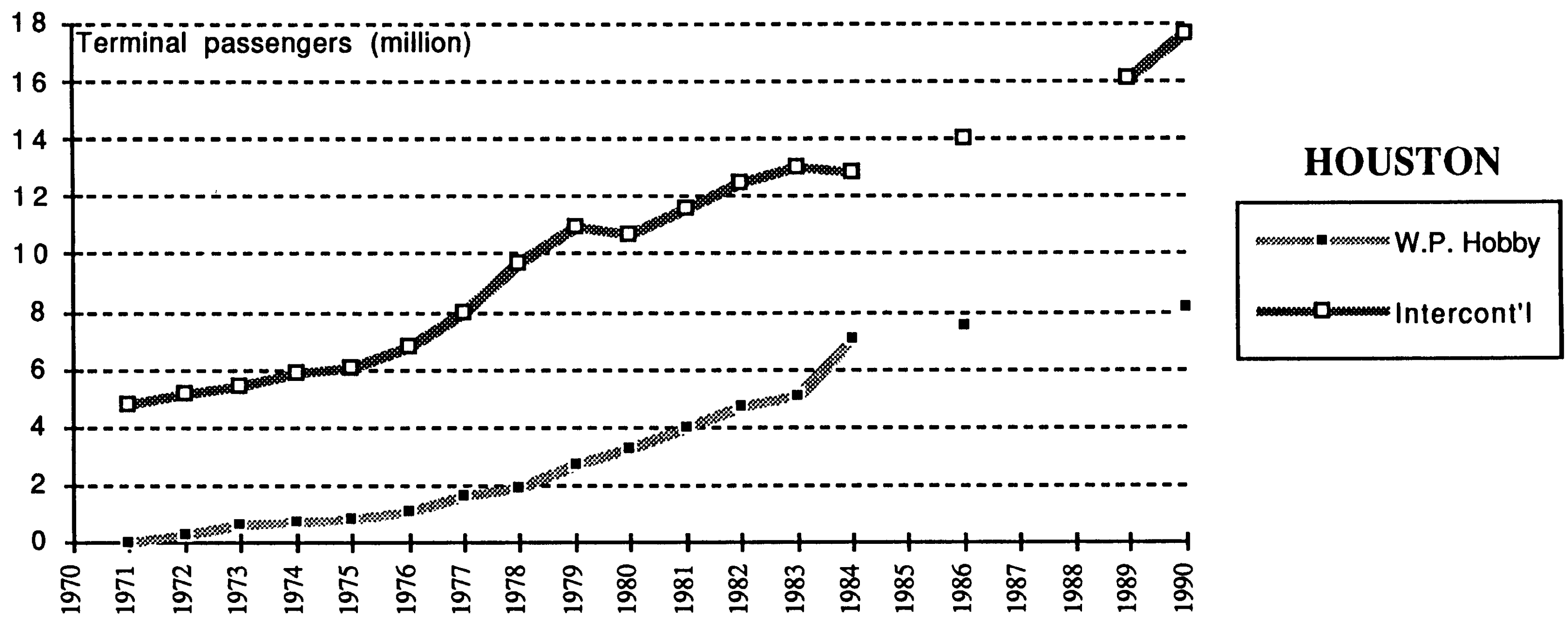
Terminal passengers (million)
PARIS
Le Bourget
Orly
CDG
25
20
15
10
5
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

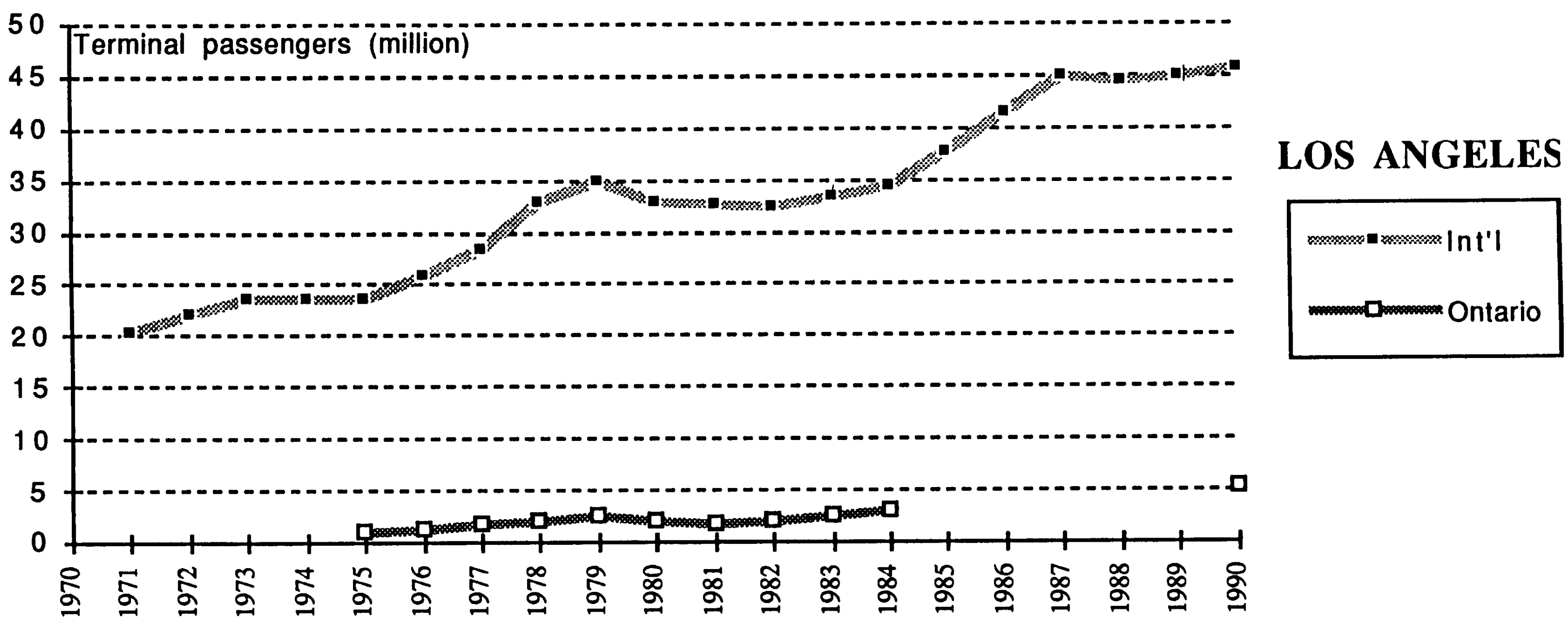

Terminal passengers (million)
16
14
12
10
8
6
4
2
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
STOCKHOLM
Arlanda
Broma

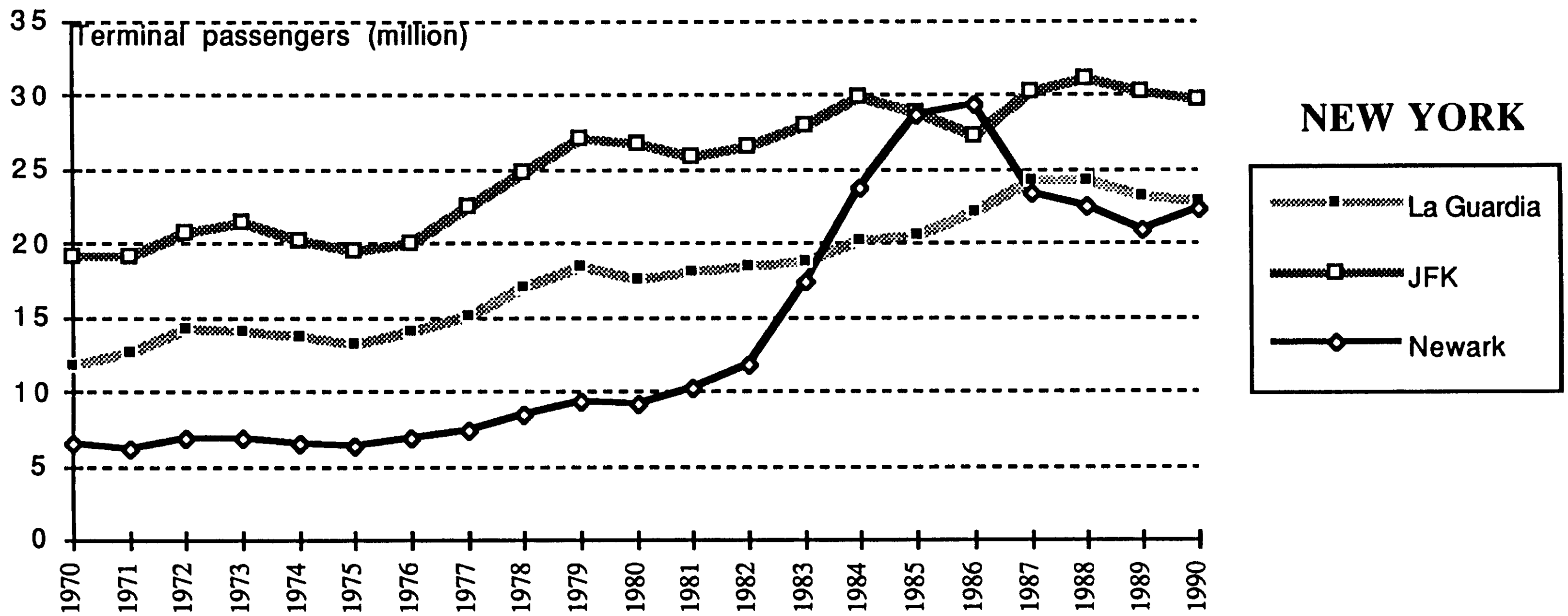

TOKYO
Terminal passengers (million)
Haneda
Narita
0
5
10
15
20
25
30
35
40
45
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990


CHICAGO
Terminal passengers (million)
O'Hare
Midway
0
10
20
30
40
50
60
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

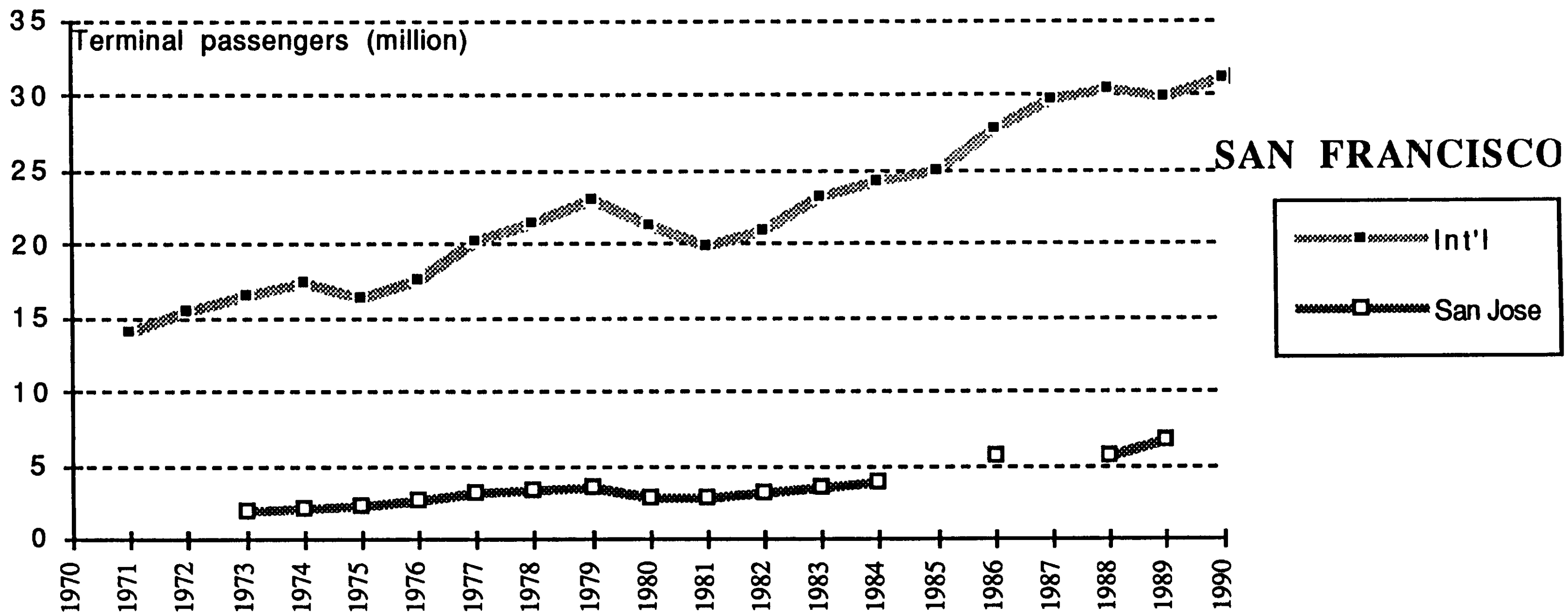

DALLAS
Terminal passengers (million)
Love Field
Fort Worth
0
5
10
15
20
25
30
35
40
45
50
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990


HOUSTON
Terminal passengers (million)
W.P. Hobby
Intercont'l
18
16
14
12
10
8
6
4
2
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

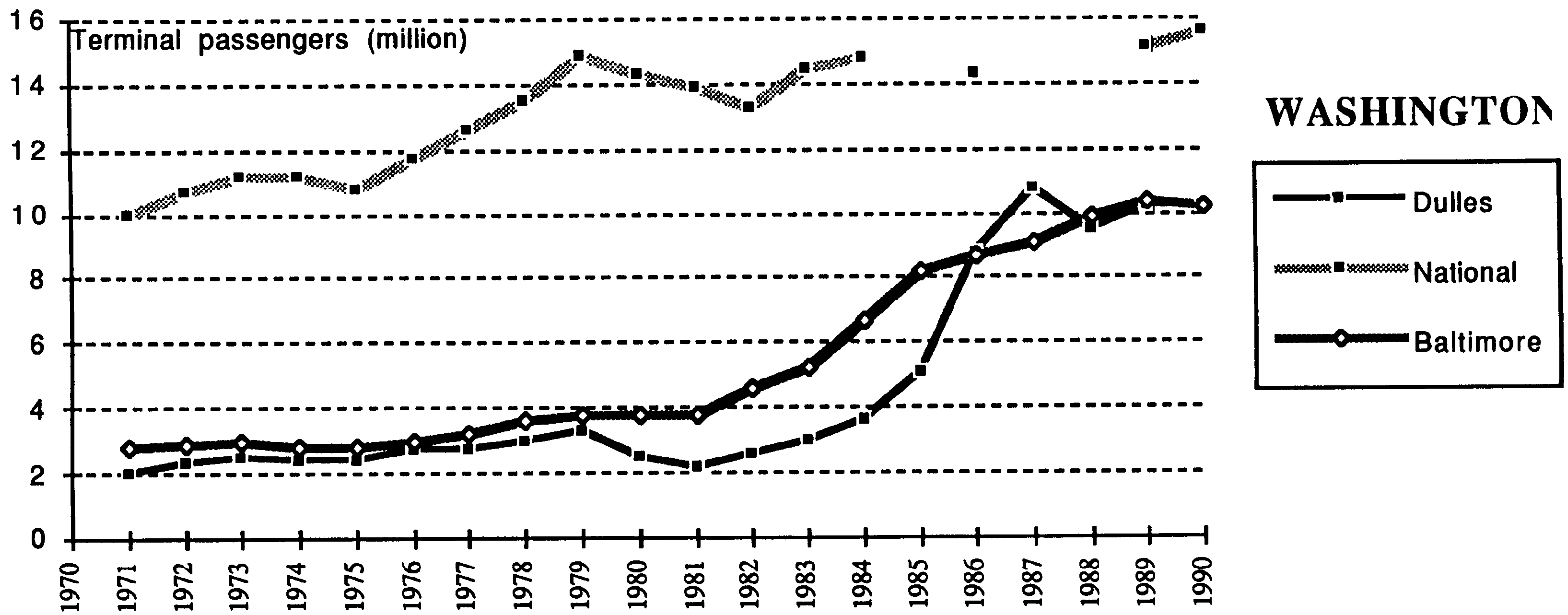

LOS ANGELES
Terminal passengers (million)
50
45
40
35
30
25
20
15
10
5
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Int'l
Ontario



Terminal passengers (million)
35
30
25
20
15
10
5
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
NEW YORK
La Guardia
JFK
Newark



Terminal passengers (million)
35
30
25
20
15
10
5
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
SAN FRANCISCO
Int'l
San Jose


Terminal passengers (million)
WASHINGTON
Dulles
National
Baltimore
16
14
12
10
8
6
4
2
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

APPENDIX 2

RESULTS

NYC (EWR, LGA, JFK) - MSP

Regression Statistics

Multiple R	0.99
R Square	0.98
Adjusted R Square	0.97
Standard Error	0.19
Observations	42

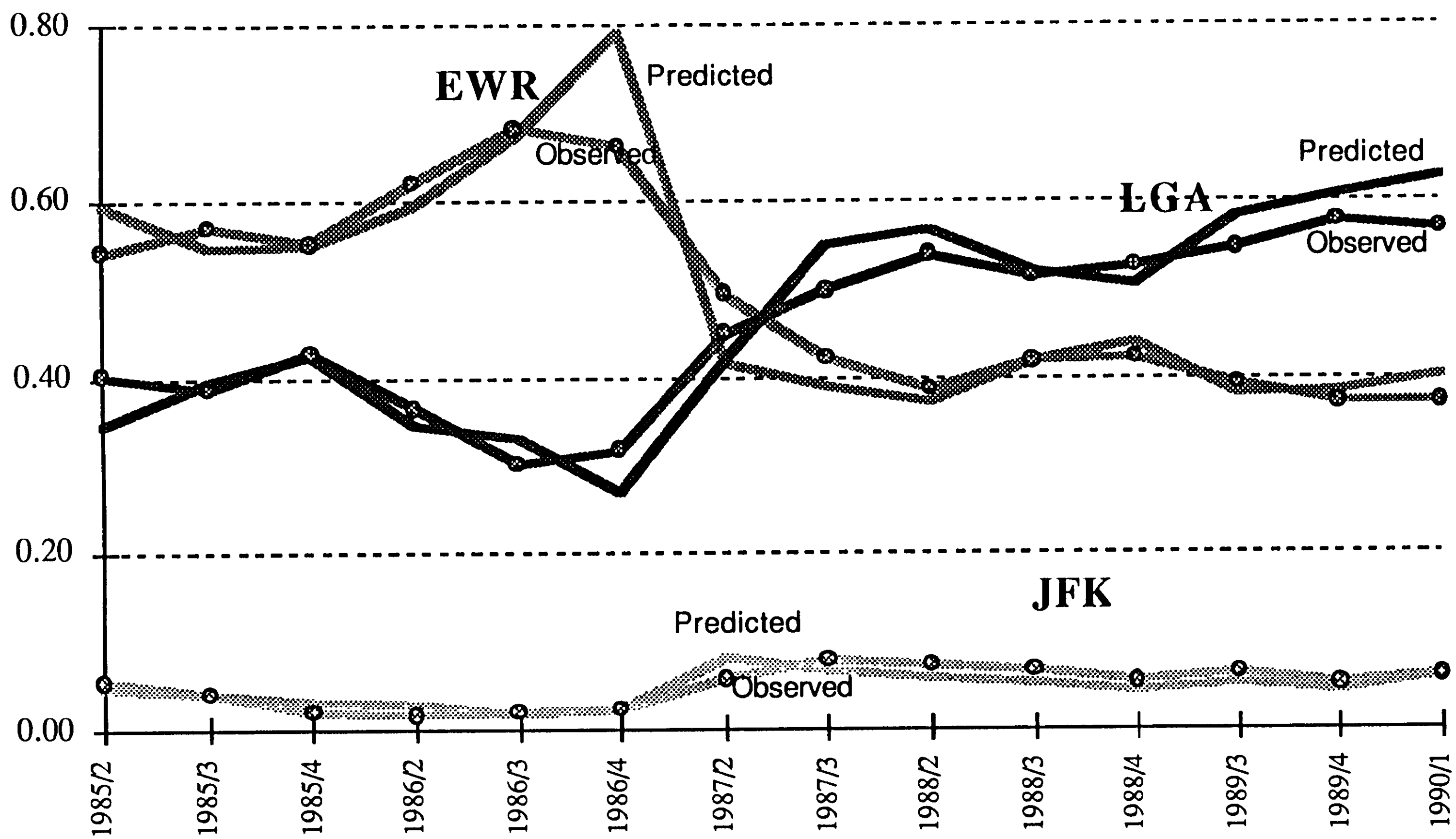
Equivalent Frequency Coefficients	
Alpha (EWR)	1
Beta (LGA)	1
Gamma (JFK)	0.5

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	56.72	11.34	304.05	2.21E-28
Residual	36	1.34	0.04		
Total	41	58.07			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-3.3942	1.6064	-2.11	4.16E-02	-6.65	-0.14
Fare	-0.8886	0.2043	-4.35	1.07E-04	-1.30	-0.47
FS	0.7481	0.1347	5.56	2.73E-06	0.47	1.02
Other Fare	1.2566	0.2073	6.06	5.76E-07	0.84	1.68
Dummy EWR	1.2462	0.1988	6.27	3.04E-07	0.84	1.65
Dummy LGA	1.5263	0.2558	5.97	7.70E-07	1.01	2.05

AIRPORT MARKET SHARES : NYC (EWR, LGA, JFK) - MSP



NYC (EWR, LGA, JFK) - PIT

Regression Statistics

Multiple R	0.98
R Square	0.96
Adjusted R Square	0.96
Standard Error	0.21
Observations	60

Equivalent Frequency Coefficients

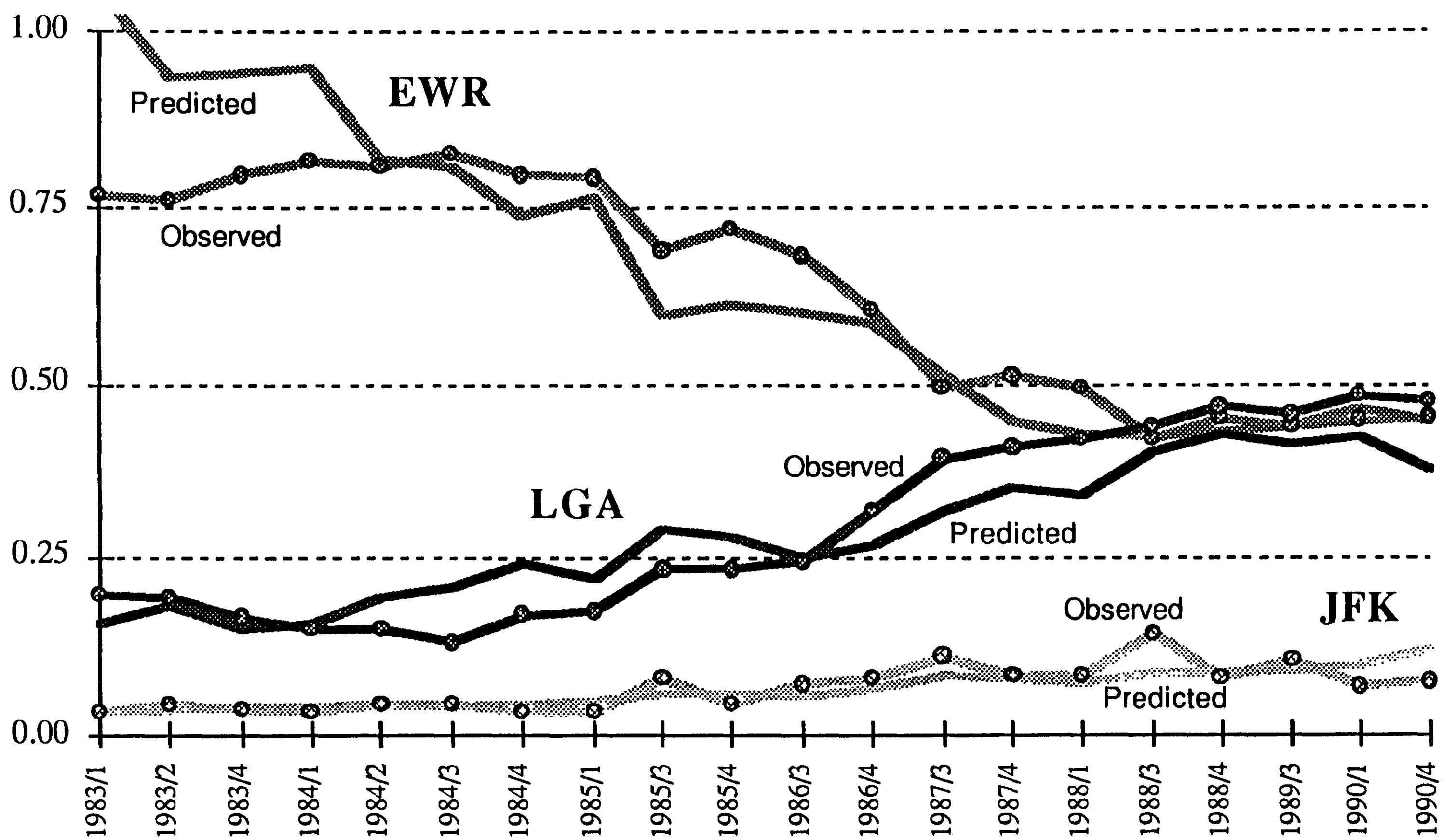
Alpha (EWR)	1
Beta (LGA)	not applicable
Gamma (JFK)	1

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	63.10	12.62	279.59	2.70E-37
Residual	54	2.44	0.05		
Total	59	65.54			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.3601	0.6942	-3.40	1.27E-03	-3.75	-0.97
Fare	-0.6869	0.1272	-5.40	1.53E-06	-0.94	-0.43
FS	0.6478	0.2053	3.15	2.63E-03	0.24	1.06
O.Fare	0.8748	0.1242	7.04	3.53E-09	0.63	1.12
Dummy EWR	1.1973	0.2271	5.27	2.43E-06	0.74	1.65
Dummy LGA	1.2855	0.1636	7.86	1.67E-10	0.96	1.61

AIRPORT MARKET SHARES : NYC (EWR, LGA, JFK) - PIT



NYC (EWR, LGA, JFK) - RDU

Regression Statistics

Multiple R	0.99
R Square	0.98
Adjusted R Square	0.98
Standard Error	0.15
Observations	51

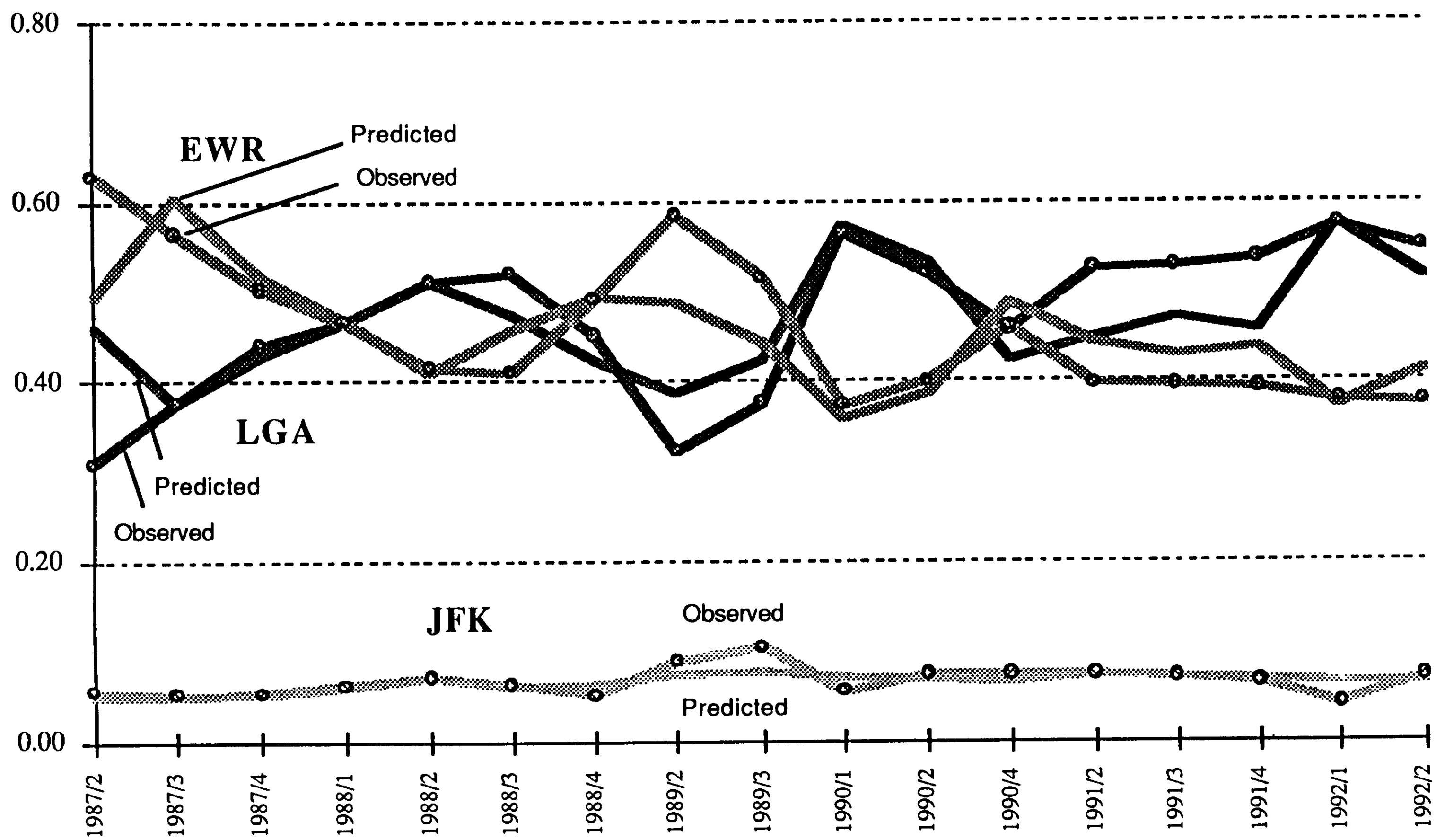
Equivalent Frequency Coefficients	
Alpha (LGA)	0.5
Beta (EWR)	1
Gamma (JFK)	1

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	42.72	8.54	392.67	6.44E-36
Residual	45	0.98	0.02		
Total	50	43.70			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.3591	0.6639	-3.55	9.06E-04	-3.70	-1.02
Fare	-0.9169	0.2162	-4.24	1.09E-04	-1.35	-0.48
FS	0.3013	0.1062	2.84	6.78E-03	0.09	0.52
Other Fare	0.9058	0.2237	4.05	2.00E-04	0.46	1.36
Dummy LGA	2.0457	0.1011	20.23	3.19E-24	1.84	2.25
Dummy EWR	1.8496	0.1480	12.49	3.13E-16	1.55	2.15

AIRPORT MARKET SHARES : NYC (EWR, LGA, JFK) - RDU



SAN FRANCISCO AREA (SFO, OAK, SJC) - LAS

Regression Statistics

Multiple R	0.93
R Square	0.86
Adjusted R Square	0.85
Standard Error	0.24
Observations	54

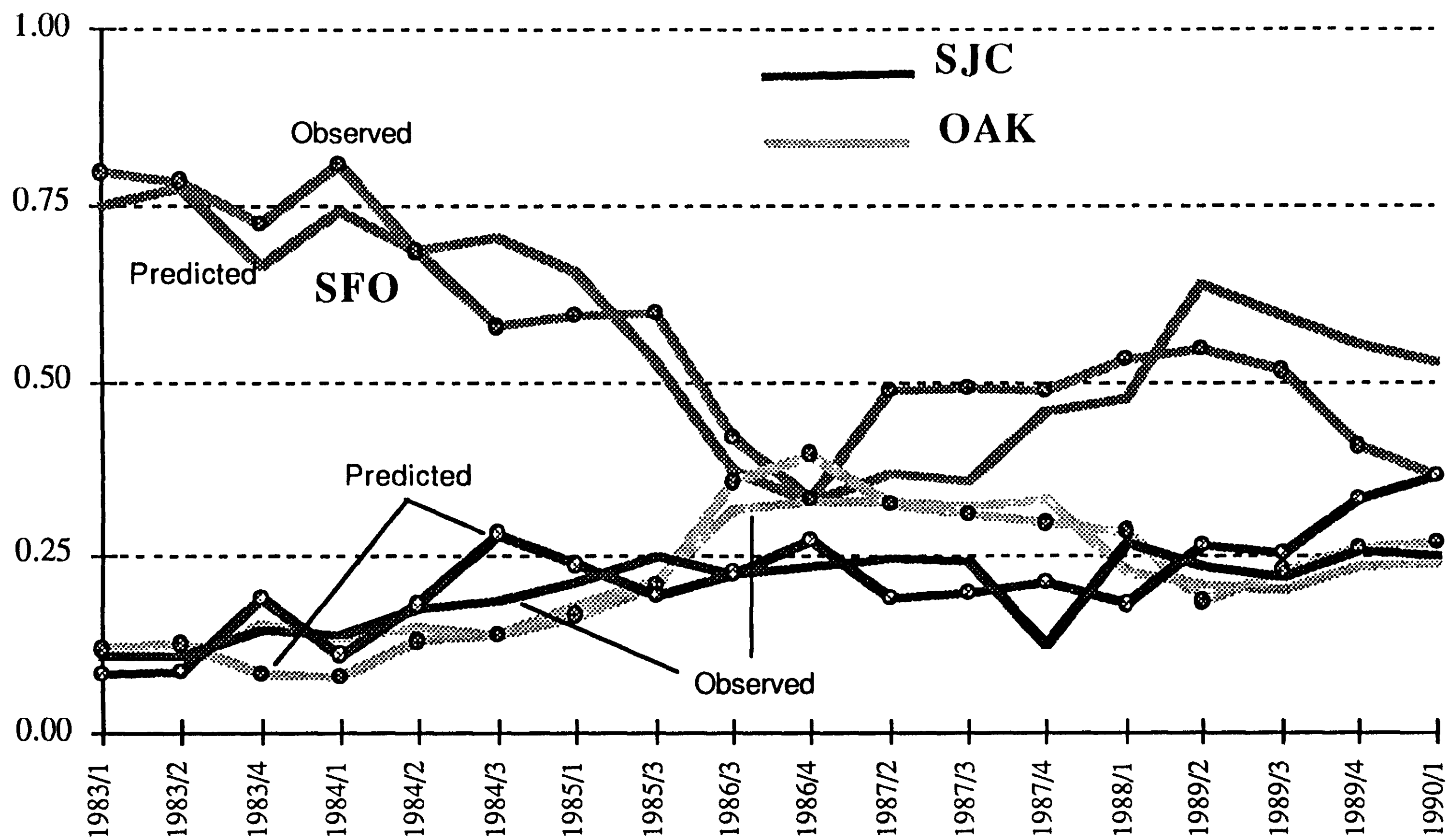
Equivalent Frequency Coefficients	
Alpha (SFO)	1
Beta (OAK)	1
Gamma (SJC)	0.5

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	4	17.40	4.35	77.94	1.27E-20
Residual	49	2.73	0.06		
Total	53	20.13			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.3574	1.1035	-2.14	3.77E-02	-4.58	-0.14
Fare	-0.2886	0.1550	-1.86	6.86E-02	-0.60	0.02
FS	0.5212	0.1134	4.60	3.03E-05	0.29	0.75
Other Fare	0.6294	0.2134	2.95	4.88E-03	0.20	1.06
Dummy SFO	0.7312	0.1979	3.70	5.54E-04	0.33	1.13

AIRPORT MARKET SHARES : SAN FRANCISCO (SFO, OAK, SJC) - LAS



SAN FRANCISCO (SFO, OAK, SJC) - PHX

Regression Statistics

Multiple R	0.98
R Square	0.96
Adjusted R Square	0.95
Standard Error	0.11
Observations	48

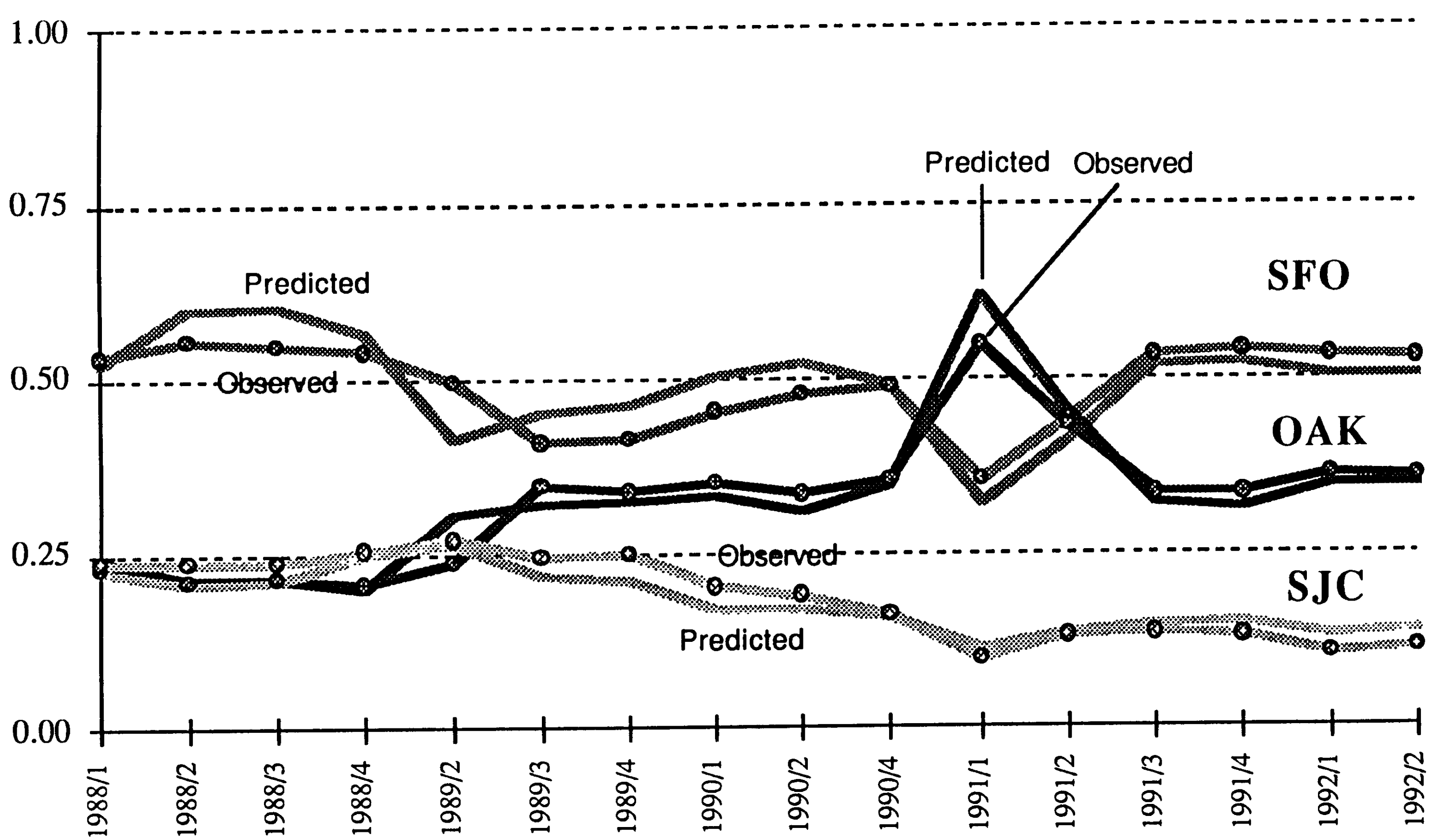
Equivalent Frequency Coefficient	
Alpha (SFO)	1
Beta (OAK)	0
Gamma (SJC)	0.5

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	4	10.90	2.72	243.92	6.04E-29
Residual	43	0.48	0.01		
Total	47	11.38			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.0377	0.5503	0.07	9.46E-01	-1.07	1.15
Fare	-0.9799	0.1106	-8.86	2.99E-11	-1.20	-0.76
FS	0.5812	0.1004	5.79	7.42E-07	0.38	0.78
Other Fare	0.8746	0.1108	7.89	6.71E-10	0.65	1.10
Dummy OAK	-0.2008	0.0567	-3.54	9.71E-04	-0.32	-0.09

AIRPORT MARKET SHARES : SAN FRANCISCO (SFO, OAK, SJC) - PHX



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SAN FRANCISCO (SFO, OAK, SJC) - SAN

Regression Statistics

Multiple R	0.97
R Square	0.95
Adjusted R Square	0.94
Standard Error	0.11
Observations	39

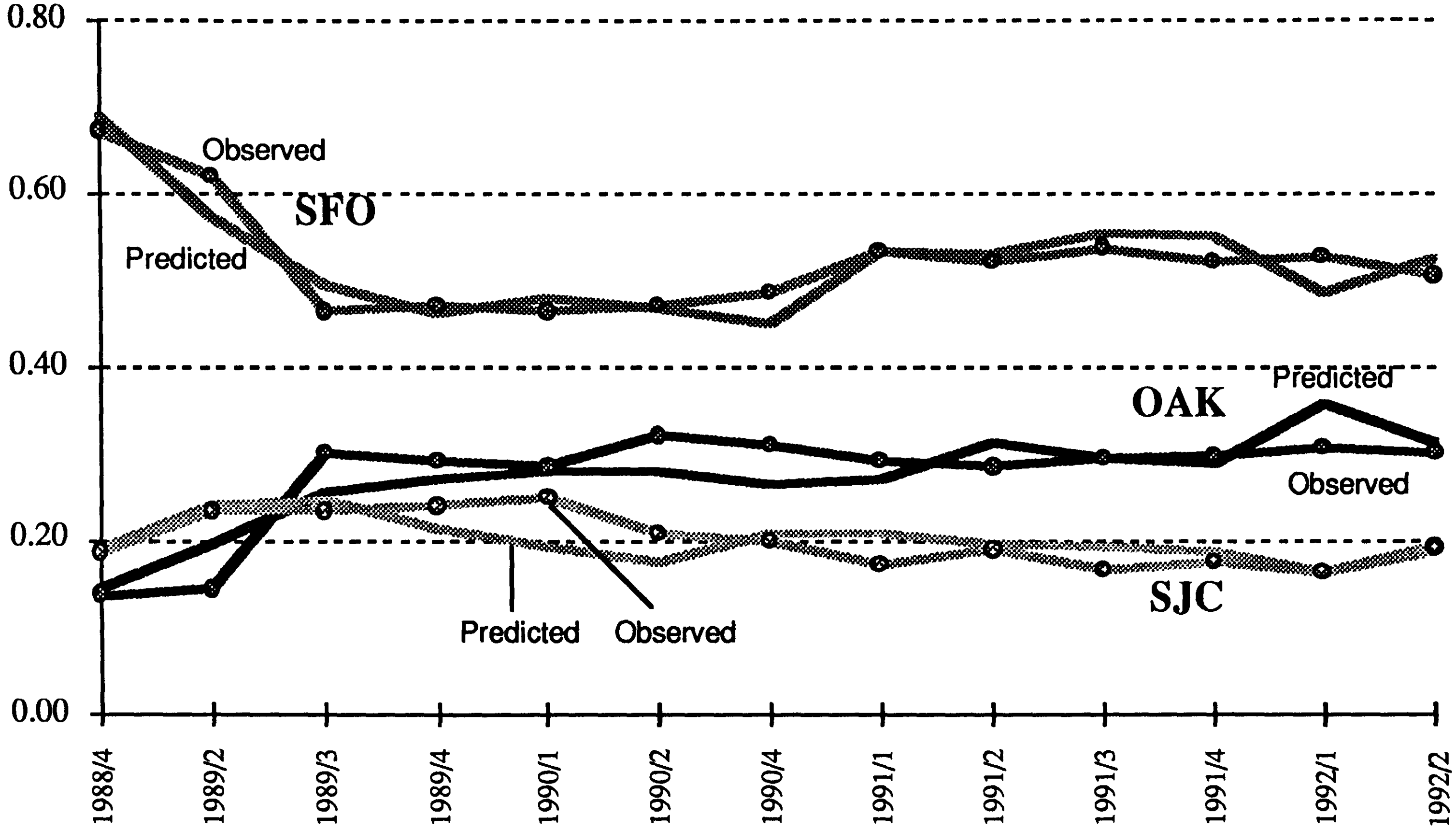
Equivalent Frequency Coefficients	
Alpha (SFO)	0
Beta (OAK)	0.5
Gamma (SJC)	1

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	7.27	1.45	118.05	4.58E-20
Residual	33	0.41	0.01		
Total	38	7.67			

	Coefficients	*tandard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.7053	0.9289	0.76	4.53E-01	-1.18	2.60
Fare	-0.8085	0.1929	-4.19	1.95E-04	-1.20	-0.42
FS	0.6683	0.1341	4.98	1.93E-05	0.40	0.94
Other Fare	0.4249	0.2012	2.11	4.24E-02	0.02	0.83
dummy SFO	0.7850	0.0674	11.64	3.16E-13	0.65	0.92
dummy OAK	0.1513	0.0750	2.02	5.18E-02	0.00	0.30

AIRPORT MARKET SHARES : SAN FRANCISCO (SFO, OAK, SJC) - SAN



WASHINGTON (DCA, IAD, BWI) - ATL

Regression Statistics	
Multiple R	0.98
R Square	0.96
Adjusted R Square	0.96
Standard Error	0.11
Observations	45

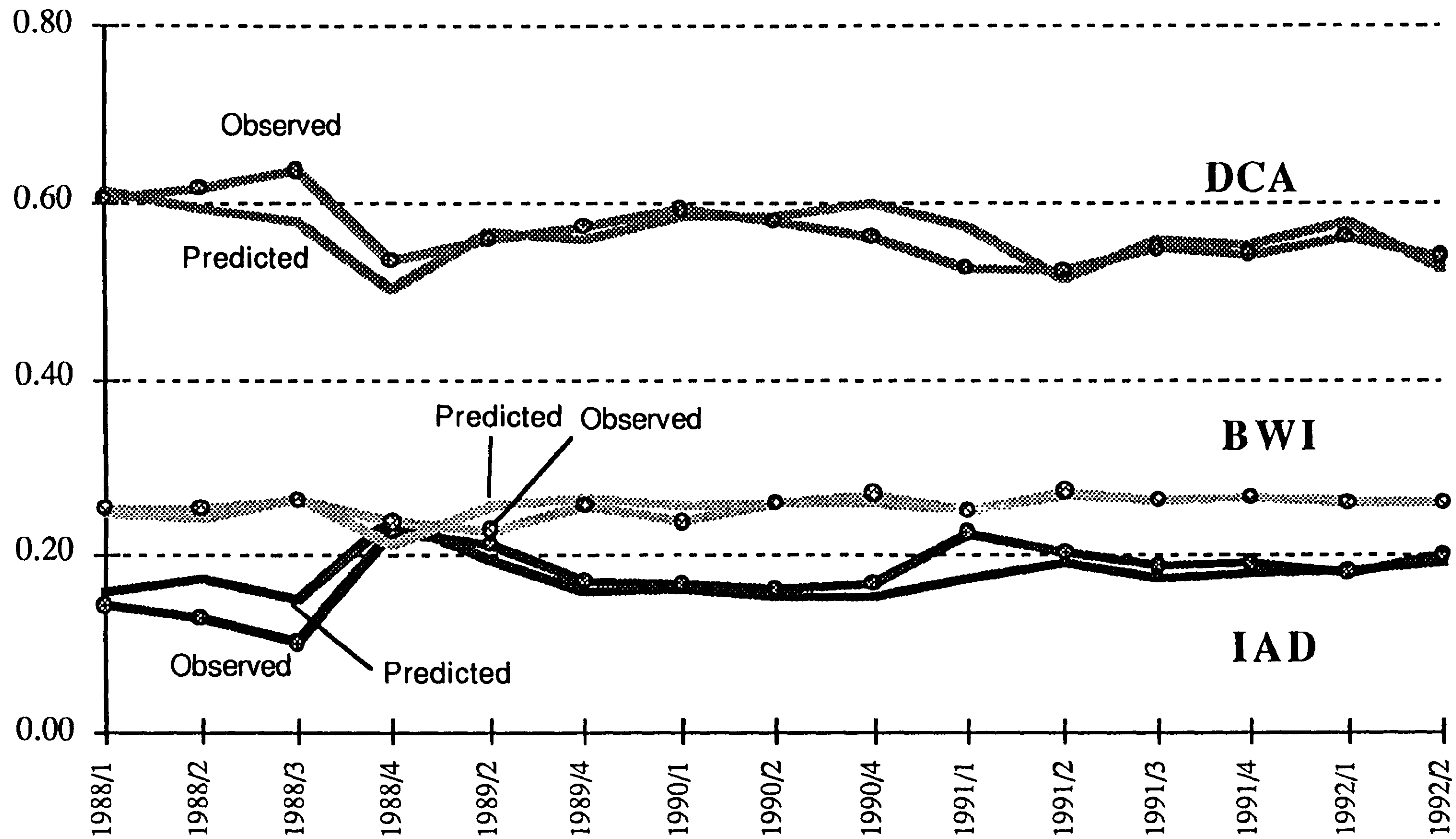
Equivalent Frequency Coefficients	
Alpha (DCA)	1
Beta (IAD)	0
Gamma (BWI)	0.5

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	11.12	2.22	197.41	1.37E-26
Residual	39	0.44	0.01		
Total	44	11.56			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.5695	1.5636	-1.00	3.22E-01	-4.73	1.59
Fare	-1.2035	0.2626	-4.58	4.61E-05	-1.73	-0.67
FS	0.5190	0.1783	2.91	5.93E-03	0.16	0.88
Other Fare	1.3958	0.3438	4.06	2.29E-04	0.70	2.09
Dummy DCA	0.3136	0.1432	2.19	3.46E-02	0.02	0.60
Dummy IAD	-0.3205	0.0740	-4.33	1.01E-04	-0.47	-0.17

AIRPORT MARKET SHARES : WASHINGTON (DCA, IAD, BWI) - ATL



WASHINGTON (DCA, IAD, BWI) - ORD

Regression Statistics

Multiple R	0.96
R Square	0.93
Adjusted R Squ	0.92
Standard Error	0.21
Observations	36

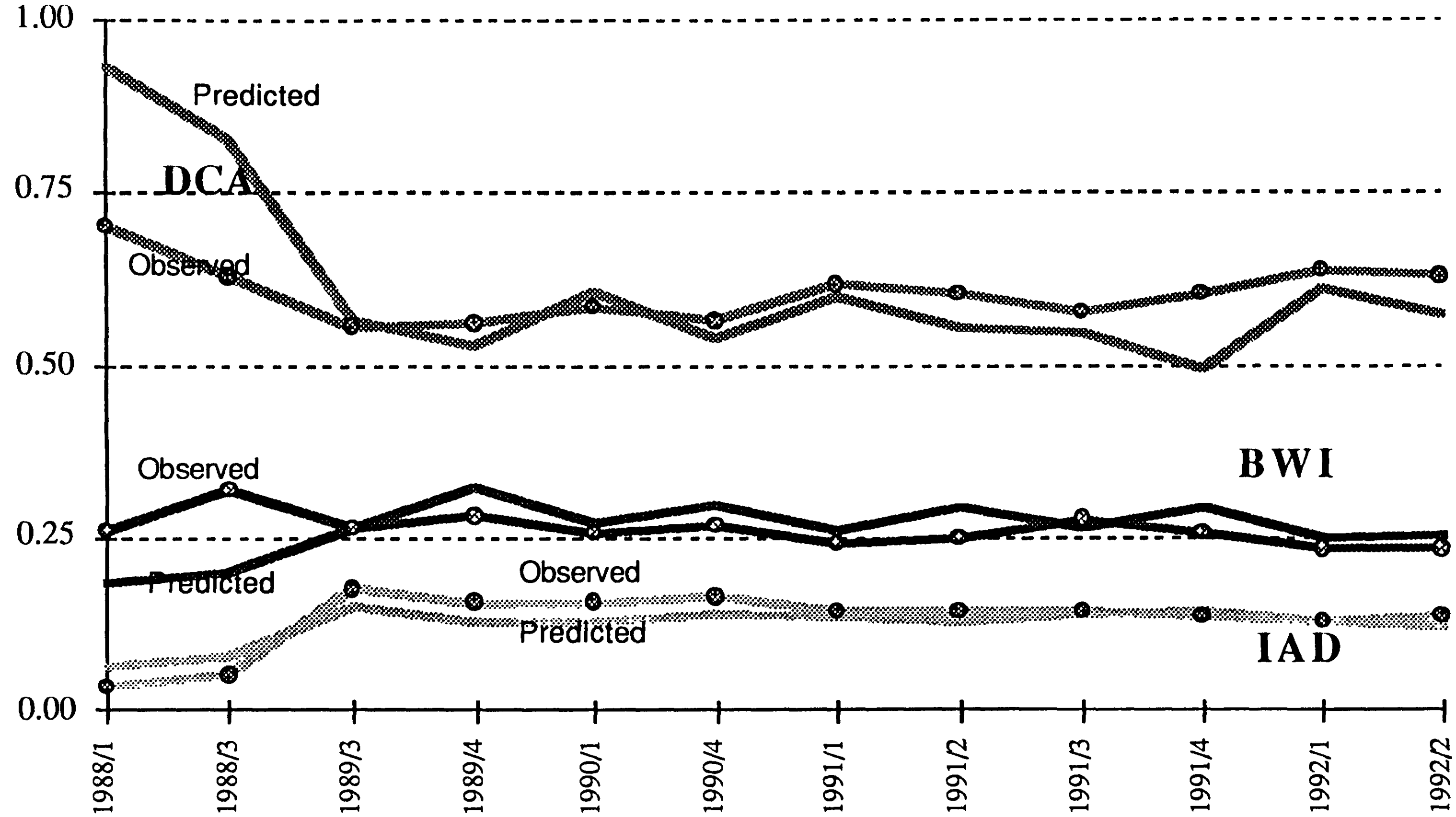
Equivalent Frequency Coefficients	
Alpha (DCA)	1
Beta (IAD)	0
Gamma (BWI)	0

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	4	16.89	4.22	97.53	4.21E-17
Residual	31	1.34	0.04		
Total	35	18.23			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.8932	1.3039	-0.68	4.98E-01	-3.55	1.77
Fare	-0.9845	0.2303	-4.27	1.69E-04	-1.45	-0.51
FS	0.4420	0.0752	5.88	1.74E-06	0.29	0.60
Other Fare	1.0750	0.2380	4.52	8.53E-05	0.59	1.56
Dummy IAD	-0.8573	0.0837	-10.24	1.80E-11	-1.03	-0.69

AIRPORT MARKET SHARES : WASHINGTON (DCA, IAD, BWI) - ORD



WASHINGTON (DCA, IAD, BWI) - RDU

Regression Statistics	
Multiple R	0.94
R Square	0.89
Adjusted R Square	0.89
Standard Error	0.37
Observations	57

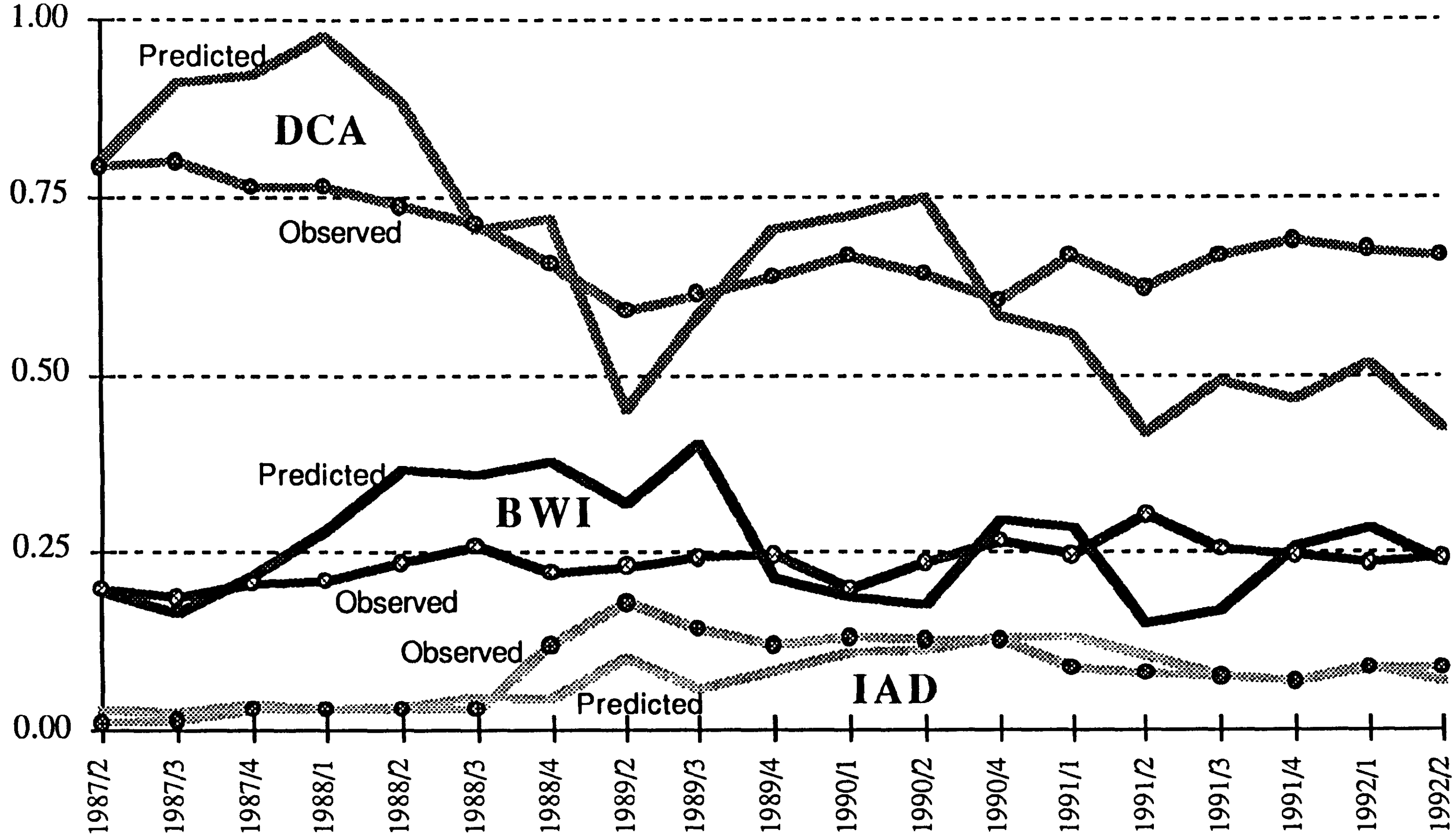
Equivalent Frequency Coefficients	
Alpha (DCA)	1
Beta (IAD)	1
Gamma (BWI)	1

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	3	60.55	20.18	146.67	1.20E-25
Residual	53	7.29	0.14		
Total	56	67.84			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-4.5414	2.0123	-2.26	2.82E-02	-8.58	-0.51
FS	1.8494	0.1792	10.32	2.77E-14	1.49	2.21
Other Fare	1.1445	0.4018	2.85	6.24E-03	0.34	1.95
Dummy IAD	-1.4980	0.1090	-13.74	4.18E-19	-1.72	-1.28

AIRPORT MARKET SHARES : WASHINGTON (DCA, IAD, BWI) - RDU



NEW YORK / NEW JERSEY

OD-markets : New York -MSP, -PIT, -RDU

Regression Statistics

Multiple R	0.98
R Square	0.96
Adjusted R Square	0.96
Standard Error	0.22
Observations	153

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	161.06	32.21	696.77	1.98E-100
Residual	147	6.80	0.05		
Total	152	167.85			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.8809	0.2610	-7.21	2.80E-11	-2.40	-1.36
Fare	-0.8298	0.0701	-11.84	3.95E-23	-0.97	-0.69
FS	0.6087	0.0578	10.54	1.08E-19	0.49	0.72
Other Fare	0.8560	0.0628	13.64	6.91E-28	0.73	0.98
Dummy EWR	1.3864	0.0813	17.04	1.23E-36	1.23	1.55
Dummy LGA	1.6097	0.0716	22.48	2.02E-49	1.47	1.75

SAN FRANCISCO BAY AREA

OD Markets : San Francisco -LAS, -PHX, -SAN

Regression Statistics

Multiple R	0.92
R Square	0.84
Adjusted R Square	0.83
Standard Error	0.22
Observations	141

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	5	33.02	6.60	140.40	1.08E-51
Residual	135	6.35	0.05		
Total	140	39.37			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.9493	0.3752	-2.53	1.26E-02	-1.69	-0.21
Fare	-0.3688	0.0623	-5.92	2.55E-08	-0.49	-0.25
FS	0.5850	0.0559	10.47	3.73E-19	0.47	0.70
Other Fare	0.4084	0.0795	5.14	9.44E-07	0.25	0.57
Dummy SFO	0.6031	0.0586	10.30	1.05E-18	0.49	0.72
Dummy OAK	0.1135	0.0474	2.39	1.81E-02	0.02	0.21

WASHINGTON / BALTIMORE

OD Markets : Washington-ATL, -ORD, -RDU

Regression Statistics

Multiple R	0.88
R Square	0.78
Adjusted R Square	0.78
Standard Error	0.40
Observations	138

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	4	78.39	19.60	119.49	4.90E-43
Residual	133	21.81	0.16		
Total	137	100.20			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-6.4392	1.2772	-5.04	1.48E-06	-8.97	-3.91
Fare	-0.7199	0.3082	-2.34	2.10E-02	-1.33	-0.11
Other Fare	1.7440	0.3319	5.25	5.76E-07	1.09	2.40
Dummy DCA	0.7749	0.0921	8.42	5.37E-14	0.59	0.96
Dummy IAD	-0.9269	0.0860	-10.77	7.63E-20	-1.10	-0.76

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