AL KAABI, KHAULA ABDULLA, Ph.D. The Geography of Air Freight and Metropolitan Economies: Potential Connections. (2010)
Directed by Dr. Keith G. Debbage. 198 pp.

Despite the recent remarkable growth of air freight shipments, much of the existing literature on the geography of air transportation has paid more attention to passenger travel than freight shipments. The purpose of this dissertation is to elevate our understanding of spatial hierarchies and nodal connectivity by determining which specific variables most influence and shape the geographic distribution of air freight by metropolitan area using stepwise regression analysis.

The empirical results suggested a regression model of five independent variables is the most simple, effective, and parsimonious solution; 71.1% of the variation in the dependent variable was explained by the independent variables. The traffic shadow effect was the most important predictor in predicting the natural log of air freight, where small metropolitan areas within the traffic shadow of larger metropolitan areas tended to generate lower levels of freight. The model also suggested that other key predictors included per capita personal income, the transportation-shipping-logistics employment market share, the number of medical diagnostic establishments, and average high technology wages. Thus, metropolitan markets with more affluent people, diverse and efficient ground support systems, freight forwarders and other transportation services, an intense agglomeration of hospitals and medical universities, a highly skilled hi-tech workforce engaged in providing computer systems design and manufacturing generate high volumes of air freight.

THE GEOGRAPHY OF AIR FREIGHT AND METROPOLITAN ECONOMIES: POTENTIAL CONNECTIONS

By

Khaula Abdulla Al Kaabi

A Dissertation Submitted to
the Faculty of The Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Greensboro
2010

Approved by

Dr. Keith G. Debbage
Committee Chair

Dedicated to my beloved family

APPROVAL PAGE

This dissertation has been approved by the following committee of the

Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair Dr. Keith G. Debbage

Committee Members Dr. Jeffrey Patton

Dr. Zhi-Jun Liu

Dr. David Mitchell

March 31, 2010

Date of Acceptance by Committee

February 19, 2010

Date of Final Oral Examination

ACKNOWLEDGMENTS

This dissertation could not have been completed without the generous help of many people.

I gratefully acknowledge the assistance and support I have received from the entire community of the University of North Carolina at Greensboro (UNCG) in the completion of this dissertation.

A study such as this can never be accomplished by just one person. Grateful acknowledgment is given to my advisor, Dr. Keith Debbage. His continual enthusiasm, patience, editorial assistance, stimulating intellectual discussion and professional suggestions, were invaluable to the completion of this dissertation. He was truly an important source of inspiration to me through the entire study.

In addition, I would like to thank the other members of my committee: Dr. Jeffrey Patton, Dr. Zhi-Jun Liu, and Dr. David Mitchell, for their interest in my subject and for their support.

Thanks in a very special way to my husband, Obaid, who has shared with me in the many long hours and years of study. I also would like to thank my dear children, Saif, Abdulla, and Budor for their abiding love and many scarifies over the past years.

Last but not least, I would like to thank my mother, father, and all my sisters who always encourage me to learn and overcome all obstacles I might face to achieve my goals.

Thank you to all of you, and every single person who has been a part of my life and education at the UNCG.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

Much of the previous literature on air transportation has paid more attention to passenger issues than air freight matters, partly because air freight has been measured as an output of air passenger service. On the other hand, air freight is playing an economically significant role in the allocation structure of many different firms and businesses, which have found that the higher line haul costs of air service can be balanced by lower charges for inventory, warehousing, and packaging. Moreover, because of its speed and the resulting savings, air freight service has grown to be a crucial asset to many manufacturers, retailers, and buyers. Nowadays, air cargo is essential in worldwide commerce, which is confirmed by the fact that about 30% of U.S. sales overseas are shipped by air (Leinbach, 2004; Moline, 2004; Murphy, Dalenberg, & Daley, 1989; Rodrigue, 2006; Yamaguchi, 2008).

Since the Second World War, the amount of cargo distributed by air transport has increased significantly, and thus air cargo has become a crucial mode of international transport for a growing variety of commodities. Between 1980 and 2004, domestic air cargo had the most rapid growth rates amongst all modes of transport in terms of ton-miles (Figure 1). Domestic demand for air cargo service in the U.S. grew the most rapidly, largely reflecting the growth in all-cargo carriers. Also, the expansion in air cargo volume is partly related to structural changes in the U.S. economy and the increased emphasis of just-in-time production methods and speed of delivery (Bell & Feitelson, 1991). Furthermore, the growth of air cargo is associated with the flow of courier business and the rise of integrators like FedEx and the United Parcel Service (UPS), which provide door-to-door and time-specified deliveries (Leinbach, 2004). By 2020, U.S. freight shipments are projected to increase to nearly 26 billion tons of cargo, valued at nearly $30 trillion, and air freight is expected to carry 15% of the total value of shipments. More specifically, Leinbach (2004) stated that

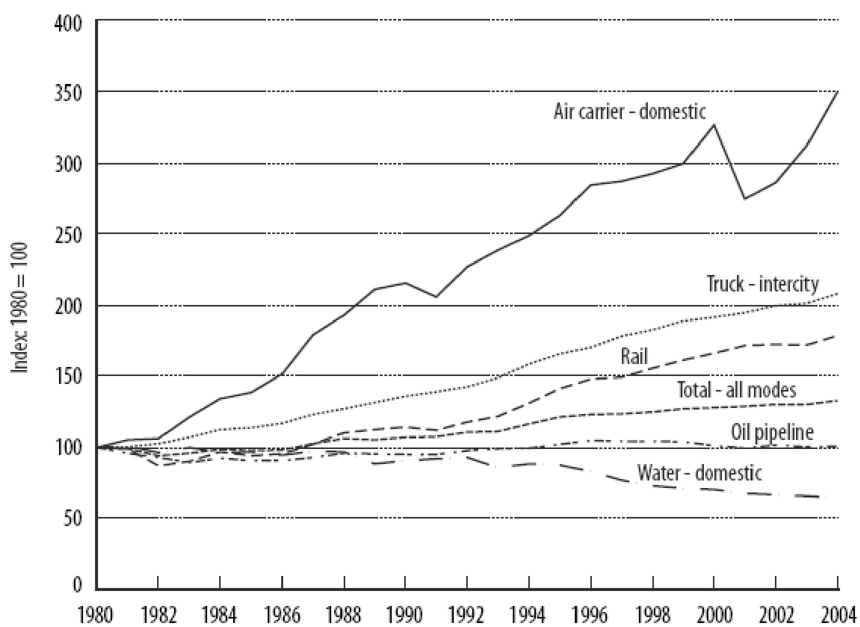

Figure 1. Growth in U.S. Domestic Freight Ton-Miles by Mode: 1980-2004

Source: U.S. Department of Transportation, Research and Innovative Technology Administration, & Bureau of Transportation Statistics, 2006

> Domestic freight volumes are expected to grow by more than 65%, increasing from 13.5 billion tons in 1998 to 22.5 billion tons in 2020. Domestic air cargo tonnage is projected to nearly triple over this period, although its share of total tonnage is expected to remain small (p. 35-36).

Therefore, air freight plays a significant role in shaping the local and regional economies, and that role will become more significant over time.

Today's modern airplanes can carry thousands of pounds of freight anywhere on the globe in twenty-four hours. The commodities that comprise the bulk of air freight shipments include high-value and time-sensitive shipments, such as electronic goods, telecommunications equipment, medical and pharmaceutical products, luxury commodities, and photographic equipment (Helms, 1989; Doganis, 1991; Rodrigue, 2006). The diverse product range means air cargo plays a significant role in meeting a variety of shippers' daily needs. Additionally, Kay (2004) argues that "an efficient, reliable and economical air cargo industry helps to create jobs, raise income levels, attract foreign investment, promote higher standards of living, and in general, act as an engine for economic development" (p. 5). For example, during the period between 1977 and 1990, Memphis (FedEx), Cincinnati (DHL), and Louisville (UPS) had employment growth rates of 53%, 64%, and 40%, respectively (Oster, Rubin, & Strong, 1997) in part due to their competitive advantage as major freight hubs. In another example, the new mid-Atlantic FedEx hub in the North Carolina Piedmont Triad area which began operation late 2009 is projected to generate nearly 20,000 new jobs and stimulate $9 billion in economic growth during the first sixteen years of operation (Lawlor, 2003). Because air transportation is the main focus of fast long-distance shipping in the United

States, developing a better understanding of how air cargo can drive and shape local employment patterns is critical.

According to Moline (2004), nowadays, several firms are increasingly concentrating on transportation and distribution approaches in order to more efficiently utilize resources and lower storage costs. Cost factors have played a significant role in elevating logistics – this includes inventory, warehousing, material-handling and packaging, and supply chain-related activities – as a vital sector of the economy. In 2001, about $1 trillion was spent on logistics by U.S. firms, where 34% of this was coupled with inventory shipping expenses. The introduction to ‘just-in-time’ manufacturing has resulted in goods arriving “in precise quantities at the time they are needed rather than being stored in a warehouse” (Moline, 2004, p. 7). Therefore, the cost for shipping the inventory declines, efficiency increases, and client desires are met with rapid speed. Al Chalabi and Kasarda (2004) have argued that airports have progressively become increasingly sophisticated hubs of operations that promote and stimulate logistics and distribution activities that can shape the new urban businesses clustered near the airport. However, Hesse and Rodrigue (2004) have argued that economic and transportation geographers need to pay more attention to logistics, transportation and freight distribution. There is also a need to further articulate the fundamental role of transportation infrastructure in attracting more investment to a region and creating regional identities.

The purpose of this dissertation is to determine which specific factors most influence and shape the geographic distribution of air freight by metropolitan area using both the U.S. Bureau of Transportation Statistics (BTS) and Census data sets. Since air freight has become one of the fastest growing sectors of the U.S. economy in general and the U.S. cargo industry in particular, the goal of this dissertation is to construct a better understanding of the critical role that air freight plays in the U.S. economy. Therefore, this dissertation will examine the traffic shadow effect, several socioeconomic variables (e.g., population, education, income, etc.), different types of manufacturing activities (e.g., high-tech, medical diagnostic, transport-shipping-freight, and pharmaceutical and biotech), and various cultural products industries (e.g., jewelry and cosmetic goods) that have the greatest potential to shape air freight volume in order to determine the underlying causal dynamics that shape variation in the 'geography of air freight' volume. For the independent variables that measure specific economic job clusters, five economic indicators will be used to assess the quality and quantity of these clusters. Those five indicators for the clusters include number of establishments, total employees, employment market share (%), total wage ($), and average wage ($). Overall, this dissertation will investigate if significant air freight volume by metropolitan area is accompanied by employment growth in related job clusters 'on the ground'.

Air cargo is rapidly increasing as U.S. businesses strive for the timely delivery of high-value goods, which in turn creates greater demand for various air freight and intermodal services. The work of this dissertation is crucial because in 2002, U.S. air freight shipments were valued at over $770 billion, almost double the $395 billion total for 1993 (U.S. BTS, 2004). Between 1991 and 2001, air freight shipment grew by 38% in terms of pounds (U.S. BTS, 2005a). U.S. BTS (2004) also argued that these growth rates are expected to continue as U.S. international trade expands and the demand for speedy and timely deliveries grows.

Overall, this dissertation will highlight the importance of spatial organization, in general, and the inter-metropolitan hierarchical system, in particular, in shaping the geography of air freight markets. Moreover, this dissertation will examine the relationships between air transportation, regional specialization, and agglomeration economies. Therefore, the work of this dissertation will contribute to the current literature on air transport geography and metropolitan economies.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this dissertation literature review is to examine the literary contributions made by geographers, economists, and other academics in the field of air transport in general and air freight in particular. The dissertation literature review is organized in the following way. In section 1, attention will be drawn to the basic research problem regarding the dissertation hypotheses. An efficient, reliable air cargo industry can be a significant engine for economic development, but up to now researchers have neglected the 'geography of air freight', and its impacts on regional economies and few have contemplated the subject material with any real depth. Section 2 discusses the key forces driving the growth of international air cargo services. Origin-destination air freight flows have recently experienced a substantial increase in cargo volume and are expected to continue to grow in the near future. Differential air freight growth rates may significantly restructure the U.S. metropolitan economy. Section 3 discusses how freighter aircraft development has shaped freight movements around the world and in the United States. Section 4 addresses the key dynamics behind the growth of the U.S. air express market, especially FedEx and UPS. These integrators are the world's largest freight transportation companies, providing fast and reliable delivery to customers and businesses around the world. Developing a better understanding of the integrators' role in shaping air freight geography will help to explain the substantial growth of air freight volume for some U.S. metropolitan markets. Section 5 addresses the various types of air cargo products since most air freight involves high-value and time-sensitive shipments. Section 6 focuses attention on regulatory concerns, including aircraft noise, congestion, and security issues in order to see how regulatory policy can influence the flow of air freight shipments. Section 7 focuses on some of the complex factors that affect air freight market, as well as freighter-operating airlines considerations when selecting an airport. Due to the limited empirical research on air freight, section 7 also addresses the influence of some potential socioeconomic factors that shape the geography of air passenger traffic. Understanding such factors can help policy makers understand the importance of preparing a sufficient airport infrastructure in order to boost air freight markets and attract highly skilled firms and employees to the region. Section 8 briefly discusses Kasarda's hypothetical concept of 'aerotropolis'. Understanding such notions might help us better understand the influence of airports in business location decisions and in developing new urban forms. Finally, the general research hypotheses will be revisited and discussed in light of the perceived lack of research reported to date in the existing literature.

1- The 'Geography of Air Freight' and Metropolitan Economies: The Missing Pieces?

The 'geography of air freight' is still a missing piece in current research studies in air transportation. Therefore, it needs and deserves more consideration and assessment particularly as it shapes and influences regional economies - this dissertation is a first step in that direction. Murphy et al. (1989) stated that most of the previous air transportation research has paid more attention to air passengers than air freight issues, partly because air freight has been considered as an afterthought to air passenger services. On the other hand, air freight plays an important role in determining the competitive strategies of several companies and businesses, which have found that the higher line haul costs of air service can be compensated for by lower charges regarding inventory, warehousing, and packaging. In addition, because of air transport's speed of shipment and the resulting cost savings, air freight service has become increasingly valuable to numerous manufacturers, retailers, and consumers. Today, air cargo is crucial in international trade, which is confirmed by the fact that about 30% of United States sales abroad (by value) are transported by air (Moline, 2004; Murphy et al., 1989). By 2020, U.S. freight shipments are projected to increase to nearly 26 billion tons of cargo, valued at nearly $30 trillion, and air freight is expected to carry 15% of the total value of shipments (Leinbach, 2004). Consequently, air freight can play a significant role in shaping the local and regional economy, and that role will become more significant over time.

Even with the growing significance of air freight particularly regarding its contribution to the local and national economy, up to now there has been no comprehensive study of the 'geography of air freight'. According to Hesse and Rodrigue (2004), Rodrigue (2004), and Vowles (2006), the significant role of freight transportation in the geography of production, consumption, and distribution of urban areas has been largely ignored. Specifically, these authors have argued that economic and transportation geographers need to pay more attention to and expand their concentration on logistics, transportation, and freight distribution. There is also a need to further articulate the fundamental role of transportation infrastructure in attracting more investment to a region and in creating various regional identities (Hesse & Rodrigue, 2004).

Hesse (2002) also argued that distribution networks, logistics, and transportation systems greatly influence economic structural change, and can also shape the physical and social environment related to these changes. On the other hand, he also suggested that it is difficult to evaluate the net-effect of transport-generating and substituting forces because of the lack of accurate data and sufficient case studies. Hesse also stated that there is a real need to clearly understand the role of logistics and freight transport, and thus "future research should be directed towards the various implications of logistics technologies, organization and infrastructure (in terms of supply and demand, customer behavior, environmental outcome, spatial dynamics)" (Hesse, 2002, p. 236). Hesse (2002) also found some evidence that e-commerce is likely to support the longstanding trends of transport growth, and he concluded that more emphasis should be placed on widely examining e-commerce with regard to the whole distribution system and to its application in firms and households.

Additionally, the concept of just-in-time production and delivery has increased the importance of air shipping for some businesses; yet, unfortunately, very few studies have investigated its implications for transport network management and how it may change the existing geographical behavior of economic activity. According to Janelle and Beuthe (1997), transportation is the least researched segment amongst all the various factors that have promoted a shift in worldwide economic activity. Moreover, the authors also state that a need exists for better research in transport geography; "for example, information on commodity flows must be tied to specific cities and urban regions (in addition to national levels of aggregation) and be available in time-series form to capture the processes and patterns of linkage between places of production and consumption" (Janelle & Beuthe, 1997, p. 206).

A fuller understanding of the complex relationships and spatial outcomes that exist regarding freight movements is a crucial component towards a better understanding of how more reliable, efficient deliveries in highly skilled sophisticated urban regions shape metropolitan economies. Woudsma (2001) has suggested that there is a demand for more research that explores and understands how substantial economic changes affect the movement of urban freight. According to Woudsma (2001), some of the factors that explain the lack of research on urban freight movement include: a tendency to focus attention on understanding automobile movements, the complexity of freight movements, and the lack of reliable data. Woudsma (2001) also stated that there is not a comprehensive understanding of freight movement costs in urban areas.

Despite this, several transport geographers have examined air passenger flows and how they have shaped regional economies (Alkaabi, 2004; Alkaabi & Debbage, 2007; Brueckner, 2003; Debbage, 1999; Debbage & Delk, 2001; Goetz, 1992; Ivy, Fik, & Malecki, 1995). Most of these studies have found that new forms of production and distribution networks connected to the 'knowledge' economy have the potential to substantially reshape the spatial distribution of air transport systems in general and the geography of air passenger demand in particular at both the international and national scale. Despite these findings, little research has been conducted by these authors regarding air freight.

The end result is that the ‘geography of air freight’ is still relatively under-researched even though it is a topic worthy of serious consideration and further investigation. What is needed is a synthesis of the ‘geography of air freight’ in order to provide a more comprehensive understanding of how the broader socio-economic context influences the ‘geography of air freight’ by metropolitan area. Consequently, the conceptual focal point of this dissertation is to examine the spatial distribution of air freight shipments by metropolitan area and determine which socio-economic factors have the greatest potential to influence and shape the geographic distribution of air freight volume in U.S. metropolitan markets ‘on the ground’.

2. Key Forces for Air Cargo Expansion

Although the ‘geography of air freight’ has been under-researched, it is important to remind the reader that this industry has experienced remarkable growth rates in recent years both nationally and internationally; therefore, this section of the literature review will discuss those factors that have most contributed to the rapid expansion of the air cargo industry.

According to Johnson and Gaier (1998), international air cargo traffic has increased at an average yearly rate of 8.6% over the last ten years, whereas passenger traffic has increased at a rate of 4.8% over the same time period. Despite the higher freight growth rates, it is the geography of air passenger transportation that has received more attention in the traditional academic literature. Additionally, Carron (1981), Gardiner, Ison, and Humphreys (2005), and Zhang and Zhang (2002) have argued that air cargo and air passengers have some significantly different features in terms of scheduling time and routing. For instance, nighttime is the perfect time for shipping cargo (with departures after 9 P.M. and arrivals in the early morning hours), while passengers prefer traveling in the morning and early evening. Cargo also travels in one direction (from a production point to a distribution node), whereas passengers tend to make round-trip journeys to and from centers of business, factories, and tourist destinations (Carron, 1981; Gardiner et al., 2005; O'Kelly, 1998; Zhang & Zhang, 2002). O'Kelly (1998) in addition argued that unlike air passengers, cargo comes in substantially different sizes, shapes and weights, and there is a growing demand for freighter aircraft and all-cargo airlines to handle the increased demand for high-speed, just-in-time delivery. These fundamentally different characteristics suggest that an understanding of air passenger networks does not necessarily imply an understanding of air cargo networks.

One of the main reasons for the rapid growth in air cargo in recent years is the unique competitive advantages that can be gained by shipping by air rather than by ground. According to Fam, Chin and Koh (1992), the growing demand for the air transportation of both passengers and goods reflects the high value placed on reducing travel times. Ohashi, Kim, Oum, and Yu (2005) argue that the choice of air cargo transshipment hub by freight forwarders is more affected by time cost (e.g., loading and unloading time at airports, customs clearance and other processing time, and waiting time for the next available flight) than the financial costs (e.g., landing fees and line-haul price): "a 1-h reduction in total transport and processing time for a particular origin–destination air cargo traffic would be more effective than a $1000 reduction in airport charges" (p. 149). Additionally, the air transportation of freight can also help to lower inventories at branch warehouses; avoid the conditions of extreme heat, humidity, and vermin (often found in ocean-going vessels); offer a larger range of air freight routes through both scheduled and non-scheduled air carriers; diminish the chances of damage to commodities compared with other shipping methods; and reduce insurance costs because of reduced theft and damage rates (Fam et al., 1992).

Bowen (2004) has summarized and listed several key factors that have boosted air freight volume in recent years. Bowen argues that the rapid expansion rates of air freight flows can be related to the rapid growth of global commerce, where extended e-commerce has played a major role in this context. Moreover, the increased production of knowledge-intensive commodities with high value-to-weight ratios (e.g., semiconductors and other electronic components) has contributed to an increase in high-value, low weight products. According to Bowen (2004), 20% of worldwide air freight tonnage was electronics and computers in 2002. These types of products can easily compensate for the high shipping costs associated with air freight because of the high price to cost ratios associated with such products. Bowen (2004) also argued that the decline in air freight prices has played a vital role in allowing for the shipping of more low-value products. According to Bowen (2004), air freight rates have decreased by more than 3% by year partly due to the introduction of larger, long-range, more fuel-efficient freighter aircraft (e.g., the Boeing 747-400F, and A380) and the addition of more liberalized air freight markets that offer more competitive environments regarding pricing. Additionally, the rise of integrators such as FedEx, UPS, TNT, and DHL has played a major role in boosting air cargo volume since they provide fast, reliable shipping coupled with door-to-door delivery service on the ground (Bowen, 2004).

According to Kasarda, Green, and Sullivan (2004), "Countries should view air routes as highways in the sky" (p. 6). According to Kasarda et al. (2004), air cargo offers certain companies the opportunity to enhance their supply chain management strategies while also reaching distant markets. Kasarda et al. (2004) also argues that businesses that generate the most sizeable benefits from air cargo frequently decrease inventory expenses, boost efficiency, enlarge their market, and add new consumers.

Moreover, Kasarda et al. (2004) argued that, although air freight carriers account for less than 2% of international commerce by weight, they ship around 40% of the world value of commerce due to the increased demand for small, light, compressed and high value-to-weight ratio products. These new forms of worldwide commerce and investment (e.g., electronic-commerce, worldwide supplying and manufacturing networks, and global businesses in perishable and high-tech commodities) tend to prefer air transportation for their shipping demands (Zhang & Zhang, 2002). Therefore, the capacity and effectiveness of air cargo services are important keys for the expansion of these new forms of globalization. The authors also argued that now anything (e.g., "heavy machinery, automobiles, high-technology equipment, textiles, footwear and fashion clothing, furniture, pharmaceuticals, seafood, live animals, fruits and vegetables, aerospace components and seasonal toys" (p. 21)) that can be put onto a big airplane is commonly transported globally by air. As a consequence, air express delivery services account for more than 70% of all air cargo consignments in the U.S., and international air cargo traffic is anticipated to triple in volume from 2000 to 2020, with worldwide air express increasing three times as quickly (Kasarda et al., 2004).

According to the U.S. BTS (2004), air freight is growing quickly because U.S. businesses require the timely delivery of expensive goods. Air freight shipments were valued at more than $770 billion in 2002, almost twice the $395 billion total for 1993 (U.S. BTS, 2004). Even though air freight's market share in terms of tons and ton-mile totals are generally still minor (less than 1%) compared to annual totals for other shipping modes, air cargo's utilization continues to expand. During the period between 1993 and 2002, tonnage totals increased by 46% and ton-mile totals grew by almost 63% (U.S. BTS, 2004). In addition, the value of commodities shipped by U.S. commerce increased from $56,000 per ton in 1993 to $75,000 per ton in 2002 (U.S. BTS, 2004).

Without any doubt, air transport in general and air freight in particular play a major role in meeting the demands of the 'new' economy. Therefore, air freight volumes have increased significantly over time. Today, the speed, agility, and reliability of delivery systems has become a key competitive advantage for some companies and businesses. However, the question is, how do air freight flows play-out spatially? How do the U.S. metropolitan economies shape and re-configure the 'geography of air freight' demand? What are the key metropolitan factors that have the potential to shape the spatial distribution of air freight markets? Providing answers to these questions is crucial because of the remarkable growth rates in air freight flows. These air freight product flows may influence employment patterns more directly than passenger flows. In other words, answers to these questions may help us better understand how to build strong regional economic markets that attract new firms and are able to produce additional jobs and workers for the local work-base.

3. Freighter Aircraft Developments

The remarkable growth of air cargo shipment volume has been partly influenced by the rapid expansion of freighter aircraft services and innovative aviation design. Over time, introducing a variety of new aircrafts into the operational fleets has indirectly contributed to the 'reshaping' of the spatial distribution of air freight markets. Today's modern aircraft can ship thousands of pounds of cargo anywhere in the world in twenty-four hours. The enhanced technology of freighter aircraft, substantial increases in freight capacity, significant fuel efficiency gains, and considerably lower air freight rates have all attracted for high-value commodities and small traditional manufacturing markets with lower-value products into air freight market.

Vowles (2006) argued that few studies have been done on aircraft development and how it increases the critical role of air transport, in general, and air freight, in particular. Pitt and Norsworthy (1999) argued that the development of the jet engine has played a beneficial role in the history of the commercial airline industry. The jet engine has several features that have changed air transportation's character, including lower maintenance costs, and a decrease in operating expenses. Developing the jet engine afforded better output and performance and profitability when connecting origin (supply) and destination (demand) markets by air (Pitt & Norsworthy, 1999).

According to Pitt and Norsworthy (1999), the first generation of air transport included the Boeing 707, 727, and 737 and the McDonnell-Douglas DC-8 and DC-9 which rapidly became the most successful long-range commercial transports serving multiple global and domestic destinations. These aircraft flew at impressive speeds (maximum of 623 miles per hour for the B707), and carried heavy payloads (67,736 pounds for the DC-8). Their high passenger capacity (maximums of 259 seats for the DC-8) effectively linked significant population centers around the globe (Pitt & Norsworthy, 1999).

Even though these types of jets contributed to increases in air cargo volume, they faced some technical difficulties. They required long, heavy landing gear in order to allow the best rotation angle for take-off without scraping the back of the fuselage on the landing field. During the 1970's, various 'wide-body' aircraft (including the Boeing 747, the DC-10, the Lockheed L1011, and the Airbus A300 series) were developed in order to overcome the limitations and the deficiencies of narrow-body aircraft, which opened the door for various worldwide businesses to exchange their products and serve growing global needs (Pitt & Norsworthy, 1999). The authors argued that these 'wide-body' jets were characterized by a larger capacity (between 296 to 500 seats depending on the aircraft type) and bigger payload weight (between 58,475 and 177,684 pounds depending on jet type). Wide bodied jets had two long walkways, improved engine design, less fuel consumption, and reduced noise levels (Pitt & Norsworthy, 1999). All in all, they were more reliable, comfortable, and profitable aircraft than earlier aircraft.

Pitt and Norsworthy (1999) and Zhang, Hui, and Leung (2004) argued that during the 1980's and the 1990's, new aircraft such as the Boeing 757, 767, 777, MD80 series, MD11, and Airbus (A320, A330, A340) entered the market place to compete with existing aircraft. These short/medium and medium/long range aircraft, with their advanced navigational systems and improved engine performance coupled with enhanced fuel efficiencies, have all contributed to moving additional numbers of people as well as freight (Pitt & Norsworthy, 1999; Zhang, et al. 2004). Even though these types of passenger aircraft have smaller space for freight compared to the all-freighter aircraft, they significantly contributed to increasing the total volume of air freight because of their reasonable market price. In 2008, the European Airbus Company introduced the largest commercial freighter aircraft ever built (the A380) to the market, and it is expected to outperform the Boeing 747- 400F both in terms of range and payload (Bowen, 2004).

O'Connor (2001) has argued that designing new types of passenger aircraft directly influences air cargo movements because over half of all air cargo moves on passenger flights and many new passenger airplanes are readily convertible to all-freighter designs, such as the Boeing 727, 737, 757, and 767. Today, most all-freighter aircraft are either converted passenger planes (e.g., 707C, DC-8C, and DC-10C) or were prepared at the factory as freighters based on the original design of passenger aircraft like the 727F and DC-10F (O'Connor, 2001; Bowen, 2004).

Bowen (2004) has argued that three major types of air freighter carriers currently dominate the market place: heavy freight airlines, combination carriers, and integrators. Heavy freight airlines ship cargo only from airport to airport and focus on long-haul services (such as Cargolux and Nippon Cargo Airlines), while combination carriers move both international passengers and cargo traffic around the world (e.g., the A-340 Airbus, the MD-11, and the Boeing 747-727-757) (O'Connor, 2001; Bowen, 2004). By 2000, around 20 large international combination carriers (e.g., Lufthansa, Korean Air, China Airlines, Aeroflot, Northwest Airline, Air France, and Singapore Airline) operated considerable freighter fleets (Bowen, 2004). The last type of carriers that operate freighter aircraft are referred to as integrators. These are companies that provide the air and ground shipping functions usually carried out by different firms (like airlines, freight forwarders, trucking firms) in order to provide 'seamless' door-to-door service (Bowen, 2004). According to Bowen (2004), FedEx, UPS, TNT, and DHL have become the largest integrators in the world by offering real-time shipment tracking and time-definite delivery services. In the 1970s, these integrators began as small-package express carriers but gradually shifted toward heavier cargo, which has traditionally been handled by forwarders (agents focusing mostly on connecting a shipper like an electronics manufacturer exporting semiconductors to an airline, shipping line or trucking firm, and/or linking transportation services companies to the consignee) and airlines (Bowen & Leinbach, 2004).

Air freight transport has increasingly played a fundamental role in the shipment of goods and services due to the increased demand for time-definite delivery, production flexibility and speed characterized by the new ‘knowledge-based’ economy. Developing more innovative cargo airplanes attracted both producers and shippers that require high speed and large capacity freighter to ship products to various urban regions across the world. The development of more sophisticated types of freighter aircraft to the overall fleet has significantly increased air freight shipments and reshaped air freight movements in some key metropolitan markets. We now turn to a more detailed overview of the air express market.

4. The Growth of the Air Express Market: FedEx - UPS

In the 1970s, the U.S. air express industry grew in response to the increased demand from shippers for reliable, door-to-door, overnight shipment. The U.S. air express market’s volume was almost $5.5 billion in 1988 (Ligon, 1992). Ligon (1992) argued that before air express service became broadly available, shippers used to depend on airlines and air freight forwarders for only expedited or emergency deliveries. The air express industry has several features that distinguish its services from other traditional air freight services that focus exclusively on airport-to-airport service. For example, unlike traditional air freight providers, major U.S. air express companies utilized several hubs with widespread geographical coverage; practiced single vendor management of shipments from door-to-door; employed computerization techniques for pickups and deliveries, tracking and billing; offered time definite and dependable delivery; handled heavier and larger commodities; and charged less compared to scheduled airlines (Helms, 1989; Ligon, 1992).

Numerous legal transformations in the U.S. transportation industry helped in developing the air express industry. A number of these reforms were caused by public demand for better air service by encouraging market competition. On November 9, 1977 the U.S. air cargo industry was deregulated under amendments to the Federal Aviation Act, Title IV, Section 418. The Motor Carrier Act of 1980 extended trucking deregulation to include vehicles controlled by air carriers, enabling air express companies to co-ordinate air freight with crucial trucking operations. Deregulation reduced significant government restrictions and "opened the door for air express to successfully compete with the scheduled airlines, air forwarders and trucking firms" (Ligon, 1992, p. 284) by lowering prices and creating a new market for overnight delivery. According to Ligon (1992, p. 285) "air express growth was one of the greatest accomplishments of deregulation."

A large portion of air express shipments originally consisted of documents; however, as air express clients started to send documents by facsimile machine or electronic mail systems, the air express document market experienced a significant decline in quantity in the late 1980s. As a result, air express companies like Federal Express decided to move into heavier weight consignments in order to enhance income, develop local and international market shares, and simplify their clients' delivery needs (Ligon, 1992).

Two decades ago, Ott (1987) and Helms (1989) argued that the air express market significantly reshaped the U.S. economy. Business firms now rely increasingly on air express delivery for materials that previously were inventoried. Quickly changing industries, such as the fashion and beauty business, now transport exclusively by express air. Catalog trades too have relied on air express firms for expanded mail order capabilities. As automated devices, personal computers and other equipment have become pervasive, air express delivery for parts and repair has become an expanding market.

Even though U.S. air express companies were slow to understand the full significance of the worldwide market, they have made several successful entries into certain foreign markets since the 1980s and now offer various global services. The increased demand for just-in-time (JIT) inventory techniques and the increased importance of global production networks also explain why some U.S. air express companies are developing their international air express market shares. Furthermore, Ligon (1992) argued that "as transportation companies have begun to recognize that their customers are not purchasing a specific mode of transportation, they have become more creative in their use of more than one mode in satisfying customers" (Ligon, 1992, p. 294). Unlike traditional air freight carriers, air express firms (e.g., Airborne and Federal Express) frequently operate central national warehouses at their hubs that serve as significant component of some of their clients' distribution systems. Ligon (1992) argued that conducting a "study of the growing role of express in a firm's distribution system could reveal to what extent the industry has enabled its customers to develop competitive advantages over competing firms" (Ligon, 1992, p. 294). Although the future of the air express industry is unstable because of the shifting worldwide scope of air shipments in addition to the shift to just-in-time production methods in the United States, it is clear that the industry is fundamentally interconnected with broader production networks, and may therefore, play a significant role in shaping a metropolitan area's economy. We now turn to a brief overview of some of the major air cargo companies in the United States and overseas.

4.1. Federal Express (FedEx)

In 1973, Federal Express (known as FedEx) initiated its operations as an integrated air express service and pioneered many of the service innovations that now characterize the U.S. air express industry. FedEx chose Memphis (TN) as its headquarters because of its central geographical location and its stable weather (Ligon, 1992), while the other U.S. air express hubs are located in Indianapolis (IN), Anchorage (AK), Fort Worth (TX), Newark (NJ), Oakland (CA), and Miami (FL) (FedEx, 2005). The company targeted small package shipments until the company was permitted by law to promote its overnight letter service. In 1989, Federal Express moved into heavyweight air freight with its acquisition of The Flying Tiger Line, the largest all-cargo air carrier in the world (Ligon, 1992).

Moline (2004) argued that since air cargo deregulation in 1977, which permitted FedEx to use larger capacity planes (such as Boeing 727s and McDonnell-Douglas DC-

10s), the FedEx Company has experienced a period of rapid growth. About 3.3 million parcels and documents are shipped nightly by FedEx Express and the company has a combined lift capacity of over 26.5 million pounds every day (Moline, 2004). FedEx airplanes routinely travel almost one-half million miles every twenty-four hours, while FedEx couriers log 2.5 million miles a day (equivalent to 100 flights around the globe) (Moline, 2004).

Ott (1987) argued that the market share of the FedEx Company will continue to be healthy as long as the company continues to provide a high level of service and effectively tracks consignments and manages information for clients. FedEx has continuously innovated by providing new mechanization services to its air clients, such as computer hardware and a metering system, and offering new parcel and letter tracking capabilities (Ott, 1987). By using the hand carried Super-Tracker machine, for example, FedEx employees help provide their customers with an accurate picture of the location of their shipments at every point on the trip (Ott, 1987). Today, FedEx Express serves every U.S. address and more than 220 countries and territories with more than 138,000 employees worldwide (FedEx, 2005).

4.2. United Parcel Service (UPS)

Due to the growing demand for faster air parcel delivery in the 1980s, UPS entered the overnight air delivery business and became the largest ground parcel carrier and air freight forwarder in the United States (UPS, 2005). In 1982, UPS started its operations from the Louisville air hub, and by 1985, UPS Next Day Air service was available in all 48 states and Puerto Rico, while Alaska and Hawaii were added later (UPS, 2005). That same year, UPS entered a new era with international air package and document service, linking the U.S. and six European nations. In 1988, UPS received authorization from the Federal Aviation Administration (FAA) to operate its own aircraft, and today UPS Airlines has become one of the 10 largest airlines in the United States. The main UPS air hubs are located in Louisville (KY), Philadelphia (PA), Dallas (TX), Ontario (CA), Rockford (IL), Columbia (SC), Hartford (CT), and Miami (FL) (UPS, 2005).

Today, UPS is the world's largest package delivery company and a leading worldwide provider of specialized delivery and logistics services. UPS manages the flow of freight, funds, and information daily in more than 200 worldwide countries and territories (UPS, 2005). By 1993, UPS was delivering 11.5 million packages and documents a day for over one million regular clients (UPS, 2005). In order to keep up with this massive growing volume, UPS had to build up new technology to maintain efficiency, keep prices competitive, and offer new customer services. Tracking is available now through the UPS Web site, and in 2000 online tracking requests reached a record-high of 6.5 million requests in a single day (UPS, 2005).

5. Air Cargo Types

Despite the current downturn (2009), the U.S. is still experiencing a remarkable growth in air cargo traffic, which is expected to continue in the near future. Therefore, developing a better understanding of what comprises air cargo will help to distinguish which types of air cargo are most influential in shaping U.S. metropolitan economies and related employment patterns. O'Connor (2001) argues that it is important to recognize the diverse products being shipped by air because they give a clear image of the significance of air cargo to the economy. Overall, the main types of cargo shipped by air include mail, expedited small-packages, and air freight products like electronic equipment, machinery and parts, auto parts and accessories, photographic tools and films, tools and hardware, metal products, medicines, pharmaceuticals, drugs, instruments (controlling, measuring, medical, optical), chemicals (elements and compounds), food preparations, edible fish, fruits and vegetables, cut flowers, various bakery products, plastic materials and articles, printed matter, footwear, animals, sporting goods, toys, and games (O'Connor, 2001). In the following subheadings, we will examine in more detail each type of air cargo traffic.

5.1. Air Freight: High-Value and Low-Weight Products

The crucial importance of air freight in shaping metropolitan economies is the tendency to ship high-value, low weight products that can generate substantial revenue and impact employment at the final destination and origin. High-tech component parts, pharmaceuticals, and medical devices are the sorts of products shipped by air, and these are all freight products consumed by highly skilled, innovative sectors of the economy. The implication here is that metropolitan areas specializing in this sort of air freight shipment may be developing competitive advantages over other metropolitan areas by providing the appropriate air cargo shipment facilities and air freight operations to affect such shipments. It is important, however, to recall that small freight items like ballpoint pens or daily articles of clothing and fashion-wear which many people may consider as low cost products are in fact high-value for transportation purposes – that is, by weight unit – and they will often ship by air.

Doganis (1991) argued that unlike air passengers, air freight is diverse. For instance, one can sort air freight by the weight of each shipment, or one may consider the types of commodities being delivered, or classify air freight by the required speed for shipping. By contrast, O'Connor (2001) argued that the idea behind low-value and high-value terms is that a high-value (per weight unit) item can bear a high transportation charge because weight is a main determinant of shipping fees. High cost shipping may comprise a small percentage of the price tag of a high-value commodity; however, it might comprise a substantial share in the price tag of low-value goods.

According to Doganis (1991), Haggerty (2004), and O'Connor (2001), recent air cargo shipments can be separated into three categories:

1- *Emergency traffic*: where the main concern is time, and the cost factor is less important. It could include life-saving drugs in a medically urgent situation (e.g.

vaccines) or shipping a machine part for an assembly line in a plant where the entire line is shutdown until the line is repaired. Emergency traffic comprises only a small quantity of recent air freight market share.

2- *Routine perishable traffic*: planned traffic, sensitive to time, and less concerned with shipping prices. This category consists of cut flowers, fish, fresh vegetables and fruits (e.g. strawberries, cherries), and printed materials (e.g. magazines and newspapers whose value expires rapidly) although the need for air service is fairly inelastic.

3- *Routine surface-divertible traffic (or routine non-perishable freight)*: in this group, the cost factor turns out to be most important, while the speed factor becomes minor to cost concerns. Some shippers prefer to send cameras, toys, and tools by air instead of using lower-cost transportation alternatives because they think that they can save in other ways in relation to what they spend for the transportation charge. For example, they may be able to avoid the costs of carrying large inventories, the costs of warehousing, and the problem of obsolescence. Additionally, the psychology of client satisfaction from fast service encourages shipment by air. The supplementary development of air cargo relies mostly on convincing shippers that it may be beneficial for them to switch some of their traffic from surface to air. Even though the public's perception of air cargo may still be coupled to the idea that most products involve time-sensitive and perishable shipments, the larger share of the traffic currently comprises products categorized as routine surface-divertible.

According to the UK Department for Transport (2000), air shipments usually have been used for high cost products, perishable commodities and emergency items (whether in the case of accidents or disasters) or commercial needs including legal documents, medical records, financial papers, computer disks, tapes, and additional parts for production. On the other hand, with the expansion in air freight capacity and the reduction in air freight rates, the range of cargo shipped by air has expanded. Today, the commodities that make up the greater part of air freight include specialist machinery (especially electronic goods), telecommunications equipment, medical and pharmaceutical products, textiles, foodstuffs, and photographic equipment.

Currently, perishable commodities like luxury foods, foreign fruits, frozen meat, fish, flowers, newspapers, and fashion clothes are the majority of products requiring air transport. Since the commercial life for these perishable commodities is short, air transportation is merely a way to move the products from maker to customer in an expeditious manner. The shipping costs are frequently high in relation to the price of the product for such goods but can be acceptable if the final customer is willing to pay a premium (UK Department for Transport, 2000).

Air transport is also used to ship regular non-perishable commodities because the savings in other costs like inventorying expenses can reimburse the high costs of air transportation, resulting in increased pressures on logistics chains and just-in-time inventory system. JIT inventory refers to the need to travel through the manufacturing supply chain to arrive at their point of consumption at exactly the time they are desired. Air freighting is mostly appropriate for these consignments because of its speed and reliability compared to long haul routes over land or sea (UK Department for Transport, 2000).

5.2. Mail

Another type of air cargo is mail, which mostly includes letters, bills and payments of account, postal cards, financial papers, and advertising. Even though this dissertation focuses most of its attention on non-mail freight, it is important to acknowledge the significance of the mail market. This subset of air cargo industry has been largely overlooked and is another 'missing piece' in air transport research that deserves further investigation and empirical analysis.

According to Johnson and Gaier (1998), mail is one segment of air cargo that represents the total shipments of U.S. and foreign Postal Service letters and small parcels that are usually transported under long-term agreements between the Postal Service and the individual carriers. However, mail does not include letters and small boxes transported with express and overnight services. According to O'Connor (2001, p. 158), "in 1998, mail accounted for about 11.5 percent of air cargo ton-miles of the U.S. scheduled airline industry, 13.7 percent of its cargo revenues, and 1.5 percent of all its operating revenues, passenger and cargo combined."

The United States Postal Service (USPS or Postal Service) is one of the largest organizations in the world, providing mail service with 807,596 employees and total operating revenue of $69 billion in 2004 (USPS, 2004). The primary mail services that USPS provides to the businesses and public include first-class mail (e.g., letters, postcards, statements, invoices, and typewritten or computer processed correspondence), standard mail (e.g., printed matter, pamphlets, catalogs, newsletters, direct mail, and merchandise), express mail (which provides guaranteed overnight delivery for documents and packages weighing up to 70 pounds), priority mail (e.g., documents, gifts, and products), periodicals (e.g., magazines and newspapers), and package services. The major markets for these services are the communications, distribution and delivery, advertising and retail markets (Sorkin, 1980; Tierney, 1988; USPS, 2004). In 2004, USPS moved over 206 billion pieces of mail for 142.3 million delivery points (USPS, 2004). Unfortunately, few researchers have addressed the role of this organization in real depth and how it influences the geography of the U.S. mailing industry. Tierney (1988) points out that even with the significant service that the USPS provides, most people still know very little about the important function of this organization. Also, Sorkin (1980) argues that even with the notable size of the U.S. Postal Service's budget and labor force and the significance of timely mail delivery to businesses and customers, there has been very little academic economic analysis of USPS.

Unlike private carriers, the USPS is a government monopoly, which means that it possesses the right under federal law to leave customers' envelopes and packages into their regular mailboxes (Olds, 1995). On the other hand, Ferrara (1990) argues that because of the government-mandated monopoly status of the USPS and the lack of competition, USPS has become less innovative which results in producing slow, unreliable, and expensive mail service. Also, O'Connor (2001) argues that certain trends in airline flight scheduling have badly influenced USPS's performance. For instance, the development of hub-and-spoke systems have reduced the number of nonstop flights resulting in slower daylight service. Additionally, many overnight flights (particularly freighter services) have been eliminated. Like other kinds of cargo, mail tends to be gathered at the end of the business day and needs overnight service. To overcome this condition, USPS decided to acquire its own fleet of airplanes to complement the services it offered through the scheduled airlines (O'Connor, 2001). However, as an alternative, USPS has also signed deals with cargo carriers whereby particular freighter airplanes are completely committed to shipping the mail, with a focus on overnight service (O'Connor, 2001). Also, according to Pellet (2005) and Taylor and Hallsworth (2000), even though USPS is currently the only mail carrier in the U.S., it now faces strong competition from e-mail and private operations such as the UPS, FedEx, and DHL which has forced USPS to improve its business policy and renovate its products and services.

5.3. Expedited Small-Package Services

Increased demand for fast and reliable delivery of small and time-sensitive packages has significantly contributed to the growth of air cargo traffic in several U.S. metropolitan areas. The rise of integrators such as FedEx and UPS has played a vital role in boosting the air express market by providing a significant level of direct door-to-door service through their own fleet of aircrafts and pickup and delivery trucks. Acquiring a better understanding of the small package air freight industry will help us to better understand the role of air transportation in highly sophisticated metropolitan markets that place a great emphasis on expedited shipment or second-day delivery.

According to O'Connor (2001), expedited small-package (or air express) is another subcategory of air cargo. "A practical definition of a 'small' package is one that can be picked up by one employee without need for mechanical aids" (O'Connor, 2001, p. 159). A lot of these packages are very small and weigh a pound or two; for instance, some of these parcels are envelopes including documents (e.g., designs and payroll, or other financial records). Other packages can weigh up to 50 pounds or 70 pounds including computer chips, medical equipment, videotapes, commodities, or substituted parts for machinery (O'Connor, 2001). O'Connor (2001) argued that this sort of service is commonly recognized as "air express" as distinguished from "air freight", and until the early 1970s, it was a quite small and a largely ignored part of air transportation.

The remarkable growth of expedited small-parcel traffic that started in the early 1970s has continued into the 2000s. According to Chan and Ponder (1979) and O'Connor (2001), an excellent example of this expansion is FedEx, which started its services in 1973 with a door-to-door service delivery of small packages.

According to Ray (1998) and O'Connor (2001), like FedEx, other carriers provide expedited small-package service like UPS and Emery. O'Connor (2001) also argued that it can be difficult to distinguish between small-package service and traditional air freight carriers as the maximum size for a shipment increased due to competition and the growing need to load space on large planes. For instance, FedEx and UPS now offer no maximum weight limits for their services (O'Connor, 2001).

O’Connor (2001) also pointed out that regularly scheduled passenger airlines also contributed to the growth of small-package services. The majority of scheduled airlines ship small packages in the belly-hold of their aircraft. Additionally, a number of airlines provide pickup and shipping service in combination with passenger service (O’Connor, 2001).

Although overnight services command high prices, small-package traffic is still growing remarkably due to the high demand for fast time-sensitive shipping from several metropolitan markets.

> Delivery is *time*-sensitive rather than *price*-sensitive…. Customers are willing to pay for time-especially when the delay of a business day can cost thousands of dollars. (For the same reason, the air express industry doesn’t suffer from the destructive price wars that have plagued the airline industry) (O’Connor, 2001, p. 160)

O’Connor (2001) argued that the new concept of “just-in-time” has played a fundamental role in developing the small-package market whereby manufacturers and retailers maintain remarkably small inventories and depend on speedy efficient delivery of raw materials, components, and completed products on a daily basis. Air express traffic has been affected by the development of electronic mail although electronic communication (such as the Internet) by customers to order products has helped the express carriers by generating additional shipments (O’Connor, 2001).

6. Regulatory Concerns: Aircraft Noise - Congestion- Security Issues

Many metropolitan airports have been significantly influenced by regulatory policy regarding aircraft noise, congestion, and homeland security issues, which can indirectly shape the flow of air freight shipments in some major metropolitan markets. Examining how policy can constrain shipments will help us to better understand air freight movements and variations in door-to-door shipping-times in some metropolitan areas that can have a significant impact on local and regional economies.

Ligon (1992) argued that air express flights usually begin during nighttime hours since sorting operations at most domestic hubs are often scheduled between 10 P.M. and 3 A.M. By 1990, there were operating hour limitations at many major U.S. airports. Some air express companies decided to move to other airports that were not as strongly constrained by nighttime noise rules. Air Freight Association found that with no established federal policy on airport noise, air express companies faced a wide range of local rules restraining operating hours, particularly through the significant nighttime hours (Ligon, 1992).

Baron (1976) and Al Chalabi and Kasarda (2004) have argued that the rapid increase in air freight volume has out-stripped airport capacity in several key locations. Al Chalabi and Kasarda (2004) have pointed out that the limited capacity expansions of the 1990s caused substantial delays during the three years previous to the 9/11 World Trade Center crisis. As a result, Al Chalabi and Kasarda (2004) argued that many air express and cargo companies had recently moved or were in the process of moving to less crowded locations. For example, FedEx, UPS, DHL, and the U.S. Postal Service have re-positioned some hubs to medium-sized and underused airports (e.g., Greensboro, NC), and they have also established secondary hubs in smaller airports resulting in a more widespread geography of air freight (Al Chalabi & Kasarda, 2004; Gardiner et al., 2005).

Medium-size hubs rarely experience major air-space congestion problems, and they frequently afford truckers direct high-speed connections to nearby interstate highways. An additional asset at medium-size hubs is the additional room for cross-docking facilities. The need for freighters to pick up and combine shipments at night (after the business day), and to organize and distribute early the next day, has encouraged some carriers to position themselves at medium-size hub airports, particularly on the periphery of major urban centers (Al Chalabi & Kasarda, 2004; Gardiner et al., 2005).

Al Chalabi and Kasarda (2004) indicated that additional space is also required for security reasons. The events of 9/11 have extended the demand for more secure services and a need to isolate cargo from passenger operations. A secure airport border, with a sufficient on-site area for cargo, seems now to be a key selling point. Because of the delays caused by significant restricted security services, many shipments are often held for twenty-four hours, thus, increasing the desire for additional storage space (Al Chalabi & Kasarda, 2004).

Al Chalabi and Kasarda (2004) have also argued that due to the significant restrictions on space and operations at large hub airports, new security concerns, and the growing emphasis on separating passenger and cargo operations, there has been a growing interest in developing all cargo-focused airports. Good examples include Huntsville International Airport in Alabama and Alliance Airport near Fort Worth in Texas.

7. Air Transportation and Economic Development

Air transportation has been, and will continue to be, a significant influence in shaping critical geographical concepts such as connectivity and linkage, development patterns at different scales, and the worldwide economy (Vowles, 2006). Since the Airline Deregulation Act of 1978, the U.S. air transport system has developed a highly interdependent network where passengers and freight are transported through major hubs, from distant spokes, to their final destinations (Button, Lall, Stough, & Trice, 1999; Cohen & Paul, 2003; Feighan, 2001; Goetz & Sutton, 1997; Zhang & Zhang, 2002). More critically, air transport explains the growth and economic development of different urban areas through the delivery of freight, services, and people from specific origins to specific destinations (Alkaabi, 2004; Alkaabi & Debbage, 2007; Brueckner, 2003; Button & Taylor, 2000; Debbage, 1999; Debbage & Delk, 2001; Goetz, 1992; Goetz & Sutton, 1997; Ivy et al., 1995; Mason, 2005; O'Connor, 2003; Oster et al., 1997). On the other hand, it is not yet clearly understood how the geography of air transport at both the global and national scale are influenced by new forms of production networks 'on the ground' that are explicitly linked to the 'new' knowledge economy.

Unlike air passenger demand, the air freight market is affected by more complex factors, such as shipping costs, the overall strength of the economy, various safety policies, and environmental policies. For example, it is harder to determine the price of shipping freight compared with the cost to move people due to the additional specialized services that are required for freight such as handling, loading, unloading, classifying, storing, packaging, warehousing, and inventorying (Cambridge Systematics, Inc., COMSIS Corporation, & University of Wisconsin – Milwaukee, 1996). Also, the local economy can significantly affect the type, weight, quantity, and prices of freight that is being shipped. For instance, a strong economy with a high gross domestic product (GDP), high average incomes, and significant customer confidence can trigger substantial consumer spending on various types of expensive commodities in large quantities (Cambridge Systematics, Inc., et al., 1996). Kasarda and Green (2005) argue that an established statistical mutually interdependent and causal relationship exists between levels of air cargo traffic and both GDP and GDP per capita. The authors also suggest that aviation liberalization, advanced customs practice, and lower government restrictions tend to generate higher levels of air freight, trade, and economic development (GDP per capita and foreign direct investment). Less clear is which specific places most benefit from these economic inter-relationships.

There are also several critical factors considered by freighter-operating airlines when selecting an airport as a hub base including night operations, final costs, airport cargo reputation, the influence of freight forwarders, airport road access, customs clearance times, financial incentives from the airport authority, and trucking times to main markets (Gardiner et al., 2005). For example, many non-integrated airlines are looking for lower charges for landing, handling, and fuel, as well as improved facilities and infrastructure when they choose an airport. Additionally, air freighter operators tend to seek locations with a significant geographic concentration of freight forwarders at an airport given their key role as an interface between shippers and airlines (Gardiner et al., 2005; Ohashi et al., 2005). As a result, it is important for airports to position themselves carefully as part of an overall supply chain system by developing links with local industries and establishing relationships with major shippers, manufacturers, traders, and forwarders on the ground. Gardiner et al. (2005) and Zhang et al. (2004) also argue that airlines with strategic alliance partners (e.g., Star alliance -Lufthansa and United, and OneWorld- American Airlines and British Airways) have been influenced to locate near to alliance partners in order to gain a better connecting service for transit cargo, allowing carriers to establish broader network coverage from one location as well as to benefit from the advantages of joint marketing.

Just-in-time pressures, e-commerce, and the increasing tendency towards outsourcing distribution have also led to increased demand for air cargo services in general and for air express services in particular. Therefore, many cities are trying to attract airlines to build up operations in their markets but this frequently requires the state and the federal governments to support financial incentives, various tax reduction schemes, and infrastructural investments (Oster et al., 1997). Despite these costs, air cargo hubs can significantly alter the economic characteristics of a metropolitan area and fundamentally change the location decisions of other businesses, as well as the overall economic structure of the region. For instance, hosting an air cargo hub can provide a longer shipping day to businesses heavily reliant on air shipments (Oster et al., 1997). Moreover, firms that rely on air cargo can accrue a price and service benefit by locating in an air cargo hub city compared with a non-hub city (Oster et al., 1997). For example, the expenses of delivery service can be lower when the shipment only has to be carried by air from the hub directly, instead of also being carried by ground or air to the hub (Oster et al., 1997). That is important to some shippers because their ability to compete and succeed relies significantly on the deadline for a shipment and the cost of that shipment.

Oster et al. (1997) also studied how changes in employment in the air cargo sector of the regional economy are connected to changes in total employment in the region. The authors studied the influence of major air freight companies on their hub city employment in Memphis (FedEx), Cincinnati (DHL), and Louisville (UPS). Oster et al. found significant employment growth in all three markets immediately after hub operations were established. However, it is important to be aware that in addition to air cargo employment there are several other factors that can cause changes in regional employment levels. Therefore, it is crucial to integrate into the study other explanatory factors in order to provide an improved understanding of how air freight shipments might change overall employment levels in a metropolitan area.

Oster et al. (1997) also tried to estimate the overall economic benefits of an air cargo hub facility on a local economy. According to Oster et al. (1997), every job at the FedEx hub in Memphis created an additional 2.75 jobs in the Memphis regional economy. Additionally, Oster et al. (1997) found that several companies established warehousing operations in Memphis in order to capitalize on the reduced shipment time benefits of being located near the hub. Examples of companies that chose to locate in Memphis, in part, because of FedEx included both Laura Ashley (a women's clothing firm) and Phillips (a producer of high-tech medical tools and computers) (Oster et al., 1997). Both companies are significant clients of Federal Express's Business Logistics Services, a sector of Federal Express concerned with stimulating the growth of warehousing and inventory facilities in FedEx markets (Oster et al., 1997).

Despite the increased importance of the 'geography of air freight', to date, there is no comprehensive empirical study that systematically addresses what factors are most significant in shaping the spatial distribution of air freight markets. Also, the critical role of government policy at all levels (federal, state, and local) in shaping innovation and technological change in the air freight industry has been largely overlooked. However, several air transport studies exist that have addressed how the geography of air passenger volume and airline route connectivity can shape regional economic growth patterns. Although the geography of air passenger markets may be fundamentally different to the 'geography of air freight', some insight may be gained by reviewing how air passenger demand shapes regional economies 'on the ground'.

Brueckner (2003) argued that passenger airline services have become significant, dynamic factors in shaping urban economic development due to increasing air passenger volume, the facilitation of face-to-face contact with firms in other cities, and through stimulating new business markets and employment growth in a region. For instance, he found that “a 10 percent increase in passenger enplanements in a metro area leads approximately to a 1 percent increase in employment in service-related industries” (Brueckner, 2003, p. 1455). However, Brueckner also found that airline passenger traffic has no influence on manufacturing or other goods-related employment levels, thus suggesting that air travel is more important regarding employment generation service-related businesses where the propensity to fly may be higher. Moreover, the author found a negative correlation existed between proximity and passenger traffic where small and medium-sized metro areas that are near a large airport experienced a diversion of traffic, which lowered local enplanements.

Brueckner (2003) also argued that both the total population in a metropolitan area and the percentage of the population over 25 with a college degree have significant effects on total passenger enplanements. A larger population base not surprisingly generated additional passenger demand. He also found that a 1% increase in population totals triggered a 1% increase in passenger enplanements, and highly educated metropolitan area tended to produce more airline traffic than poorly skilled areas. These results partly confirm the idea that highly educated people are more likely to work in jobs that significantly depend on business travel and face-to-face contact. Brueckner (2003) also found that highly educated metropolitan areas are not always preferred locations for manufacturing or other goods-related businesses.

Ivy et al. (1995) argued that highly skilled firms with nonstandard activities demand access to a highly professional labor pool, access to producer services, advanced transportation networks, information technology, and sophisticated communication infrastructure. Therefore, these nonstandard activities paid less attention to income rates, location costs, taxation, congestion, pollution, crime, and increased competition. Ivy et al. (1995) stated that unlike highly skilled firms that care more about locating in highly sophisticated agglomerative urban economies, blue-collar manufacturing producers with standardized production focus more on how to reduce labor costs, taxes, transportation costs, and how to achieve larger benefits for the companies by positioning themselves in low wage areas.

Ivy et al. (1995) found a statistically positive linkage existed between changes in air service connectivity (measured by airline flight schedules of the major U.S. commercial airline carriers) and administrative and auxiliary employment levels (e.g., research laboratories and financial services) by U.S. metropolitan area for the period between 1978 and 1988. This finding indicates that air service connectivity plays a key factor in making industrial sites attractive to professional firms that require face-to-face contacts with other customers, companies, and markets.

Unlike Ivy et al. (1995) who examined route connectivity levels, Debbage (1999) examined air passenger volume for the 10 largest airports in the U.S. Carolinas, and found that those metropolitan areas that experienced a significant growth in air service passenger volume (e.g., Charlotte and Raleigh-Durham) generated higher levels of administration and auxiliary employment. Debbage and Delk (2001) also confirmed some of the early research conducted by Ivy et al. (1995) and Debbage (1999) by examining the changing administrative and auxiliary employment levels and air passenger volume for the top fifty urban-airport complexes in the United States from 1973 to 1996. Debbage and Delk (2001) found that

> as administrative and auxiliary-related jobs and industries shifted away from the traditional manufacturing centers of the Northeast and Midwest to the South and West, the air transportation network appeared to experience a similar geographic shift as it broadened into a more deconcentrated air transportation network system. (p. 166)

Major airports play critical roles in serving as key points of exchange in the global economy. Nooteboom (1999) argued that reputation, linkages, and confidence are important keys to knowledge exchange, which is most easily accomplished when spatial, cognitive and cultural distances are reduced. Similar issues are likely to accrue for high-tech and skilled employees who are concerned with shared research and development activities that require frequent face-to-face interactions.

Alkaabi and Debbage (2007) and Alkaabi (2004) found that statistically significant relationships exist between air transport passenger volume and economic growth in select sectors by US metropolitan areas, where the ability of certain metropolitan areas to attract high-level firms and create employment opportunities in both the professional, scientific, and technical services sector and high-tech sector are systematically linked to the geography of air passenger demand. Alkaabi and Debbage (2007) and Alkaabi (2004) argued this is partly due to the importance of face-to-face interactions and the need for high levels of airline route connectivity at the main airport.

Although some research has been conducted that examine the links between air passenger traffic and regional economic performance, the impact of air freight traffic on the metropolitan economy has not been fully empirically tested. It is crucial that we better understand how the 'geography of air freight' volume is spatially distributed, and what the most influential factors are that manipulate air freight flows. How does air cargo volume at a hub airport create economic activity in the metropolitan area? And how does the growth of specific economic activities like high-tech, biotech, and other industries relate to the growth of air freight volume? We now turn to a useful overarching conceptual framework for much of this research agenda – the aerotropolis concept.

8. Kasarda's Aerotropolis (Airport City)

The introduction of e-marketplaces with the expansion of business-to-business (B2B) supply-chain transactions, and the increased demand for networking, speed, and reliability has played a fundamental role in restructuring spatially a new urban form around major airports called 'aerotropolis'. The concept of the 'aerotropolis' or 'airport city' has been largely adopted in recent academic and commercial literature, most notably by Dr. John D. Kasarda - known in some circles as 'The Father of the Aerotropolis'. Kasarda argued that airports may shape business locations and urban development in the 21st century the way in which highways did in the 20th, railroads in the 19th, and seaports in the 18th centuries (Al Chalabi & Kasarda, 2004; Leinbach, 2004). Many of the major international gateway airports are giving rise to this new urban form called 'aerotropolis', where aviation-intensive businesses and related enterprises extend up to 15 miles (25 kilometers) outward from airports along transportation corridors that branch out from the central urban core areas (Al Chalabi & Kasarda, 2004; Leinbach, 2004).

'Aerotropolis' can be a powerful engine of local economic development, attracting air-commerce-linked businesses to the land surrounding major airport generating a center of activity, similar to the form and function of central business districts (CBDs) in the downtown areas of major cities. The 'aerotropolis' form is actually a highly networked system with sophisticated multimodal surface connections. One outcome is that accessibility may replace central location as the most crucial business-location and commercial-real-estate organizing principle (Al Chalabi & Kasarda, 2004). Thus, time-cost access to the airport will determine land value and particular business locations. Kasarda argued that different kind of firms will compete against each other for airport accessibility to benefit from the lower time and cost of moving people and products to and from the airport and – via the flight networks – to regional and global markets (Al Chalabi & Kasarda, 2004; Kasarda, 2000). Al Chalabi and Kasarda (2004) also argued that land values, lease rates, and commercial use will be measured by accessibility to the airport from alternatives sites through connecting highway and rail routes.

'Aerotropolis' represents the spatial manifestation of the interaction of industries related to time-sensitive manufacturing, e-commerce, telecommunications and third-party logistics firms; entertainment, hotel, retail complexes and exhibition centers; and business offices (Kasarda, 2008; Pinkowski, 2007). A hypothetical illustration of 'aerotropolis' is shown in Figure 2. Clusters of business parks, logistics parks, industrial parks, distribution centers, information technology complexes, and wholesale merchandise marts are situated around the airport and next to the transportation corridors radiating from them. Various alternative interpretations of 'aerotropolis' already exist around

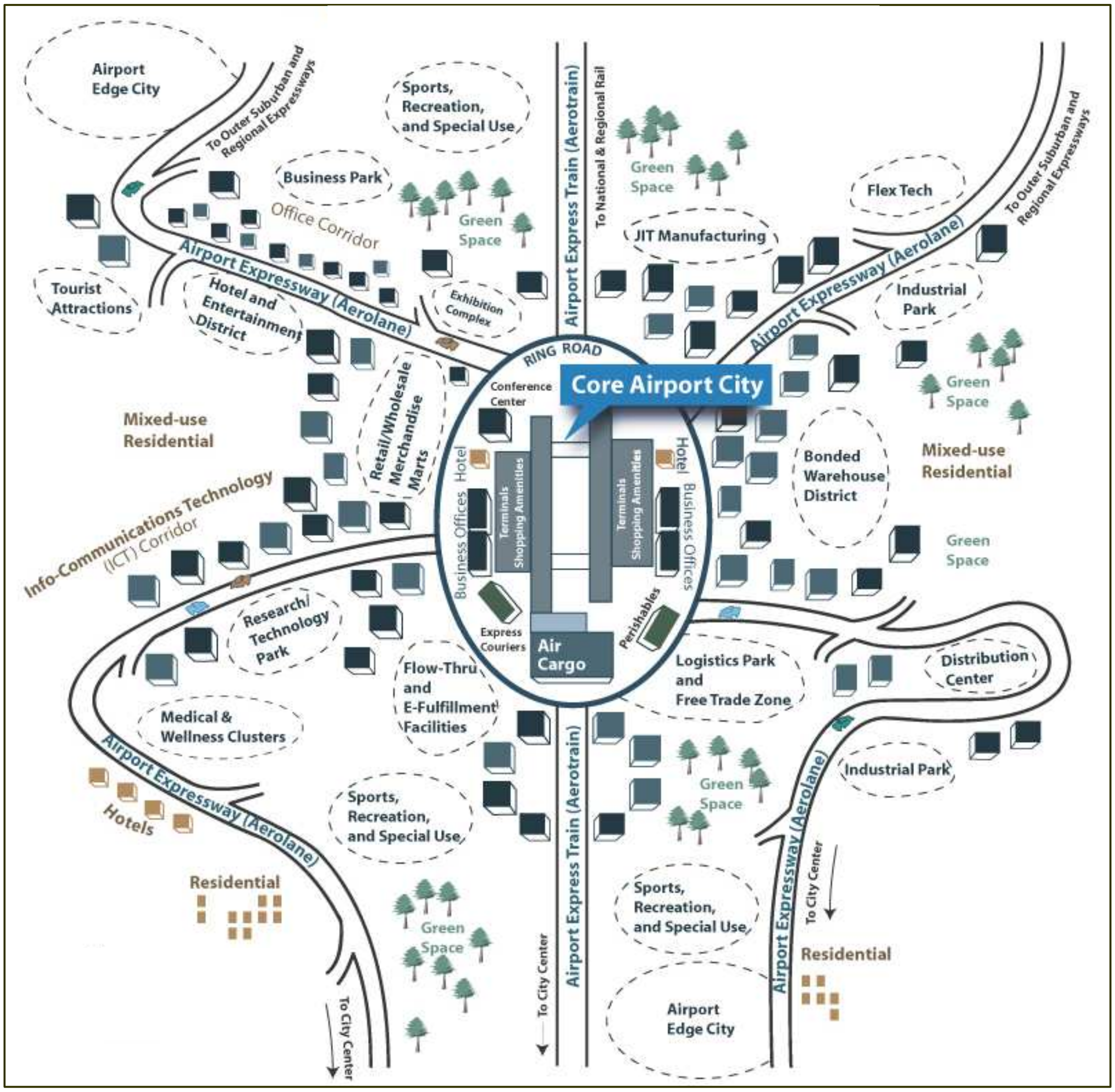

Figure 2. Kasarda's Hypothetical Diagram of Airport City or Aerotropolis
Source: Kasarda, 2008

many of the major gateway airports of the world including: Chicago O'Hare, Dallas/Fort Worth, Miami, New York Kennedy, Washington Dulles, Los Angeles, London Heathrow, Paris Charles de Gaulle, and Amsterdam Airport Schiphol, and Al Maktoum International Airport in Dubai (Al Chalabi & Kasarda, 2004; Kasarda, 2008). Some of these airports have become regional intermodal surface transportation nodes and major employment, shopping, meeting, entertainment, and distribution destinations. Even smaller specialized air cargo airports in the United States, such as Fort Worth Alliance Airport and Rickenbacker Airport in Columbus, Ohio, are generating 'mini-aerotropolis' in the form of low-density cluster and spine development. Left unanswered in Kasarda's aerotropolis theories is which key variables best explain the geography of air freight which, in all likelihood, will shape the geography of aerotropolis. This dissertation is one of the first steps in that direction.

In the upcoming decades, major airports will continue to impact business location decisions as well as urban growth and form (Kasarda, 2008). Therefore, understanding the concept of 'aerotropolis' might help us better explain the intense spatial agglomeration of time-sensitive industries and transportation-shipping-logistics activities around some airports for some metropolitan markets. Also, the notion of airport city will help us better understand how air freight 'in the sky' shapes the metropolitan economy and urban form 'on the ground'.

9. Conclusion

Several earlier studies have already theoretically pointed out the significant role that transportation plays in shaping local and regional economies, suggesting that this role will become more significant over time. Metropolitan markets can benefit from major airport-related development through increased freight connectivity levels, various efficiency gains, and access to new markets. Due to the increased emphasis on just-in-time delivery and the growing significance of logistics, transportation and freight distribution, this dissertation attempts to enhance our understanding of the 'geography of air freight' shipments by U.S. metropolitan area by determining which specific factors most influence and shape the geographic distribution of air freight shipment. More specifically, this dissertation examines several socioeconomic variables (e.g., population, education, income, and poverty) and different types of industrial sectors (e.g., high-tech, biotech, medical diagnostic) in order to determine the underlying causal dynamics that shape variation in the 'geography of air freight' volume. This study identifies some of the key regional businesses and industries that policy makers and economic developers need to consider when designing a regional development policy in order to stimulate airport-related development and air freight shipment volume by weight.

In this sense, the dissertation is a first step towards a broader-based understanding of how the 'geography of air freight' 'in the air' can be influenced by the geography of metropolitan labor markets 'on the ground'. By focusing on air freight, the dissertation complements the work already done studying the geography of air passengers and enhances our overall understanding of the dynamic growth and change affecting U.S. metropolitan areas. We now turn to a discussion of both the key research hypotheses posed in this dissertation and some general research design/methodology issues.

CHAPTER III

RESEARCH DESIGN

1. Research Hypotheses

The central research hypothesis of this dissertation is that the geography of air freight 'in the air' is systematically connected to the geography of regional economic performance 'on the ground'. Specifically, the more detailed hypotheses include:

- The geography of air freight by metropolitan area adheres to an explicit spatial hierarchy that is controlled by both the freight integrators at their major sorting hubs in the center of the country and several key international gateway destinations on the east and west coast.
- Variations in air freight volume by metropolitan area are largely a function of specific socio-economic indicators such as overall measures of per capita income and skill levels given the propensity for air freight volumes to be higher in more sophisticated agglomerative economies that require high levels of connectivity and trade in high-value, low-weight product shipments.
- The geography of air freight is directly linked to the composition of the metropolitan economy as measured by the percent of the labor force in key industries like transportation, shipping and logistics. It will be argued that

metropolitan economies that specialize in supply chain related industries will have a competitive advantage with respect to air freight shipments.

- The traffic shadow effect will play a significant role in shaping the geography of air freight whereby traffic diversion from smaller metropolitan areas to proximate larger metropolitan markets is a significant undercurrent to fully understanding spatial variation in air freight shipments at the metropolitan scale.

2. Data Sources and Definitions

2.1. The Dependent Variable: Air Freight

Air freight in this dissertation is defined as revenue freight by pounds, which **includes all forms of property, other than mail and passenger baggage transported by air** (U.S. BTS, 2005b; U.S. Government Printing Office, 2009). Air freight data were gathered from the T-100 Market (All Carriers) Table, which combines domestic and international market data, that was included under Air Carrier Statistics (Form 41 Traffic) Database in the U.S. BTS web site (U.S. BTS, 2005a).

Air freight data include shipments by foreign air carriers, large certificated air carriers, domestic all-cargo air carriers, and small certificated and commuter air carriers (U.S. BTS, 2005c). For example, foreign air carriers are required to report all flights to and from the United States. Also, small aircraft with 60 seats or less or 18,000 pounds or less of payload capacity will be reported (U.S. BTS, 2005c). Moreover, the categories of traffic data reported on T-100 have been extended to comprise detailed nonstop segments and on-flight market data for all military, domestic all-cargo, and domestic charter flights (U.S. BTS, 2005c). It should be noted that air freight volume at military airports were not included in the dissertation analysis given the fundamentally different nature of military airports relative to civilian airports.

Air freight data were collected for all origin airports that generated more than 100,000 pounds in 2003. Much like the FAA-defined passenger enplanements (i.e. boarding passengers), air freight volume data are based on flight departures not arrivals. Of course, air freight that is shipped via two or more connecting flights will then be counted multiple times. Consequently, air freight data not only capture the significance of 'originating' markets where the product is generated, but also capture the significance of air freight hub markets like Memphis where it is resorted. Since labor markets tend to be regional markets not exclusively city-based markets as measured by commuting behavior, air freight data were collected by Metropolitan Statistical Area (MSA) and Combined Statistical Area (CSA) based upon the June 6, 2003 definitions by the Office of Management and Budget. However, it should be noted that some metropolitan areas have multiple airports within a single MSA or CSA and these are indicated in Appendix A for the 2003 air freight data. For the MAs listed in Appendix A, the air freight weight totals were aggregated together to be consistent with those MSAs and CSAs that had only a single airport that generated more than 100,000 pounds of air freight in 2003.

2.2. The Independent Variables

2.2.1. Socioeconomic Characteristics

Based on the previous literature, thirty-three different socio-demographic-economic explanatory variables were identified for use in this dissertation (Table 1). It is hypothesized that certain key socioeconomic variables (such as total population, percentage growth rate in population, personal income, per capita personal income, and education levels) will vary systematically with spatial variation in air freight by metropolitan area. The socioeconomic characteristics that will be addressed in this dissertation are the following:

a. Total Population

The population data were gathered by MSA and CSA from the Regional Economic Information System-Bureau of Economic Analysis (BEA) using Table CA1-3 population (number of persons) for 2003 (BEA, 2005a). The BEA uses the Census Bureau's midyear population estimates. Except for college students and other seasonal populations, which are measured on April 1, the population for all years is estimated on July 1 (BEA, 2005b). Some of the literature (e.g., Taaffe, 1956) has suggested that the critical mass of the market as measured by total population is a key factor influencing air freight markets and passenger hubs.

Table 1. Thirty-Three Independent Variables included in the Study

#	Independent Variables
1	High-Tech Employment
2	High-Tech Establishments
3	High-Tech Total Wages
4	High-Tech Employment Market Share
5	Average High-Tech Employee Wage
6	Medical Diagnostic Employment
7	Medical Diagnostic Establishments
8	Medical Diagnostic Total Wages
9	Medical Diagnostic Employment Market Share
10	Average Medical Diagnostic Employee Wage
11	Pharmaceutical and Biotech Employment
12	Pharmaceutical and Biotech Establishments
13	Pharmaceutical and Biotech Total Wages
14	Pharmaceutical and Biotech Employment Market Share
15	Average Pharmaceutical and Biotech Employee Wage
16	Cultural Products Employment
17	Cultural Products Establishments
18	Cultural Products Total Wages
19	Cultural Products Employment Market Share
20	Average Cultural Products Employee Wage
21	Transportation-Shipping-Logistics Employment
22	Transportation-Shipping-Logistics Establishments
23	Transportation-Shipping-Logistics Total Wages
24	Transportation-Shipping-Logistics Employment Market Share
25	Average Transportation-Shipping-Logistics Employee Wage
26	Total Population
27	Total Personal Income
28	Per Capita Personal Income
29	Total Employment in all Industries
30	Total Population in Poverty
31	Total Population (25 to 64 Years) with Bachelor’s Degree or Higher (2005)
32	Percent Growth Rate of Population (2000-2003)
33	Traffic Shadow Effect

b. Percent Growth Rate of Population (2000-2003)

The percent growth rate of population was calculated from 2000 to 2003 using the BEA's population data from Table CA1-3 population. This variable will help to capture variation in growth rates by metropolitan area where it is expected that fast growing metropolitan areas should outperform slower-growing or declining markets with suspect to the volume of air freight shipment.

c. Total Personal Income ($)

The data for personal income were collected for each MSA and CSA from the BEA website using Table CA1-3 personal income (thousands of dollars) for 2003 (BEA, 2005a). The BEA defined personal income as the income that is received by all persons from all sources.

> It is calculated as the sum of wage and salary disbursements, supplements to wages and salaries, proprietors' income with inventory valuation and capital consumption adjustments, rental income of persons with capital consumption adjustment, personal dividend income, personal interest income, and personal current transfer receipts, less contributions for government social insurance (BEA, 2005c, ¶1).

Much like with total population, some studies suggest that the overall aggregate wealth of a metropolitan area is a key predictor of air freight performance.

d. Per Capita Personal Income ($)

The data for per capita personal income (dollars) were collected from the BEA using Table CA1-3 for 2003 by MSA and CSA (BEA, 2005a). According to BEA, this measure of income is calculated as the personal income of the residents of a given area divided by the resident population of the area. In computing per capita personal income, BEA uses the Census Bureau's annual midyear population estimates (BEA, 2005d).

Per capita income is frequently used as a measure of the wealth of the population of a nation, particularly in comparison to other nations. It is useful because it is widely known and produces a clear-cut statistic for comparison purposes. It is expected that metropolitan areas with high per capita personal income ship high rates of air freight poundage.

e. Total Population in Poverty

Poverty data were gathered from the Small Area Income and Poverty Estimates (SAIPE) program, which is created by the U.S. Census Bureau to provide more current estimates of selected income and poverty statistics for all states and counties (see Appendix B) (U.S. Census Bureau, 2009a).

Since the SAIPE program offers poverty data only by states, counties, and school districts, this dissertation constructed this variable by aggregating up county data that make up each MSA/CSA included in this study (U.S. Census Bureau, 2009b). It is hypothesized that MSA/CSA with a large population in poverty will tend to underperform regarding air freight shipments and it is assumed that an inverse relationship exists.

f. Education: Total Population with a BA and Higher (25-64 Years Old)

Ohlemacher (2006) argued that the percent of college graduates is the largest predictor of economic well-being for cities. Therefore, in order for metropolitan areas to succeed and generate good- paying jobs it needs to be attractive to well-educated populations. This dissertation analyzed education levels based on data collected from the 2005 American Community Survey (ACS), published by the U.S. Census Bureau (2005a). This variable will include population from 25 to 64 years with a bachelor’s degree or higher.

2.2.2. The Manufacturing Sectors

It is hypothesized based on the existing literature that certain key manufacturing activities tend to ship a disproportionate level of airfreight shipments including industries such as medical diagnostic, high-tech, transportation-shipping-logistics, pharmaceutical and biotech. Data for these indicators were collected from the Quarterly Census of Employment and Wages (QCEW) program that is available through the U.S. Bureau of Labor Statistics (BLS, 2005a). The QCEW program publishes monthly counts of employment and wages reported by employers and it is available at the county, MSA, state, and national levels by industry (BLS, 2005b). The QCEW data are classified based on the North American Industry Classification System (NAICS) which rigorously defines all industrial sectors in the United States. It is hypothesized that as the economic indicators for these industrial sectors (such as medical diagnostic, high-tech, transportation-shipping-logistics, and pharmaceutical and biotech) and cultural products (e.g., jewelry and cosmetic goods) increase as measured by number of jobs, establishments and average wages, air freight volume will increase in a similar fashion.

a. Medical Diagnostic Industries

One of the most rapidly growing sectors in the U.S. economy is the medical diagnostic industry. Of course, given the requirement for the rapid delivery of diagnostic results to clients and the low weight product, this sector is particularly susceptible to shipments by air. In this dissertation, specific NAICS codes were used to capture this industry including:

- NAICS 42345: Medical, Dental, and Hospital Equipment and Supplies Wholesalers

According to the 2002 Economic Census (2005a), this industry consists of firms mostly "engaged in wholesaling medical professional equipment, instruments, and supplies (except ophthalmic equipment, instruments and goods used by ophthalmologists, optometrists, and opticians)".

- NAICS 6215: Medical and Diagnostic Laboratories

This industry includes firms recognized as medical and diagnostic laboratories mostly “engaged in providing analytic or diagnostic services, including body fluid analysis and diagnostic imaging, generally to the medical profession or to the patient on referral from a health practitioner” (2002 Economic Census, 2005b).

- NAICS 33911: Medical Equipment and Supplies Manufacturing

2002 Economic Census (2005c) defined this industry as companies largely “engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are laboratory apparatus and furniture, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures, and orthodontic appliances” (¶1)

b. High-Tech Industries

Although there is no one standard definition of what hi-tech means, the hi-tech industries in this dissertation are selected based on the perceived level of technical sophistication of the product produced by an industry. Many hi-tech products such as laptops and related electronic products are shipped by air. Therefore, it is hypothesized as high-tech employment increases, air freight will increase. The hi-tech industries in this dissertation include the following sectors:

- NAICS 5415: Computer Systems Design and Related Services

According to the 2002 Economic Census (2005d), this sector includes businesses largely

> engaged in providing expertise in the field of information technologies through one or more of the following activities: (1) writing, modifying, testing, and supporting software to meet the needs of a particular customer; (2) planning and designing computer systems that integrate computer hardware, software, and communication technologies; (3) on-site management and operation of clients' computer systems and/or data processing facilities; and (4) other professional and technical computer-related advice and services.

- NAICS 334: Computer and Electronic Product Manufacturing

According to the 2002 Economic Census (2005e), this sub-sector group includes companies that manufacture computers, computer peripherals, communications equipment, and related electronic products, and firms that produce components for such products.

c. Transportation-Shipping-Logistics Industries

The main types of organization involved in logistics and distribution comprise: transportation companies, logistics service providers, wholesalers, trading companies, retailers, and e-tailers (Dicken, 2007). This sector includes several subsectors that were chosen for this dissertation because of their various functional services that become necessary to facilitate freight processing. Also, these subsectors were chosen among others since they tended to generate substantial employment rates. A recent study by the

North Carolina Board of Science and Technology (2000) confirms much of this logic. These industries included:

- NAICS 4921: Couriers

According to the 2002 Economic Census (2005f), this industry includes establishments mainly engaged in providing air, surface, or combined courier delivery services of parcels usually between metropolitan areas or urban centers. The establishments of this industry form a network of courier local pick-up and delivery services that act to supply their clients' requirements.

- NAICS 49311: General Warehousing and Storage

The 2002 Economic Census (2005g) stated that this category consists of establishments mainly engaged in operating merchandise warehousing and storage facilities. These firms usually handle commodities in containers (e.g. boxes, barrels, and/or drums) using equipment (e.g. forklifts, pallets, and racks). They are not specialized in managing bulk products of any particular type, size, or amount of goods or products.

- NAICS 49319: Other Warehousing and Storage

According to 2002 Economic Census (2005h), this group of industry comprises establishments largely engaged in operating warehousing and storage facilities (excluding general merchandise, refrigerated, and farm product warehousing and storage).

- NAICS 4885: Freight Transportation Arrangement

This industry set includes firms largely engaged in organizing the transportation of freight between shippers and carriers. These companies are commonly recognized as freight forwarders, marine shipping agents, or customs brokers and offer a combination of services spanning transportation modes (2002 Economic Census, 2005i).

- 488991: Packing and Crating

This industry group includes businesses mostly engaged in packing, crating, and otherwise preparing commodities for shipping (2002 Economic Census, 2005j).

d. Pharmaceutical and Biotech Industries

Many pharmaceutical and biotech products are shipped by air. Therefore, it is hypothesized that as pharmaceutical and biotech employments increase, air freight volume will increase. Like previous studies by the Milken Institute (2004) and the Brookings Institution (2000), this dissertation will choose the following NAICS codes to represent the pharmaceutical and biotech sectors:

- NAICS 32541: Pharmaceutical and Medicine Manufacturing

The 2002 Economic Census (2005k) defined this industry as firms primarily engaged in one or more of the following:

1. manufacturing biological and medicinal products;
2. processing (i.e., grading, grinding, and milling) botanical drugs and herbs;
3. isolating active medicinal principals from botanical drugs and herbs; and

4. manufacturing pharmaceutical products intended for internal and external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.

- NAICS 5417: Scientific Research and Development Services

According to the 2002 Economic Census (2005l), this industry consists of businesses engaged in performing original investigation undertaken on a systematic basis to achieve new knowledge (research) and/or the application of research findings or other scientific knowledge for the formation of new or considerably enhanced products or processes (experimental development).

e. Cultural Products: Jewelry and Cosmetic Goods

Some studies have argued that high value low weight products such as jewelry, precious stone, and cosmetic products are more likely to ship by air. Recent U.S**.** BTS data indicate that pearls, stones, and metals imitation jewelry was one of the four most important commodities regarding air freight shipments in the NAFTA region in 2004 (U.S. BTS, 2005d). Therefore, this dissertation will investigate empirically the relationship that exists between air freight volume and jewelry and cosmetic products that include the following sub-sectors:

- NAICS 42394: Jewelry, Watch, Precious Stone, and Precious Metal Merchant Wholesalers

According to the 2002 Economic Census (2005m), this industry includes companies largely engaged in the commercial “wholesale distribution of jewelry, precious and semiprecious stones, precious metals and metal flatware, costume jewelry, watches, clocks, silverware, and/or jewelers' findings" (¶1).

- NAICS 33991: Jewelry and Silverware Manufacturing

According to Census Bureau (2003), this type of industry includes firms mainly engaged in one or more of the following activities:

1. manufacturing, engraving, chasing, or etching jewelry;
2. manufacturing metal personal goods (i.e., small articles carried on or about the person, such as compacts or cigarette cases);
3. manufacturing, engraving, chasing, or etching precious metal solid, precious metal clad, or pewter cutlery and flatware;
4. manufacturing, engraving, chasing, or etching personal metal goods (i.e., small articles carried on or about the person, such as compacts or cigarette cases);
5. stamping coins;
6. manufacturing unassembled jewelry parts and stock shop products, such as sheet, wire, and tubing;
7. cutting, slabbing, tumbling, carving, engraving, polishing, or faceting precious or semiprecious stones and gems;
8. recutting, repolishing, and setting gem stones; and
9. drilling, sawing, and peeling cultured and costume pearls.

- NAICS 44612: Cosmetics, Beauty Supplies, and Perfume Stores

According to the 2002 Economic Census (2005n), this industry includes establishments recognized as cosmetic or perfume stores or beauty supply shops mainly engaged in retailing cosmetics, perfumes, toiletries, and personal grooming products.

f. The Key Economic Indicators

The data for all the manufacturing activities were collected from the BLS website for 2003 by using the NAICS code for each host metropolitan area. The magnitude of each of these manufacturing activities will be measured by four key economic indicators which include:

- ***Number of establishments*:** an establishment is an economic unit, such as a farm, factory, store, or mine, that produces products or offers services. It is usually at a single physical location and engaged in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. Occasionally, a single physical location includes two or more different and important activities. Each activity is accounted as a separate establishment if separate records are reserved, and the various activities are classified under different NAICS industries (BLS, 2006). This indicator should help us understand the agglomerative tendencies for each MA.
- ***Total employees*:** represent the overall number of covered workers who worked during, or received pay for, the pay period that included the 12th day of the month. Almost all employees are reported in the State in which their jobs are physically located (BLS, 2006). This variable should help to demonstrate the variability in employment generation rates by MA.
- ***Employment market share (%):*** was calculated by dividing total number of employee for any given industry for each MSA/CSA by the total number of

employees in all industries, and then multiplying the outcome by 100. The indicator provides an assessment of the level of economic specialization of each metropolitan area.

- ***Total wages ($)*:** covered employees total compensation paid during the calendar quarter, regardless of when the services were performed.
- ***Average wages ($)*:** average wages per employee for any given industry is calculated by dividing its total wages by its total employees.

2.2.3. Traffic Shadow Effect (Dummy Variable)

This dissertation utilized a modified version of Brueckner's (2003) proximity variable to capture the traffic shadow effect. It is hypothesized that shippers located in small and medium-sized metropolitan areas that are located fairly close to larger metropolitan markets will tend to ship their air freight via the larger market due to the preponderance use of flight connections and flight services in the larger markets, thus, reducing freight shipment volume in the smaller markets. In order to capture the traffic diversion effect triggered by proximity to a larger metropolitan market, this dissertation constructed a dummy variable to capture the 'traffic shadow effect'. The variable is set equal to one for smaller metropolitan areas (less than 30 million pounds in air freight volume by metropolitan area) that are within 100 miles of a metropolitan area containing a large airport (generating greater than 30 million pounds in air freight).

Based on the "natural breaks" of the univariate frequency count, the threshold line of 30 million pounds seemed to be an appropriate cut-off point. The 100 miles cut-off (nearly two hours ground transport time) was chosen as an appropriate distance for driving freight to a larger airport in a nearly metropolitan area based on the pioneering 'traffic shadow effect' research developed by Taaffe (1956 & 1959). The physical distance between airports is measured using ArcMap software. This dissertation expects to find a negative relationship exists between the traffic shadow effect and air freight activity by metropolitan area.

3. The Geographic Unit of Analysis

The geographic unit of analysis used in this dissertation includes Metropolitan Statistical Areas (MSA) and Combined Statistical Areas (CSA). MSA's and CSA's are an appropriate measure to capture metropolitan labor pools sine they are defined by commuting patterns, which usually represent the regional catchment areas for many industries included in this dissertation. Moreover, airports tend to have metropolitan-wide market areas and the MSA and CSA is the most suitable spatial unit to capture that market appeal. Only metropolitan markets with more than 100,000 enplaned air freight pounds were chosen for this study. Although, due to the disclosure issue some MSA's and CSA's were not included. The total number of MSA's and CSA's included in this dissertation is 110.

4. Data Analysis and Research Methodology

First, a descriptive analysis will be conducted by examining the spatial distribution of air freight by MSA/CSA focusing in particular on the key hub-and-spoke markets and traditional coastal gateways using market share data derived from the U.S. Bureau of Transportation Statistics. In the hub-and-spoke metropolitan markets, particular attention will be paid to the key role of the integrated all-cargo carriers (e.g., FedEx and UPS) and the traditional combination carriers (e.g., American, Delta and United) in places like Chicago, Dallas, and Atlanta. Particular emphasis will be placed on air freight market share data in order to focus on how certain carriers utilize market power to manipulate and shape the geography of air freight. By doing so, the analysis helps explain the economies of scope and scale, competitive advantage, and at times geographic monopoly power exercised by, for example, FedEx in Memphis and UPS in Louisville.

Next, a regression analysis will be conducted on the dependent variable (air freight demand by weight) and a group of independent variables in order to underline the key predictors shaping the geography of air freight by metropolitan area. A key focus in the selection of the independent variables will be an attempt to disentangle what sort of industrial composition in a metropolitan economy is most likely to be affiliated with significant air freight demand. Additionally, the literature has suggested that various "critical mass" measures that capture aggregate population and various socio-economic characteristics in a metropolitan economy are key predictors and these are also included in the initial regression model. Most of the data was derived from the U.S. Bureau of Transportation Statistics and the U.S. Census Bureau. Before running the regression analysis, different analytical procedures will be conducted such as transforming the dependent variable to improve linearity and the distribution of the data. Also, a correlation matrix (Spearman) of the dependent and independent variables will be calculated to capture which of the potential predictors are highly correlated with air freight and less correlated with other predictors. The final regression model will be tested for multicollinearity issues, normality of residuals, homogeneity of variance, and linearity. Moreover, a brief rationalization will be provided regarding the influence of some missing data on the final model. After that, a detailed interpretation of the selected model will be provided.

Third, a descriptive analysis of the geography of the selected predictors will be provided including the spatial distribution of the following variables: per capita personal income, traffic shadow effect, transportation-shipping-logistics employment market share, medical diagnostic establishments, and average high-tech employee wage. Then, a summary of the findings will be provided including a brief rationalization of why some potential predictors were excluded.

Data for some of the variables in this dissertation were analyzed and visualized by using various diagrams including maps, tables, line graphs, pie-charts, histograms, and normal q-q plots. Maps were constructed using ArcGIS software, where data were classified into different classes using the 'Natural Breaks' method. These maps were used to examine the spatial distribution of the key independent variables and the dependent variable. Tables were also included in this dissertation to list the independent variables used in this study and to show the top-ranked metropolitan markets for the response variable and some of the explanatory variables. In addition, line graphs were constructed to illustrate air freight trends from 1990 to 2006. Moreover, a number of pie-charts were included in this dissertation to illustrate relative magnitudes or the percent of air freight by class service, carrier market shares, and airports in the New York CSA. Histograms and normal q-q plots were also used in this dissertation to examine the normality of the air freight data (response variable) before and after performing a natural log transformation. In addition, a number of different analytical diagrams and procedures were used in this dissertation to check if the regression assumptions were met and if the model is the best fit. Details on these analytical and diagnostic procedures were discussed in the empirical results section.

In this dissertation, multiple linear regression analysis was used as the main research method to measure the relationship between air freight weight (dependent variable) and different socio-economic and industrial sectors (dependent variables) and to build a model that well predicts air freight volume. To build the regression model, the stepwise selection procedure was executed using the SPSS Analytical Software (version 10.0 and 16.0). Even though there are other methods for selecting the explanatory variables (e.g., forward selection, backward elimination, Maxr, and Minr), stepwise selection procedure was chosen as the most appropriate method. Stepwise is a mixture of forward selection and backward elimination procedures. It resembles forward selection except that after entering a variable into the model, it removes any variables already in the model that are no longer significant predictors. This means that at each step, you enter a new variable using the same rules as in forward selection (add variables that result in a significant increase in R^2), then examine the variables already in the model for removal, using the same rules as in backward elimination (remove variables that change R^2 least) (Norušis, 2002).

In the stepwise selection method, there are two criteria: one for entering a variable and one for removing a variable. The significance level (p-value) for entering the variable should be smaller than the significance level (p-value) for removing a variable (Norušis, 2002). The significance level that was used in this dissertation for entering a variable is 0.05 and for removing a variable it was 0.10.

5. Research Limitations

This dissertation focuses on air freight by weight since data on air freight volume (in pounds) are more widely available than air freight value ($) by airport or metropolitan area. However, limited air freight value data by airport were published by the U.S. Department of Commerce, Foreign Trade Division. The U.S. Department of Commerce data suggest that a systematic relationship exists between air freight volume and value[1]. The assumption here is that studying the geography of air freight by weight will provide some insight into the geography of air freight by value. This dissertation also just

[1] A Spearman's correlation coefficient was calculated for air freight volume (pounds) and value ($) using the U.S. Department of Commerce data for the 31 largest airports in the United States for 2003. The correlation coefficient value was 0.36 at the 5% level of significance. The 31 airports included in this analysis accounted for 77% of the national market share for air freight value exports by airport.

examines the geography of air freight activity for just 2003 and did not examine air freight growth rates over time.

Also, there are some missing NAICS data because of the confidentiality and non-discloserure rules. This dissertation also analyzed air freight data at the metropolitan scale with limited intra-metropolitan analysis. For multi-airport metropolitan areas like New York and Los Angeles further research needs to be conducted to better understand how intra-metropolitan effects can shape the geography of air freight. However, this dissertation is the first at better understanding which regional economy metrics best explain the spatial variation in air freight production.

CHAPTER IV

FINDINGS

International and domestic enplaned freight volume by U.S. carriers grew from 6.7 billion pounds in 1990 to 14.6 billion pounds in 2001 – a 117.9 % increase (Figure 3). The rapid growth in air freight can be largely explained by the rapid changes in the methods of industrial production since 1978 including the introduction of just-in-time inventory, e-commerce and the Internet, as well as the development of faster and larger cargo jet aircraft. However, from 2003 to 2006, international and domestic enplaned freight poundage increased by just 6.3% (Figure 3) largely due to the slow down in enplaned freight traffic growth caused by the aftermath of 9/11, the Iraq war, the severe acute respiratory syndrome (SARS) crisis in Asia, and the rise in jet fuel prices since late 2004. The end result has been the diversion of some air freight traffic to less expensive ocean shipping lanes (Boeing, 2005 and 2007). Despite this slowdown, world air freight levels have grown by 3.1% in the first half of 2006 compared with 2005 (Boeing, 2007). Additionally, over the next 20 years, the freighter fleet is expected to double, and world air cargo traffic is expected to triple over current levels (Boeing, 2007).

The remarkable growth in air freight volume over the past few decades has led to significant shifts in the geography of air freight provision 'on the ground' by both airport and metropolitan market. However, little empirical research has been conducted regarding the spatial patterns of major U.S. air freight markets and how they can be shaped by metropolitan economies 'on the ground'. Therefore, one of the main purposes of this dissertation is to explore the spatial distribution of the air freight market in the United States by metropolitan area.

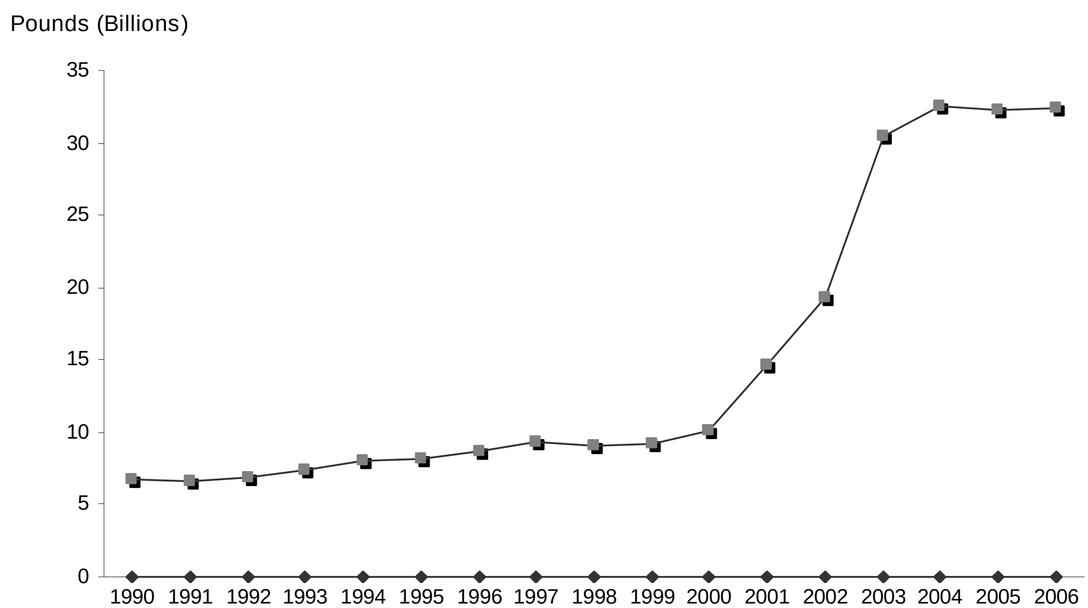

Figure 3. Enplaned Freight Growth by U.S. Carriers, 1990-2006
Source: Author's calculations based on data extracted from the U.S. BTS, 2007

Note: In October 2002, the U.S. BTS officially introduced new standards that adjusted the reporting requirements for air carrier traffic and capacity data. These new regulations expanded the definition of how air freight cargo was defined (U.S. BTS, c2005), therefore accounting for the sharp increase from 2001 to 2002. This figure now combines domestic and international market data reported by U.S. air carriers.

The chapter will be organized by first proceeding with a discussion of the two major types of air freight markets in the United States. The classification will include air freight markets that offer a conventional hub and spoke operation (e.g., FedEx in Memphis) versus markets with a more diverse coastal international gateway orientation (e.g., LAX or JFK). Additionally, particular attention will be focused on the type of air carriers that dominate in each of these respective markets (e.g. all-cargo airlines versus conventional passenger airlines) so as to better understand how the competitive strategies of each airline shapes the overall geography of air freight.

1. Spatial Distribution of Air Freight by MSA/CSA

In 2003, the mean air freight volume by metropolitan market was 232 million pounds for the 110 metropolitan areas included in this dissertation (Figure 4). The largest air freight market was Memphis with more than 3.9 billion pounds, and the smallest air freight market was Columbus, GA, with just 125,528 pounds. Figure 4 illustrates the spatial distribution of air freight volume by metropolitan area while Table 2 lists the fifteen metropolitan areas that generated the largest air freight volume in 2003. These fifteen markets accounted for roughly two-thirds of the total air freight poundage in the U.S., and the largest markets included Memphis, Los Angeles, New York, Louisville, and Miami. These five markets accounted for 40% of the U.S. total enplaned freight by weight (Table 2). Thus, just a few air freight nodes appear to control the national system indicating that a process of intense geographic concentration and regional specialization

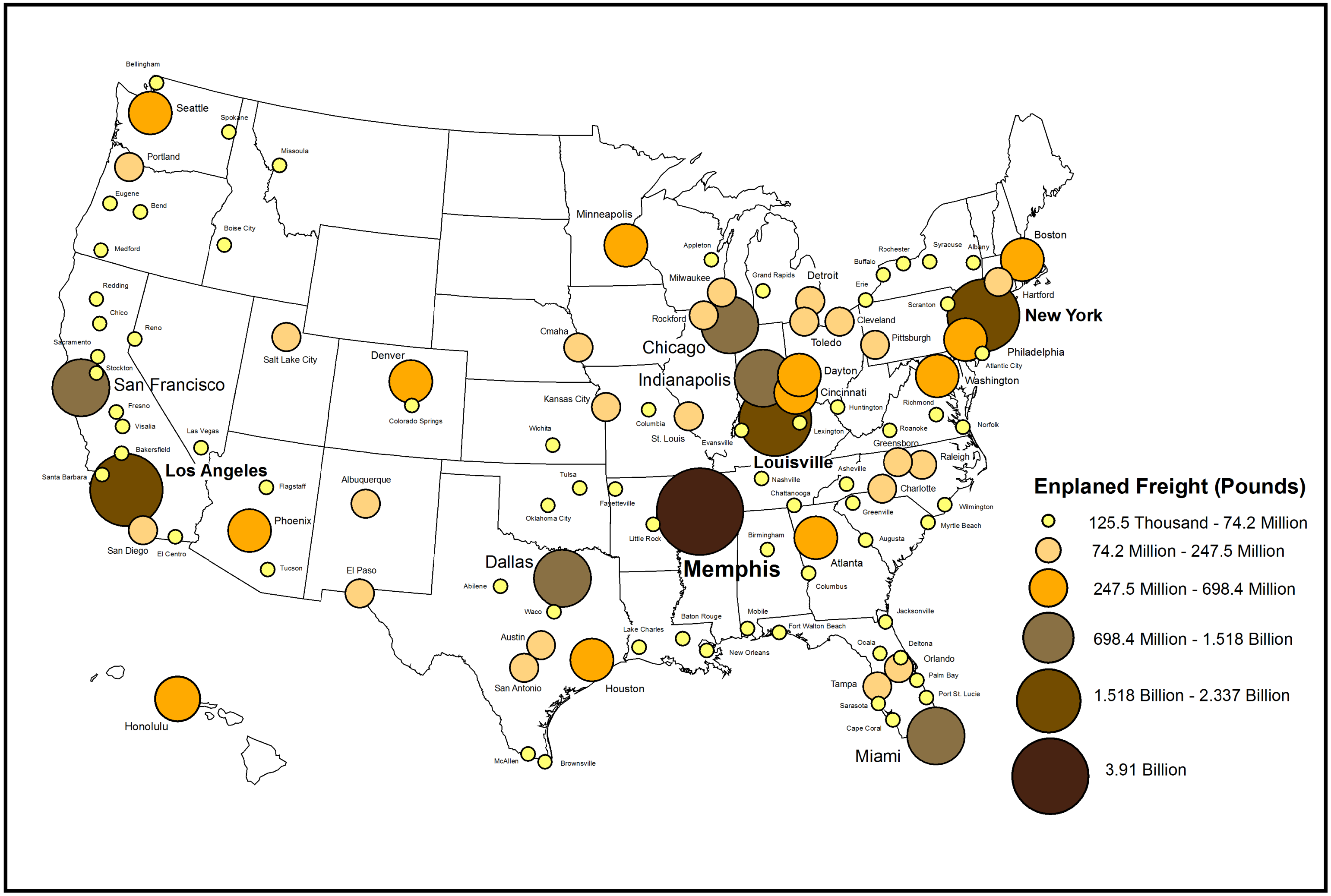

Figure 4. Spatial Distribution of Total Domestic and International Enplaned Freight (Pounds) By Metropolitan Area, 2003

Table 2. Largest Air Freight Markets by Metropolitan Area, 2003

Rank	Metropolitan Statistical Area/Combined Statistical Area	Total Enplaned Freight (Pounds)	% Share of U.S. Total Enplaned Freight by weight
1	Memphis, MSA	3,911,091,183	13.40
2	Los Angeles-Long Beach-Riverside, CSA	2,337,955,813	8.01
3	New York-Newark-Bridgeport, CSA	2,164,841,988	7.42
4	Louisville-Elizabethtown-Scottsburg, CSA	1,821,149,366	6.24
5	Miami-Fort Lauderdale-Miami Beach, MSA	1,518,866,711	5.20
6	San Jose-San Francisco-Oakland, CSA	1,337,720,693	4.58
7	Chicago-Naperville-Michigan, CSA	1,216,327,390	4.17
8	Indianapolis-Anderson-Columbus, CSA	981,910,898	3.36
9	Dallas-Fort Worth, CSA	870,003,045	2.98
10	Atlanta-Sandy Springs-Gainesville, CSA	698,390,018	2.39
11	Philadelphia-Camden-Vineland, CSA	613,764,469	2.10
12	Cincinnati-Middletown-Wilmington, CSA	490,243,431	1.68
13	Seattle-Tacoma-Olympia, CSA	464,410,426	1.59
14	Boston-Worcester-Manchester, CSA	443,043,955	1.52
15	Honolulu, MSA	420,566,720	1.44
Total		19,290,286,106	66.08

Source: Author's calculations based on data extracted from U.S. BTS, 2005a

may be fundamentally shaping the geography of air freight in the United States.

One major factor that may have triggered the intense geographic concentration of air freight volume to a few select metropolitan markets was the rapid growth of the express parcels. In 2003, 79.6% of the U.S. enplaned freight was carried by all-cargo carriers while just 20.4% of the U.S. enplaned freight was carried by passenger/cargo carriers (Figure 5). Express parcels have largely been dominated by both FedEx and UPS. These two companies realized early on that the traditional passenger airlines were overlooking two key aspects of the air freight market. These needs included the high-speed delivery of small packages and door-to-door delivery service. Traditionally, passenger airlines mainly focused on providing airport-to-airport freight delivery and largely depended on other intermediaries like freight forwarders for pick up and delivery to the final customer.

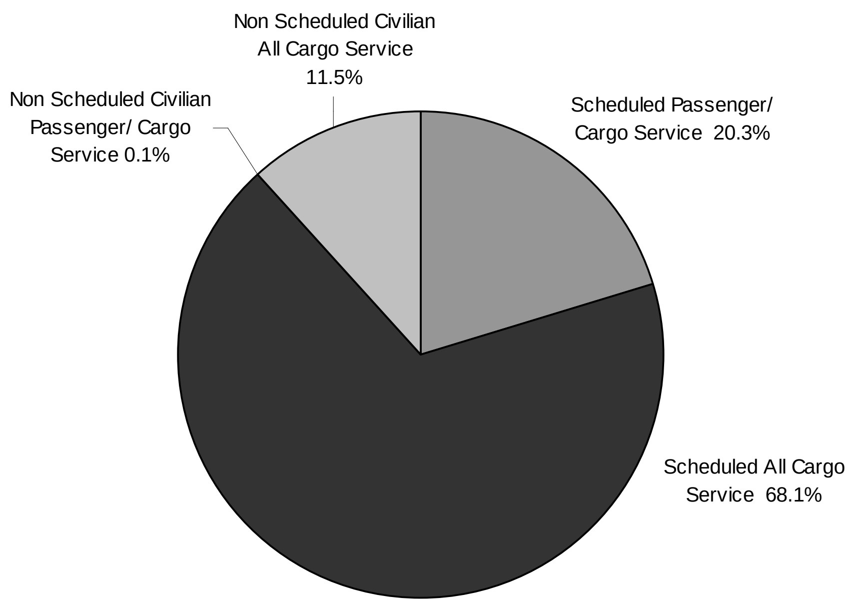

Figure 5. U.S. International and Domestic Enplaned Freight by Class Service (%), 2003
Source: data were extracted from U.S. BTS, 2005e

By contrast, FedEx and UPS played a key role for many businesses by operating an overnight service with reliable pick up and delivery service to every address in the United States using their own fleet of aircraft and trucks. Both companies now control a significant proportion of the air freight market. A visual inspection of Figures 6 and 7 suggests that FedEx and UPS are more dominant in the United States market than overseas. In 2003, FedEx and UPS collectively handled 68% of total U.S. domestic enplaned freight (pounds) but only 13.4% of the international enplaned freight (pounds) (Figures 6 and 7). Both FedEx and UPS have had a difficult time penetrating the international market. Part of this can be explained by the uniqueness of America's geography. The availability of an affluent market, a well developed national economy especially on the east and west coasts, and the large distances between each coasts enabled FedEx and UPS to establish a logic for a centrally located hub that acted as a transshipment point between the U.S. eastern and western markets. Also, the relatively homogeneous regulatory system created a perfect environment for FedEx and UPS cargo operations to successfully grow and extend across the United States. On the other hand, the different governmental regulations regarding air routes, landing rights in the different foreign countries, as well as the intense competition from other foreign carriers across international routes made it harder to replicate the Memphis and Louisville experience across the world. For example, the EU 'open' market is largely inclusive to EU national carriers and FedEx and UPS have had more difficulty capturing a significant market share in that part of the world.

Another carrier with considerable U.S. domestic freight traffic is ABX Air with a 6% market share of total U.S. domestic enplaned pounds in 2003 (Figure 6). ABX Air is a cargo airline based in Wilmington, OH, and it provides overnight express small-package services and freight distribution in the U.S., Canada, and Puerto Rico. ABX Air became a public company in 2003 as part of the innovative merger of DHL and Airborne, in which DHL retained ownership of Airborne's ground operations and spun off its air operations as ABX as part of a broader contract and hub services agreement between both companies. Of course, the recent decision by DHL to discontinue its air and ground operations within the United States market and cutting 9,500 jobs may really change the

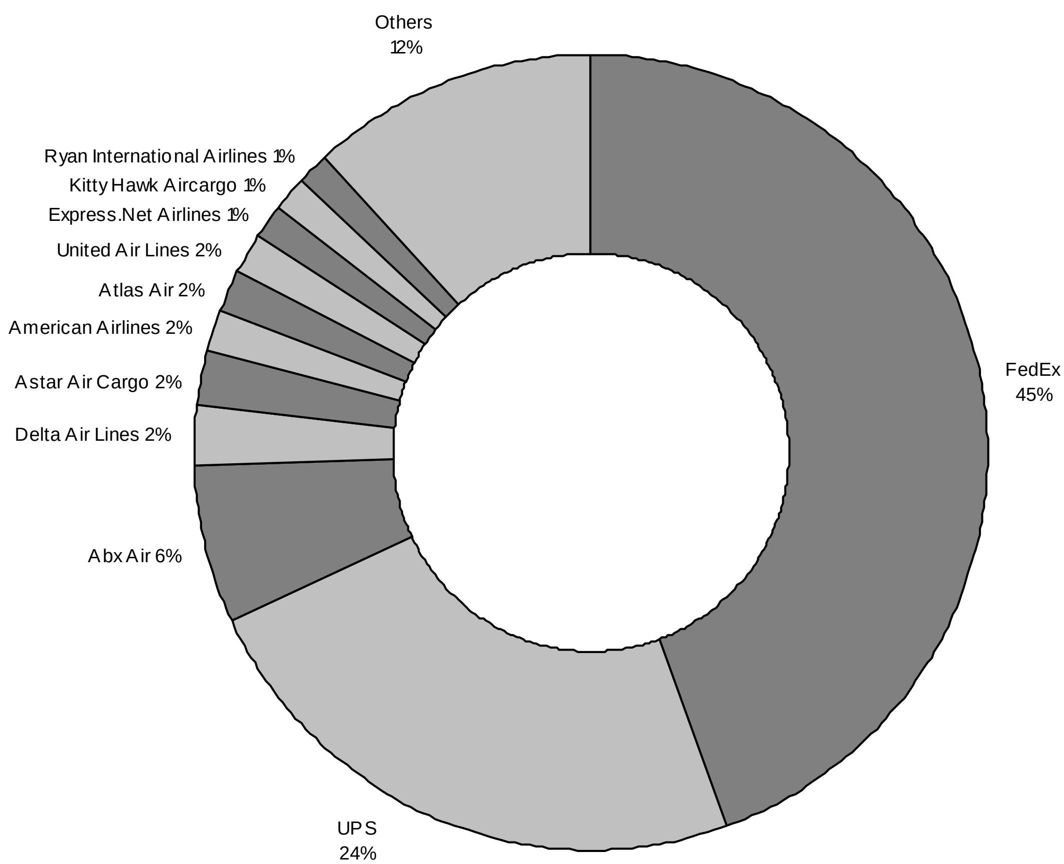

Figure 6. Carriers' Market Shares of the Total U.S. Domestic Enplaned Freight (%) in 2003
Source: Author's calculations based on data extracted from U.S. BTS, 2005f

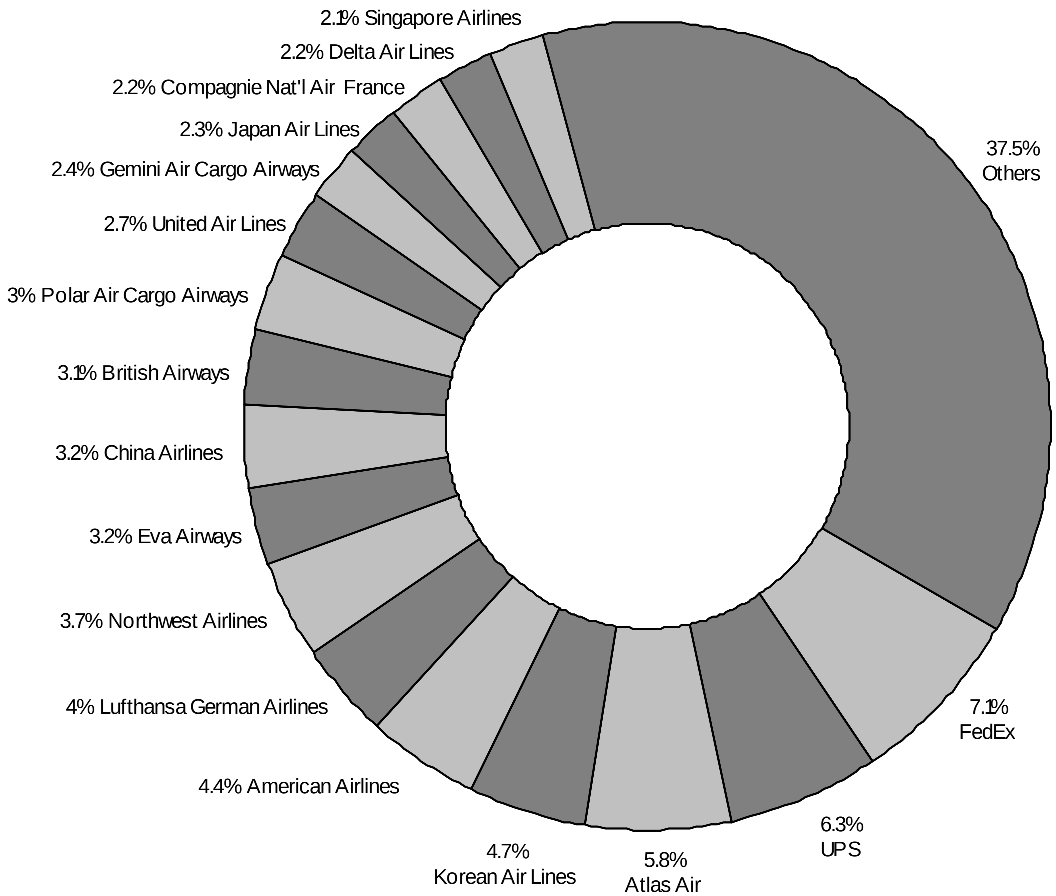

Figure 7. Carriers' Market Shares of the International Enplaned Freight (%) in 2003
Source: Author's calculations based on data extracted from U.S. BTS, 2005g

geography of air freight (AirGuide Business, 2008; Smith, 2008).

In addition, the conventional passenger airlines play a significant role, especially the three legacy airlines (American Airlines, Delta, and United Airlines) that have traditional hub systems that transport both freight and passengers. These three legacy carriers collectively shipped 6% of the total U.S. domestic enplaned freight (Figure 6), which is equivalent to ABX Air's market share in 2003.

Unlike the U.S. domestic market, no single carrier dominates the international market. In fact, the largest market share overseas is accounted for by a large number of small carriers (37.5%) categorized as ‘others’ in Figure 7. Despite FedEx’s struggles overseas, it is still the leading international freight carrier with a 7.1% market share followed by UPS (6.3%) and Atlas Air (5.8%) (Figure 7). Also, combination carriers (passenger and cargo service) played a significant role across international air routes by carrying a large volume of freight poundage in the upper deck or in the belly hold of passenger carriers. Examples of these competitive combination carriers include Korean Air Lines (4.7%), American Airlines (4.4%), Lufthansa (4%), Northwest Airlines (3.7%), EVA Airways (3.2%), China Airlines (3.2%), and British Airways (3.1%) (Figure 7). Therefore, combination airlines represent a substantive competitive challenge for integrated all-cargo carriers across the global networks.

The chapter now turns to a more detailed explanation of the geography of air freight by focusing on the leading metropolitan markets in the United States based on whether they were a conventional hub-and-spoke system with just one or two dominant carriers or an international coastal gateway with a large number of competing airlines.

1.1. Hub-and-Spoke Markets

The development of complex hub-and-spoke systems after the deregulation of the U.S. airline industry in the 1970s played a significant role in restructuring the distribution networks of air freight markets in the United States, and therefore merits more detailed attention. Instead of a point-to-point pattern, many carriers adopted a hub-and-spoke network system during the 1980s where cargo arrived at a hub point from many origins (spokes) and was then sorted and reshipped to an intermediate or final destination. An airline operating a hub-and-spoke system enjoys numerous competitive advantages. For example, passenger/freight carriers can efficiently profit from network-based economies of scale and scope. In other words, an effective hub system can increase airline revenue flows resulting from concentrating flow density along the network links between the major hubs. Hub networks can also offer geographic monopoly power for the dominant carrier by controlling a large number of gates and landing slots at a key hub airport, and thus protect itself against other competing airlines that may want to enter the market.

Integrators (like FedEx and UPS) and several combination carriers (like Delta Air Lines and American Airlines) are examples of carrier types that have adopted hub-and-spoke strategies. However, these four carriers are characterized by several differences in the levels of spatial concentration of their operation and the nature of their distribution networks that requires additional explanation if we are to fully understand the geography of air freight markets in the United States. This dissertation will now elaborate on the geography of the major hub-and-spoke markets operated by FedEx and UPS.

1.1.1. The Integrated All-Cargo Carrier Hub Markets

Four decades ago, air freight markets were mainly concentrated in the traditional coastal gateways (e.g., JFK Airport in New York), which were largely served by traditional passenger carriers like Pan Am, TWA, Eastern, and Tower Air. However, the rise of all-cargo integrators (like FedEx and UPS) during the 1970s led to dramatic changes in both the air cargo industry and the overall national economy. Because of their reliable fast delivery services coupled with on-time door-to-door distribution, the all-cargo integrators' services became increasingly valuable to manufacturers, retailers, and consumers. For example, the short life expectancy of perishable products (e.g., magazines, flowers, and fresh fruits) and increasingly fickle consumer spending behavior regarding brand loyalty elevated the importance of speed of delivery. Also, the onset of online shopping and an expectation that ordered items be delivered immediately further increased the significance of rapid delivery. As a result, companies like FedEx and UPS rapidly emerged and swiftly developed a significant market share. In 2003, FedEx shipped by air over 10.2 billion pounds of air freight (44% of U.S. total) domestically, while UPS transported over 5.4 billion pounds (24% of U.S. total).

Both FedEx and UPS chose strategic locations for their major facilities at airports in central locations, with uncongested runways, large terminal capacities, accessible loading facilities, and relatively cheap labor pools. Also, their locations tended to experience good weather conditions that permit aircraft operations with a minimum of weather delays, and fewer regulatory restrictions (e.g., frequency of flights and aircraft noise). For example, Zhang (2003, p. 134) found that

> airports that are closer to shippers and have lower total costs and lower delivery times inevitably are strong candidates for a regional air cargo hub. This suggests the importance of geographical location, costs and

> delivery times as competitive factors in a regional and global competition among airports to attract cargo traffic.

These circumstances have fundamentally shaped the geography of the all-cargo integrator markets in the U.S. For example, both FedEx and UPS have operated the bulk of their network out of a small number of medium-sized metropolitan markets located in the center of the country (e.g., Memphis, Louisville, and Indianapolis) (Figure 4). These carriers have also extended the hub-and-spoke model and established additional regional mini-hubs in places like Newark (NJ), Oakland (CA), Ontario (CA), and Miami (FL). These regional hubs were usually located in large gateway markets and satisfied regional niches by absorbing the surplus freight from surrounding large airports with high levels of congestion and limited terminal capacity. For example, FedEx established a regional hub at Newark to serve the New York market by operating the additional freight traffic coming from or going to Europe and other parts of the world because the congested JFK Airport was less capable of handling large freight volumes. Some of the issues raised by these regional mini hubs (e.g., FedEx in Newark and Oakland) will be addressed later on in the chapter.

a. Memphis and the FedEx System

In 2003, Memphis was the largest air freight metropolitan market in the United States with more than 3.9 billion pounds of enplaned air freight (13.4 % of the U.S. total) (Table 2 and Figure 4). Of that total, over 224 million pounds (5.7%) were shipped internationally, while over 3.6 billion pounds (94.3%) were distributed domestically confirming that Memphis International Airport is largely a domestic hub.

Air freight traffic in Memphis is significantly larger than any other metropolitan market and it generated more than twice the overall freight weight shipped through Louisville and the UPS hub (Table 2). FedEx has a 97.6% market share in Memphis, and this reflects its well-established network dominance over any other carrier at Memphis International Airport. FedEx's hub-and-spoke route network in Memphis essentially provides national market coverage (Figure 8). In 2003, the Memphis-Newark route was the most significant capturing 3.4% of enplaned freight weight originating out of Memphis, although Los Angeles (3.3%) was nearly as important. Other destinations with large freight traffic market shares from Memphis included Orlando (2.4%), Seattle (2.3%), Chicago (2.3%), Miami (2.2%), Dallas (2.1%), and New York (2%) (Table 3). Five out of the top fifteen destinations originating from Memphis are regional hubs for FedEx including Newark, Miami, Dallas, Anchorage, and Oakland (Table 3). Also, the two biggest destinations (Newark and Los Angeles) are coastal gateways to the world, where much of the received freight traffic from Memphis were reshipped to overseas markets through these gateways.

FedEx's application of new technologies (e.g., information-based solutions and bar-code electronic tracking) within the airport itself improved its capability to gather, organize, and distribute millions of parcels within a short period of time. The significant turn around time in package shipments and the application of 'state of the art' sorting computerization technologies has elevated certain markets as preferred locations for time-

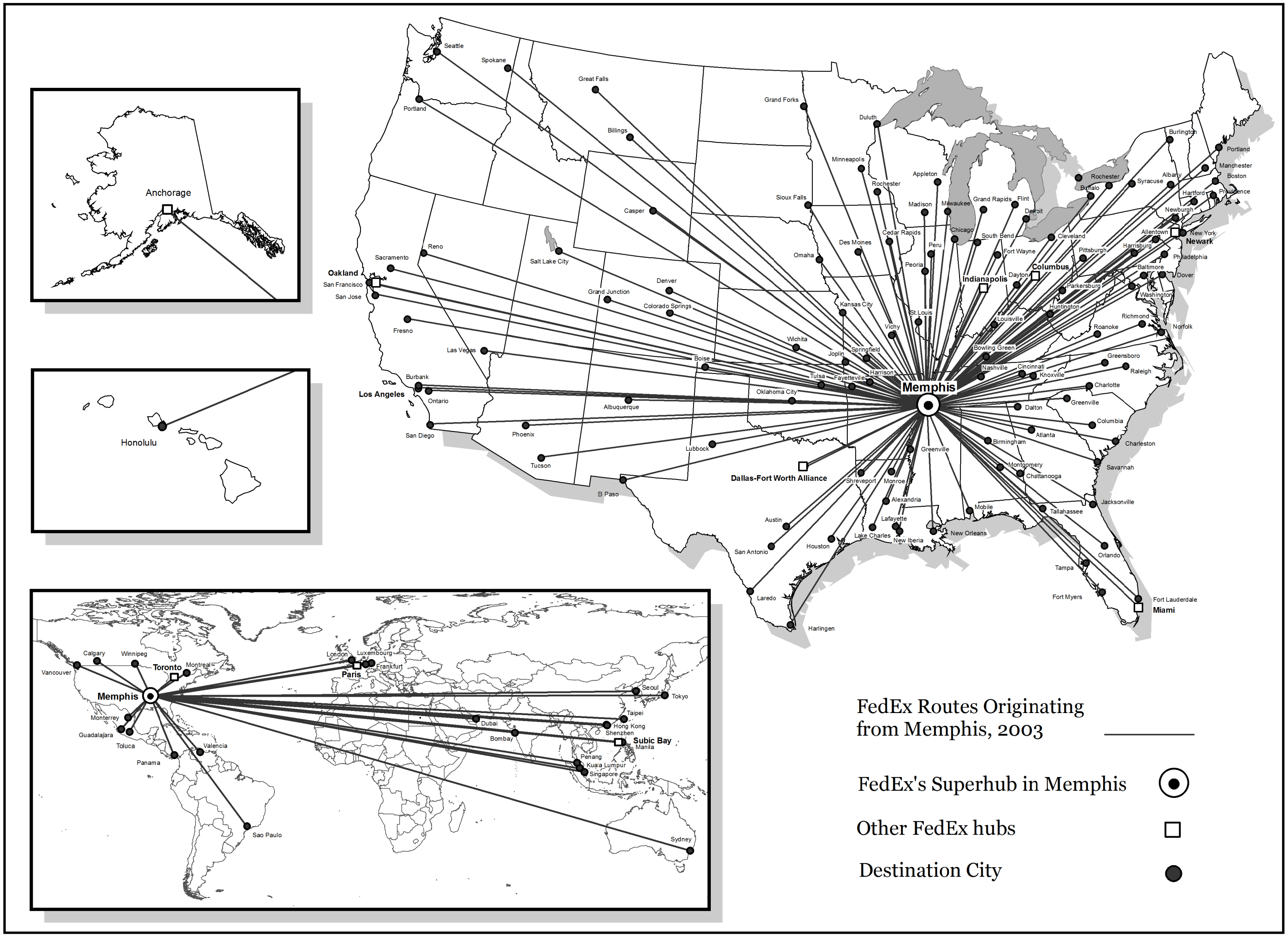

Figure 8. FedEx Route Networks Originating from the Memphis Hub, 2003
Source: Author’s calculations based on information extracted from U.S. BTS, 2005h

Table 3. Proportion of FedEx's Freight Traffic Originating in Memphis for other Destinations in 2003

Rank	**Destination**	**Enplaned Freight Pounds**	**Destination Share (%) of FedEx's Total Enplaned Freight Originating from Memphis**
1	**Newark, NJ**	128,613,160	3.4
2	Los Angeles, CA	126,289,380	3.3
3	Orlando, FL	93,220,200	2.4
4	Seattle, WA	87,748,320	2.3
5	Chicago, IL	86,569,860	2.3
6	**Miami, FL**	82,984,056	2.2
7	**Dallas/Ft.Worth, TX**	79,874,520	2.1
8	New York, NY	75,239,060	2.0
9	Ontario/San Bernardino, CA	73,532,980	1.9
10	Boston, MA	72,542,880	1.9
11	Philadelphia, PA	72,136,540	1.9
12	Denver, CO	70,184,100	1.8
13	**Anchorage, AK**	68,471,994	1.8
14	**Oakland, CA**	68,331,760	1.8
15	Atlanta, GA	65,997,780	1.7
Total		1,251,736,590	32.8

Source: Author's calculations based on information extracted from U.S. BTS, 2005h
Note: bold face indicates FedEx hub

sensitive businesses like biotech and computer companies.

In this way, the development of a FedEx hub can have a positive impact on metropolitan economies. For example, FedEx's integrated air and ground transportation network has attracted several time-sensitive companies to Memphis (e.g., Cell Genesys Company, Laura Ashley, Phillips, Nike, Apple Computer, and Disney Stores) and created additional jobs and tax revenues. Cargo operations at Memphis International Airport also had a total economic impact of more than $19.5 billion in the production of goods and services, and supported a total of 155,872 jobs, leading to total earnings of nearly $5.6 billion in 2004 (Sparks Bureau of Business and Economic Research, 2005).

b. Louisville and the UPS System

Although Louisville is substantially smaller than Memphis regarding air freight volume (i.e. 1.8 billion pounds versus 3.9 billion pounds, respectively) it hosts the primary sorting hub operation for UPS (Table 2 and Figure 4) and it is the fourth largest market in the United States. UPS located their major hub in Louisville largely because of its central location, available terminal capacity, and well-established surface transportation network. In 2003, UPS dominated the Louisville International Airport with a 98% market share of enplaned freight weight. Louisville's central geographic location has enabled UPS to efficiently and rapidly serve U.S. markets from across the country (Figure 9).

Much like FedEx, UPS operates a hub-and-spoke network in Louisville. In 2003, UPS shipped over 47.6 million pounds internationally but distributed more than 1.7 billion pounds domestically suggesting UPS has a similar domestic/international mix to that of FedEx. In 2003, the Louisville-Anchorage route was the most significant

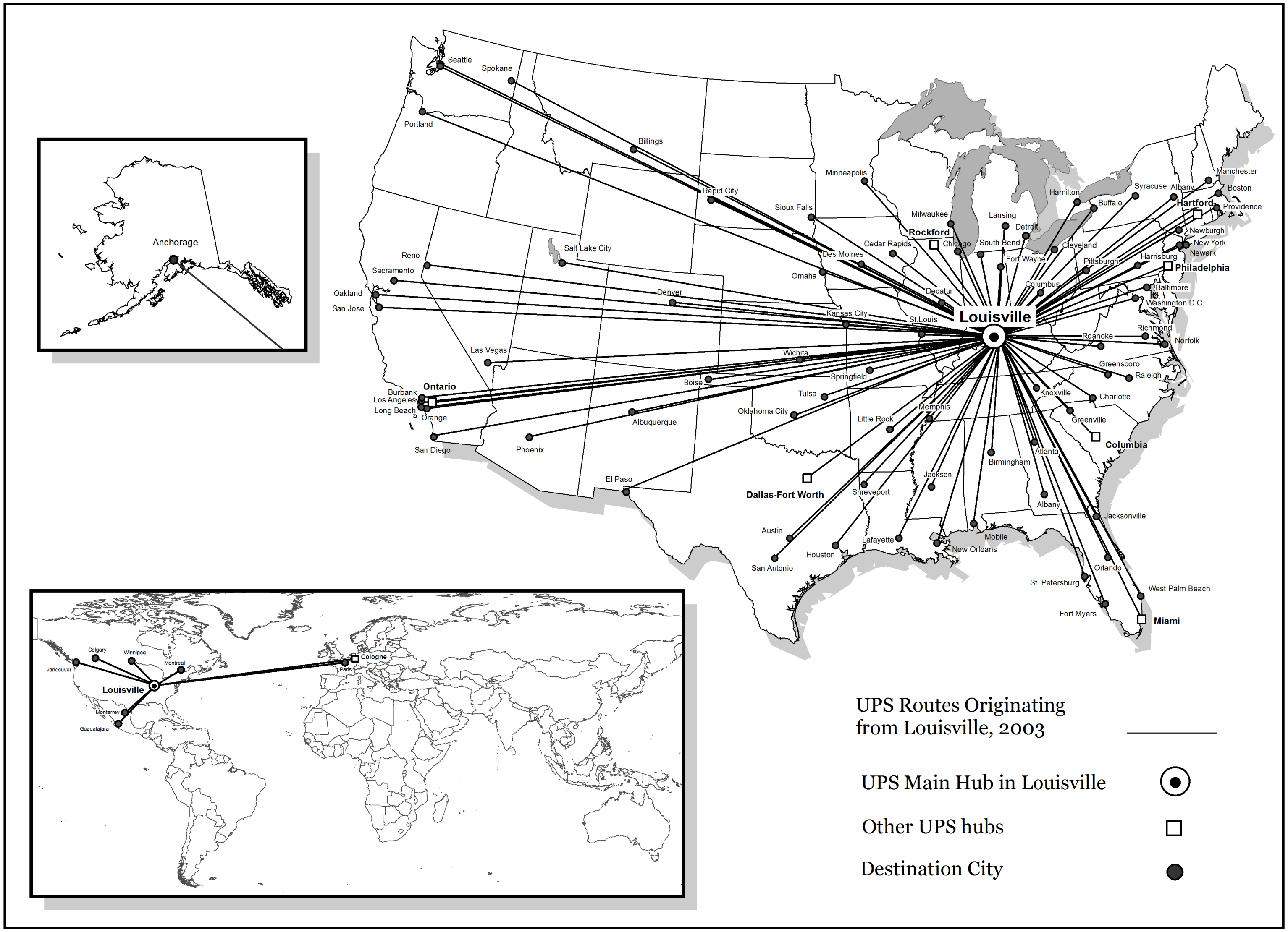

Figure 9. UPS Route Networks Originating from the Louisville Hub, 2003
Source: Author's calculations based on information extracted from U.S. BTS, 2005i

capturing 5.6% of enplaned freight weight originating from Louisville which was noticeably larger than the market share for the second largest route (Louisville-Philadelphia at 4.6%) (Table 4 and Figure 9). The Anchorage route reflected the importance of the substantial volume of time-sensitive commodities being shipped by air between Asia and the United States. From a spherical perspective, Anchorage enjoys relatively short distance aviation routes between the United States and Asia (the great circle route), which can result in less fuel consumption costs. Other UPS air routes originating at Louisville with a substantial market share included Ontario (4.4%), Dallas (4%), Newark (3.9%), and Denver (2.8%) (Table 4 and Figure 9). The top fifteen routes (46.4%) in the UPS network are more important to UPS than the top fifteen in FedEx (32.8%) in terms of market share (Table 3 and 4). UPS appears to be funneling a lot of its air freight poundage through just a select number of places, whereas FedEx seams to be more diverse and ships to many more markets.

Several truck-based and intermodal distribution businesses (like computer parts and automotive parts) have relocated to the Louisville metropolitan area to benefit from the UPS cargo facilities. Examples of companies doing e-commerce in Louisville include Nike and Gateway Computers, and examples of companies doing traditional transportation manufacturing activities include the General Electric Company and Ford Motor Company (Oxford Economic Forecasting, 2006). The importance of Louisville as a global and domestic air cargo hub has provided the necessary ingredients for developing the city and state economy by creating additional jobs both inside and near to the airport. In 2007, more than 43,000 total jobs and $1.8 billion in total payroll were

Table 4. Proportion of UPS' Freight Traffic Originating in Louisville for other Destinations in 2003

Rank	Destination City Name	Enplaned Freight Pounds	Destination Share (%) of UPS' Total Enplaned Freight Originating from Louisville
1	Anchorage, AK	100,426,134	5.6
2	**Philadelphia, PA**	82,157,695	4.6
3	**Ontario/San Bernardino, CA**	78,308,201	4.4
4	**Dallas/Ft.Worth, TX**	71,042,146	4.0
5	Newark, NJ	69,961,786	3.9
6	Denver, CO	49,720,580	2.8
7	Phoenix, AZ	46,955,054	2.6
8	Houston, TX	45,569,480	2.6
9	Seattle, WA	44,093,918	2.5
10	**Miami, FL**	42,693,387	2.4
11	Portland, OR	41,712,957	2.3
12	San Juan, PR	41,549,002	2.3
13	**Hartford, CT**	40,881,915	2.3
14	Albuquerque, NM	38,333,710	2.1
15	Salt Lake City, UT	36,000,208	2.0
Total		829,406,173	46.4

Source: Author's calculations based on information extracted from U.S. BTS, 2005i
Note: bold face indicates UPS hub

generated in the Louisville metropolitan area by the Louisville International Airport and the UPS air hub (Louisville Regional Airport Authority, 2007).

The UPS Company was first founded in 1907 (Table 5), and it has been serving the U.S. market for a much longer time than FedEx. In 2006, UPS revenue ($47.5 billion) exceeded FedEx revenue ($35.2 billion) (Table 5). That is partly explained by the larger size of the UPS Company in terms of its labor force and its ground-delivery market. UPS employed 427,700 workers in 2006, while FedEx used only 275,000 employees (Table 5). Even though FedEx had a larger air fleet (672 aircraft) than UPS (607 aircraft), the ground fleet of UPS was bigger and more diverse and sophisticated than FedEx's (Table 5). In 2006, UPS operated 89,521 package cars, vans and motorcycles; 11,479 tractors; and 65,983 trailers (Table 5). On the other hand, FedEx had 14,000 company tractors; 19,000 owner operator tractors, straight trucks and vans; and just 44,000 straight trucks and vans (Table 5). Also, UPS seemed to be more popular to online retailers and customers than FedEx. In 2006, UPS received an average of 15 million daily online tracking requests, while FedEx received just over 3 million tracking requests daily (Table 5).

Table 5. FedEx and UPS, 2006

	FedEx	**UPS**
Founded[1]	1971	1907
Revenue[1]	$35.2 billion	$47.5 billion
Employees[1]	275,000	427,700 (360,600 U.S.; 67,100 International)
Equipment[1]	• 14,000 company tractors • 19,000 owner operator tractors, straight trucks and vans • 44,000 straight trucks and vans • 672 aircraft	• 89,521 package cars, vans and motorcycles • 11,479 tractors • 65,983 trailers • 607 aircraft
FedEx.com[2]**/UPS.com**[3]	more than 3 million tracking requests daily	average 15.0 million daily online tracking requests

Sources:
1. Polk Commercial Vehicle Solutions and Innovative Computer Corporation, 2007
2. FedEx, 2007
3. UPS, 2007

1.1.2 Combination Carriers: Traditional Passenger Connecting Hubs

Like integrators, many traditional passenger carriers (e.g., Delta Air Lines in Atlanta) embraced the hub-and-spoke concept during the 1980s, where passengers as well as freight are connected to the main hub airport to switch flights to reach their final destination with the same airline. A significant amount of air freight travels on passenger flights, so it is important that we better understand the geography of combination carriers and their influence on air freight markets.

Combination carriers can be classified into both legacy carriers and low-cost carriers. Examples of U.S. legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, Northwest Airlines, United Airlines, and US Airways while the low-cost carriers include AirTran Airways, ATA Airlines (now shutdown), and Southwest Airlines. Each of these types of carriers operates a distinctive air network structure. For example, low-cost carriers largely operate a point-to-point system, while legacy carriers apply a hub-and-spoke system to their air routes. It should be noted that some metropolitan markets that serve as connecting hubs include more than one airport where one airport is dominated by a legacy carrier (e.g., American Airlines at Dallas-Fort Worth International Airport) and the other by a low-cost carrier (e.g., Southwest Airlines at Dallas Love Field Airport).

Combination carriers largely operate in intermediate connecting hubs but also in specific global gateway markets like Los Angeles and New York. This differential geography reflects the distinctive competitive advantage of each of these places and the diverse strategies that combination carriers practice in individual markets. For example, combination carriers serving gateway markets usually aim to benefit from their large population base and the diverse industrial economy to fill their planes to capacity with passengers and freight. Also, the combination carriers tend to benefit from the widespread availability of freight forwarders and diverse logistic firms in gateway markets that are capable of handling and redistributing air freight to the final customer. These U.S. gateway markets will be explored in more detail in section 1.2.

Combination carriers have also situated themselves in 'intermediate' centers to benefit from their central geographic locations in efficiently serving surrounding small markets (spokes) by connecting their passengers and freight traffic to a wide variety of final destinations. We now examine in more detail three major U.S. connecting hubs (Chicago, Dallas, and Atlanta) that are dominated by one of the three leading U.S. legacy carriers.

a. Chicago-Naperville-Michigan, IL-IN-WI, CSA

In 2003, the Chicago-CSA ranked in seventh place for air freight with over 1.2 billion enplaned pounds which accounted for 4.17% of the U.S. total (Table 2; Figure 4). The substantial freight volume at Chicago is partly related to its central location in the Midwest and the diverse regional economy in the Greater Chicago area.

The O'Hare International Airport is the largest airport in the Chicago metropolitan area, operating 98.3% of the metropolitan area's air freight traffic. It is also

United Airlines largest hub operation and a secondary hub for American Airlines (after Dallas/Fort Worth). Although United Airlines and American Airlines established major connecting passenger hubs at O'Hare during the 1980s, they both handled less than 16% of O'Hare Airport's total enplaned freight in 2003. On the other hand, air freight integrators had a much stronger presence at O'Hare, where more than 19% of its enplaned air freight was operated by FedEx and 6.61% by UPS. The small shares of United Airlines (8.13%) and American Airlines (6.38%) in terms of air freight were partly related to the drop off in traffic after the September 11 attacks and to soaring oil prices, which led to both airlines canceling several existing and planned routes and eliminating several seats on certain aircraft types to cut expenses.

The second largest airport in the Chicago-CSA is Midway International Airport. Midway International Airport is heavily used by low-cost carriers where it serves as a focus city for Dallas-based Southwest Airlines, Indianapolis-based ATA Airlines, and Orlando-based AirTran Airways. These carriers have non-stop flights from the Midway International Airport to several destinations. In 2003, Southwest Airlines accounted for 80% of the total enplaned freight at the Midway International Airport, followed by ATA Airlines (10.4%).

Although O'Hare International Airport was built in 1960 to replace the congested Midway International Airport with the expectation that it would be one of the largest air freight distribution centers in the world, the capacity constraints and high congestion levels at O'Hare Airport have limited growth opportunities. The nearby medium-sized Rockford Airport (75 miles northwest of O'Hare) has grown recently to handle surplus freight traffic. In 2003, the Rockford International Airport originated over 220 million enplaned pounds. Due to Rockford's competitive locational advantage, UPS established a regional hub at the Rockford International Airport where it accounts for over 90% of air enplaned freight in 2003. Other airports benefiting from the acute congestion levels at O'Hare Airport include Indianapolis and Detroit (Willow Run Airport).

Due to O'Hare's congested runway and resulting delays in flight schedules, the city of Chicago has recently committed to a $6.6 billion capital investment plan involving airfield reconfiguration, terminal developments, and landside improvements (City of Chicago, 2007). The final outcome will be an airport with parallel runways rather than intersecting ones to increase the airport's capacity and improve the need to reduce operations in particular wind conditions. The expansion of O'Hare Airport is anticipated to generate an additional 195,000 jobs and another $18 billion in revenues (City of Chicago, 2007). It is also expected to save the airlines about $370 million and passengers $380 million a year (City of Chicago, 2007).

b. Dallas-Fort Worth, TX, CSA

In 2003, the Dallas-Fort Worth-CSA was the ninth ranked metropolitan area in air freight weight with more than 870 million enplaned pounds, which accounted for 2.98% of the U.S. total. The Dallas-Fort Worth-CSA included the following airports: the Dallas-Fort Worth International Airport (more than 680 million pounds), the Fort Worth Alliance Airport (more than 150 million pounds), and the Dallas Love Field Airport (more than 39.6 million pounds). Dallas's significant total air freight traffic can be partly explained by its unique geographical location that enabled it to efficiently function as a transfer point for flights coming from and going to other cities throughout the Southern United States. The Dallas airports likely have benefited from the high concentration of telecommunications companies (e.g., Texas Instruments, Alcatel, AT&T, Ericsson, Fujitsu, MCI, Nokia, Rockwell, Sprint, and Verizon, CompUSA, and Canadian Nortel) and video game companies (e.g., id Software) in the market that preferred shipping their products by air.

In 2003, the Dallas-Fort Worth International Airport accounted for 78.16% of the total enplaned freight traffic originating from the Dallas-Fort Worth-CSA, followed by the Fort Worth Alliance Airport with a 17.28% market share and the Dallas Love Field Airport with a 4.55% market share. The Dallas-Fort Worth International Airport hosts the hub operations for both American Airlines and American Eagle. Even though the Dallas-Fort Worth International Airport largely serves as a fortress hub for American Airlines in term of passengers, American Airlines also handled just under 15% of enplaned freight at the Dallas-Fort Worth International Airport in 2003. By contrast, UPS and FedEx accounted for 28.88% and 22.15%, respectively, of the originating air freight traffic from the Dallas-Fort Worth International Airport.

The Dallas-Fort Worth International Airport is one of the busiest airports in the U.S. in terms of aircraft movements and passenger traffic although the nearby Fort Worth Alliance Airport has recently grown to serve the growing demand for international and domestic air freight shipments in the Dallas-Fort Worth market. FedEx established a regional hub at Fort Worth Alliance Airport and it accounts for nearly 99% of the airport's enplaned freight in 2003.

The Dallas Love Field Airport was the main airport for Dallas until 1974, when the Dallas-Fort Worth International Airport opened. Love Field is now Dallas's secondary airport and serves as a fortress hub for Southwest Airlines. Despite the dominance of Southwest Airlines at Love Field in terms of the passenger market, it only handled about 24% of the airport's originating enplaned freight in 2003. By contrast, the cargo airline ABX Air accounted for over half of the originating enplaned freight traffic (53.45%) at Dallas Love Field Airport.

c. Atlanta, CSA

The tenth ranked Atlanta-CSA is another major connecting hub in the U.S. with a considerable volume of enplaned freight which exceeded 698 million pounds and accounted for 2.39% of the U.S. total in 2003. The international and domestic air freight demand at the Atlanta-CSA is largely served by the Hartsfield-Jackson Atlanta International Airport. The Hartsfield-Jackson Atlanta International Airport is a major hub for the legacy carrier Delta Air Lines. In 2003, Delta Air Lines shipped 39.09% of Hartsfield's originating enplaned freight, followed by FedEx with 18.09%, UPS with 8.54%, and Comair Inc. with 2.92%. Several foreign carriers have also operated at the Hartsfield-Jackson Airport like Lufthansa German Airlines (3.51%), Korean Air Lines Co. Ltd. (3.34%), and Japan Air Lines Co. Ltd. (2.57%).

Atlanta has gained competitive advantages through its unique geographical location. The remarkable centrality of Atlanta in the south-east makes it an ideal distribution point. Therefore, Delta Airlines established a connecting hub at Hartsfield Airport to link many domestic flights coming from the smaller hinterland cities to the other U.S. destinations. Also, Atlanta's location on the Atlantic coast enabled it to act as a U.S. gateway to Latin America, Europe, Asia, and Africa. Hartsfield-Jackson Airport is considered the largest employment center in the State of Georgia with 56,000 employees and a payroll of $2.4 billion (City of Atlanta, 2007). The airport has a direct and indirect economic impact of about $5.6 billion on the local and regional economy (City of Atlanta, 2007).

Hartsfield-Jackson is one of the busiest airports in the world in terms of passenger traffic and number of flights, as well as in terms of landings and take-offs. In 2000, the City of Atlanta started a ten-year, $5.4 billion Hartsfield Development Program to relieve congestion pressure at the airport and enable the airport to meet future demands, which is estimated to be at 121 million passengers by 2015 (Anonymous, 2006; SPG Media Limited, 2007). The expansion plans include a new fifth runway, expansion of the east international terminal, a new consolidated rental car facility, a proposed new south terminal, improvements to the Central Passenger Terminal Complex, other airfield improvements, and support facilities (SPG Media Limited, 2007). The new fifth runway is anticipated to increase the capacity for landings and takeoffs by 40%, from an average of 184 flights per hour to 237 flights per hour (SPG Media Limited, 2007).

1.2. Traditional Coastal Gateways

The geography of the U.S. air freight market is also well established along the U.S. coasts such as in Los Angeles, New York, Miami, and San Francisco (Figure 4). These large markets serve the domestic marketplace and act as global gateways for the United States. In 2003, these four places collectively shipped 25.21% of the U.S. total enplaned freight (Table 2). This significant freight traffic was partly related to their importance to manufacturing and assembling parts produced in other markets, as well as their substantial transportation infrastructures and sophisticated multimodal distribution systems. The international air traffic at these gateways reflects their significant global accessibility and networks of trade, research, and tourism. Of course, the role of combination carriers in carrying substantial amounts of this freight traffic across the international routes can not be ignored. Many U.S. and foreign passenger carriers operate at these four markets and ship considerable freight weights in their belly holds to many global destinations. Now we turn to a more detailed examination of each of these four metropolitan gateways regarding their freight market shares, key airports, and dominant carriers.

1.2.1. West Coast

California by itself stands as a significant generator along the western coast of the U.S. for international and domestic air freight traffic accounting for 13.46% of the U.S.

total enplaned pounds in 2003. The key metropolitan markets in California included the Los Angeles-Long Beach-Riverside-CSA, San Jose-San Francisco-Oakland-CSA, San Diego-Carlsbad-San Marcos-MSA, Sacramento-Arden-Arcade-Truckee-CSA, and Fresno-Madera-CSA (Figure 10 (A)). These five markets collectively shipped 3.9 billion enplaned pounds in 2003. Also, over 24.7 million pounds were shipped from a number of scattered smaller markets in California including the Stockton-MSA, Santa Barbara-Santa Maria-Goleta-MSA, El Centro-MSA, Redding-MSA, Visalia-Porterville-MSA, Chico-MSA, and Bakersfield-MSA (Figure 10 (A)). In 2003, both the Los Angeles-CSA and the San Francisco-CSA played a substantial role in handling and shipping the local commodities to the other global and national markets. In 2003, the Los Angeles and San Francisco gateways collectively shipped 93.56% of California's total enplaned freight and 12.59% of the U.S. total weight. Therefore, it is appropriate to explore in more detail the air freight market in these two metropolitan areas.

Los Angeles-Long Beach-Riverside, CA, CSA

The Los Angeles-CSA is one of the largest U.S. Pacific gateways (Figure 4) that is supported by major freight facilities and operates an extensive air network to many global cities with faster, larger, longer-range new airplanes. In 2003, the Los Angeles-CSA shipped by air over 2.3 billion enplaned pounds and ranked second nationally with a 8.01% market share of the U.S. total (Table 2). The Los Angeles freight market is largely driven by its international trade, entertainment (e.g., television, motion pictures, and

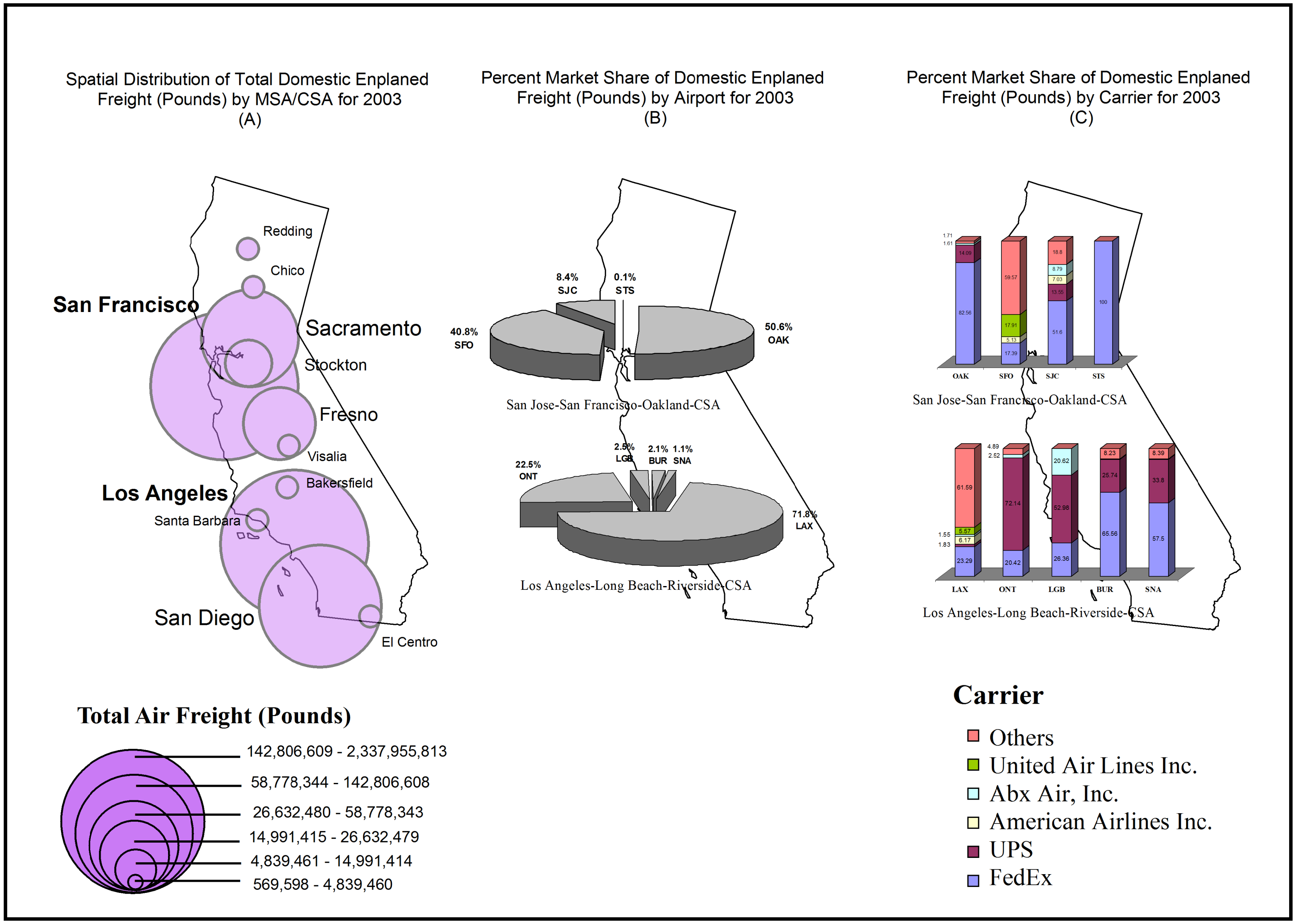

Figure 10. Air Freight Markets in California, 2003

recorded music), aerospace, technology, petroleum, fashion, apparel, tourism, and health and medicine industries. The Los Angeles-CSA hosts five major airports including: the Los Angeles International Airport (LAX) (1.7 billion pounds), the Ontario International Airport (ONT) (526 million pounds), the Long Beach Daugherty Field Airport (LGB) (59.3 million pounds), the Burbank Bob Hope Airport (BUR) (48.2 million pounds), and the John Wayne International Airport (SNA) (25.6 million pounds) (Figure 10 (B)).

LAX Airport shipped the highest percentage (71.81%) of the Los Angeles-CSA total enplaned pounds, and it is the busiest airport in the state of California. It is also a major gateway to many international destinations in Latin America, Europe, Asia, and Oceania. In terms of passengers, it is a major hub for United Airlines and Alaska Airlines, a secondary hub for Delta Air Lines, and a focus city for American Airlines, Southwest Airlines, Qantas, and Air New Zealand. However, in terms of air freight, these carriers shipped a smaller share of LAX's total enplaned freight. For example, in 2003 the passenger carrier American Airlines accounted for 6.17% of the airport enplaned freight, followed by United Airlines (5.57%), Delta Air Lines (3.70%), and Southwest Airlines (1.80%) (Figure 10 (C)). By contrast, the all-cargo carrier FedEx shipped 23.29% of the airport's total enplaned pounds (Figure 10 (C)) while many Asian carriers also operated at the airport including Korean Air Lines (3.14%), Singapore Airlines (2.30%), Japan Air Lines (2.26%), China Airlines (2.10%), and Eva Airways (1.95%).

LAX is the world's fifth-busiest airport in passenger traffic and eleventh-busiest in cargo traffic, serving over 61 million passengers and shipping 1.9 million tons of freight in 2006 (Airports Council International, 2007a and 2007b). Therefore, the Los Angeles City Council on August 15, 2007 approved a $1.2 billion project to improve airport security, safety, and service in order to relieve the congestion pressure at the airport and to be able to handle international flights using the A380 mega-jumbo (Los Angeles World Airports, 2007).

The second leading airport in the Los Angeles-CSA, in terms of enplaned freight, is ONT accounting for 22.5% of the region's total enplaned freight (Figure 10 (B)). It is the West Coast air and truck hub for UPS and is a major distribution point for FedEx. In 2003, UPS shipped by air more than 72% of the airport's total enplaned pounds, followed by FedEx with a 20.42% share (Figure 10 (C)). Due to Ontario's long, the airport is frequently used as a substitute landing site for large aircraft when LAX is inaccessible because of weather conditions or for other reasons. Ontario Airport is also an important replacement airport for trans-Pacific flights to refuel their aircrafts after the long trip.

Besides LAX and ONT airports, the Los Angeles-CSA depended on a multiple airport system of smaller airports because of its vast physical size. Many of the area's most well-known attractions are closer to alternative airports than to the LAX Airport. For instance, Hollywood and Griffith Park are closer to the BUR Airport; while the SNA Airport is close to Disneyland, the Honda Center, Angel Stadium of Anaheim, and other Orange County attractions. In 2003, the integrators largely dominated cargo operations at these medium-small airports. For example, FedEx shipped 26.36% of total enplaned pounds at the LGB Airport, 65.56% of total enplaned pounds at the BUR Airport, and 57.5% of total enplaned pounds at the SNA Airport (Figure 10 (C)). UPS also transported by air around 53% of total enplaned pounds at the LGB Airport, 26% of total enplaned pounds at the BUR Airport, and nearly 34% of total enplaned pounds at the SNA Airport (Figure 10 (C)).

San Jose-San Francisco-Oakland, CA, CSA

The San Francisco-CSA is another significant Pacific gateway (Figure 4) with a substantial international and domestic enplaned freight. In 2003, more than 1.3 billion enplaned pounds (4.58% of U.S. total) were shipped from the San Francisco-CSA, the sixth ranking metropolitan area (Table 2). This air freight traffic is largely related to the high concentration of semiconductor and computer-related industries (e.g., Adobe Systems, Cisco, Apple Computer, and Microsoft) at the Silicon Valley in southern San Francisco. Also, positioning San Francisco as a biotechnology and biomedical hub and research center increased its dependence on air transport. The San Francisco-CSA included four airports: the Oakland International Airport (OAK) (677 million pounds), the San Francisco International Airport (SFO) (546 million pounds), the San Jose International Airport (SJC) (113 million pounds), and the Sonoma County Airport (STS) (1 million pounds).

The SFO Airport has flights to destinations throughout the Americas and is a major gateway for Europe, Asia, and Australasia-Oceania. The airport benefits from the adjacent freeway U.S. Route 101 and Interstate 380 by providing further connections to the region. The availability of widebody jet service at SFO has also contributed in shipping large freight volumes to the Pacific Rim. In 2003, the U.S. legacy carrier, United Air Lines had a 17.91% share of freight at SFO Airport followed by American Airlines (5.13%), and Delta Air Lines (3.87%). Several all-cargo carriers also operated at SFO Airport like FedEx (17.39% market share) (Figure 10 (C)), followed by Astar Air Cargo Inc. (4.26%), and Atlas Air Inc. (3.76%). Moreover, the SFO Airport has hosted several foreign carriers with substantial enplaned freight volumes like Japan Air Lines (5.56%), Eva Airways (4.72%), Nippon Cargo Airlines (3.78%), Asiana Airlines (3.28%), Korean Air Lines (3.11%), China Airlines (2.83%), and British Airways (2.51%).

Interestingly, the OAK Airport generated more enplaned freight (almost 50.64% of the total San Francisco-CSA market) (Figure 10 (B)) than the SFO Airport which was the main originator of air passenger traffic. The OAK Airport appeared to compensate for the SFO Airport's capacity constraints and it rapidly became an air cargo hub for both FedEx and UPS (Figure 10 (C)). Even though the OAK passenger market is dominated by the low cost carrier Southwest Airlines, it only carried 1.28% of the airport enplaned pounds in 2003. By contrast, integrators like FedEx operated 82.56% of OAK enplaned freight, followed by UPS with 14.09%.

Other airports largely dominated by FedEx include the STS Airport with a 100% market share and the SJC Airport with a 51.6% market share (Figure 10 (C)). Overall, FedEx has a notable, well-established presence in San Francisco, shipping more than half (53.34%) of the total freight traffic. On the other hand, UPS operated a smaller share of the San Francisco-CSA total enplaned freight (8.28%) in comparison to its Los Angles-CSA share (22.5%).

1.2.2. Northeastern Coast

New York-Newark -Bridgeport, NY-NJ-CT-PA, CSA

The New York-CSA is the largest U.S. trans-Atlantic air freight gateway and it connects North America's freight traffic to several distant markets in Europe, Africa, and the Middle East. Therefore, it is an important node in the flow of commodities both in the production and distribution processes. Besides its distinctive global role, it also provides some domestic hub facilities serving mainly East Coast destinations. In 2003, New York was the third ranked metropolitan area in air freight weight and it originated over 2.1 billion enplaned freight pounds (7.42 % of U.S. total) (Table 2; Figure 4). This significant freight volume can be explained by New York status as a global center of international business and commerce and as home for many high-tech industries like bioscience, software development, game design, and Internet services. It is also a major center for finance, insurance, real estate, media, fashion, and the arts in the United States. New York is also a home to the most complex and extensive transportation network in the U.S. including a massive subway system, bus and railroad systems, airports, landmark bridges and tunnels, and ferry service.

In 2003, the New York-CSA included the following eight major airports: the John F. Kennedy International Airport (JFK) (1.3 billion enplaned pounds), the Newark

International Airport (EWR) (836 million enplaned pounds), the Stewart International Airport (SWF) (29 million enplaned pounds), the La Guardia Airport (LGA) (19 million enplaned pounds), the Long Island-Macarthur Airport (ISP) (2.3 million enplaned pounds), the Republic Field Airport (FRG) (697,720 enplaned pounds), the Westchester County Airport (HPN) (631,997 enplaned pounds), and the East 34th Street Airport (TSS) (115,424 enplaned pounds) (Table 6).

JFK was the largest airport in the New York-CSA captuting 59% of the metropolitan area's total enplaned freight in 2003 (Figure 11). It was the top international air passenger gateway to the United States in 2004, and it was the leading freight gateway to the country by value of shipments in 2003 (Bureau of Transportation Statistics, U.S. Department of Transportation, 2006 and 2004). It is a major international gateway hub for American Airlines and Delta Air Lines operating 8.5% and 3.86% of the airport's enplaned freight, respectively, in 2003. Also, all-cargo carriers accounted for a larger share of the JFK's enplaned freight including FedEx (almost 7.5%), Atlas Air Inc. (almost 4.3%), Polar Air Cargo Airways (4.04%), and Gemini Air Cargo Airways (almost 4%). Several foreign carriers also operated at the JFK airport with substantial international freight volume such as Lufthansa German Airlines (almost 6%), Korean Air Lines (4.23%), Japan Air Lines (3.74%), Asiana Airlines (3.65%), China Airlines (3.01%), Singapore Airlines (2.58%), Nippon Cargo Airlines (2.58%), and British Airways (2.56%). According to the Bureau of Transportation Statistics and the U.S. Department of Transportation (2004), some of the shipments imported and exported through JFK comprise electrical machinery, woven and knit apparel, medical instruments, footwear, plastics, and paper.

Table 6. International and Domestic Enplaned Freight (Pounds) Market Shares of New York-Newark-Bridgeport-CSA's Airports, 2003

Airport	**Domestic Enplaned Freight**	**International Enplaned Freight**	**Total**
Kennedy International Airport (JFK)	315,596,731	961,423,942	1,277,020,673
Newark Liberty International Airport (EWR)	629,856,092	205,795,581	835,651,673
Stewart International Airport (SWF)	23,424,938	5,698,626	29,123,564
La Guardia Airport (LGA)	18,048,809	1,274,903	19,323,712
Long Island-Macarthur Airport (ISP)	2,277,225	0	2,277,225
Republic Field Airport (FRG)	697,720	0	697,720
Westchester County Airport (HPN)	631,997	0	631,997
East 34th Street Airport (TSS)	115,424	0	115,424
Total	990,648,936	1,174,193,052	2,164,841,988

The top three JFK origin-destination trade route pairs on nonstop segments in 2003 were in Europe including London, Brussels, and Frankfurt (Bureau of Transportation Statistics, U.S. Department of Transportation, 2004). On the other hand, these European airports act mostly as a link in a global supply chain where most of the markets are in fact in Asia (Bureau of Transportation Statistics, U.S. Department of Transportation, 2004). The top destination markets for cargo flying out of JFK in 2003 were Tokyo, Seoul, and London; the top origin markets for imports at JFK were Seoul, Hong Kong, Taipei, and London (Bureau of Transportation Statistics, U.S. Department of Transportation, 2004).

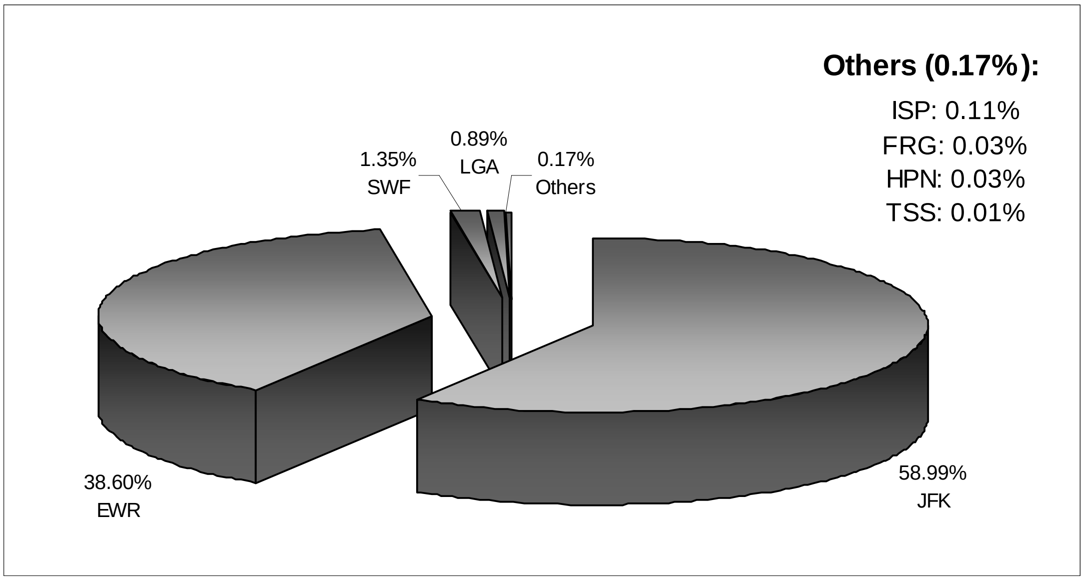

Figure 11. Percent Market Share of the International and Domestic Enplaned Freight (Pounds) by Airport in the New York-Newark-Bridgeport CSA, 2003
Source: Author's calculations based on data extracted from U.S. BTS, 2005k

The second leading airport in the New York-CSA is EWR, which accounted for almost 38% of the region's total enplaned freight in 2003 (Figure 11). The EWR Airport acts as a domestic hub to and also functions as an international gateway challenging JFK with its non-stop scheduled airline routes to several Asian destinations, such as Hong Kong, Beijing, and India. In 2004, EWR became the fifth busiest U.S. gateway for nonstop international air travel in terms of passengers (Bureau of Transportation Statistics, U.S. Department of Transportation, 2006). EWR is a secondary hub for Continental Airlines, which accounted for 10.55% of EWR's total enplaned pounds in 2003. FedEx Express also operates one of its ten major cargo hubs at Newark (Figure 8).

In 2003, FedEx accounted for 52.59% of the airport's enplaned pounds, followed by UPS (16.72%) and ABX Air (3.49%).

1.2.3. Southeastern Coast

Miami-Fort Lauderdale-Miami Beach, FL, MSA

Miami-MSA is a major gateway for U.S. and Latin America traffic. In 2003, it ranked fifth with over 1.5 billion pounds of the international and domestic shipments and accounted for 5.2% of the U.S. total (Table 2). The Miami-MSA hosted the Miami International Airport (MIA) (more than 1.3 billion pounds), the Fort Lauderdale-Hollywood International Airport (FLL) (more than 173 million pounds), the Palm Beach International Airport (PBI) (over 23 million pounds), and the Opa Locka Airport (OPF) (over 4 million pounds). This significant international and domestic air freight traffic hub is partially explained by its local economic growth, large local Latin American and European populations, and strategic geographic location between North America and Latin America.

MIA is the largest airport in the region, accounting for almost 86.8% of Miami-MSA's total enplaned freight in 2003. MIA Airport acts as a global gateway handling most long-haul flights to and from South Florida. The airport is a hub for American Airlines, accounting for 9.64% of MIA Airport's enplaned freight in 2003. It is also a hub for cargo airlines UPS and FedEx, accounting for 12.76% and 6.42% of market share, respectively. Other cargo airlines operating at the airport include Florida West

Airlines (5.95%), Amerijet International (5.44%), Gemini Air Cargo Airways (4.68%), and Atlas Air Inc. (4.60%).

The second leading airport at the Miami-MSA is the FLL Airport with nearly an 11.39% market share of freight traffic in the metropolitan area. Although FLL Airport is a hub for the passenger airline Spirit Air Lines, it only accounted for 0.62% of the airports' total enplaned freight in 2003. By contrast, FedEx dominated the majority of the FLL Airport freight traffic (64%), followed by UPS (6.11%), Delta Air Lines (6.01%), and ABX Air (5.81%).

1.3. Conclusion

Overall, there is a substantial geographic concentration and specialization of air freight operations across a select few U.S. markets. More specifically, the geography of air freight by weight has largely clustered in some 'intermediate' domestic hubs (e.g., Memphis, Louisville, and Indianapolis) and in several conventional international gateways (e.g., Los Angeles, New York, Miami, and San Francisco). The concentration of air freight traffic at these 'intermediate' metropolitan markets is largely related to the specialized services of integrators (e.g., FedEx and UPS) in sorting and reshipping cargo to other U.S. domestic destinations. However, air freight traffic at the international gateways is largely related to the agglomeration of diverse economies, an intense geographic concentration of freight forwarders, as well as passenger carriers (e.g., American Airlines, United Air Lines, and Delta Air Lines), that transport substantial amounts of freight across international routes.

By exploring the geography of U.S. air freight by metropolitan market, we found that for many cargo airlines a large hub airport location by itself does not create comparative advantage. There are other factors influencing the spatial distribution of all-cargo carriers and passenger airlines that are also at play. For example, environmental restrictions (e.g., noise limits and night curfews), high airport user charges, congestion, and a shortage in slot availability at certain international gateways have pushed several cargo carriers and integrators to search for more accessible secondary airports. By contrast, combination carriers operating international routes concentrate more in larger economic markets with a substantial presence of passenger airline operations and an array of freight forwarders. Overall, it is essential for airports to be an integral part of the freight supply chain if a metropolitan area is to build a compatible cluster of air cargo-related activities.

This dissertation also found that air transport geography plays a complementary in many U.S. markets. For example, in California, even though FedEx and UPS companies are operating in both the San Francisco and Los Angeles markets, FedEx tends to largely dominate the San Francisco market while UPS has a more substantial share in Los Angeles. The notion of complementarity can be seen through the distribution of each of FedEx and UPS's main operations in two separate neighboring markets reflecting the development of collaborative and competitive strategies between these two companies. Furthermore, even within a single metropolitan market, the major airports in the market often establish complementary niches. For example, the San Francisco International Airport largely focuses on serving major passenger carriers such as United Air Lines, American Airlines, and Delta Air Lines. Since the airport largely functions as an international gateway, several Asian passenger carriers also ship a considerable amount of freight at the Airport such as Japan Air Lines, Eva Airways, Asiana Airlines, Korean Air Lines, and China Airlines. However, due to the capacity constraints at the San Francisco International Airport, the Oakland International Airport has grown to become a major regional air cargo hub. Unlike the San Francisco International Airport, the Oakland International Airport is largely dominated by all-cargo carriers including FedEx and UPS. Although these two airports supply different markets and rely on particular types of carriers with different business models, both airports serve as effective complements in distributing San Francisco cargo by air.

Based on the dissertation data set, the traditional U.S. passenger carriers (e.g., American Airlines, United Air Lines, and Delta Air Lines) have operated a smaller share of U.S. shipments compared to the integrators like FedEx and UPS and these freight carriers often twice carry more freight than the passenger carriers even in the large passenger hub markets like Chicago and Dallas. Therefore, the traditional passenger-oriented combination carriers are facing a serious challenge from the integrators as long as they continue to treat cargo as a secondary service and reduce their passenger belly hold capacity on short and medium haul routes.

To face the challenge, combination carriers need to extend their markets and improve their cargo services by increasing the frequency of passenger flights to an extensive variety of destinations and by merging them with high-speed and door-to-door services. Another solution is to establish a closer collaboration with freight integrators, which would provide the traditional passenger airlines direct access to a growing express freight markets while also allowing freight integrators to coordinate shipments on combination airlines' scheduled passenger flights. The next section of the chapter analyzes how specific socioeconomic variables shape the geography of air freight across U.S. metropolitan markets.

2. Empirical Results

The main goal of this dissertation is to empirically determine the most influential variables in shaping the geography of air freight metropolitan markets in the United States in 2003. Based on the previous literature, thirty three different socio-demographic-economic variables were identified for use in the regression model (Table 1). Stepwise variable selection procedure is the method that was used in this dissertation to build a regression model using the SPSS Analytical Software (version 10.0). Regression analysis was performed to examine the relationship between the dependent variable (air freight pounds) and the independent variables, and to help identify a group of variables that best predicts air freight traffic.

2.1. Procedures for Model Selection

2.1.1. Transforming the Dependent Variable

It is crucial to make sure that the dependent variable (air freight) has a linear relationship with the independent variables and it is normally distributed before starting the regression analysis. To examine linearity, I looked at the added variable plots which indicated that the dependent variable does not have a reasonable linear relationship with many of the included explanatory variables in this dissertation. To examine the normality of the dependent variable, I used a histogram and normal probability plot as shown in Figures 12 and 13. There are a number of factors indicating this variable is not normal. For example, the histogram distribution and the skewness value of 4.2 indicate that air freight is positively skewed. Also, the Q-Q plot suggests that air freight is not normal given the deviations from the line of best fit.

Given the curvilinear relationships, positive skewness and deviation in Figures 12 and 13, a natural log transformation was performed to improve the linearity, change the shape and spread of the distribution of air freight data, and make the distribution more normal. Such a transformation on the dependent variable may help to linearize a curvilinear regression relation (Kutner, Nachtsheim & Neter, 2003) and increase predictive power (Bobko, 2001). Natural log is a more preferable logarithmic transformation since coefficients on the natural-log scale are directly interpretable as approximate proportional differences (Gelman & Hill, 2007).

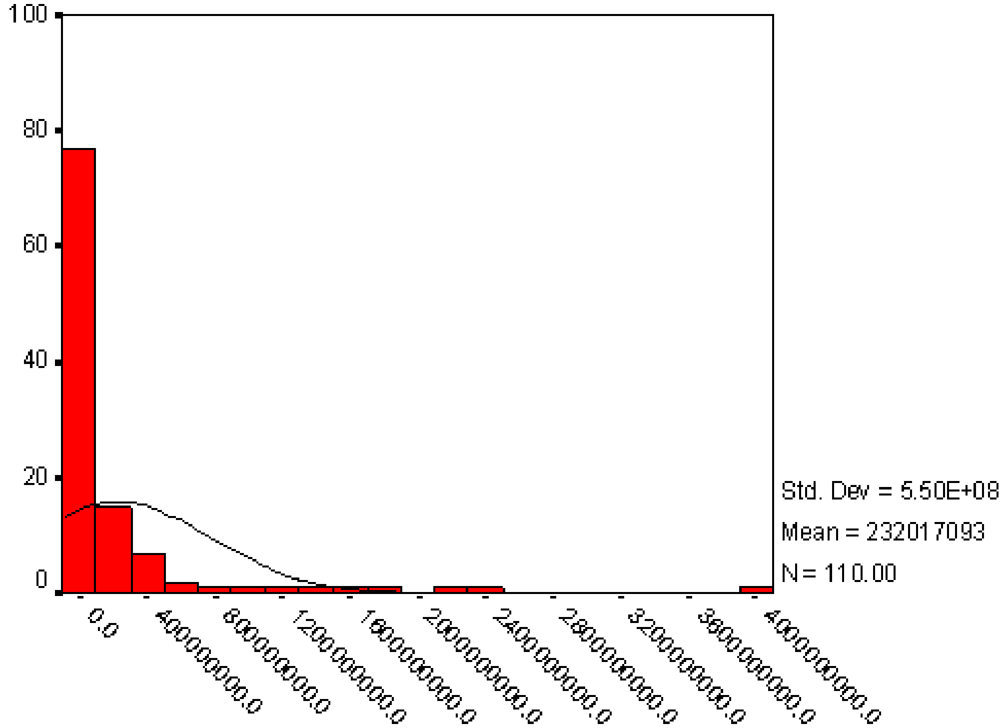

Figure 12. Histogram of Enplaned Freight (Pounds), 2003

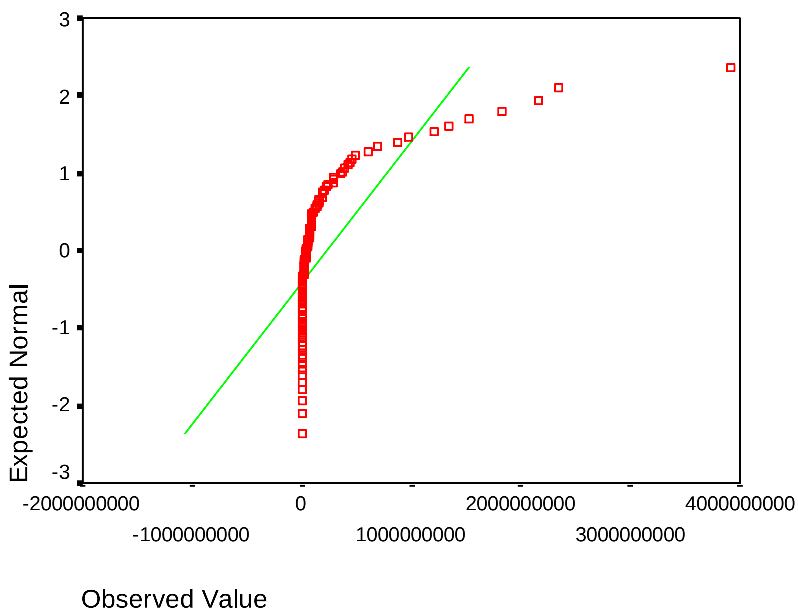

Figure 13. Normal Q-Q Plot of Enplaned Freight (Pounds), 2003

After the transformation, the added variable plots showed more linear relationships existed between the dependent variable and independent variables. Figures 14 and 15 present histogram and Q-Q plots after changing the scale on which air freight is measured. The natural log transformation was successful, resulting in a much more normal distribution. Also, the skewness and kurtosis after the transformation are -0.2 and -0.9 respectively, which verify the normality of the natural log of air freight. Therefore, taking the natural log of the dependent variable seems to have successfully reduced the impact of outliers and non-linearity, and produced a more normally distributed variable. Now it makes sense to compute the multiple linear regression equation using the values of the transformed variable in place of the original variable.

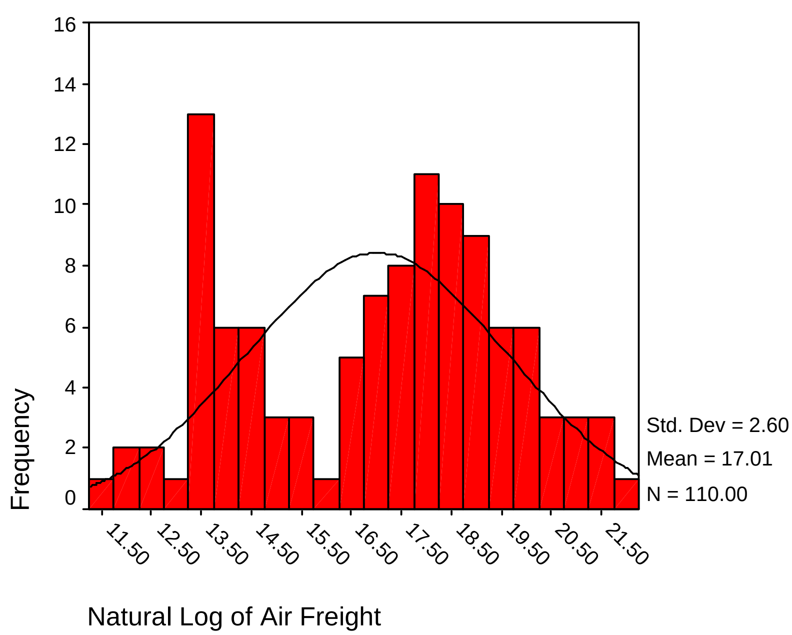

Figure 14. Histogram of Natural Log of Enplaned Freight (Pounds), 2003

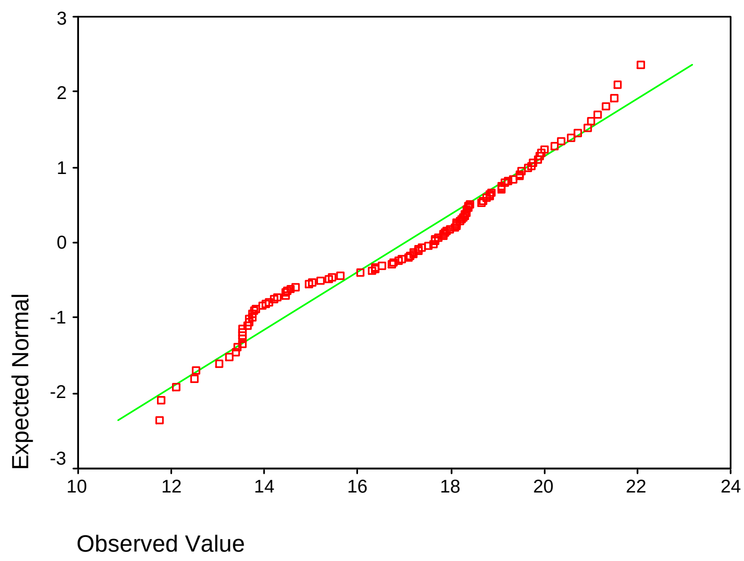

Figure 15. Normal Q-Q Plot of Natural Log of Enplaned Freight (Pounds), 2003

2.1.2. Correlation Analysis

Before running the stepwise regression procedure, it is very important to include in the model only the most relevant variables to air freight traffic. Including less relevant variables in the model will increase the standard errors of the coefficients without improving prediction. Therefore, a correlation matrix of dependent and independent variables was developed using Spearman's rank correlation coefficient. Any independent variable with a moderate or high correlation coefficient (0.5 and above) with the dependent variable was selected as a potential candidate to be included in the regression model. Based on this criterion, twenty-five independent variables were selected in the regression analysis (Table 7).

Table 7. Independent Variables Used in the Regression Analysis

#	Independent Variables	**Spearman Correlation (r_s) with Natural Log of Air Freight**
1	High-Tech Employment	.776
2	High-Tech Establishment	.834
3	High-Tech Total Wages ($1,000)	.767
4	Average High-Tech Employee Wage ($1,000)	.593
5	Medical Diagnostic Employment	.743
6	Medical Diagnostic Establishment	.840
7	Medical Diagnostic Total Wages ($1,000)	.760
8	Pharmaceutical and Biotech Employment	.709
9	Pharmaceutical and Biotech Establishment	.798
10	Pharmaceutical and Biotech Total Wages ($1,000)	.717
11	Average Pharmaceutical and Biotech Employee Wage ($1,000)	.583
12	Cultural Products Employment	.799
13	Cultural Products Establishment	.832
14	Cultural Products Total Wages ($1,000)	.793
15	Transportation-Shipping-Logistics Employment	.812
16	Transportation-Shipping-Logistics Establishment	.877
17	Transportation-Shipping-Logistics Total Wages ($1,000)	.802
18	Transportation-Shipping-Logistics Employment Market Share (%)	.504
19	Total Population	.846
20	Total Personal Income ($1,000)	.855
21	Per Capita Personal Income ($1,000)	.681
22	Total Employment in all Industries	.862
23	Total Population in Poverty	.784
24	Total Population (25 to 64 Years) with Bachelor’s Degree or Higher (2005)	.845
25	Traffic Shadow Effect	-.562

Note: correlations are significant at the 0.01 level (2-tailed)

2.2. Why is this Model the Best Fit? – Diagnostic Results

The chosen final regression model was the best fit, in part, since there are no serious multicollinearity problems among the selected independent variables, and it meets most of the regression assumptions including linearity, normality, and homogeneity of variance. Another assumption for the multiple regression is that the errors associated with one observation should not be correlated with the errors of any other observation. However, this assumption (independence of error terms) is only relevant when the data comprise a time series. Since the data in this dissertation is not time series data, there is no need to test for the independence of the error terms. Now we move to a more detailed interpretation of the following diagnostics and assumptions:

2.2.1. Multicollinearity Diagnostics

Multicollinearity is one of the main issues that need to be examined during any regression analysis. To inspect if the independent variables are highly intercorrelated, various collinearity statistics were used, including tolerance, variance inflation factor (VIF), and the condition index. When tolerance is close to 0 (less than 0.1) there is a high multicollinearity of that variable with other independents and the b and beta coefficients will be unstable (Norušis, 2002).

VIF is simply the reciprocal of tolerance, and when VIF exceeds 5 (Montgomery & Peck, 1982; Rogerson, 2006) or 10 (Chatterjee & Hadi, 2006; Montgomery & Peck, 1982; Ott & Longnecker, 2001; Rawlings, Pantula & Dickey, 1998) there is a likelihood of high levels of multicollinearity and instability in the b and beta coefficients. Another way of assessing multicollinearity in a final model is to look at the condition index, where a condition index over 30 suggests a serious multicollinearity problem (Rawlings et al., 1998). Overall, multicollinearity is not an issue in the chosen model since all the VIFs are less than 2 and the tolerances are more than .548. Also, the condition indexes are all less than 23 for the five independent variables which suggested that no multicollinearity problems exist.

2.2.2. Outlier Diagnostics

There are issues that can arise during the analysis that, while strictly speaking, are not assumptions of regression, but are none the less of great concern to geographers. It is important to look for unusual and influential observations that are substantially different from all other observations and might make a substantive difference in the results of the regression analysis. Outliers can have a significant effect on the magnitude of correlations. Given that regression slopes are determined by correlations and standard deviations, regression parameters can also be considerably affected by outliers (Bobko, 2001).

Therefore, the leverage values, Cook's distance, and partial regression plots were used to identify any usual and influential observation for the five selected independent variables. The results of the leverage and Cook's distance indicate that Dallas is a potential outlier that might substantively influence the regression model. It also stands out as an anomaly in the average high-tech wage rate partial regression plot. To examine the influence of this outlier, the stepwise procedure was performed again excluding Dallas from the data set. The outcome model without Dallas is similar to the one with Dallas, including the following selected explanatory variables: per capita personal income; traffic shadow effect; transportation-shipping-logistics employment market share; medical diagnostic establishment; and average high-tech employee wage. The implication is that Dallas does not substantively impact the regression parameters since dropping Dallas did not cause substantial changes in the fitted model. Dallas also did not change the direction of the relationship between the natural log of air freight and the average high-tech employee wage when excluding the metropolitan area from the chosen model. Therefore, the model including Dallas was selected as the best fit model in predicting air freight volume.

2.2.3. Examining the Normality of Residuals

The assumption that the residuals are normally distributed is needed only for the tests of significance and the construction of the confidence interval estimates of the parameters. Norušis (2002) suggested using studentized deleted residuals to look for violations of the regression assumptions because they make it easier to spot an outlier. The stem-and-leaf plot of the studentized deleted residuals was used first to examine the shape of the distribution. The distribution looks relatively normal, symmetric, and has a single peak. The Q-Q plot of the studentized deleted residuals was also used to examine the normality. A visual inspection of the Q-Q plot of the studentized deleted residuals indicates that the residuals are from a normal population since they fall close to the straight line except for the four outlying points. The standardized residual histogram provides another way of visually assessing if the assumption of a normally distributed residual error is met. The final model seems robust since the histogram suggests a small amount of positive skew which should not substantively affect the conclusions.

The normal P-P plot of the regression standardized residual is another test for normally distributed residual error. Under perfect normality, the plot will be a 45-degree line. A visual inspection to the normal P-P plot indicates that the residuals are behaving reasonably normally and approximate the line of best fit.

2.2.4. Examining Homogeneity of Variance (Homoscedasticity)

Another assumption of ordinary least squares regression is that the variance of the residuals should be homogeneous across all levels of the predicted values, also known as homoscedasticity (Norušis, 2002). If residuals are non-constant then the residual variance is said to be 'heteroscedastic'. If the model is rigorous, there should be no pattern in the data points and the residuals are evenly scattered around the line. This assumption can be checked by a visual examination of a plot of the studentized deleted residuals against the predicted values of the natural log of air freight. Most of the residuals fall in a horizontal band around 0, indicating a homogeneity of variance.

2.2.5. Linearity

Multiple regression assumes that the relationship between the response variable and the predictors is linear. Multiple regression can only accurately estimate the relationship between dependent and independent variables if the relationships are linear in nature. To evaluate the linearity assumption, Norušis (2002) suggested examining the studentized residuals against the predicted values. A scatterplot of studentized residuals indicates a linear relationship between the residuals and the predicted values.

Norušis (2002) also suggested using partial regression plots to assess the adequacy of the regression model. If the assumption of linearity is met, the partial regression plot is linear (Norušis, 2002). The residual partial regression plots for the selected five independent variables in the model were visually examined, and they almost meet the assumption of linearity. Moreover, an examination for both added variable plots and residual plots indicated that linearity relationships existed between the natural log of air freight and the five predictors.

2.2.6. Some Missing Data

Although the final model seems to meet most of the assumptions of regression modeling, there might be some underestimation in a few metropolitan markets due to the lack of data in some areas (see chapter 3: research limitation section). Now we interpret the selected model in detail.

2.3. Model Interpretation

The summary results of the regression analysis for air freight are listed in Table 8. The final regression model includes five independent variables with the R-square value of 0.71 (Table 9).

Table 8. Summary Statistics of Selected Model using Stepwise Selection Method

Model		R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	P-Value
1	-per capita personal income	.364	.359	.364	.364	.000
2	-per capita personal income -traffic shadow effect	.548	.539	.183	.183	.000
3	-per capita personal income -traffic shadow effect -transportation-shipping-logistics employment market share	.647	.637	.099	.099	.000
4	-per capita personal income -traffic shadow effect -transportation-shipping-logistics employment market share -medical diagnostic establishments	.692	.680	.045	.045	.000
5	-per capita personal income -traffic shadow effect -transportation-shipping-logistics employment market share -medical diagnostic establishments -average high-tech employee wage	.711	.697	.62211	.019	.011

Table 9. The Final Regression Model

Variable *	**Unstandardized Coefficients**		**Standardized Coefficients**	**Change in AF as a Ratio = exp(B)**	**Change in AF (%) = [exp(B) – 1]*100**
	B	**Std. Error**	**Beta**		
Constant	4.782	.436			
Per Capita Personal Income ($1,000)	.055	.016	.237	1.057	6%
Traffic Shadow Effect	-.969	.147	-.366	0.379	-62%
Transportation-Shipping-Logistics Employment Market Share (%)	.661	.116	.308	1.937	94%
Medical Diagnostic Establishment (#)	.001	.000	.230	1.001	0.1%
Average High-Tech Employee Wage ($1,000)	.010	.004	.170	1.010	1%

* All variables are significant at the 1% level

$$LN(AF) = 4.782 + 0.055\,PC - 0.969\,TSE + 0.661\,TSL + 0.001\,\mathrm{MD} + 0.01\,HT$$

Where,

LN (AF) = logarithm of air freight

PC = per capita personal income ($1,000)

TSE = traffic shadow effect: proximity

TSL = transportation-shipping-logistics employment market share (%)

MD = # of medical diagnostic establishments

HT = average high-tech employee wage ($1,000)

Before providing some explanations of the chosen model equation, it is crucial to provide some context on how to use the b coefficients, and to understand the logic behind converting the natural log of Y back to the original variable. In the multiple regression equation, usually the b coefficient of X shows how much Y changes when X changes by one unit and the values of the other independent variables do not change. Where $X_2 - X_1 = 1$ represents how much X_1 changes, and $Y_2 – Y_1 = b_1$ represents the difference in Y. However, when the logarithm of Y is used as the dependent variable, b_1 represents how much Ln Y changes when X_1 changes by one unit. To calculate how much Y changes when X_1 changes by one unit, the natural log of Y needs to be converted back to Y by computing the exponential for every b coefficient (unstandardized coefficient). After transforming the natural log of Y to the original Y value, it is very important to keep in mind that the change in Y when X_1 changes by one unit represents a ratio change and not the actual difference between $Y_2 – Y_1$. To calculate the change in Y in terms of a percentage, the ratio change in Y [exp(b)] needs to be subtracted by 1 and then multiplied by 100 as followed: [exp(b) – 1]*100.

For example, the b coefficient (0.055) of the first independent variable in the equation (per capita personal income) does not represent the actual unit change in air freight when per capita personal income changes by $1,000. Since the air freight variable is measured on a natural log, the coefficient of 0.055 represents the difference in the natural log of air freight when per capita personal income changes by $1,000. In order to get the change in air freight (in terms of a ratio), the natural log of air freight needs to be transformed back to the original air freight values. Therefore, the exponential was computed for the b coefficient of the per capita personal income ($e^{0.055} = 1.056541$). To calculate the percent change in air freight, subtract 1 from 1.056541 and then multiply the output by 100, which equals almost 6%. When per capita personal income increases by one thousand dollars, air freight will increase by around 6%, while holding the other independent variables constant.

Similarly, the traffic shadow effect was calculated as a ratio of air freight ($e^{-0.969} = 0.379462$) and the change in air freight equals -62%. When the metropolitan area is under a traffic shadow effect, air freight will decrease by 62%, while holding the other explanatory variables constant. The exponential for the b coefficient of the transportation-shipping-logistics employment market share is $e^{0.661} = 1.936728$ and the change in air freight is almost 94%. For every 1% increase in the transportation-shipping-logistics employment market share the predicted air freight will increase by a 94%, assuming the rest of the predictors remain unchanged. The exponential for the b coefficient of the medical diagnostic establishment is $e^{0.001} = 1.001001$ and the change in air freight equals 0.1%. For every one firm increase in medical diagnostic establishment air freight will increase by 0.1% while holding the other explanatory variables constant. The exponential for the b coefficient of the average high-tech employee wage is $e^{0.01} = 1.01005$ and the change in air freight equals 1%. When the average high-tech employee wage increases by one thousand dollars, air freight will increase by 1%, assuming the other predictors remain constant.

The adjusted R-squared is a standard, arbitrary, downward adjustment to penalize for the possibility that, with many independents, some of the variance may be due to chance. The more independents involved, the more the adjustment penalty. Since only five independents are observed, the penalty is minor (Table 8). The p-value for the 'Change Statistics' shows the significance level associated with adding the variable for that step. Each of the five steps is significant (p-value less than 0.05) (Table 8).

The analysis-of-variance (ANOVA) was used to examine the overall significance of the model (that is, of the regression equation) for the five steps. The significance of the p-value is below .05, indicating the models for each step are significant. Therefore, a statistically significant relationship exists between the natural log of air freight and the five predictors.

Table 8 also lists the change in the R squared statistic that is produced by adding or deleting an independent variable. If the R squared change associated with a variable is large, that means that the variable is a good predictor of the dependent variable. The first explanatory variable to enter the model is the per capita personal income explaining 36.4% of the variance in the natural log of air freight with a significant level (p-value) below .000 (Table 8). The suggestion here is that metropolitan areas enjoying a higher per capita personal income tend to produce a higher volume of air freight shipments. This inference validates some of the earlier studies (Cambridge Systematics et al., 1996; Kasarda & Green, 2005) where high income levels can generate substantial consumer spending on different types of expensive merchandise in large quantities (especially high value/low weight products), creating an extensive demand for air freight delivery.

To investigate the relative importance of each independent variable in predicting the natural log of air freight, the absolute magnitudes of the beta coefficients (standardized regression coefficients) are provided in Table 9. Betas are only compared within a model, not between models, and adding or subtracting variables in the equation will affect the size of the betas. Also, the t-test results are listed in Table 9 to show the significance of each b coefficient. It is possible to have a regression model which is significant overall based on the F test, but where a particular coefficient is not significant. Even though per capita personal income is the first independent variable entered into the model and it explains the highest variability in the natural log of air freight, it is the third most important independent variable in predicting the natural log of air freight within the model ($\beta = .237$, $t = 3.327$, $p = .001$) (Table 9) based on the standardized coefficients.

It is the traffic shadow effect that is the most powerful standardized coefficient even though it was the second independent variable entered into the model and it accounted for just 18.3% of the variation in the natural log of air freight with a significant level (p-value) below .000 (Table 8). Despite the importance of the traffic shadow effect, it has been largely neglected in the recent academic literature. Although one exception to this rule is the work of Brueckner (2003) who looked at how spatial proximity influences and shapes airline passengers demand. Although Brueckner used a 145 miles threshold to capture the proximity effect and this dissertation used 100 miles, he found a similar negative inverse relationship existed. It is revealing to see how this explicitly spatial phenomenon has such a profound influence on air freight traffic. Small metropolitan areas that originate less than 30 million enplaned pounds of air freight and that are within 100 miles of a nearby larger airport in an adjacent metropolitan area that generated more than 30 million pounds appear to experience a sort of 'traffic shadow effect'. As a result, these small markets tend to experience considerable freight losses since shippers seem to prefer to drive their freight to the closest large airport to enjoy the high quality cargo services and the frequent flight schedules they often times provide to many U.S. and global destinations. Examining the standardized beta in Table 9 confirms that the traffic shadow effect is the most important explanatory variable in predicting the natural log of air freight within the model (β = -.366, t = -6.581, p = .000).

The third independent variable to enter the model is the transportation-shipping-logistics employment market share accounting for 9.9% of the variation in the natural log of air freight with a significant level (p-value) below .000 (Table 8). However, based on the standardized coefficients, the transportation-shipping-logistics employment market share is the second important independent variable in predicting the natural log of air freight within the model (β = .308, t = 5.693, p = .000) (Table 9). The diverse functional services of this sector are apparently essential to facilitate freight processing and distribution. Firms in this sector are mainly engaged in the following: providing air, surface, or combined courier delivery services; operating commodities warehousing and storage facilities; organizing the transportation of freight between shippers and carriers (e.g., freight forwarders); packing, crating, and preparing commodities for shipping. Metropolitan markets generating a disproportionate share of transportation-shipping-logistics services experience extensive air freight demand. Despite the strong relationship between air freight and transportation-shipping-logistics employment market share, it is less clear which comes first – a real chicken and egg issue. Therefore, future research needs to empirically examine the causal relationship between these two variables in more detail.

The number of medical diagnostic establishments by metropolitan area is the fourth explanatory variable entered into the model explaining 4.5% of the variation in the natural log of air freight with a significance level below .000 (Table 8). Based on the standardized Beta values, it is also the fourth most important predictor in predicting the natural log of air freight within the model (β = .230, t = 3.485, p = .001) (Table 9). The suggestion here is that this sector of the economy is highly linked to air freight given the necessity for the quick delivery of diagnostic results to customers and the proliferation of high-value, low weight products. Firms engaged in wholesaling medical professional equipment, instruments, and supplies; providing analytic or diagnostic services; manufacturing medical equipment and supplies (e.g., laboratory apparatus, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures, and orthodontic appliances) have high propensities to ship by air and metropolitan areas hosting a large number of different medical diagnostic firms seem to create a substantial demand for air freight.

The fifth and final predictor to enter the model was average high-tech employee wages accounting for 1.9% of the variance in the natural log of air freight with a significance level equal to .011 (Table 8). It is also the fifth most important variable in predicting the natural log of air freight within the model based on the standardized coefficients (β = .170, t = 2.594, p = .011) (Table 9). The implication here is that metropolitan markets offering above average high-tech wage rates will experience higher air freight shipment volumes. Companies offering a high wages to highly skilled employees engaged in either computer systems design and related services or manufacturing computer and electronic products will have a higher tendency to ship their high-value and low-weight products by air, which might attract cargo carriers and freight forwards to the region in response to that demand.

3. The Geography of the Selected Explanatory Variables

3.1. The Spatial Distribution of Per Capita Personal Income

It has been hypothesized that metropolitan markets with high per capita personal income levels would likely generate a substantive level of air freight shipments, in terms of weight and value. The empirical results of the stepwise regression suggests that a positive relationship exists between per capita personal income and air freight, where more affluent metropolitan markets are apparently more likely to ship freight by air. Using the BEA database, per capita personal income mainly includes earnings, transfer payments, dividend, interest, and rent. Per capita income appears to be an appropriate surrogate measure of overall healthy productive economies that seem to substantively contribute to shaping the geography of air freight by metropolitan area.

Having said that, the relationship between air freight and per capita personal income is not a straightforward one. For example, even though Memphis (the FedEx super hub) is the leading air freight market in 2003 as measured by weight of shipments, it only ranked 38th in per capita personal income (Figures 4 & 16). Part of the logic for

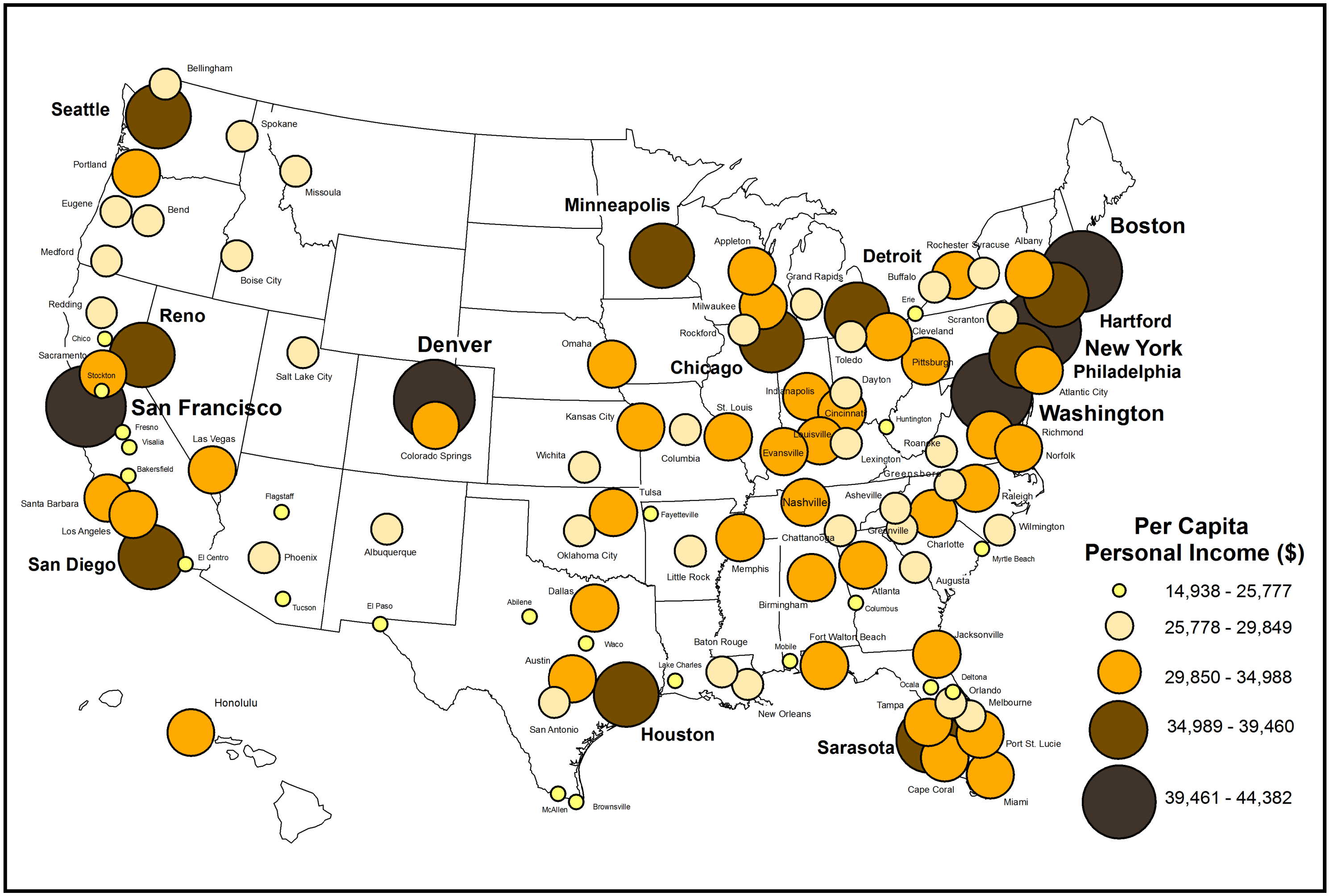

Figure 16: The Spatial Distribution of Per Capita Personal Income, 2003

Table 10. The Top Fifteen Metropolitan Markets in terms of Per Capita Personal Income, 2003

Rank	MSA/CSA	Per Capita Personal Income ($)
1	San Jose-San Francisco-Oakland, CA, CSA	44,382
2	Boston--Worcester--Manchester, MA-NH-ME-CT CSA	41,159
3	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV CSA	41,096
4	New York-Newark -Bridgeport, NY-NJ-CT-PA CSA	40,842
5	Denver-Aurora-Boulder, CO CSA	39,461
6	Minneapolis-St. Paul- St. Cloud, MN-WI CSA	37,762
7	Reno-Sparks, NV MSA	37,620
8	Hartford-West Hartford-Willimantic, CT CSA	37,565
9	Seattle-Tacoma-Olympia, WA CSA	37,200
10	Sarasota-Bradenton-Venice, FL MSA	36,999
11	Philadelphia-Camden-Vineland, PA-NJ-DE-MD CSA	36,695
12	Chicago-Naperville-Michigan, IL-IN-WI CSA	35,740
13	Detroit-Warren-Flint, MI CSA	35,657
14	San Diego-Carlsbad-San Marcos, CA MSA	35,620
15	Houston-Baytown-Huntsville, TX CSA	34,989

this is that much of the air-based freight in Memphis is connecting and not originating freight. Thus, the high levels of air freight volume in Memphis are not necessarily a reflection of the local economy. Similar relationships seem to apply to Louisville (UPS hub) and Indianapolis (FedEx hub) (Figures 4 & 16). Even though Louisville and Indianapolis ranked fourth and eighth respectively in terms of air freight volume, they ranked 39th and 26th respectively in terms of per capita personal income. Much of the air freight traffic at Louisville and Indianapolis is also connecting and not locally originating.

On the other hand, for some of the international gateway markets, a strong relationship appears to exist between per capita personal income and air freight, especially in New York. In 2003, New York ranked fourth ($40,842) in terms of per capita personal income and ranked third in terms of air freight, with more than 2.164 billion pounds (Figure 16; Table 10; Figure 4; Table 2). In the same year, net earnings accounted for nearly 70% of New York's personal income, while dividend, interest, rent, and transfer receipts collectively accounted for only 30% of New York's personal income (Regional Economic Information System & Bureau of Economic Analysis, 2008). The high per capita personal income levels in New York can be partly explained by New York's diverse and productive economy, which seems to play a role in shaping air freight volume. Besides the originating freight shipments out of New York, the New York airports also effectively link many connecting domestic and international freight traffic packages to their final destinations, leading to substantial value in New York's air freight market.

The San Francisco metropolitan market is another gateway with high air freight volume (1.337 billion pounds, ranked sixth) and high per capita personal income ($44,382, ranked first) (Figures 4 & 16; Tables 2 & 10). In 2003, net earnings accounted for nearly 73% of San Francisco's personal income, whereas dividend, interest, rent, and transfer receipts altogether accounted for only 27% of San Francisco's personal income (Regional Economic Information System & Bureau of Economic Analysis, 2008). According to Newman (2001), the high per capita personal income in the San Francisco metropolitan market is largely related to the high wages in industries like business services including: software development, prepackaged software, data processing services, and computer rental and leasing; industrial machinery and equipment manufacturing; and electronics and other electric equipment manufacturing, which includes semiconductor manufacturing. These types of industries tend to have a high predisposition to ship high-value and low-weight products by air, which may partly explain San Francisco's high level of air freight volume.

Other examples that support the general trend of the positive relationship between per capita personal income and air freight include Boston, Washington D.C., Seattle, Chicago, and Houston. For example, Boston ranked second in terms of per capita personal income ($41,159) and fourteenth in terms of air freight (Figure 16 & 4; Table 10). The high per capita personal income of Boston is partly related to its high wage industries in high-tech, health care, and biotechnology that rely heavily on air freight shipments. Boston generated over 443 million enplaned pounds in 2003, largely reflecting the importance of its regional medical economy in shaping its air freight market share.

The affluent economies in all these leading markets reflect their highly skilled labor forces in more sophisticated and well-paid jobs like information technology, medical care, biotechnology, and aerospace technology. For example, Seattle ranked ninth in terms of per capita personal income ($37,200) largely because of its diverse, well-paid labor pool, including aerospace (e.g., Boeing Corp.), programming and software applications (e.g., Crowley Maritime Corp. and Microsoft Inc.), and biotechnology (e.g., Corixa, Immunex, and ZymoGenetics) (Gray, Golob & Markusen, 1996). These high-skilled, well-paid jobs have a high tendency to ship many of their high-value and low-weight products by air, which partly explains the high air freight volume at Seattle in 2003 (464.4 million pounds, ranked thirteenth).

Although overall a positive relationship exists between per capita personal income and air freight in Los Angeles, Miami, and Dallas, per capita personal incomes are relatively low, even though air freight volume is high (Figures 16 & 4). In 2003, the per capita personal incomes in Los Angeles, Miami, and Dallas were respectively, $31,551 (ranked thirty-fifth), $32,762 (ranked twenty-fourth), and $33,733 (ranked nineteenth). One possible explanation for the relatively low per capita personal income in these markets is the high level of low-wage employment, since these three metropolitan markets have experienced high immigration rates (Migration Policy Institute, 2008). For example, in 2006 almost half of the Los Angeles County workforce (46%) was foreign born and over 40% of immigrant adults in Los Angeles County had less than a high school education (Migration Policy Institute, 2008). Moreover, non-labor income like dividend, interest, rent, and transfer receipts collectively accounted for 40% of Miami's personal income (Regional Economic Information System & Bureau of Economic Analysis, 2008).

Interestingly, some medium-size metropolitan markets such as Reno, Hartford, Sarasota, and San Diego generated substantial per capita personal income levels although air freight levels were also low (Figures 16 & 4; Table 10). The high per capita personal income in Reno ($37,620, ranked seventh) can be partly explained by its significant workforce in the hotel and casino business, gold mining activities, health care, distribution services, transportation and logistics, and real estate and construction projects (University of Nevada, 2006). In 2003, net earnings accounted for nearly 64% of Reno's personal income, while dividend, interest, rent, and transfer receipts collectively accounted for 36% of Reno's personal income (Regional Economic Information System & Bureau of Economic Analysis, 2008). On the other hand, the Reno metropolitan market ranked fifty-third in terms of air freight weight, which is an indication that some affluent markets do not necessarily generate substantial demand for air freight services.

The high per capita personal incomes of the Hartford metropolitan area ($37,565, ranked eighth) is partly related to Hartford's role as a home to many of the world's insurance companies (such as Travelers, Aetna, and The Hartford Financial Services Group, Inc.) and large corporations like United Technologies (City of Hartford, n.d.). However, in 2003, Bradley International Airport in Hartford generated less than expected air freight shipments (150.3 million pounds, ranked thirtieth; Figure 4). This is partly because the Hartford region is also served by other neighboring airports, such as John F. Kennedy International and LaGuardia in New York and Logan International in Boston (Connecticut Department of Transportation, 2006) which might capture some of Hartford's freight traffic.

Overall, the per capita personal income variable reflects the skill levels and productivity rates of the entire population as well as the mix of industries in places like San Francisco, Boston, Washington D.C., New York, and Denver. It seems that measures of overall affluence are key predictors of active air freight markets, where wealthy consumers can purchase high-value low-weight products. It appears that wealthy metropolitan areas tend to create the type of industries that need to ship by air.

3.2. The Geography of the Traffic Shadow Effect

The traffic shadow effect is a major concept in transport geography, and Taaffe, Gauthier, and O'Kelly (1996) were one of the first transport geographers to identify the traffic shadow effect on the geography of shipments. Broadly defined, the traffic shadow effect articulates the hierarchical shadow cast by large markets on nearby smaller markets. The general notion is that larger markets are capable of "capturing" the hinterland of nearby smaller markets given the broader range of services and amenities frequently offered in the larger market.

Figure 17 illustrates in more detail a hypothetical example of how the traffic shadow effect theoretically operates between two proximate metropolitan areas. The shaded areas to the north of the large and small metropolitan areas represent the shadow effect cast by each airport. Companies generating high-value, low-weight products that need to be shipped by air may be located closer to the smaller metropolitan area illustrated in Figure 17 but prefer the more distant larger airport because it offers more flights, more destinations, and better services. The overall impact is that smaller markets located near larger markets may generate lower levels of air freight volume than expected. On the other hand, as the distance increases between any given large market and smaller market, the traffic shadow effect will likely diminish in magnitude given the greater distances

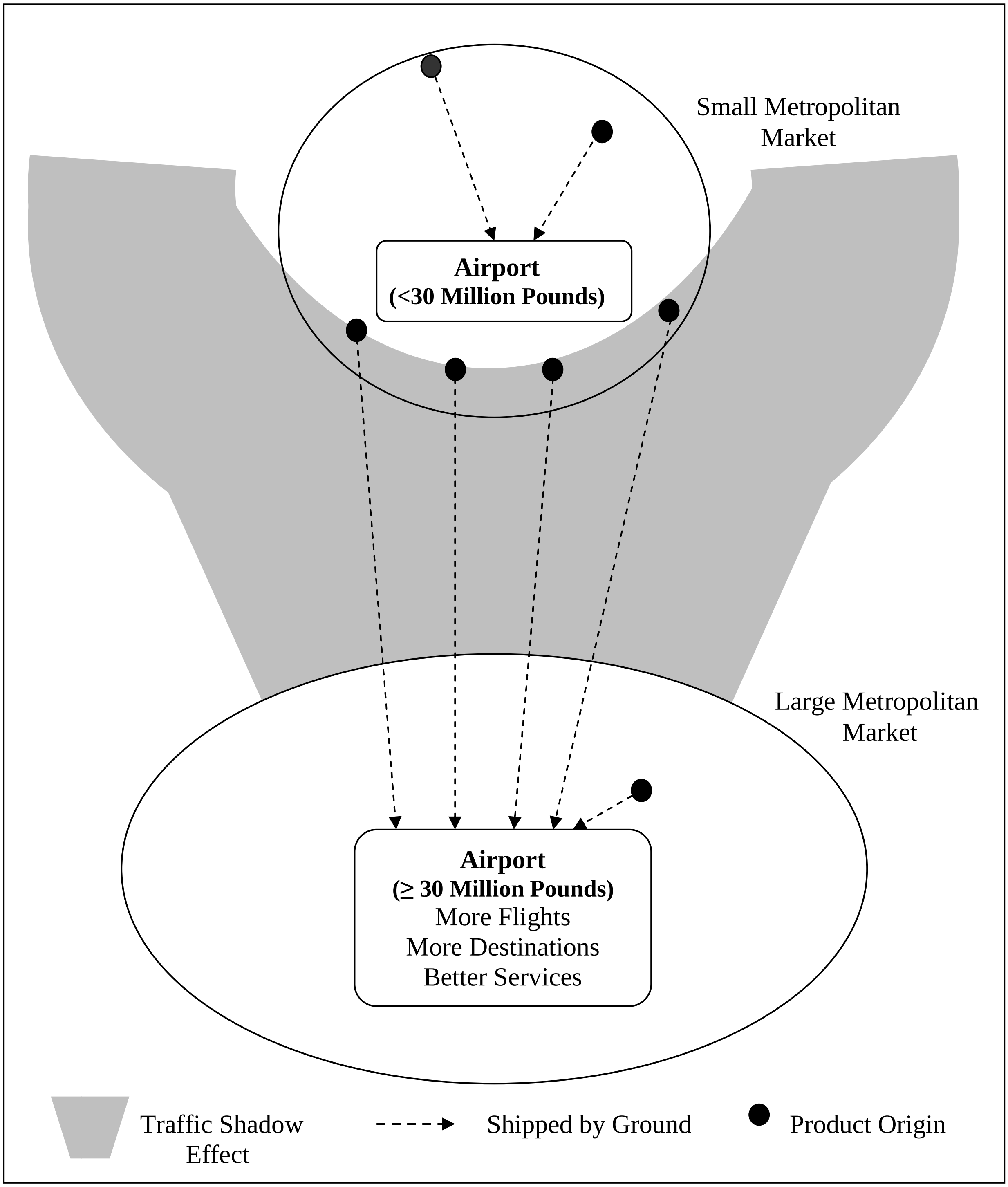

Figure 17. Hypothetical Traffic Shadow Effect for Two Metropolitan Markets

products must then be shipped by truck.

Before discussing the model results, it should be noted that since the data for air freight were collected by MSA/CSA, it is not possible to estimate the traffic shadow effect of different airports located within a single MSA or CSA. That said, the traffic shadow effect cast by one metropolitan area on an adjacent metropolitan area was analyzed in this dissertation if the adjacent MA generated fewer than 30 million pounds of air freight and was within 100 miles of a larger MA airport (≥ 30 million pounds). For example, within the Los Angeles metropolitan area the traffic shadow effect was not calculated between Los Angeles International Airport (large airport) and John Wayne International Airport (small airport) since they are both located within the same metropolitan area. However, the Roanoke Regional Airport (ROA) in Virginia was considered to be within the traffic shadow of the Piedmont Triad International Airport (GSO) in Greensboro, NC, since they are within 100 miles of each other and in separate metropolitan areas (Figure 18).

We now turn to a discussion of the model results and the explicit role of the traffic shadow effect. Unlike per capita personal income, the traffic shadow effect has a negative parameter estimate sign indicating an inverse relationship existed with air freight volume. Small MAs under the traffic shadow of larger MAs will tend to generate lower levels of freight, especially relative to other equivalent small airports in different locational settings that are not in a traffic shadow. Part of the logic for this effect is the substantial impacts that the large MA airports have on attracting shippers and freight forwarders through their frequent flight schedules and sophisticated cargo services.

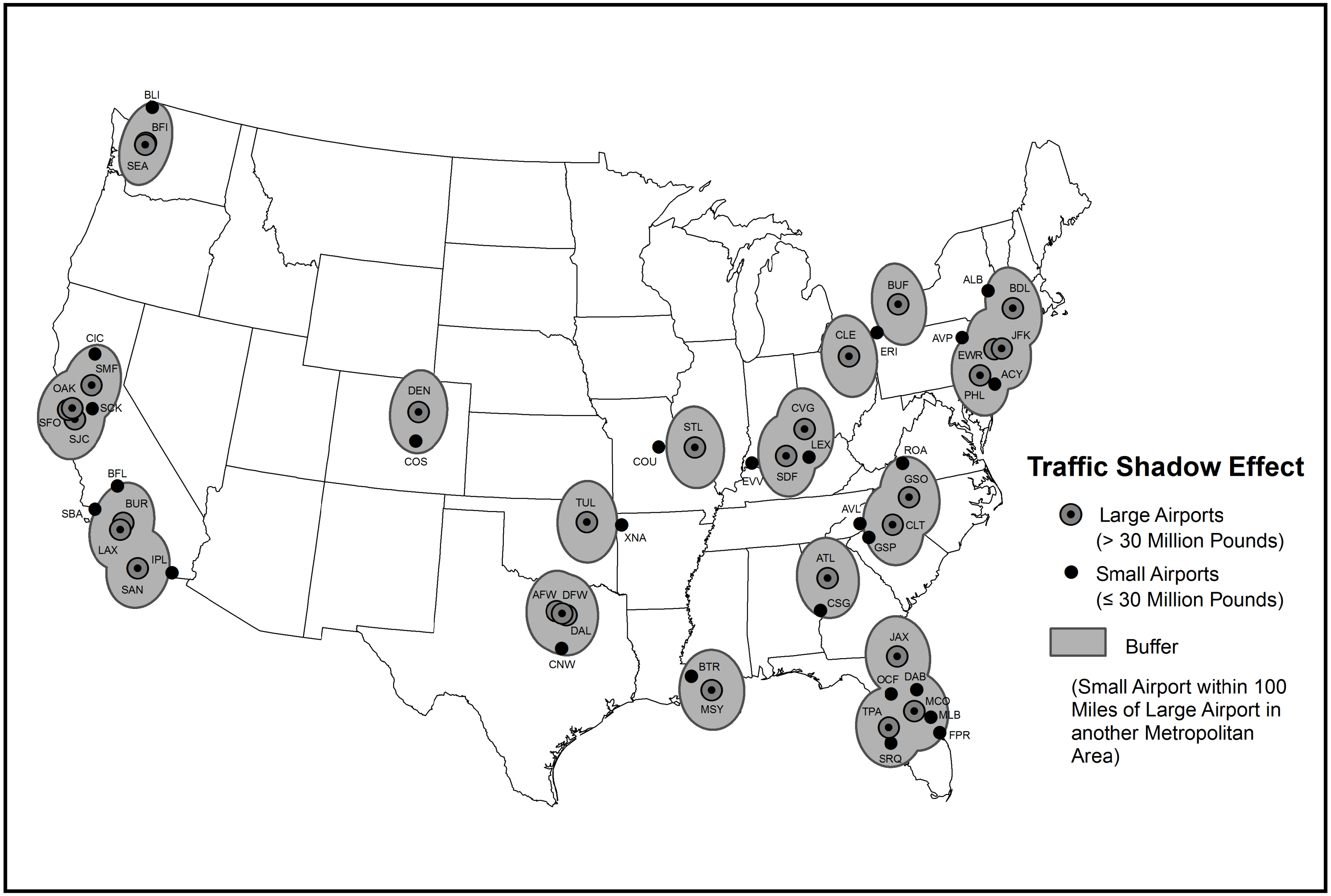

Figure 18: The Geography of the Traffic Shadow Effect

Furthermore, even though the traffic shadow effect is the second variable entered into the regression model, it is the most influential coefficient, indicating the importance of this predictor in shaping air freight markets across U.S. metropolitan areas in 2003.

Analyzing the 26 'small' air freight markets (< 30 million pounds) that were located within a traffic shadow and comparing their freight performance with those small markets more than 100 miles from a larger market can help us better understand the real impacts of a traffic shadow. The average freight volume of small airports that are within a traffic shadow was 4.8 million enplaned pounds, while the average freight volume of small airports more than 100 miles from a nearby large market was nearly 7.9 million enplaned pounds. It is likely that small markets within a traffic shadow generated less air freight because demand had been 'diluted' by the attraction of the broader range of services and amenities of the nearby larger airport. For example, Will Rogers World Airport (OKC) located in the Oklahoma City metropolitan area shipped more than 38 times (i.e., 29.7 million enplaned pounds) the volume generated at Northwest Arkansas Regional Airport (XNA) located in the nearby Fayetteville metropolitan area (i.e., 761,671 enplaned pounds). The lower enplaned freight share at Fayetteville might partly relate to its proximity and related traffic diversion to the larger Tulsa International airport (TUL) (Figure 18).

Another notable example includes Baton Rouge Metropolitan Airport (BTR) in Louisiana and Tucson International Airport (TUS) in Arizona. In 2003, Baton Rouge only shipped 266,032 enplaned pounds, which is 85 times less than the total amount of air freight shipped through the nontraffic-shadow airport of Tucson (23.1 million enplaned pounds). It is likely that the nearby Louis Armstrong New Orleans International Airport (MSY) diverted some of Baton Rouge's freight traffic 'on the ground' (Figure 18). The explicit contrast between traffic-shadow/nontraffic-shadow airports in terms of air freight volume clearly demonstrates the importance of the traffic shadow effect on the geography of air freight.

A visual inspection of Figure 18 also suggests two very different competitive contexts. The first category includes small airports under the traffic shadow effect of just one proximate large airport (e.g., Colorado Springs and Denver, Greenville (SC) and Charlotte). The second category includes small airports under the traffic shadow effect of more than one large airport. For example, Waco, TX, is under the traffic shadow effect of three large airports: Dallas-Fort Worth International (DFW), Dallas Love Field (DAL), and Fort Worth Alliance (AFW) (Figure 18). All three large airports are located in the Dallas metropolitan area.

Small airports that are under the traffic shadow effect of two or three large airports tend to have more 'freight loss' than a small airport under the traffic shadow effect of only one large airport. The average freight volumes of small airports under the traffic shadow effect of one large airport was 5.6 million enplaned pounds, while average freight volumes for small airports under the traffic shadow effect of more than one large airport is only 3.3 million enplaned pounds. For example, Colorado Springs shipped 12.9 million enplaned pounds in 2003, while Waco generated only 1.3 million enplaned pounds.

Despite the critical influence of the traffic shadow effect in diverting air freight traffic from small to large U.S. airports and the complex spatial hierarchy of the geography of shipments, it has been a largely overlooked topic in the literature. Therefore, further research is needed to inspect this concept under different competitive situations.

3.3. The Spatial Distribution of Transportation-Shipping-Logistics (TSL) Employment Market Share (%)

The existing literature has suggested that transportation-shipping-logistic (TSL) industries have the potential to significantly shape the geography of air freight in the United States. Dicken (2007, p. 411) quoted Min and Keeler (2001) and argued that

> time- and quality-based competition depends on eliminating waste in the form of time, effort, defective units, and inventory in manufacturing-distribution systems … [requiring] firms to practice such logistical strategies as just-in-time management, lean logistics, vendor-managed inventory, direct delivery, and outsourcing of logistics services so that they become more flexible and fast, to better satisfy customer requirements.

Logistics are involved in every component of the supply chain: sourcing of raw materials, parts inventory, warehousing, packaging, materials handling, and distributing final products to the customers. With the continuous growth of just-in-time inventory control, the importance of air cargo continues to be heightened in corporate supply chains, where the transport of urgent supplies (e.g., medical materials), auto components, or computer parts is necessary. In order to meet the essential shipping deadlines for these products, many companies depend on air courier firms, freight forwarders, and logistics specialists' services.

The transport/logistics index utilized in this dissertation includes the sum of the following five NAICS-based economic activities:

- NAICS 4885: freight transportation arrangement
- NAICS 488991: packing and crating
- NAICS 4921: couriers
- NAICS 49311: general warehousing and storage
- NAICS 49319: other warehousing and storage

A detailed NAICS-based definition of each of the five transport/logistics sub-sectors is provided in the research and design chapter.

The TSL employment market share explanatory variable was the third predictor entered into the regression model and the second most powerful coefficient after the traffic shadow effect variable. The empirical results of the stepwise regression suggest a strong positive relationship existed between air freight volume and TSL employment market share. Metropolitan areas with more diverse and efficient ground support systems (e.g., operating merchandise warehousing and storage facilities), freight forwarders, and transportation services tended to generate a higher volume of air freight shipments.

Although Memphis was the most important air freight market in the United States in 2003, it only ranked twelfth in terms of the TSL employment market share (1.26%; Table 11; Figures 4 & 19). The high volume of air freight at Memphis is largely related to the FedEx super hub, where many packages are transited, sorted, and then reshipped to their final destinations. Much of the air freight demand in Memphis is less related to the Memphis market and more related to the national and international shipments that are sorted and transferred through the FedEx hub each day. That said, in 2003, freight transportation arrangement firms accounted for 40.2% (127 firms) of all Memphis's logistic firms and 40% of all Memphis's logistic jobs (2,976). More specifically, general warehousing and storage establishments accounted for 25% (80 firms) of all Memphis's logistic firms and employed 60% (4,475 workers) of Memphis's total logistic workforce. Freight transportation arrangement companies and general warehousing and storage firms are the biggest logistic sub-sectors in the Memphis supply chain largely due to the presence of the FedEx Super Hub.

On the other hand, the positive relationship between air freight volume and TSL employment market share is more clearly pronounced in other connecting hubs like Louisville and Indianapolis (Figures 4 & 19). For example, Louisville ranked first in terms of the TSL employment market share and fourth in terms of air freight volume (Tables 2 & 11). In 2003, courier firms accounted for almost 23% of Louisville's total logistic firms (46 companies) and nearly 73% of total logistic jobs in Louisville (15,224); general warehousing and storage companies accounted for 36% of all logistic firms in Louisville (73 firms) and 21% of Louisville's total logistic jobs (4,419); freight transportation arrangement establishments accounted for 30% of Louisville's total logistic firms (61) and almost 5% of all logistic jobs in Louisville (1,011). Of course, the

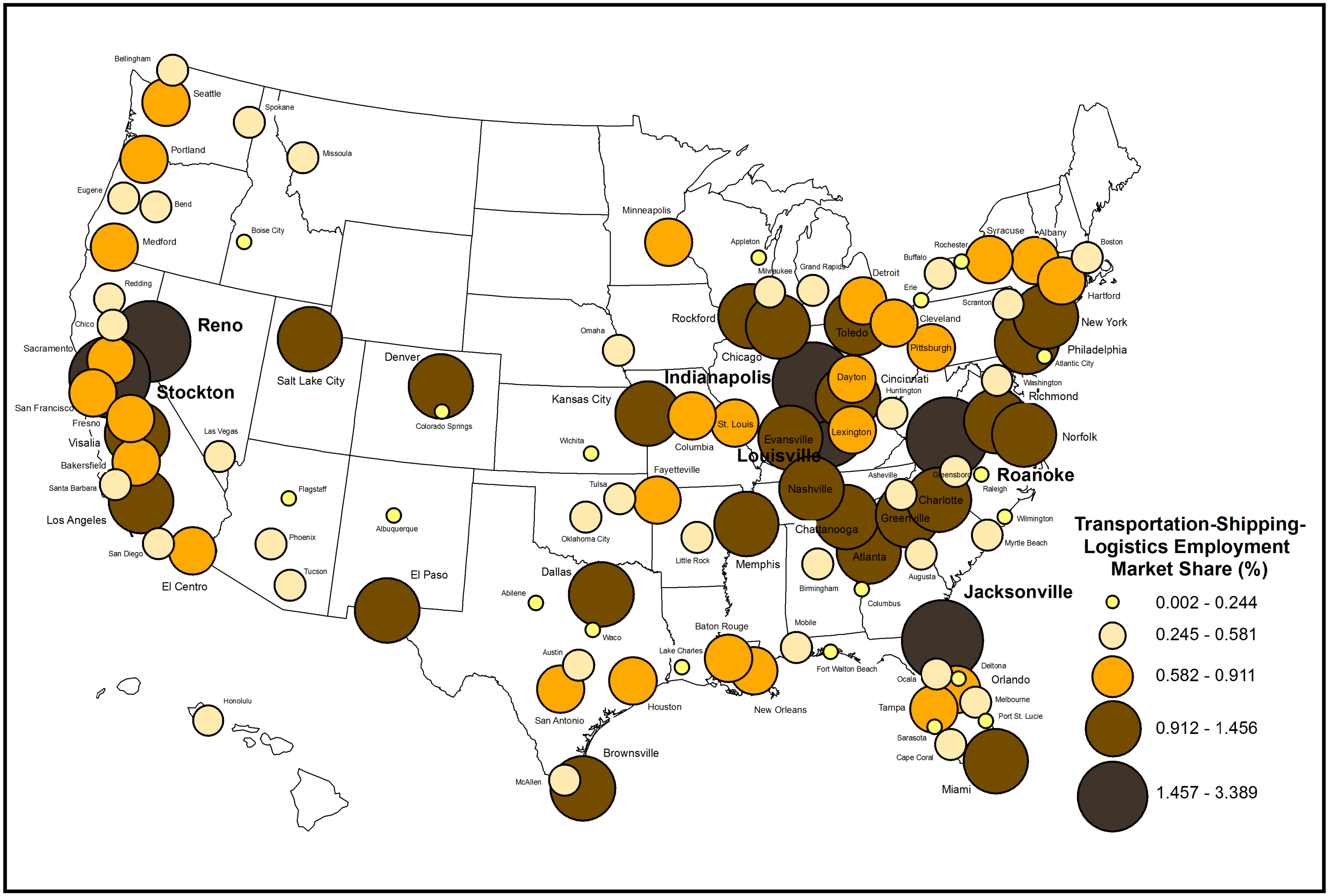

Figure 19: The Spatial Distribution of Transportation-Shipping-Logistics Employment Market Share (%), 2003

Table 11. The Top Fifteen Metropolitan Markets in terms of Transportation-Shipping-Logistics Employment Market Share, 2003

Rank	**MSA/CSA**	**Employment Market Share (%)**
1	Louisville-Elizabethtown-Scottsburg, KY, CSA	3.39
2	Reno-Sparks, NV MSA	2.23
3	Stockton, CA MSA	2.01
4	Indianapolis-Anderson-Columbus, IN CSA	1.90
5	Jacksonville, FL MSA	1.70
6	Roanoke, VA MSA	1.69
7	Visalia-Porterville, CA MSA	1.46
8	Evansville, IN--KY MSA	1.38
9	Toledo-Fremont, OH CSA	1.38
10	Atlanta-Sandy Springs-Gainesville, GA CSA	1.29
11	Kansas City- Overland Park- Kansas City, MO-KS CSA	1.26
12	Memphis, TN--AR--MS MSA	1.26
13	Chattanooga- Cleveland-Athens, TN CSA	1.24
14	Cincinnati-Middletown-Wilmington, KY-OH-IN, CSA	1.22
15	Rockford-Freeport-Rochelle, IL CSA	1.17

leading Louisville company in these sub-sectors is UPS.

Unlike FedEx, UPS Company owns and operates a much larger ground fleet. UPS services cover a wide range of logistical activities including quick air or low-cost ground delivery, global trade financing, Web retailing and call centers, and warehousing and supply-chain management (Rodrigue, Comtois, & Slack, 2008). The company also acts as a third-party logistics provider using its existing infrastructures and management capabilities, and has developed strategic alliances with those producers and distributors. Examples of other companies providing couriers services in the Louisville metropolitan market include Bee Line Courier Service and Zip Express Courier Service (ReferenceUSA, 2008).

A similar pattern is also found in the Indianapolis metropolitan area. In 2003, Indianapolis ranked eighth in terms of air freight volume with over 981.9 million enplaned pounds, accounting for 3.36% of the U.S. total, and it ranked fourth in terms of the TSL employment market share (1.90%; Tables 2 & 11; Figures 4 & 19). Couriers companies accounted for 29% of Indianapolis's total logistic firms (81) and 50% of all Indianapolis's logistic jobs (8,940); general warehousing and storage companies accounted for 29% of Indianapolis's logistic firms (82) and 40% of total Indianapolis logistic jobs (7,109); freight transportation arrangement firms accounted for 33% of Indianapolis's total logistic firms (92) and 9% of all logistic jobs in Indianapolis (1,669). FedEx is the leading Indianapolis logistic firm, which operated in 2003 over 96% of Indianapolis's enplaned pounds. The FedEx Indianapolis hub is an important part of the entire FedEx Express network, where the central location of Indianapolis in the heartland of the United States provides the FedEx Company with a competitive edge, and relieves some traffic pressure at the FedEx Memphis hub. Another example of a company focusing on providing couriers services for the Indianapolis metropolitan market is Alvan Motor Freight Inc. (ReferenceUSA, 2008).

Even though Indianapolis is a secondary FedEx hub, it surprisingly generated a higher employment market share of the TSL sector than did Memphis (1.90% vs. 1.26%, respectively). This is partly because Indianapolis is home to 1,500 logistics-focused companies (such as Celadon Group, Inc, Ozburn-Hessey Logistics, Logisco, Online

Transport, Inc and Venture Logistics), employing more than 50,000 skilled workers in 2007 (Indy Partnership, 2008). Moreover, in 2003, the population base for Indianapolis (1,916,919) was much bigger than in Memphis (1,238,028). Nearly 18,000 of Indianapolis's employees work in the TSL sector while only 7,451 people in Memphis work in TSL services.

Unlike Louisville and Indianapolis, the relationship between air freight volume and TSL employment market share is not as straightforward for some smaller markets like Reno and Stockton. Reno and Stockton ranked second (2.23%) and third (2.01%) respectively in terms of TSL employment market share but generated surprisingly low air freight volumes (Table 11; Figures 19 & 4). In 2003, general warehousing and storage companies accounted for more than half of Reno and Stockton's total logistic firms (62%: 89 firms, and 66%: 45 firms, respectively) and employed more than half of Reno and Stockton's logistic workers (63%: 2,751 employees, and 88%: 3,734 employees, respectively). Couriers companies also accounted for 16% of all Reno's logistic firms (23) and 13% of Stockton's total logistic firms, and employed nearly 34% of Reno's logistic workers (1,476) and almost 11% of Stockton's total logistic workers (461). Examples of couriers companies operating in Reno include Silver State Couriers and A Sprint Delivery, and in Stockton include Trans Box Couriers (ReferenceUSA, 2008). Also, a number of companies have chosen to base their regional operations in Stockton (e.g., Duraflame, Pac-West Telecommunications, and Golden State Lumber Company) to benefit from the relatively inexpensive land, intermodal freight transport facilities, and its connections to the rest of the nation through a network of freight railways (e.g., Union Pacific and BNSF Railway).

It is possible that Reno and Stockton have unusually large TSL sectors because of their relative proximity to San Francisco and due to the crucial importance of their respective railyards. Warehousing terminals are very space consuming and San Francisco has very high land value and it is very dense and congested with limited space for trucks and terminals. Consequently, many TSL operators in San Francisco may be opting to locate in lower cost markets like Stockton and Reno.

In addition to Reno and Stockton, the Jacksonville and Roanoke metropolitan generated disproportionately large TSL sector even though air freight shipments in both markets were fairly limited (Figures 4 & 19). The high TSL employment market share at Jacksonville is largely because it is a big shipping port city. The location of Jacksonville on the St. Johns River has played a major role in developing the local economy of Jacksonville by stimulating a range of port-related activities (e.g., vessel-related services, cargo handling, container services, warehousing, and trucking services). Development opportunists around the Jacksonville riverport and seaport have largely contributed in developing the region's transportation, shipping, and logistic industry. Jacksonville is the largest deepwater port in the south and one of the leading ports in the U.S. for automobile imports. In 2003, JAXPORT handled 7.3 million tons of cargo, including 544,062 vehicles **(**Jacksonville Port Authority, 2008). On the other hand, the air freight market is relatively small in Jacksonville (55.1 million enplaned pounds) in comparison to other competing national markets (Figure 4). In part, that might be related to the small size and limited services of the local airport as well as the intense competition from other larger airports in Miami, Orlando, and Tampa.

Surprisingly, Roanoke also generated a high TSL employment market share (ranked sixth) even though its air freight volume is relatively low. The high TSL employment market share of Roanoke is largely related to companies focus in providing couriers services and general warehousing and storage services. The Norfolk Southern Railway, which operates its marketing headquarters and some maintenance facilities in Roanoke, undoubtedly plays a significant role in Roanoke's TSL sector and helped attract different sorts of logistic-related companies to the area. The Norfolk Southern's freight rail system provides rail service for most of the New River Valley region. It also offers a widespread intermodal network that serves eastern North America involving the transportation of freight in a container or vehicle, using multiple modes of transportation (rail, ship, and truck).

The positive relationship that exists between TSL employment market share and air freight is relatively pronounced in some of the larger traditional metropolitan markets including New York, Los Angeles, Chicago, San Francisco, Dallas, and Miami (Table 12). These markets have developed as leading air cargo markets as well as major transportation and logistic centers in absolute terms. The substantive TSL employments in these markets are partly related to their large population bases, diverse economies, and well-established multimodal logistic facilities. These international gateways also host many comprehensive, multimodal shipping companies like FedEx and UPS.

Table 12. The Top Fifteen Metropolitan Markets in terms of Transportation-Shipping-Logistics Employment, 2003

Rank	MSA/CSA	Employment
1	New York-Newark -Bridgeport, NY-NJ-CT-PA CSA	90,040
2	Los Angeles-Long Beach-Riverside, CA, CSA	72,237
3	Chicago-Naperville-Michigan, IL-IN-WI CSA	50,414
4	Atlanta-Sandy Springs-Gainesville, GA CSA	29,444
5	Philadelphia-Camden-Vineland, PA-NJ-DE-MD CSA	27,717
6	San Jose-San Francisco-Oakland, CA, CSA	27,360
7	Dallas-Fort Worth, TX CSA	26,890
8	Miami-Fort Lauderdale-Miami Beach, FL MSA	22,540
9	Louisville-Elizabethtown-Scottsburg, KY, CSA	20,897
10	Detroit-Warren-Flint, MI CSA	19,864
11	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV CSA	18,609
12	Houston-Baytown-Huntsville, TX CSA	18,348
13	Indianapolis-Anderson-Columbus, IN CSA	17,718
14	Seattle-Tacoma-Olympia, WA CSA	15,776
15	Minneapolis-St. Paul- St. Cloud, MN-WI CSA	15,327

The availability of truck, rail, port, and airport infrastructures at most of these larger metropolitan markets has also allowed them to establish more complex logistic supply chains. In 2003, courier establishments accounted for nearly 21% of New York's total logistic firms (752) and almost half of New York's logistic jobs (50%: 44,873). Examples of courier companies serving the New York metropolitan market included Urban Express, FedEx, and Quick International Courier (ReferenceUSA, 2008). Freight transportation arrangement companies also accounted for more than half of all logistic firms in New York (54%: 1,945 firms) and nearly 21% of total New York logistic jobs (18,780). Atlas Air Worldwide Holdings, Janel World Trade LTD, Pacific CMA Inc, and

Genco Shipping & Trading LTD are examples of companies focusing on providing freight transportation arrangement services to the New York metropolitan market (ReferenceUSA, 2008). In addition, general warehousing and storage companies accounted for 19% of New York's total logistic firms (687) and almost 26.5% of total logistic jobs in the New York metropolitan area (23,825).

Overall, the transportation-shipping-logistics industry seems to be the underlying infrastructure that facilitates the rapid movement of goods in industries that specialize in the shipment of high-value low-weight products. That said, it is the geography of transportation-shipping-logistics employment market share that is most important which suggests that it is not always about the size of the industry, but the level of specialization. For instance, smaller populated markets like Indianapolis and especially Louisville generated a higher market share in TSL than larger markets such as New York, Los Angeles, and Chicago.

3.4. The Spatial Distribution of Medical Diagnostic Establishments

Medical diagnostic services are one of the fastest growing industries in the U.S. economy and this sector increasingly depends on the rapid air freight delivery of its products. Examples of medical diagnostic services that might be shipped by air include: medical professional equipment, the results of analytic or diagnostic and laboratory tests, laboratory apparatuses, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures, and orthodontic appliances. Therefore, it has been hypothesized that metropolitan areas with a more complex cluster of medical diagnostic establishments tend to generate a higher volume of air freight shipments. The medical diagnostic index developed in this dissertation included the total sum of the following three NAICS sub-sectors:

- NAICS 33911: Medical Equipment and Supplies Manufacturing
- NAICS 42345: Medical, Dental, and Hospital Equipment and Supplies Wholesalers
- NAICS 6215: Medical and Diagnostic Laboratories

The empirical results of the regression model indicated that the number of medical diagnostic establishments by metropolitan areas is positively related to air freight, and it is the fourth most powerful coefficient. It appears that places with an intense agglomeration of hospitals, clinics, medical universities and colleges, and different medical diagnostic-related businesses will tend to generate a high volume of air freight shipments. Having said that, the relationship between the medical diagnostic industry and air freight traffic is not straightforward. Three of the most substantive air freight markets - Memphis, Louisville, and Indianapolis - only ranked 41st, 42nd, and 26th, respectively, in terms of total number of medical diagnostic firms in each market (Table 2; Figure 4; Figure 20). Of course, these three markets act as major air cargo connecting hubs and the air freight volume at these switching hub markets is not necessarily a function of the originating traffic and their local productive economies. On the other hand, a positive relationship existed between medical diagnostic establishments and air freight in the international gateways (e.g., New York, Los Angeles, Miami, Chicago,

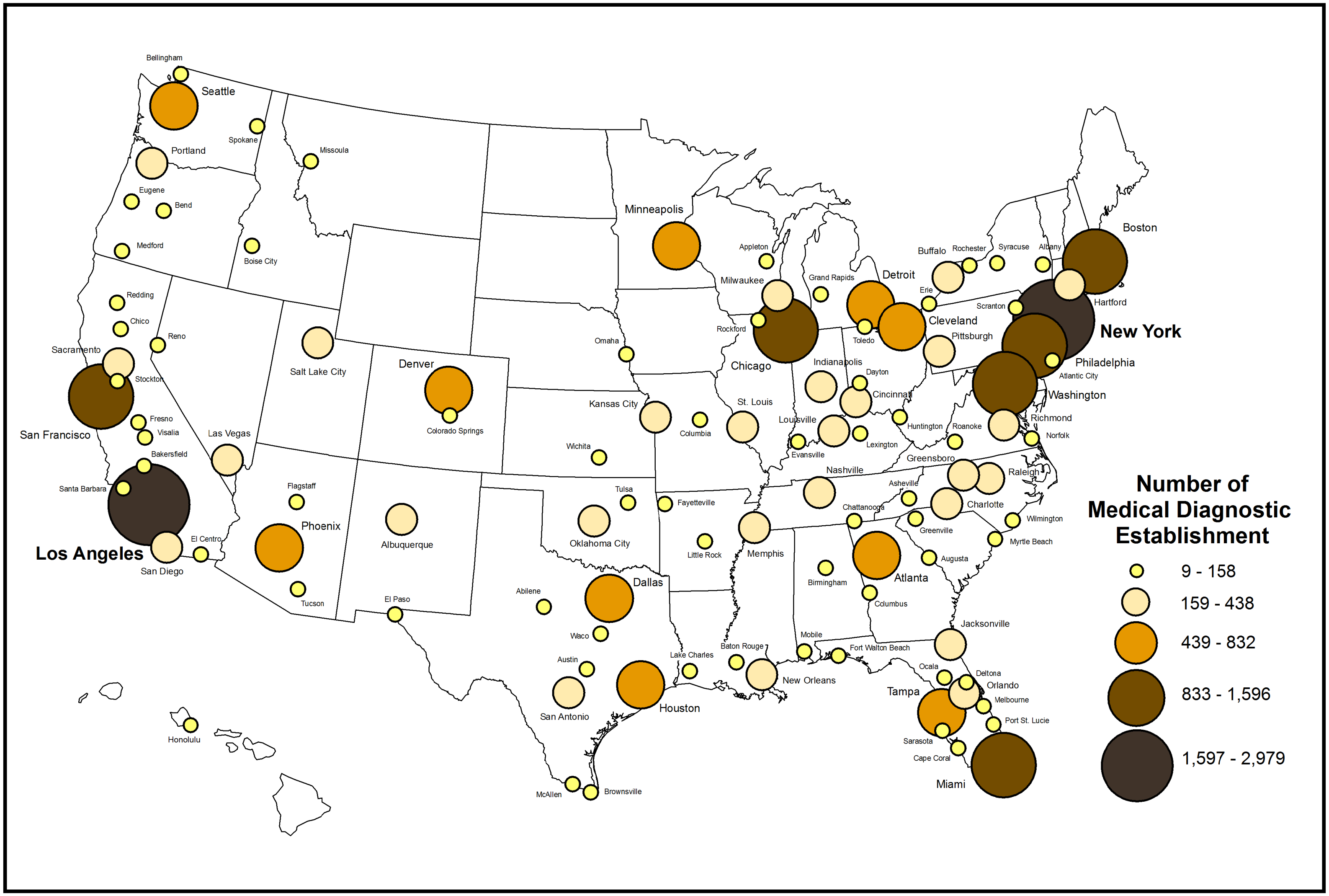

Figure 20: The Spatial Distribution of Medical Diagnostic Establishments (#) by Metropolitan Area, 2003

Boston, and San Francisco), where large amounts of their air freight traffic are originating and are more directly related to their diverse and intense health care clusters (Table 13).

Table 13. The Top Fifteen Metropolitan Markets in terms of Medical Diagnostic Establishment, 2003

Rank	MSA/CSA	Number of Establishment	Employment
1	New York-Newark-Bridgeport, NY-NJ-CT-PA CSA	2,979	50,814
2	Los Angeles-Long Beach-Riverside, CA CSA	2,194	48,224
3	Miami-Fort Lauderdale-Miami Beach, FL MSA	1,596	15,968
4	Chicago-Naperville-Michigan, IL-IN-WI CSA	1,323	23,956
5	Boston-Worcester-Manchester, MA-NH-ME-CT CSA	1,087	21,778
6	San Jose-San Francisco-Oakland, CA, CSA	958	7,737
7	Philadelphia-Camden-Vineland, PA-NJ-DE-MD CSA	937	8,888
8	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV CSA	914	8,104
9	Dallas-Fort Worth, TX CSA	832	14,207
10	Seattle-Tacoma-Olympia, WA CSA	763	6,821
11	Denver-Aurora-Boulder, CO CSA	741	8,560
12	Atlanta-Sandy Springs-Gainesville, GA CSA	716	12,495
13	Houston-Baytown-Huntsville, TX CSA	670	4,681
14	Phoenix-Mesa-Scottsdale, AZ MSA	661	4,055
15	Detroit-Warren-Flint, MI CSA	601	3,787

A good example of this positive relationship is New York. In 2003, the New York metropolitan market ranked third in terms of air freight and shipped more than 2.164 billion enplaned pounds by air (Table 2; Figure 4). The New York metropolitan market is served by three major airports (JFK, Newark, and LaGuardia) and a series of small airports like Stewart, Long Island-MacArthur, Westchester County, and Republic Field Airport (Appendix A). In the same year, New York ranked first in terms of medical diagnostic establishments (2,979) and employed 50,814 workers in this industry (Table 13; Figure 20). The opportunities for developing a strong medical cluster in this most populous market in the United States are substantial. For example, companies focusing on providing medical equipment and supplies manufacturing services accounted for 34% of all New York medical diagnostic firms (1,014) and 41% of total New York medical diagnostic jobs (21,005). Examples of such companies include Pfizer Inc., Colgate-Palmolive Co., Forest Laboratories Inc., Le Croy Corp., and AFP Imaging Corp. (ReferenceUSA, 2008). Medical, dental, and hospital equipment and supplies wholesalers accounted for almost 33% of all New York medical establishments (972) and employed 22% of New York's total medical diagnostic workers (11,336). Establishments concentrated in this medical sub-sector include Colgate-Palmolive Co., A & J Care Inc., Jamaica Hospital Nursing Home, Landauer Metropolitan Inc., Oxygen Media, and Widex Hearing Aid (ReferenceUSA, 2008). Medical and diagnostic laboratories also accounted for 33% of New York's total medical firms (993) and 36% of all New York medical jobs (18,473). Lutheran Medical Center, Good Samaritan Hospital, Phelps Memorial Hospital Center, Hudson Valley Hospital Center, Summit Park Labs, and Genzyme Corp. are some examples of establishments that focus on providing medical and diagnostic laboratories services (ReferenceUSA, 2008).

In summary, the medical diagnostic establishment variable seems to capture some of the geography air freight. A complex and diverse cluster of medical diagnostic-related establishments is clearly evidenced especially in the international air freight gateways (i.e., New York, Los Angeles, Miami, Chicago, Boston, and San Francisco). Therefore, the absolute size of the market as measured by diagnostic establishments plays a key role in shaping the geography of air freight volume. On the other hand, this is not the case for major connecting hubs like Memphis, Louisville, and Indianapolis, where air freight is largely sorted and then reshipped to their final destinations. That said, it appears a strong medical cluster with lots of establishments creates a more productive market and increases the demand for fast and reliable air freight delivery.

3.5. The Spatial Distribution of Average High-Tech Employee Wage

The empirical results of the stepwise regression analysis indicated that average high-tech wages was the fifth most important explanatory variable in predicting air freight volume by metropolitan area. The implication is that metropolitan markets involved in highly skilled, well-paid high-tech labor pools are expected to ship a disproportionate amount of high-value and low-weight computers, software, and related products by air. The average wage in high-tech variable developed for this dissertation included the following two NAICS sectors:

- NAICS 334: Computer and Electronic Product Manufacturing
- NAICS 5415: Computer Systems Design and Related Services

Average wages can be a good indicator of the overall skill levels of a community relative to other metropolitan areas. It is assumed that metropolitan markets with high average employee wages in high-tech industries tend to employ more skilled engineers and designers - the sort of workers, who usually engage in planning and designing computer systems and other professional and technical computer-related services. It is assumed that metropolitan areas with sophisticated high-tech production will have a higher propensity to ship high-value and low-weight products by air than other markets.

The relationship between average high-tech employee wages and air freight shipment is clearly more pronounced in the 'high tech' gateways of Dallas, San Francisco, and New York (Figure 21). In 2003, Dallas ranked first in terms of average high-tech wages ($ 185,956) and ninth in terms of air freight weight with more than 870 million enplaned pounds (Tables 14 & 2). Dallas is sometimes referred to as the Texas' 'Silicon Valley' or the 'Silicon Prairie' because of its high concentration of telecommunications companies, where the 'Telecom Corridor' is the focal point of various technological businesses. The 'Telecom Corridor' located in Richardson, a northern suburb of Dallas, is home to more than 600 high-tech companies (Richardson Economic Development Partnership, 2008). Telecommunications accounted for 30% of the Telecom Corridor's high-tech cluster, while software applications accounted for almost 16% followed by electronic equipment (13%) and semiconductor devices (12.5%) (Table 15).

Examples of companies operating in the Dallas metropolitan market that focus on computer and electronic product manufacturing include Vought Aircraft Industries Inc.,

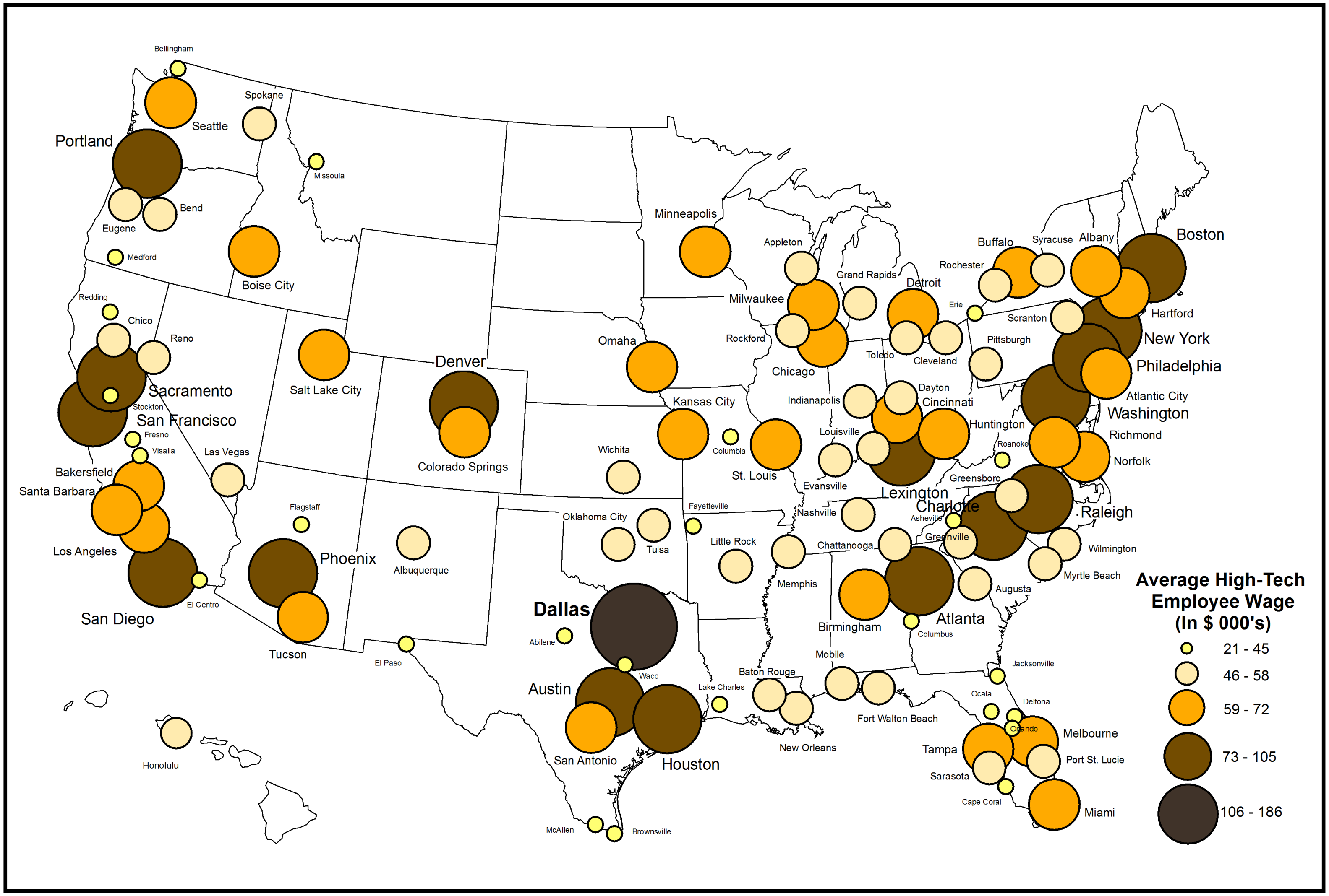

Figure 21: The Spatial Distribution of Average High-Tech Employee Wage, 2003

Table 14. The Top Fifteen Metropolitan Markets in terms of Average High-Tech Wages, 2003

Rank	MSA/CSA	Average High-Tech Wages ($)
1	Dallas-Fort Worth, TX CSA	185,956
2	San Jose-San Francisco-Oakland, CA CSA	104,750
3	Charlotte-Gastonia-Salisbury, NC-SC CSA	87,447
4	Lexington-Fayette-Frankfort-Richmond, KY CSA	84,412
5	Boston-Worcester-Manchester, MA-NH-ME-CT CSA	83,323
6	Austin-Round Rock, TX MSA	81,214
7	Raleigh-Durham-Cary, NC CSA	80,884
8	Sacramento-Arden-Arcade-Truckee, CA-NV CSA	80,685
9	New York-Newark-Bridgeport, NY-NJ-CT-PA CSA	80,148
10	Houston-Baytown-Huntsville, TX CSA	79,830
11	Denver-Aurora-Boulder, CO CSA	79,550
12	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV CSA	78,436
13	Phoenix-Mesa-Scottsdale, AZ MSA	76,959
14	San Diego-Carlsbad-San Marcos, CA MSA	75,050
15	Philadelphia-Camden-Vineland, PA-NJ-DE-MD CSA	74,563

Table 15. Richardson's Telecom Corridor High-Tech Clusters

High-Tech Clusters	# Firms	% Market Share
Telecommunications	168	30.0
Software	89	15.9
Electronic Equipment	72	12.9
Semiconductor	70	12.5
Networks and IT	59	10.5
Other High-Tech	102	18.2

Source: Author's calculations based on information extracted from Richardson Economic Development Partnership, 2008

Raytheon Co., ST Microelectronics Inc., Maxim Integrated Products Inc., Banc Tec Inc., Ericsson Inc., and Nokia America Inc. (ReferenceUSA, 2008). The largest firms providing computer systems design and related services included Electronic Data Systems Corp., CompuCom Systems Inc., Xerox Corp., Affiliated Computer Service Inc., MICROSOFT Corp., and Perot Systems Corp. (ReferenceUSA, 2008). Such highly skilled companies tend to produce high-value and low-weight computer and software-related products, which have a tendency to be shipped by air.

The San Francisco metropolitan area is another high-tech market with above average high-tech wages and substantial air freight shipments. In 2003, San Francisco ranked second in terms of average high-tech wages and sixth in terms of air freight weight (Tables 14 & 2). Silicon Chip Valley is located in the southern part of the San Francisco Bay Area, and it is the leading high-tech region in the world, where thousands of high-tech companies are headquartered and agglomerated including Adobe Systems, Advanced Micro Devices, Agilent Technologies, Apple Inc., Applied Materials, Business Objects, Cisco Systems, eBay, Google, and Hewlett-Packard. It is also home to universities with strong technical research capabilities, such as Berkeley and Stanford. In 2003, the San Francisco metropolitan area had around 545,000 students enrolled in college or graduate school, and around 41% of its residents aged 25 years and over had a bachelor's degree or higher (U.S. Census Bureau, 2003 American Community Survey, 2007). The highly educated and highly skilled San Francisco workforce largely explains its high earning rates, particularly in high-tech industries. In 2003, more than 1.3 billion enplaned pounds were shipped out of the San Francisco market with a substantial share of computer and electronic products. Examples of the largest companies, in terms of employment size, focusing on computer and electronic product manufacturing included Western Digital Corp., Cisco Systems Inc., Intel Corp., Advanced Micro Devices Inc., Agilent Technologies Inc., Sanmina-Sci Corp., and TCI Intl Inc. (ReferenceUSA, 2008). The largest businesses providing computer systems design and related services include Oracle, Cisco Systems Inc., Oracle Corp., Advanced Micro Devices Inc., and Yahoo Inc. (ReferenceUSA, 2008). As noted, Cisco Systems Inc. provides services related to both NAICS 334 and 5415 since it is a large corporation focused on designing and selling networking and communications technology and services under five brands, namely Cisco, Linksys, WebEx, IronPort, and Scientific Atlanta. The agglomeration of such highly skilled and multifunctional firms plays a key role in increasing the demand for air freight delivery especially of high-value and low-weight products. Other smaller markets that generated above average high-tech wages and significant air freight shipments included Lexington, Austin, Raleigh-Durham, and Sacramento.

Having said that, the strong relationship that exists between air freight and average high-tech wages is not straight forward particularly in the three major air freight sorting hubs of Memphis, Louisville, and Indianapolis. Even though Memphis, Louisville, and Indianapolis ranked first, fourth, and eighth respectively in terms of air freight by weight, they ranked sixty-sixth, seventy-second, and forty-eighth respectively in terms of average high-tech employee wages in 2003. The large proportion of enplaned air freight in these three markets is largely related to the integrators' connecting freight traffic, where packaging and reshipping activities is the primary focus not high-tech product generation.

However, the overall geography of average high-tech wages by metropolitan areas shapes the geography of air freight by weight. The more skilled and innovative high-tech markets in places like Dallas, San Francisco, New York, Charlotte, Boston, Austin, and Raleigh tended to generate higher levels of air freight shipments. Overall, it appeared that good high-tech wages acted as growth engines for the 'new economy' resulting in a disproportionate share of U.S. air freight traffic.

3.6. Summary

To summarize, it appeared that the geography of air freight was shaped by at least five key explanatory variables. First, metropolitan markets that successfully attracted additional freight from surrounding nearly, smaller metropolitan markets will tend to be more robust markets and trigger substantial demand to ship by air (the so-called traffic shadow effect). Second, the transportation-shipping-logistic sector acted as a key industry in the larger set of key industries in shaping the geography of air freight. More specifically, it is very important to have a well-established and efficient ground transport system to facilitate freight management and distribution. Developing a productive logistics network 'on the ground' is a key competitive advantage for metropolitan markets to flourish if the transport-shipping-logistics sector is disproportionately large as a percentage of total employment. Third, metropolitan markets with above average per capita economies will tend to originate considerable amounts of air freight shipments by air. Fourth, metropolitan areas with an intense agglomeration of medical centers will tend to create additional demands for fast delivery in order to transport diagnostic results on time to their customers. Fifth, metropolitan markets offering above average high-tech wages will tend to have a higher propensity to ship their high-value and low-weight products by air.

Other explanatory variables targeted in the existing literature as potential predictors of air freight were not included in the final model because they had a high level of multicollinearity and were less powerful predictive than the selected variables. Although some of the existing literature has suggested that pharmaceutical and biotech, in addition to the cultural products industries play a substantial role in shaping air freight demand, the results in this dissertation suggest a more powerful predictor of the proportion of the metropolitan labor pool employed directly on transportation-shipping and logistics related industries. That said, TSL is only a powerful explanatory variable when measured as a percent share of total employment, not as an aggregate indicator of the total number of jobs in TSL. Consequently, it is not the absolute size of the TSL market that is necessarily the key trigger for air freight, it is instead the level of TSL specialization in the metropolitan economy. However, it was the actual number of medical diagnostic establishments that was selected to enter the model and not the number of jobs in medical-related industries. This suggests that an agglomerative effect and a proliferation of medical-related firms and related inter-industry linkages and diagnostic labs generates disproportionate levels of high-value and low-weight goods and therefore substantial air freight demand. Apparently less relevant in this case were the number of hi-tech jobs or the hi-tech percent share of total jobs perhaps because average wages best captures the skill levels needed to manufacture high-value and low-weight computer related products which tend to be shipped by air. Of course, the assumption here is that wage rates are a crude proxy for skill levels and this may not always be the case.

CHAPTER V

CONCLUSION

The geography of air freight is an under-studied research arena despite its increasing importance as a key component of many firms' competitive advantage. For example, many small and large enterprises are now able to ship their products on-time to their customers all around the world using air freight services. Also, the savings resulting from using air freight delivery by reducing the need for inventory, warehousing, and packaging is another competitive advantage to many companies. Less well understood is how the appropriate mix of economic activity 'on the ground' shapes the geography of air freight 'in the air'. This dissertation is one of the first attempts to help better understand the connection that exist between regional economies 'on the ground' and freight movements 'in the air'.

This dissertation also highlights the importance of concepts like complementarity, transferability, and intervening opportunity in facilitating freight flow, distribution systems, and spatial interaction between metropolitan markets. The existence of sufficient demand and supply for time-sensitive, high-value and low-weight products across metropolitan markets make these goods transferable by air. However, the existence of intervening opportunity might reduce the level of spatial interaction between two markets and divert freight traffic 'on the ground' to another nearby, competing destination with a greater range of freight services. For example, some companies producing high-value, low-weight products that need to be shipped by air may be located in smaller metropolitan area but may prefer the more distant larger airport because of its attractive beneficial amenities including: additional flights, more destinations, lower fares, and better services.

The findings of this dissertation validate some of the earlier theoretical research that assumed new economy products such as micro-electronics, computer and aerospace components, medical devices, and other high value-to-weight products accounted for a considerable portion of air freight traffic. The rapid advent of just-in-time manufacturing processes, where particular parts must arrive for assembly at specific times, has also played a key role in increasing the demand for air freight delivery.

The analysis of the geography of air freight traffic suggests a substantial spatial concentration and hierarchy of air freight volume exists in several intermediate cargo hubs like Memphis, Louisville, and Indianapolis and in a select few major international gateways (e.g., Los Angeles, New York, and San Francisco). Part of the logic relates to the key role FedEx and UPS plays in Memphis, Louisville, and Indianapolis where the economy of these markets largely depends on the sorting and redistributing of transited freight from other places. In these connecting hubs, it is not always the case that substantial air freight volume is necessarily linked to thriving and sophisticated local economies ‘on the ground’. By contrast, the major international gateways tended to generate a considerable volume of air freight traffic, in part, because of diverse and sophisticated economies that originated freight demand that effectively complemented those freight shipments coming in from across the world.

This dissertation discovered that the geography of air freight was mostly influenced and shaped by the following key independent variables: the traffic shadow effect, the transportation-shipping-logistics employment market share, per capita personal income, the number of medical diagnostic establishments, and average high-tech employee wages. The most powerful influence appeared to be the traffic shadow effect where small metropolitan markets under the traffic shadow of larger metropolitan markets tended to produce lower levels of freight. Also, metropolitan markets are more likely to ship freight by air if they offer a disproportionately diverse and efficient ground support systems with a wide range of employment with freight forwarders and other transportation services, high per capita incomes, an intense agglomeration of medical related establishments, and offer above average wage rates in computer systems design and manufacturing.

Although the traffic shadow effect is a very important spatial influence on the geography of air freight, it has been largely neglected in the recent academic literature. Therefore, future research needs to examine this concept under different competitive contexts. Future research might also include on assessment of the traffic shadow effect of smaller airports <u>within</u> each individual metropolitan area instead of just <u>between</u> metropolitan areas. In this dissertation, the <u>inter-metropolitan</u> traffic shadow effect was calculated but the <u>intra-metropolitan</u> effects were not analyzed. Several recent studies have also indicated that a number of congested large international airports (e.g., JFK and LAX) are experiencing such a high level of freight and passenger traffic that 'surplus loads' are being redirected back into nearby adjacent airport (a sort of reverse 'traffic shadow effect). A better understanding of these complex competitive arenas may require surveying and interviewing different transportation and logistic companies regarding their ‘connections’ to different airports. Future research might also define proximity based on the actual driving time instead of the physical distance as used in this dissertation. Also, congestion, speed limits, working hours, types of trucks, types of streets, and the number of highway lanes are other complex elements that need to be further considered in any future research if we are to better understand and precisely measure the traffic shadow effect.

Analyzing the overall spatial distribution of per capita personal income by metropolitan area provides some insight into how affluent markets with high levels of skills and productivity shape the geography of air freight markets. Future research might examine in more detail the relationship that exists between spending and consuming patterns and income levels, and how that relationship in turn affects air freight demand. Future research might also study different aspects of personal income (e.g., earnings, dividend, interest, rent) to provide a better assessment of the overall wealth of the metropolitan economy and thereby the air freight market.

The disproportionate presence of major logistic and distribution industries are essential in facilitating the flow of goods within each metropolitan market in order to ensure that the right products are at the right place at the right time in the right quantity. Future research clearly needs to focus on the intra-metropolitan geography of transportation/shipping/logistics related companies of selected metropolitan areas to better understand the relationships and linkages that exist within and between various transportation/shipping/logistics clusters. Such research will also help to precisely capture the well-served/underserved metropolitan markets. More detailed analysis of the transportation/logistics sub-sectors might also help us to better understand the corporate strategies and locational preferences of transportation/shipping/logistics firms, and the level of concentration or dispersion of each sub-sector across each metropolitan market.

The findings in this dissertation also suggest that metropolitan markets with a large agglomeration of medical universities and health centers tend to trigger more air freight shipments. Future research might investigate in more detail the role of spatial agglomeration, accessibility, and establishment level linkages that exist in the key medical diagnostic industry cluster to better understand how it shapes air freight shipments.

Transport geographers might also examine the role of the high-tech sector in generating air freight shipments based on the education and skill levels that exists in each market. Is it the high-tech blue-collar market or is it the high-tech professional-technical-managerial market that triggers more demand for air freight delivery? With the global economy and outsourcing trends, future studies might look at different stages of the production process and determine the stage most dependent on air freight services. Future research might also investigate the impact of global semiconductor competition between the U.S. and Japan and how it affects their dependence on air freight delivery. Other research might also investigate the factors affecting the ability of a high-tech company to start up or expand in a region and how that affects air freight demand. Such factors might include the availability of cheap and functional space, labor costs, energy costs, transportation infrastructure, and the existence of an innovative network that consists of entrepreneur and relative capital that might facilitate the production of high-tech strategies.

Overall, the results of this dissertation indicate that geography matters, since the empirical assessment of the geography of air freight has helped us better understand how connections between economic activities ‘on the ground’ shape air freight shipments ‘in the air’. The analysis of air freight reminds us all of the crucial role that nodal connectivity levels and spatial hierarchies play in understanding geographically explicit phenomenon. The spatial concentration of air freight shipments to just a few key nodes or metropolitan areas is evidence of this effect (e.g., Memphis and Louisville). Based on the findings of the stepwise regression model, the most influential variable appeared to be the traffic shadow effect, which speaks directly to the influence of spatial hierarchy on the geography of air freight shipments.

The finding of this dissertation also suggests that the ‘aerotropolis’ vision where air freight ‘in the sky’ can shape economic development ‘on the ground’ really matters. Thus, regional economies may be able to shape air freight demand by restructuring land uses ‘on the ground’ to facilitate air freight related developments. Of course, there is a ‘chicken and an egg’ issue here since it is not fully understood what are the primary causes and effects and that needs to be more closely scrutinized.

Even with the recent 2009 economic slowdown and the 2008 spike in fuel costs, it is clear that speed of delivery and sophisticated supply chains will be a key part of competitive advantage. Better understanding the underlying geography of air freight can provide some insight into competitive advantage, spatial hierarchy, and the crucial role of connectivity – it is likely a subject matter that will become more, not less, important in the years to come.

REFERENCES

AirGuide Business. (2008). Air Cargo News.

Airports Council International. (2007a). Passenger Traffic 2006 FINAL. Retrieved November 6, 2007 from http://www.airports.org/cda/aci_common/display/main /aci_content07_c.jsp?zn=aci&cp=1-5-54-55_666_2__

Airports Council International. (2007b). Cargo Traffic 2006 FINAL. Retrieved November 6, 2007 from http://www.airports.org/cda/aci_common/display/main/ aci_content07_c.jsp?zn=aci&cp=1-5-54-4819_666_2__

Al Chalabi, M., & Kasarda, J. D. (2004). Airports: Short- and Long-Term Trends. In *Just in Time Real Estate: How Trends in Logistics are Driving Industrial Development* (81-104). Washington, D.C.: ULI - Urban Land Institute.

Alkaabi, K. (2004). *The Geography of Air Transport and Skilled Labor Markets by Metropolitan Area, 1997*. Unpublished Master Thesis, University of North Carolina at Greensboro, Greensboro.

Alkaabi, K., & Debbage, K. (2007). The Geography of Air Transport and Skilled Labor Markets by Metropolitan Area. *Journal of Air Transport Management*, 13, 121-30.

Anonymous. (2006). Drives retrofit key in life safety system at Atlanta airport. *Engineered Systems*. 23 (1).

Baron, P. (1976). Improving Door-to-Door Freight Transport-Some Notes on a Decentralized Air-Cargo Handling System. *Pergamon Press*, 10, 389-390.

BEA. (2005a). Local Area Personal Income. Retrieved March 6, 2006 from http://www.bea.gov/bea/regional/reis/

BEA. (2005b). Population. Retrieved March 6, 2006 from http://www.bea.gov/bea/ regional/definitions/nextpage.cfm?key=Population

BEA. (2005c). Personal Income. Retrieved March 6, 2006 from http://www.bea.gov /bea/regional/definitions/nextpage.cfm?key=Personal%20income

BEA. (2005d). Per Capita Personal Income. Retrieved March 6, 2006 from http://www.bea.gov/bea/regional/definitions/nextpage.cfm?key=Per%20capita%20personal%20income

Bell, M. E., & Feitelson, E. (1991). U.S. Economic Restructuring and Demand for Transportation Services. *Transportation Quarterly*, 45 (4), 517-538.

BLS. (2005a). State and County Employment and Wages from the Quarterly Census of Employment and Wages (2001 forward). Retrieved March 6, 2006 from http://data.bls.gov/PDQ/outside.jsp?survey=en

BLS. (2005b). Quarterly Census of Employment and Wages. Retrieved March 6, 2006 from http://www.bls.gov/cew/home.htm

BLS. (2006). Employment and Wages, Annual Averages 2001. Retrieved March 7, 2006 http://www.bls.gov/cew/cewbultn.htm#2a

Bobko, P. (2001). Correlation and Regression: Application for Industrial Organization Psychology and Management. Second Edition. London: Sage Publications.

Boeing, (2005). World air cargo forecast 2004-2005. Retrieved October 24, 2007 from http://www.boeing.com/commercial/cargo/WACF_2004-2005.pdf

Boeing, (2007). World air cargo forecast 2006-2007. Retrieved October 24, 2007 from http://www.boeing.com/commercial/cargo/01_01.html

Bowen, J. T. (2004). The Geography of Freighter Aircraft Operations in the Pacific Basin. *Journal of Transport Geography*, 12, 1–11.

Bowen, J., & Leinbach, T. (2004). Market Concentration in the Air Freight Forwarding Industry. *Tijdschrift voor Economische en Sociale Geografie/Journal of Economic and Social Geography,* 95(2), 174-188.

Brookings Institution. (2002). *Signs of Life: The Growth of Biotechnology Centers in the U.S.*

Brueckner, K. (2003). Airline Traffic and Urban Economic Development. *Urban Studies,* 1455-1469.

Bureau of Transportation Statistics, U.S. Department of Transportation (2004). America’s Freight Transportation Gateways. Retrieved November 8, 2007 from http://www.bts.gov/publications/americas_freight_transportation_gateways/pdf/entire.pdf

Bureau of Transportation Statistics, U.S. Department of Transportation (2006). Table 2.3: Top 20 U.S. Gateways for Nonstop International Air Travel: 2000–2004. retrieved November 8, 2007 from http://www.bts.gov/publications/us_international_travel_and_transportation_trends/2006/html/chapter_02/table_02_03.html

Button, K., Lall, S., Stough, R., & Trice, M. (1999). High-Technology Employment and Hub Airports. *Journal of Air Transport Management*, 5, 53-59.

Button, K., & Taylor, S. (2000). International Air Transportation and Economic Development. *Journal of Air Transport Management*, 6, 209-222.

Cambridge Systematics, Inc., COMSIS Corporation, & University of Wisconsin – Milwaukee. (1996). Quick Response Freight Manual: Final Report. *U.S. Department of Transportation*. Retrieved February 11, 2006 from http://tmip.fhwa.dot.gov/clearinghouse/docs/quick/Quick.pdf

Carron, A. S. (1981). *Transition to a Free Market: Deregulation of the Air Cargo Industry*. Washington, D.C.: The Brookings Institution.

Census Bureau (2003). 2002 NAICS Definitions: 339 Miscellaneous Manufacturing. Retrieved April 4, 2006 from http://www.census.gov/epcd/naics02/def/NDEF339.HTM#N33991

Chan, Y., Ponder, R.J. (1979). The Small Package Air Freight Industry in the United States: A Review of the Federal Express Experience. *Pergamon Press Ltd*, 13A, 221-229.

Chatterjee, S., & Hadi, A. S., (2006). Regression Analysis by Example. Fourth Edition. New Jersey: Wiley-Interscience.

City of Atlanta. (2007). Atlanta International Airport: Fact Sheet. Retrieved October 15, 2007 from http://www.atlanta-airport.com/default.asp?url=http://www.atlanta-airport.com/sublevels/airport_info/factpage.htm

City of Chicago, (2007). Learn About OMP. Retrieved October 9, 2007 from http://egov.cityofchicago.org/city/webportal/portalContentItemAction.do?topChannelName=SubAgen&contentOID=536902909&Failed_Reason=Session+not+found&contenTypeName=COC_EDITORIAL&com.broadvision.session.new=Yes&Failed_Page=%2fwebportal%2fportalContentItemAction.do

City of Hartford, (n.d.). City of Hartford History. Retrieved April 28, 2008 from http://www.hartford.gov/history/

Cohen, J. P., & Paul, C. J. M. (2003). Airport Infrastructure Spillovers in a Network

System. *Journal of Urban Economics*, 54 (3), 459-473.

Colclough, G., & Tolbert, C. (1992). *Work in the fast lane: flexibility, divisions of labor, and inequality in high-tech industries*. Albany: State University of New York Press.

Connecticut Department of Transportation. (2006). Inventory of System Airports. In *Connecticut Statewide Airport System Plan* (chap. 2). Retrieved June 24, 2008 from http://www.ct.gov/dotinfo/lib/dotinfo/Chapter_2_Inventory.pdf

Debbage, K. G. (1999). Air Transportation and Urban-Economic Restructuring: Competitive Advantage in the US Carolinas. *Journal of Air Transport Management*, 5 (4), 211-221.

Debbage, K., & Delk, D. (2001). The Geography of Air Passenger Volume and Local Employment Patterns by US Metropolitan Core Area: 1973-1996. *Journal of Air Transport Management*, 7, 159-167.

DHL Holdings (USA), Inc. (2004). *History*. Retrieved February 27, 2005 from http://www.dhl-usa.com/Company/History.asp?nav=AboutDHLUSA /CompanyInfo/History

Dicken, P. (2007). *Global Shift: Mapping the Changing Contours of the World Economy*. Fifth Edition. (pp. 411-413). New York: The Guilford Press.

Doganis. R. (1991). *Flying off Course: The Economics of International Airlines*, Second Edition, New York: Routledge.

Fam, R., Chin, J., & Koh, T. (1992). Air Transportation. Retrieved February 27, 2005 from http://www.malaysiaexports.com/inex13.5.airwaybill.htm

FedEx. (2005). *FedEx Express Facts*. Retrieved May 27, 2005 from http://fedex.com/us/about/today/companies/express/facts.html?link=4

FedEx, (2007). FedEx Corporation. Retrieved September 30, 2007 from http://www. fedex.com/us/about/today/companies/corporation/facts.html

Feighan, A. R. (2001). Traffic Distribution in Low-Cost and Full-Service Carrier Networks in the US Air Transportation Market. *Journal of Air Transport Management*, 7(5), 265-275.

Ferrara, P. J. (1990). Ending the Postal Monopoly. In P. J. Ferrara (Ed.), *Free the Mail: Ending the Postal Monopoly*. (pp. 1-10). Washington: Cato Institute.

Gardiner, J., Ison, S., & Humphreys, I. (2005). Factors Influencing Cargo Airlines' Choice of Airport: An International Survey. *Journal of Air Transport Management*, 11 (6), 393-399.

Gelman, A., & Hill, J. (2007). Data Analysis Using Regression and Multilevel/Hierarchical Models. New York: Cambridge University Press.

Goetz, A.R. (1992). Air Passenger Transportation and Growth in the U.S. Urban System, 1950-1987. *Growth and Change*, 23, 218-242.

Goetz, A. R., & Sutton, C. J. (1997). The Geography of Deregulation in the U.S. Airline Industry. *Association of American Geographers*, 87 (2), 238-263.

Gray, M., Golob, E., & Markusen, A. (1996). Big Firms, Long Arms, Wide Shoulders: The 'Hub-and-Spoke' Industrial District in the Seattle Region. *Regional Studies*. 30 (7), P. 651-666.

Haggerty, A. C. (2004). Commercial Market for Cargo Operations Aviation Systems Architecture. *Massachusetts Institute of Technology,* Retrieved June 14, 2005 from http://ocw.mit.edu/NR/rdonlyres/Aeronautics-and-Astronautics/16-886 Spring2004/A090313D-52EA-4D4B-B3E0-F139D161C6BE/0/08_cargopra tion1.pdf

Helms, M. M. (1989). A Structure Conduct Performance Analysis of the Expedited Small Package Industry. *Transportation Quarterly*, 43 (1), 101-122

Hesse, M., & Rodrigue, J. P. (2004). The Transport Geography of Logistics and Freight Distribution. *Journal of Transport Geography*, 12 (3), 171-184.

Hesse, M. (2002). Shipping News: the Implications of Electronic Commerce for Logistics and Freight Transport. *Resources, Conservation and Recycling*, 36 (3), 211-/240.

Indy Partnership (2008). Logistics and Distribution: Indianapolis Region Competitive by Nature. Retrieved June 10, 2008 from http://www.iedc.com/pdfs/2008/2008-logistics.pdf

Ivy, R. L., Fik, T. J., & Malecki, E. J. (1995). Changes in Air Service Connectivity and Employment. *Environment and Planning*, 27, 165-179.

Jacksonville Port Authority (2008). Marine Statistics. Retrieved June 16, 2008 from http://jaxport.com/sea/g_stats.cfm

Janelle, G. D., & Beuthe, M. (1997). Globalization and Research Issues in

Transportation. *Journal of Transport Geography*, 5 (3), 199-206.

Johnson, J. P., & Gaier, E.R. (1998). Air Cargo Operations Cost Database. *National Aeronautics and Space Administration*.

Kay, D. (2004). Air Cargo: Engine for Economic Development. *TIACA Times*. Retrieved March 9, 2005, from http://www.tiaca.org/content/TIACA_TIMES_0604.pdf

Kasarda, J. D., (2000). Logistics & the Rise of Aerotropolis. *Real Estate Issues*, 25 (4).

Kasarda, J. D., (2008). Airport Cities: The Evolution. Aerotropolis. Retrieved January 25, 2009 from http://www.aerotropolis.com/articles.html

Kasarda, J. D., & Green, J. D. (2005). Air Cargo as an Economic Development Engine: A Note on Opportunities and Constraints. *Journal of Air Transport Management*, 11 (6), 459-462.

Kasarda, J. D., Green, J., & Sullivan, D. (2004). Air Cargo: Engine of Economic Development. Retrieved March 26, 2005 from http://www.kenan-flagler.unc.edu/assets/documents/kasarda01large.pdf

Kutner, M. H., Nachtsheim, C. J., & Neter, J. (2003) Applied Linear Regression Models. Fourth Edition. Irwin: McGraw-Hill.

Lawlor, J. (2003). Piedmont Carolina Sees Jobs, Noise in FedEx Hub. *Planning*, 36-37.

Leinbach, T. R. (2004). City Interactions: The Dynamics of Passenger and Freight Flows. In S. Hanson & G. Giuliano (Eds.), *The Geography of Urban Transportation*. Third Edition. (pp. 30-58). New York: The Guilford Press.

Ligon, G. C. (1992). Development of the U.S. Air Express Industry: 1970-1990. *Transportation Quarterly*, 46 (2), 279-294.

Los Angeles World Airports. (2007). Airport Construction Projects. Retrieved November 3, 2007 from http://www.lawa.org/lax/laxexpect.cfm

Louisville Regional Airport Authority, (2007). Louisville Ranked 3rd Busiest Cargo. Retrieved September 10, 2007 from http://www.flylouisville.com/

Markusen, A., Hall, P., & Glasmeier, A. (1986). *High tech America: The what, how, where, and why of the sunrise industries*. Boston: Allen & Unwin.

Mason, K. J., (2005). Observations of Fundamental Changes in the Demand for Aviation Services. *Journal of Air Transport Management*, 11 (1), 19-25.

Migration Policy Institute (2008). Los Angeles on the Leading Edge: Immigrant Integration Indicators and their Policy Implications. Retrieved June 23, 2008 from http://www.migrationpolicy.org/pubs/NCIIP_Los_Angeles_on_the_Leading_Edge.pdf

Milken Institute. (2004). America's Biotech and Life Science Clusters: San Diego's Position and Economic Contributions. Retrieved April 29, 2008 from http://www.milkeninstitute.org/publications/publications.taf?function=detail&ID=312&cat=ResRep

Moline, A. (2004). Understanding Logistics and the Supply Chain Process. In *Just in Time Real Estate: How Trends in Logistics are Driving Industrial Development* (pp. 7-28). Washington, D.C.: ULI - Urban Land Institute.

Montgomery, D. C., & Peck, E. A. (1982). Introduction to Linear Regression Analysis. New York: John Wiley & Sons.

Murphy, P., Dalenberg, D., & Daley, J. (1989). Improving International Trade Efficiency: Airport and Air Cargo Concerns. *Transportation Journal*, 29 (2).

Newman, J. L. (2001). Local Area Personal Income, 1997-99 -Rating. Survey of Current Business, retrieved April 19, 2008 from http://findarticles.com/p/articles/mi_m3SUR/is_5_81/ai_75905963

Nooteboom, B., 1999. Innovation, Learning, and Industrial Organization. *Cambridge Journal of Economics*, 23, 127-150.

North Carolina Board of Science and Technology (2000). *High-Tech Clusters in North Carolina*. Retrieved April 11, 2006 from http://www.ncscienceandtechnology.com/PDF/Vision2030/cluster_final.pdf

Norušis, M. J. (2002). SPSS 11.0 Guide to Data Analysis. New Jersey: Prentice Hall.

O’Connor, K. (2003). Global Air Travel: Toward Concentration or Dispersal. *Journal of Transport Geography*, 11 (2), 83-92.

O’Connor, W. E. (2001). *An Introduction to Airline Economics*. Sixth Edition. Westport: Praeger.

Ohashi, H., Kim, T. S., Oum, T. H., & and Yu, C. (2005). Choice of Air Cargo

Transshipment Airport: An Application to Air Cargo Traffic to/from Northeast Asia. *Journal of Air Transport Management*, 11 (3), 149-159

Ohlemacher, S. (2006). AP Analysis: College Graduates Chase Jobs, Culture to Big Cities. *News & Record*, Retrieved April 12, 2006 from http://www.news-record.com/apps/pbcs.dll/article?AID=/20060410/NEWSREC0101/60410007/1001/NEWSREC0201

O'Kelly, M. E. (1998). A Geographer's Analysis of Hub-and-Spoke Networks. *Journal of Transport Geography*, 6 (3), 171-186.

Olds, K. B., (1995). The Challenge to the U.S. Postal Monopoly, 1839-1851. *The Cato Journal*, 15 (1), Retrieved January 25, 2009, from http://www.cato.org/pubs /journal/cj15n1-1.html

Oster, J. C. V., Rubin, B. M., & Strong, J. S. (1997). Economic Impacts of Transportation Investments: The Case of Federal Express. *Transportation Journal*, 37 (2).

Ott, J. (1987). Federal Express Plans New Hub, Buys McDonnell Douglas Freighters. *Aviation Week and Space Technology*, 45.

Ott, R. L., & Longnecker, M. (2001). An Introduction to statistical Methods and Data Analysis. Fifth Edition. Australia: Duxbury.

Oxford Economic Forecasting. (2006). The Importance of the Express Delivery Industry for the East Midlands Economy. *East Midlands Development Agency*. Retrieved October 19, 2007 from http://www.emda.org.uk/uploaddocuments/eastmidlandsexpressreport130106.pdf

Pellet, J. (2005). The Future of Mail: CEOs Discuss How to Head off Postage Hikes. (ROUNDTABLE). *Chief Executive (U.S.),* 207.

Pinkowski, C. G., (2007). The National Lodging Market and How Memphis Fits "Inn". *Business Perspectives*, 19 (1).

Pitt, I. L., & Norsworthy, J.R. (1999). *Economics of the U.S. Commercial Airline Industry: Productivity, Technology and Deregulation*. Boston: Kluwer Academic Publishers.

Polk Commercial Vehicle Solutions, & Innovative Computer Corporation, (2007). Transport Topics Top 100 For-Hire Carriers. Retrieved September 30, 2007 from http://progressive.playstream.com/truckline/progressive/TT100For-Hire8-27.pdf

Ray, B. (1998). New Options for Time-Sensitive Deliveries. *Logistics Management & Distribution Report*, 37 (12), 18.

Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (1998). Applied Regression Analysis: A Research Tool. Second Edition. New York: Springer.

ReferenceUSA. (2008). Business Databases: U.S. Businesses. Retrieved July 2, 2008 from http://www.referenceusa.com/

Regional Economic Information System, & Bureau of Economic Analysis (2008). Table CA05: Personal income by major source and earnings by NAICS industry. Retrieved July 25, 2008 from http://www.bea.gov/regional/reis/

Richardson Economic Development Partnership. (2008). High-Tech Clusters. Retrieved August 2, 2008 from http://www.telecomcorridor.com/Home/LocalBusiness /High-Tech-Clusters.aspx

Rodrigue, J. P. (2004). Freight, Gateways and Mega-Urban Regions: The Logistical Integration of the BostWash Corridor. *Tijdschrift voor Economische en Sociale Geografie/Journal of Economic and Social Geography*, 95 (2), 147–161.

Rodrigue, J. P. (2006). The Geography of Transport Systems. *Hofstra University*. Retrieved March 3, 2006, from http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c4en.html

Rodrigue, J. P, Comtois, C., & Slack, B. (2008). UPS: Logistical Management of Distribution Networks. The Geography of Transport Systems. Retrieved May 27, 2008 from http://people.hofstra.edu/geotrans/eng/ch5en/appl5en/ch5a2en.html

Rogerson, P. A. (2006). Statistical Methods for Geography: A Student’s Guide. London: SAGE Publications.

Smith, A. (2008). DHL to Cut 9,500 U.S. Jobs. *CNNMoney.com*. Retrieved January 21, 2009 from http://money.cnn.com/2008/11/10/news/companies/dhl/index.htm

Sorkin, A. L. (1980). *The Economics of the Postal System: Alternatives and Reform*. Lexington/ Massachusetts: D.C. Health and Company

Sparks Bureau of Business and Economic Research. (2005). The Economic Impact of Memphis International Airport. Retrieved September 2, 2007 from http://www.mscaa.com/EcImpactFinal.pdf

SPG Media Limited, (2007). Hartsfield-Jackson Atlanta International Airport

(ATL/KATL), GA, USA. retrieved October 22, 2007 from http://www.airport-technology.com/projects/hartsfield_jackson/

Taaffe, E. J. (1959). Trends in Airline Passenger Traffic: A Geographic Case Study. *Annals of the Association of American Geographers* 49 (4), 393-408.

Taaffe, E. (1956). Air Transportation and United States Urban Distribution. Geographical Review, 46 (2), 219-38.

Taaffee, E. J., Gauthier, H. L., and O'Kelly, M. E. (1996). Geography of Transportation. Second Edition, (pp. 72). New Jersey: Prentice Hall, Upper Saddle River.

Taylor, M., Hallsworth, A. (2000). Power Relations and Market Transformation in the Transport Sector: the Example of the Courier Services Industry. *Journal of Transport Geography*, 8 (4), 237-247

Tierney, J. T. (1988). *The U.S. Postal Service: Status and Prospects of a Public Enterprise*. Massachusetts: Auburn House Publishing Company.

2002 Economic Census. (2005a). 42345 Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/naics/sector42/42345.htm

2002 Economic Census. (2005b). 6215 Medical and Diagnostic Laboratories. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/naics/sector 62/6215.htm

2002 Economic Census. (2005c). 33911 Medical Equipment and Supplies Manufacturing. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/naics/ sector31/33911.htm

2002 Economic Census. (2005d). 5415 Computer Systems Design and Related Services. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/ naics/sector54/5415.htm

2002 Economic Census. (2005e). 334 Computer and Electronic Product Manufacturing. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/naics /sector31/334.htm

2002 Economic Census. (2005f). 4921 Couriers. Retrieved March 6, 2006 from http://www.census.gov/econ/census02/naics/sector48/4921.htm

2002 Economic Census. (2005g). 49311 General Warehousing and Storage. Retrieved

March 6, 2006 from http://www.census.gov/econ/census02/naics/sector48/493 11.htm

2002 Economic Census. (2005h). 49319 Other Warehousing and Storage. Retrieved March 7, 2006 from http://www.census.gov/econ/census02/naics/sector 48/49319.htm

2002 Economic Census. (2005i). 4885 Freight Transportation Arrangement. Retrieved March 7, 2006 from http://www.census.gov/econ/census02/naics/sector 48/4885.htm

2002 Economic Census. (2005j). 488991 Packing and Crating. Retrieved March 7, 2006 from http://www.census.gov/econ/census02/naics/sector48/488991.htm

2002 Economic Census. (2005k). 32541 Pharmaceutical and Medicine Manufacturing. Retrieved March 7, 2006 from http://www.census.gov/econ/census02/naics /sector31/32541.htm

2002 Economic Census. (2005l). 5417 Scientific Research and Development Services. Retrieved March 7, 2006 from http://www.census.gov/econ/census02/naics/sector 54 /5417.htm

2002 Economic Census. (2005m). 42394 Jewelry, Watch, Precious Stone, and Precious Metal Merchant. Retrieved March 7, 2006 from Wholesalers http://www.census .gov/econ/census02/naics/sector42/42394.htm

2002 Economic Census. (2005n). 44612 Cosmetics, Beauty Supplies, and Perfume Stores. Retrieved March 7, 2006 from http://www.census.gov/econ/census02 /naics/sector44/44612.htm

UK Department for Transport. (2000). UK Air Freight Study Report, Retrieved February 27, 2005 from http://www.dft.gov.uk/stellent/groups/dft_aviation/documents/ page/dft_aviation_503316.hcsp

University of Nevada. (2006). Technical Report: Identifying the Economic Drivers and Import Substitution Opportunities for the Western Nevada Study Area with Applications to the City of Sparks: Executive Summary. Retrieved April 20, 2008 from http://www.ag.unr.edu/uced/reports/technicalreports/fy2005_2006/2005_06 _06.pdf

UPS. (2005). *Company History*. Retrieved May 27, 2005 from http://www.ups.com/content/us/en/about/history/index.html

UPS, (2007). UPS Fact Sheet. Retrieved September 30, 2007 from http://www.pressroom

.ups.com/mediakits/factsheet/0,2305,866,00.html?mkname=companyinfo

U.S. BTS. (2005a). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers) Table: Sum: On-Flight Market Freight Enplaned (pounds) by Origin, 2003.

U.S. BTS. (2005b). Air Carriers: T-100 Market- Air Freight Definitions. Retrieved March 3, 2006, from http://www.transtats.bts.gov/TableInfo.asp?Table_ID=292&DB_Short_Name=Air%20Carriers&Info_Only=0

U.S. BTS. (2005c). Final Rule Changes to T-100 and T-100(f) Traffic Reporting Systems. Retrieved March 9, 2005, from http://www.bts.gov/programs/airline_information/accounting_and_reporting_directives/number_261.html

U.S. BTS. (2005d). *U.S.-North American Trade and Freight Transportation Highlights*. Retrieved April 11, 2006 from http://www.bts.gov/publications/us_north_american_trade_and_freight_transportation_highlights/

U.S. BTS. (2005e). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers): On-Flight Market Freight Enplaned (pounds) by Class, 2003.

U.S. BTS. (2005f). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Domestic Market (All Carriers) Table: Sum: On-Flight Market Freight Enplaned (pounds) by UniqueCarrier, 2003.

U.S. BTS. (2005g). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 International Market (All Carriers): Sum: On-Flight Market Freight Enplaned (pounds) by UniqueCarrier, 2003.

U.S. BTS. (2005h). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers) Table: Tennessee, 2003.

U.S. BTS. (2005i). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers) Table: Kentucky, 2003.

U.S. BTS. (2005j). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers), Table: California, 2003.

U.S. BTS. (2005k). Air Carrier Statistics (Form 41 Traffic)-All Carriers: T-100 Market (All Carriers), Table: New York & New Jersey, 2003.

U.S. BTS. (2004). Air and Air/Truck. Retrieved March 5, 2005, from http://www.bts.gov/programs/freight_transportation/html/air.html

U.S. BTS. (2007). Air Carrier Statistics (Form 41 Traffic)-U.S. Carriers: T-100 Market (US Carriers Only) Table: Sum: On-Flight Market Freight Enplaned (pounds) Table, 1990-2006.

U.S. Census Bureau. (2005a). 2005 American Community Survey. Retrieved March 7, 2006 from http://factfinder.census.gov/

U.S. Census Bureau (2009a). About SAIPE. Retrieved January 4, 2009 from http://www.census.gov//did/www/saipe/about/index.html

U.S. Census Bureau (2009b). State and County Interactive Tables. Retrieve January 4, 2009 from http://www.census.gov/did/www/saipe/county.html

U.S. Census Bureau. (2006). Poverty Thresholds 2003. Retrieved January 27, 2009 from http://www.census.gov/hhes/www/poverty/threshld/thresh03.html

U.S. Census Bureau, 2003 American Community Survey. (2007). San Francisco-Oakland-San Jose, CA CMSA. Retrieved August 3, 2008 from http://www.census.gov/acs/www/Products/Profiles/Single/2003/ACS/Tabular/380/38000US73622.htm

U.S. Department of Transportation, Research and Innovative Technology Administration, & Bureau of Transportation Statistics. (2006). *Freight in America: A New National Picture*, Washington, DC., 22.

U.S. Government Printing Office. (2009). Section 03 Definitions for Purposes of This System of Accounts and Reports – Freight. *Electronic Code of Federal Regulations*. Retrieved February 1, 2009 from http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4a64caea3549c576931f47ed38f2b468&rgn=div5&view=text&node=14:4.0.1.1.23&idno=14#PartTop

USPS. (2004). *Financial Highlights*. Retrieved May 31, 2005 from http://www.usps.com/history/anrpt04/

Vowles, T. M. (2006). Geographic Perspectives of Air Transportation. *The Professional Geographer*, 58 (1), 12-19.

Wikipedia, (2007). LA/Ontario International Airport. Retrieved November 6, 2007 from http://en.wikipedia.org/wiki/Ontario_airport

Woudsma, C. (2001). Understanding the Movement of Goods, Not People: Issues, Evidence and Potential. *Urban Studies*, 38 (13), 2439–2455.

Yamaguchi, K. (2008) International trade and air cargo: Analysis of US export and air transport policy. *Transportation Research Part E: Logistics and Transportation Review*, 44 (4), 653-663.

Zhang, A. (2003). Analysis of an International Air-Cargo Hub: the Case of Hong Kong. *Journal of Air Transport Management*, 9 (2), p. 123-138.

Zhang, A., Hui, Y. V., & Leung, L. (2004). Air Cargo Alliances and Competition in Passenger Markets. *Transportation Research Part E: Logistics and Transportation Review*, 40 (2), 83-100.

Zhang, A, & Zhang, Y. (2002). A Model of Air Cargo Liberalization: Passenger vs. All-Cargo Carriers. *Transportation Research Part E: Logistics and Transportation Review*, 38 (3-4), 175-191.

APPENDIX A. LIST OF MULTIPLE AIRPORTS BY MSA/CSA, 2003

#	MSA/CSA	Total Air Freight (Pounds) 2003	Multiple Airports	Total Air Freight (Pounds) 2003
1	Los Angeles-Long Beach-Riverside, CA, CSA	1,624,014,126	Los Angeles, CA: Los Angeles International	965,271,964
			Ontario/San Bernardino, CA: Ontario International	525,627,715
			Long Beach, CA: Long Beach Daugherty Field	59,321,283
			Burbank, CA: Burbank Bob Hope	48,224,575
			Santa Ana, CA: John Wayne International	25,568,589
2	San Jose-San Francisco-Oakland, CA, CSA	1,024,851,778	Oakland, CA: Metropolitan Oakland International	672,990,021
			San Francisco, CA: International	243,658,400
			San Jose, CA: San Jose International	107,204,197
			Santa Rosa, CA: Sonoma County	999,160
3	San Diego-Carlsbad-San Marcos, CA, MSA	135,995,272	San Diego, CA: San Diego International Lindbergh Field	135,385,196
			San Diego, CA: Miramar Nas	367,586
			San Diego, CA: North Island Nas	242,490
4	Santa Barbara-Santa Maria-Goleta, CA MSA	4,839,460	Santa Barbara, CA: Santa Barbara Municipal	3,785,260
			Santa Maria, CA: Santa Maria Public	1,054,200
5	Eureka-Arcata-Fortuna, CA MSA	972,838	Eureka, CA: Murray Field	859,640
			Eureka/Arcata, CA: Arcata/Eureka	113,198
6	San Luis Obispo-Paso Robles, CA MSA	868,920	San Luis Obispo/Paso Robls, CA: San Luis Obispo County	766,880
			San Luis Obispo/Paso Robls, CA: Paso Robles Municipal	102,040
7	Anchorage, AK MSA	792,442,228	Anchorage, AK: Anchorage International	791,897,353
			Anchorage, AK: Merrill Field	544,875
8	Ketchikan, AK MSA	5,497,908	Ketchikan, AK: Ketchikan International	4,973,147
			Ketchikan, AK: Ketchikan Waterfront Sea Plane Base	524,761

9	Cleveland-Akron-Elyria, OH CSA	98,414,579	Cleveland, OH: Hopkins International	94,156,830
			Akron/Canton, OH: Akron/Canton Regional	4,257,749
10	Columbus-Marion-Chillicothe, OH CSA	50,575,821	Columbus, OH: Rickenbacker International	47,388,521
			Columbus, OH: Columbus International	3,187,300
11	Dallas-Fort Worth, TX CSA	714,119,752	Dallas/Ft.Worth, TX: Dallas/Ft Worth International	524,137,106
			Dallas/Ft.Worth, TX: Fort Worth Alliance	150,364,242
			Dallas, TX: Dallas Love Field	39,618,404
12	Houston-Baytown-Huntsville, TX CSA	237,454,001	Houston, TX: Houston Intercontinental	221,212,460
			Houston, TX: William P Hobby	16,241,541
13	Brownsville-Harlingen-Raymondville, TX CSA	29,286,115	Harlingen/San Benito, TX: Harlingen Industrial Airprk	16,389,834
			Brownsville, TX: Brownsville South Padre Is	12,896,281
14	Chicago-Naperville-Michigan, IL-IN-WI CSA	520,549,353	Chicago, IL: O Hare	500,275,491
			Chicago, IL: Chicago Midway	20,273,862
15	Honolulu, HI MSA	351,409,656	Honolulu, HI: Honolulu International	343,291,418
			Lihue, HI: Lihue Airport	7,276,012
			Hoolehua, HI: Molokai	842,226
16	Miami-Fort Lauderdale-Miami Beach, FL MSA	513,276,648	Miami, FL: Miami International	317,297,167
			Fort Lauderdale, FL: Fort Lauderdale International	172,193,230
			West Palm Beach/Palm Beach, FL: Palm Beach International	23,342,533
			Miami, FL: Opa Locka	443,718
17	Tampa-St. Petersburg-Clearwater, FL MSA	86,607,841	Tampa, FL: Tampa International	65,697,376
			St. Petersburg, FL: St. Petersburg International	20,910,465
18	New York-Newark - Bridgeport, NY-NJ-CT-PA CSA	990,648,936	New York, NY: Kennedy International	315,596,731
			Newburgh/Poughkeepsie, NY: Stewart	23,424,938
			New York, NY: La Guardia	18,048,809

			Islip, NY: Long Island-MacArthur	2,277,225
			Farmingdale, NY: Republic Field	697,720
			White Plains, NY: Westchester County	631,997
			New York, NY: East 34th Street	115,424
			Newark, NJ: Newark Liberty International	629,856,092
19	Buffalo-Niagara-Cattaraugus, NY CSA	63,994,554	Buffalo, NY: Buffalo Niagra International	54,643,034
			Niagara Falls, NY: Niagara Falls International	9,351,520
20	Boston-Worcester-Manchester, MA-NH-ME-CT CSA	366,111,947	Boston, MA: Logan International	280,314,665
			Manchester, NH: Manchester	85,797,282
21	Bemidji, MN MSA	383,755	Bemidji, MN: Nary National Shefland Field	215,240
			Bemidji, MN: Bemidji Beltrami County	168,515
22	Seattle-Tacoma-Olympia, WA CSA	360,333,736	Seattle, WA: Seattle/Tacoma International	247,779,507
			Seattle, WA: King County - Boeing Field	112,554,229
23	Detroit-Warren-Flint, MI CSA	175,545,661	Detroit, MI: Detroit Metro Wayne County	155,697,757
			Flint, MI: Bishop	13,375,206
			Detroit, MI: Willow Run	6,472,698
24	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV CSA	277,293,239	Washington, DC: Dulles International	139,188,424
			Washington, DC: Washington National	7,835,950
			Baltimore, MD: Baltimore/Washington International	130,116,403
			Winchester, VA: Winchester Regional	152,462
25	Norfolk-Newport News, VA-NC MSA	31,728,620	Norfolk, VA: Norfolk International	31,043,675
			Norfolk, VA: Norfolk Nas	684,945
26	Mobile-Daphne-Fairhope, AL CSA	11,482,193	Mobile, AL: Mobile Aerospace	11,188,772
			Mobile, AL: Mobile Regional	293,421

Source: U.S. BTS, 2005a

APPENDIX B. POVERTY THRESHOLDS FOR 2003 BY SIZE OF FAMILY AND NUMBER OF RELATED CHILDREN UNDER 18 YEARS (DOLLARS)

Size of family unit	Weighted average thresholds	Related children under 18 years								
		None	One	Two	Three	Four	Five	Six	Seven	Eight or more
One person (unrelated individual).......	9,393									
Under 65 years..............................	9,573	9,573								
65 years and over..........................	8,825	8,825								
Two persons.................................	12,015									
Householder under 65 years...........	12,384	12,321	12,682							
Householder 65 years and over......	11,133	11,122	12,634							
Three persons..............................	14,680	14,393	14,810	14,824						
Four persons................................	18,810	18,979	19,289	18,660	18,725					
Five persons................................	22,245	22,887	23,220	22,509	21,959	21,623				
Six persons..................................	25,122	26,324	26,429	25,884	25,362	24,586	24,126			
Seven persons..............................	28,544	30,289	30,479	29,827	29,372	28,526	27,538	26,454		
Eight persons...............................	31,589	33,876	34,175	33,560	33,021	32,256	31,286	30,275	30,019	
Nine persons or more......................	37,656	40,751	40,948	40,404	39,947	39,196	38,163	37,229	36,998	35,572

Source: U.S. Census Bureau, 2006