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Air Cargo Operations Cost Database

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April 1998

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Abstract

The United States, and much of the industrialized world, is in the midst of a tremendous period of growth in air traffic services. One sector that has experienced particularly strong growth is the air cargo industry. Over the past 10 years, worldwide air cargo traffic has grown at an average annual rate 8.6 percent. Furthermore, it is generally accepted that this phenomenal growth in air cargo traffic will continue through at least the year 2005. Such sustained growth will undoubtedly impact the demand for cargo aircraft. A primary motivation for this study is to address the questions of how large this impact on demand for cargo aircraft will be, and what proportion of the demand for cargo aircraft is likely to be satisfied by new cargo aircraft.

To assist NASA in the analysis of these and related issues, we built a set of integrated mathematical models that (1) estimate the direct operating costs associated with air cargo operations, (2) predict the future volume of air cargo traffic, and (3) estimate the future fleet sizes and composition necessary to meet the predicted growth rates.

Air Cargo Operations Cost Database

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Executive Summary

The United States, and most of the industrialized world, will face unprecedented growth in air traffic services over the next 15 years. Meeting this growth will be a technological and economic challenge. Many U.S.-manufactured passenger aircraft are expected to satisfy a large portion of this growth in demand. These aircraft represent the "state of the art" in terms of combining technical and economic performance. Behind the sales of these passenger aircraft lies a large portion of the U.S. technological base and a significant portion of the nation's high tech jobs and gross domestic products (GDP).

The air cargo portion of the air traffic services market will experience an even greater growth rate, accompanied by its own demand for cargo aircraft. Because of the historical structure of the air cargo marketplace, this cargo aircraft demand translates into disproportionally fewer new cargo aircraft, resulting in much lesser contributions to the nation's technological base both in terms of manufacturing jobs produced and the increase in GDP.

We expect the worldwide inventory of cargo aircraft to grow to approximately 4,950 aircraft by year-end 2015. This translates to more than 3,500 cargo aircraft being added to the current fleet. Almost 1,700 of those cargo aircraft will come from the ranks of the older, converted, and possibly upgraded passenger fleets. The remaining 1,800 or so cargo aircraft will be split among wide body, narrow body, and turboprop cargo aircraft.

From a manufacturer's perspective, any of those three payload segments is large enough to justify a targeted aircraft, assuming it was a passenger aircraft. Unfortunately, the cargo market has not historically purchased large numbers of new aircraft. The reasons run the gamut from poor balance sheets to cheap substitutes in the form of used, converted passenger aircraft. The first response of most carriers to the increase in demand for cargo services will not be to purchase new cargo aircraft, but to better utilize current capacity. The second likely response will be to purchase excess belly-hold capacity from the passenger carriers. The last strategic response will be the purchase of new cargo aircraft by both existing carriers and new entrants to the air cargo industry. Increased efficiencies in both the use of the current cargo fleet and the belly carrying capacity of the expanding passenger

fleet will drive the number of new cargo aircraft sales to less than 1,800. These factors restrict the potential market for a large all cargo aircraft.

The key cost driver for the air cargo industry is direct operating cost (DOC). A survey of the current cargo fleet yields a set of economic tradeoff curves that convert specific operating and design parameters, such as stage length, capacity, and utilization to DOC. These curves form the basis for calculating future cargo operating costs of the next generation of cargo aircraft, whether it is a new design or a converted passenger aircraft.

The tradeoff curves exhibit the well-known trend of DOC decreasing as either cargo capacity or stage length increases. But the analytical form of the DOC cost drivers provides a direct estimate of the change in DOC in response to changes in aircraft design or mission. Similarly, the tradeoff curves identify a target level of DOC that new aircraft must meet to be competitive with existing cargo aircraft.

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Chapter 1

Introduction

The United States, and much of the industrialized world, is in the midst of a tremendous period of growth in air traffic services. This growth presents unprecedented challenges to the operation of an efficient and safe air transportation system, but at the same time, also presents unprecedented opportunities to members of the aviation community.

One sector that has experienced particularly strong growth is the air cargo industry. Over the past 10 years, worldwide air cargo traffic has grown at an average annual rate 8.6 percent while passenger traffic has grown at a rate of 4.8 percent. Furthermore, it is generally accepted that the phenomenal growth in air cargo traffic will continue through at least the year 2005. Such sustained growth will undoubtedly impact the demand for cargo aircraft. A primary motivation for this study is to address the questions of how large this impact on demand for cargo aircraft will be and what proportion of the demand for cargo aircraft is likely to be satisfied by new cargo aircraft.

The objective of this study is to provide NASA with the ability to estimate the direct operating costs associated with air cargo operations. The effort will define and examine the direct operating costs (DOCs) associated with cargo traffic; develop a suite of analytical models used to predict the volume of air cargo traffic and direct operating costs of air cargo aircraft; estimate the future fleet sizes and composition necessary to meet the predicted growth rates; and analyze the market for air cargo in terms of the opportunities for an all-cargo transport.

To support the evaluation of the potential for a new all-cargo transport, this study provides an analysis of some fundamental issues. First, using financial data from Department of Transportation (DOT) Form 41 reports, the study quantifies the operating costs of aircraft currently in the cargo fleet. Second, using traffic and operational data from DOT Form 41 reports, the study projects the number of cargo aircraft that will be required to meet the estimated demand for air cargo services. Third, using an analytic model of aircraft retirement, the study estimates the number and composition of passenger aircraft that are likely to be converted to cargo aircraft.

This report presents the results of the study outlined above. This section ends with an overview of the methodology, data sources, and limitations of the study. Chapter 2 defines the key concepts of the study, including operating costs and types of cargo. Chapter 3 presents the air cargo operating cost database used as the analytic basis for the rest of the study. Chapter 4 presents the data and statistical analysis of the U.S. domestic air cargo industry, focusing upon fleet composition and DOCs in multiple dimensions. Chapter 5 presents the direct operating costs of the United States cargo costs at the equipment level. Chapter 6 expands the data and statistical analysis to include the 25 largest international carriers and repeats the analysis of Chapter 4 on the international level. Chapter 7 presents a set of predictive models and extends the analysis to the future of the cargo industry. Chapter 8 presents an analysis of the supply and demand for cargo aircraft. The conclusions and summary are presented in Chapter 9, while related data and previous cargo related studies are analyzed in the appendices. A glossary of aviation-related terminology used throughout the study is in Appendix A.

METHODOLOGY

The general approach taken for the study is relatively straightforward. First, the concept and delineation of operating cost is defined for air transportation in general. The concept is subsequently modified specifically for air cargo operations. The result is a direct comparison of operating costs between passenger and cargo service. Next, the definition and delineation of the various types of cargo is performed. Statistics regarding cargo operating costs, cargo operating revenues, cargo traffic, and employment are gathered for United States flag carriers from DOT Form 41 reports. A database is constructed and the United States market is segmented into three categories: passenger operations with dedicated all-cargo aircraft, passenger operations with belly cargo service only, and all-cargo operations. For each carrier, the operating costs are calculated for the 9-year period 1986 through 1995. Operating costs are subsequently calculated for each carrier category and for the industry as a whole. Similar analysis is performed on the largest 25 international air cargo carriers.

Using data from AvSoft's ACAS Fleet Information System, we next examine the size and composition of the current air cargo fleet. The operating costs are calculated separately for each type of aircraft in the current air cargo fleet. The goal is to derive more accurate estimates of operating costs for past, present, and future aircraft types than the carrier-level analysis allows. We also examine the size and composition of the current passenger fleet in order to identify the aircraft most likely to be converted to cargo aircraft.

Using results from an econometric estimate of air cargo demand, we develop an analytic model to forecast cargo traffic growth for the entire world and separately for U.S. carriers. Parameters derived from the cost database are then utilized to determine revenues and carrier operating costs for the forecast period. Finally, we estimate the number and composition of cargo aircraft required to meet the future demand.

Data Sources

One of the legacies of a regulated U.S. airline industry is a vast quantity of data describing the operations and status of individual carriers and the domestic industry as a whole. The collection of these data is mandated by the DOT and the data are subsequently made available to the general public. This comprehensive set of data is known as the Form 41 Data. It consists of financial and traffic data specifically composed of a series of monthly, quarterly, and annual reports that describe the status of the carrier. The specific data series are called schedules. A list of Form 41 schedules is shown in Appendix B.

Unfortunately, there is no international counterpart of the Form 41 Data. International data were gathered from two major sources, the International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO). IATA provided two sets of data for this study*: World Air Transport Statistics* and the *Freight Forecast 1995-1999*. ICAO provided *Traffic of Commercial Air Carriers*, *Financial Data of Commercial Air Carriers*, and *Civil Aviation Statistics of the World*. Since the international data are not publicly available at the same level of detail as the Form 41 Data, the calculations of international parameters should be viewed with an additional degree of uncertainty.

Additional sources of data include *The Boeing World Air Cargo Forecast* for 1994 through 1997, *AvSoft ACAS Fleet Information System*, and *AirClaims International Aircraft Price Guide*.

Limitations of the Study

Air cargo service is usually provided as part of an integrated transportation system. This study assumes that (1) such a system can be easily disaggregated into its component pieces and, most importantly, (2) that all costs are separable. These assumptions obviously conflict with the modern structure of the firm, but are required given the level of detail in publicly available data.

The production of air cargo services requires a large and varied number of inputs. This study looks exclusively at those costs defined and found on Form 41 Schedule Reports. Because the study is strictly limited to air cargo operating costs, the associated costs of air cargo ground operations are not examined or addressed. These are mainly composed of the fixed and variable costs associated with a ground network for the initial collection and terminal distribution of the shipped goods. In reality, the ground network costs play an integral part in the profitability of the air cargo industry as a whole and affect individual firms in terms of corporate strategy and capital allocation decisions such as route structure, aircraft allocation, and aircraft purchase. For the purposes of this study, issues related to ground distribution networks are assumed to be indirectly represented in the firm-level revenues, profits, and costs. However, no attempt has been made to explicitly calculate these costs.

Another limitation is the issue of air transportation services as a joint production function with two outputs: passenger transportation services and cargo transportation services. This issue arises whenever cargo is shipped in the hold of passenger aircraft. The basic question is how to allocate the operating costs of such aircraft when used to produce joint production. This split does not affect the calculation of profitability for the industry as a whole or at the level of the firm, but it does directly affect profitability at the level of both the cargo unit and the passenger unit. There is no “correct” way to make this determination, although some methods are preferred to others. The opinion of the authors is that it is best solved as either a transfer function type of problem where the allocation should be made so as to optimize total profits. Alternatively, the Shapley value approach could be used, depending upon how uncertainty is formulated.[1] Since this approach was beyond the scope of the study, we decided to perform the analysis by allocating joint production costs in proportion to the revenues generated. However, a feature was added to the database to enable users to vary the allocation rule, according to personal preferences.

The final limitation concerns the integrity and validity of the Form 41 source data. We assume that the Form 41 data are reported completely and accurately to the DOT by the individual carriers. Furthermore, we assume that all of a carriers’ operations are reflected in the Form 41 data. This assumption is violated whenever a carrier subcontracts portions of its operations to a third party. Under this situation, the calculation of DOC at the level of the firm will be incomplete. However, to the extent that the third-party operators are also represented in the Form 41 data, the equipment-level and industry-level analysis will remain accurate.

[1] The Shapley value approach is a solution technique for an n-person game where the value of a game to a player is their average marginal worth to all coalitions in which that player might participate. When applied to this work, this approach yields an order-insensitive form of pricing where costs and profits can be allocated to either the passenger side or the cargo side by the marginal value they bring to the total enterprise. For a fuller treatment, see Shubik, p. 180.

Chapter 2
Key Concepts

INTRODUCTION

This chapter introduces the key concepts, definitions, and industry conventions underlying the construction of the cost database and the analysis in the following chapters. The air travel industry standard concepts of direct and indirect operating costs are introduced and subsequently modified for air cargo operations. Standard definitions are given for the various types of air cargo identified in the study. These include both scheduled and nonscheduled freight, mail, and small package express.

OPERATING COSTS

The traditional economic approach to short-run cost allocation is to distinguish between fixed and variable costs. Fixed costs are defined as short-run costs that do not vary with the quantity of output. Conversely, variable costs are those costs that do vary with the quantity level that the firm produces.[1] These definitions imply that fixed costs are those costs a firm incurs in the short run even when it produces nothing. Variable costs, on the other hand, are those costs that a firm can avoid in the short run by producing no output.[2]

Closely related to these definitions is the concept of marginal cost. Marginal cost measures the change in total cost that results from a change in the level of output. Since fixed costs do not vary with output, marginal costs are completely independent of fixed costs. Thus, in the short-run approach, fixed costs are considered to have no impact on economic decisions. This fact leads to a potential deficiency in the short-run approach for capital-intensive industries. The basic problem is that the short-run approach neglects the long-run impact of changes in output on fixed costs. Therefore, for industries with large amounts of capital equipment, such as the airline industry, it may be inappropriate to employ the short-run approach.

The alternative is to take a long-run approach in which all costs are viewed as variable. This long-run view of cost allocation has been adopted in the industry standard concept of operating costs. Under the operating costs approach, the primary dichotomy is between direct and indirect operating costs. With regard to the airline industry, DOCs are composed of the categories of flying operations, direct

[1] Brofenbrenner, et al. p. G-33.

[2] Nicholson, p. 300.

maintenance of flight equipment, and flight equipment capital costs. Indirect operating costs (IOCs) are composed of direct maintenance of ground property and equipment, servicing of flying operations, administration and sales, and depreciation of ground property and equipment. Tables 2-1 and 2-2 detail the components of each cost category. All of the cost components are derived from the DOT Form 41 schedules. Explanations of the individual cost components and details regarding the assignment of individual accounting items to a cost category are described in Appendix B.

Table 2-1. Direct Operating Costs

Cost category	Component
Flying operations	Flight crew costs Cabin crew costs Fuel and oil Aircraft rental Hull insurance Injuries, loss, and damage
Direct maintenance of flight equipment	Labor-airplane Labor-engine Material-airplane Material-engine Maintenance burden
Flight equipment capital costs	Depreciation-flight equipment Amortization-capital leases

Table 2-2. Indirect Operating Costs

Cost category	Component
Direct maintenance of ground property and equipment	Maintenance-ground property and equipment
Servicing of flying operations	Passenger servicing Aircraft servicing Traffic servicing
Administration and sales	Servicing administration Reservation and sales Advertising and publicity General administration
Depreciation	Depreciation-ground property and equipment

PASSENGER OPERATING COSTS VERSUS CARGO OPERATING COSTS

There are several discrepancies between the operating costs of passenger aircraft and those of cargo aircraft. An obvious distinction with regard to DOC cost categories is the exclusion of cabin crew costs for cargo aircraft. Other less obvious discrepancies result from differences in average aircraft age between passenger operations and cargo operations. Specifically, the fact that cargo aircraft tend to be significantly older than passenger aircraft leads to substantially higher fuel and maintenance costs. Conversely, cargo aircraft enjoy significantly lower hull insurance, aircraft rental, and flight equipment capital costs.

In terms of IOC, the discrepancies between passenger operations and cargo operations may be less obvious. Table 2-3 summarizes the discrepancies between IOC cost components for passenger and cargo operations. All else equal, passenger IOC is expected to exceed cargo IOC since the former contains many cost components that the latter lacks. In addition, cargo IOC is expected to comprise a smaller percentage of the total operating costs than passenger IOC.

Table 2-3. Passenger-Cargo IOC Components

Category	Passenger	Cargo	Both
Passenger food and beverage	x		
Passenger service other	x		
Line service			x
Baggage handling	x		
Cargo handling			x
Passenger advertising and publicity	x		
Passenger reservations and sales	x		
Freight sales, advertising, and publicity		x	
Property advertising and publicity			x
Property reservation and sales			x
Maintenance: ground property and equipment			x
Depreciation: ground property and equipment			x
Depreciation: maintenance equipment			x
General administration			x

Generally, it is more appropriate to discuss operating costs in average terms per measure of output than in absolute terms. The air transportation industry generally uses two measures of average cost. The first is calculated by dividing costs by a measure of total capacity. The second is formed by dividing costs by a measure of employed capacity. For passenger operations, the average cost measures are cost per available seat mile (ASM) and cost per revenue passenger mile (RPM).[3] For

[3] See Appendix A for a complete definition of each term.

U.S. cargo operations, the measures are cost per available ton mile (ATM) and cost per revenue ton mile (RTM). The international community uses the metric equivalent given by cost per available tonne kilometer (ATK) and cost per revenue tonne kilometer (RTK). It is easy to convert between RPM and RTM because airlines use a standard reporting convention of 200 pounds per passenger including baggage. It is similarly straightforward to convert between RTM and RTK or ATM and ATK by the formula 1 ton mile equals 1.46 tonne kilometers.

WHAT IS "CARGO"

We begin with the widest possible definition of cargo as goods transported by ship, aircraft, truck, or other vehicle. Air cargo represents a small subset that is transported on aircraft. Air cargo has the highest value per pound of any freight shipped in the United States. It also is the least used method of shipping in terms of both tonnage and ton-miles. According to the U.S. DOT, Bureau of Transportation Statistics, the tonnage and ton-miles of air cargo account for approximately one-tenth of 1 percent of the United States total cargo weight, but account for seven-tenths of 1 percent of the total value of United States shipped goods.

We divide air cargo into two smaller classifications, freight and mail. Mail refers exclusively to shipments of U.S. and foreign Postal Service letters and small packages that are generally shipped under long-term contracts between the Postal Service and the individual carriers. Mail does *not* include letters and small packages shipped with express and overnight services, which are included in freight. We further subdivide freight into scheduled and non-scheduled components.

Chapter 3
Air Cargo Operating Cost Database

Our analysis is based on data contained in the Air Cargo Operating Cost Database. The Database is composed of a series of linked Excel spreadsheets that have been compiled from a variety of sources including *The Boeing World Air Cargo Forecast*, United States DOT Form 41 filings, *AvSoft ACAS Fleet information system*, and several ICAO statistical digests. The database consists of annual observations spanning the 11-year time period from 1985 to 1995, but it has been designed to allow for the inclusion of additional years. This chapter details the design and use of the database and describes the steps required to update the database.

DESIGN

There are two geographic regions represented in the database: the United States and the rest of the world (ROW). The main source of data for the United States region is the Form 41 filings. The main source of data for the ROW is the ICAO statistical digest. There are two types of worksheets in the database: historical data and analysis. Historical data worksheets simply contain the raw data directly from the source. Analysis worksheets manipulate the raw data to calculate various statistics or perform some type of analysis. For ease of identification, all analysis worksheets have the word *Analysis* in the worksheet title.

There are five general types of historic data compiled in the database: traffic series, financial series, detailed cost series, employment series, and aircraft fleet inventory data. Traffic series include statistics that measure cargo volumes, aircraft activity, fuel consumption, and system capacity. Table 3-1 is an example of a traffic worksheet. With the exception of cargo ATMs and cargo RTMs, the line item titles and corresponding account numbers are taken directly from the Form 41 reporting schedules.

The financial series worksheet includes statistics that measure revenues, costs, and profits at a summary level of detail. By convention, revenues are reported as negative costs and actually appear in the database as negative numbers. Table 3-2 is an example of a financial series worksheet. All data entries are expressed in nominal U.S. dollars.

Table 3-1. A Representative Traffic Series Worksheet

Elements	Total: all-cargo airlines	
	1994	1995
K110.0 Enplaned passengers—scheduled service	0	0
K140.0 RPMs—scheduled revenue service (000's)	0	0
K240.0 Revenue ton miles—scheduled service (000's)	7,989,729	8,528,976
K280.0 Available ton miles—scheduled service (000's)	13,233,207	13,997,440
K320.0 ASMs—scheduled revenue service (000's)	0	0
K410.0 Revenue aircraft miles—scheduled service	268,998,583	276,898,557
K510.0 Departures performed—scheduled service	448,662	453,751
V510.0 Revenue aircraft departures performed—nonscheduled	256,814	263,041
Z110.0 Enplaned passengers—scheduled and nonscheduled service	3,516,286	3,098,274
Z140.0 RPMs—scheduled and nonscheduled service (000's)	3,995,380	3,803,193
Z240.0 Revenue ton miles—scheduled and nonscheduled service (000's)	11,893,797	13,758,357
Z247.0 Freight revenue ton miles—scheduled and nonscheduled (000's)	11,002,161	12,954,914
Z249.0 Mail revenue ton miles—scheduled and nonscheduled (000's)	125,031	125,126
Z280.0 Available ton miles—scheduled and nonscheduled service (000's)	19,880,492	22,552,565
Z320.0 ASMs—scheduled and nonscheduled service (000's)	5,469,194	5,200,239
Z410.0 Revenue aircraft miles—scheduled and nonscheduled service	423,350,736	545,167,008
Z420.0 Nonrevenue aircraft miles	0	0
Z510.0 Departures performed—scheduled and nonscheduled service	632,067	665,573
Z610.0 Revenue airborne hours	1,051,250	1,113,138
Z620.0 Nonrevenue airborne hours	24,296	20,364
Z630.0 Block hours	1,208,525	1,265,779
Z650.0 Total airborne hours	1,070,114	1,129,462
Z820.0 Aircraft days—carrier routes	415,508	384,666
Z921.0 Gallons of fuel	1,668,786,796	1,869,666,966

The detailed cost series worksheet focuses exclusively on operating costs and presents the data at a much finer level of detail. Four categories of operating costs are delineated and reported: flight operations (FO), maintenance (Mtn.), depreciation (Dpr.), and amortization (Amr.). As discussed below, detailed cost series are also presented separately for individual equipment types. Since the DOT Form 41 filings generally report costs at a much finer level of detail than the ICAO digests, analysis of non-U.S. air carriers should be treated with an additional degree of uncertainty. Table 3-3 is an example of a detailed cost series worksheet.

Table 3-2. A Representative Financial Series Worksheet

Elements	Total: all-cargo airlines	
	1994	1995
3905.0 Revenue mail	-220,681,863	-286,043,976
3906.0 Revenue property	-4,483,292,933	-5,916,168,315
3906.1 Revenue property—freight	-4,471,874,517	-5,916,168,315
3906.2 Revenue property—excess baggage	-11,418,416	0
3907.0 Revenue charter	-2,413,901,815	-2,314,001,653
3907.1 Revenue charter—passenger	-280,378,930	-276,571,726
3907.2 Revenue charter—property	-2,133,522,885	-2,037,429,927
3919.0 Revenue air transport—other	-115,968,951	-87,318,539
3919.1 Revenue reservation cancellation fees	-1,273,471	288,558
3919.2 Revenue misc. operating revenues	-114,695,480	-87,607,097
4898.0 Revenue transport related	-5,824,762,883	-6,109,987,196
4999.0 Revenue total operating revenue	-13,058,608,445	-14,713,519,638
5100.0 Expenses—flying operations	2,648,379,490	3,169,653,505
5400.0 Expenses—maintenance	1,372,364,497	1,655,637,609
5500.0 Expenses—passenger service	15,069,062	19,910,333
6400.0 Expenses—aircraft and traffic servicing	1,163,475,577	1,423,376,717
6700.0 Expenses—promotion and sales	313,059,830	351,523,741
6800.0 Expenses—general and administrative	588,248,201	704,340,524
6900.0 Expenses—general and administrative	102,436,376	186,547,886
7000.0 Expenses—depreciation and amortization	711,333,724	846,762,935
7100.0 Expenses—transport related	5,352,888,202	5,629,807,996
7199.0 Expenses—total operating expenses	12,267,254,959	13,987,561,246
7999.0 Operating profit or loss	-791,353,486	-725,958,392
8181.0 Nonoperating interest on long-term debt and capital leases	211,374,624	182,920,575
8182.0 Nonoperating interest expenses—other	4,861,052	25,014,955
8185.0 Nonoperating foreign exchange gain or loss	4,566,221	1,250,742
8188.5 Nonoperating capital gains/losses—operating properties	-12,086,051	-43,620,738
8188.6 Nonoperating capital gains/losses—other	0	0
8189.0 Nonoperating other income and expenses—	-41,673,282	2,882,622
8189.1 net		
8199.0 Nonoperating income and expense	167,042,564	168,448,156
8999.0 Income before tax	-624,310,922	-557,510,236
9100.0 Income tax expense	250,383,232	232,355,362
9899.0 Net income	-376,473,690	-330,318,747

Table 3-3. A Representative Detailed Cost Series Worksheet

Elements	Total: all-cargo airlines	
	1994	1995
5123.0 Flight operations—pilots and co-pilots	467,011,019	567,195,027
5124.0 Flight operations—other flight personnel	44,487,531	41,612,572
5128.1 Flight operations—trainees and instructors	36,342,544	44,790,609
5136.0 Flight operations—personnel expenses	95,666,806	114,112,711
5141.0 Flight operations—professional and technical fees and expenses	16,222,225	22,624,710
5143.7 Flight operations—aircraft interchange—outside	179,000	0
5145.1 Flight operations—aircraft fuel	780,809,986	831,858,426
5145.2 Flight operations—aircraft oil	1,594,214	1,818,056
5147.0 Flight operations—aircraft rentals	633,757,810	732,576,392
5153.0 Flight operations—other supplies	2,986,493	4,305,826
5155.1 Flight operations—insurance purchase—general	44,685,546	50,788,392
5157.0 Flight operations—employee benefits and pensions	83,371,070	86,836,982
5158.0 Flight operations—injuries, loss and damage	5,784,042	-116,335
5168.0 Flight operations—taxes—payroll	26,423,312	35,688,368
5169.0 Flight operations—taxes—other than payroll	25,509,175	33,173,174
5171.0 Flight operations—other expense	135,419,906	193,576,243
5199.0 Flight operations—total flying operations	2,400,250,679	2,760,841,153
5225.1 Maintenance—maintenance airframe labor	163,792,027	200,900,256
5225.2 Maintenance—maintenance engineering labor	78,424,314	87,585,152
5243.1 Maintenance—maintenance airframe outside representative	194,525,988	223,119,512
5243.2 Maintenance—maintenance engineer outside representative	118,003,565	162,722,114
5243.7 Maintenance—maintenance aircraft interchange charges-outside	4,832,454	7,274,254
5246.1 Maintenance—maintenance materials—airframe	120,847,536	138,034,016
5246.2 Maintenance—maintenance materials—engines	58,421,064	63,848,998
5272.1 Maintenance—maintenance airframe airworthiness provisions	94,972,322	113,382,806
5272.3 Maintenance—maintenance airframe overhead deferred	-13,171,498	3,849,155
5272.6 Maintenance—maintenance aircraft engine airworthiness provisions	168,367,698	422,948,290
5272.8 Maintenance—maintenance aircraft engine overhead deferred	-312,941	3,632,240
5278.0 Maintenance—total direct maintenance—flight equipment	988,702,529	1,427,296,793
5279.6 Maintenance—applied maintenance burden—flight equipment	136,122,555	164,343,038
5299.0 Maintenance—total flight equipment maintenance	1,124,825,084	1,591,639,831
7073.9 Obsolescence—net obsolescence and deterioration—expendable parts	10,000	4,713
7074.1 Amortization—amortization—development and pre-operation	3,501,787	4,675,972
7074.2 Amortization—amortization—other intangibles	21,785,197	27,384,902
7075.1 Depreciation—depreciated airframes	258,482,594	284,121,322
7075.2 Depreciation—depreciated aircraft engines	131,828,577	146,324,445
7075.3 Depreciation—depreciated airframe parts	31,709,288	35,085,972

Table 3-3. A Representative Detailed Cost Series Worksheet (Continued)

Elements	Total: all-cargo airlines	
	1994	1995
7075.4 Depreciation—depreciated engine parts	10,484,485	17,624,946
7075.5 Depreciation—depreciated other flight equipment	8,530,261	4,201,692
7075.6 Depreciation—total depreciation—flight equipment	445,751,961	495,863,947
7075.8 Depreciation—depreciated hangar and equipment	65,712,401	77,286,020
7075.9 Depreciation—depreciated ground equipment	150,476,024	198,835,690
7076.1 Amortization—amortization—capital leases flight equipment	2,475,996	2,131,673
7076.2 Amortization—amortization—capital leases—other	5,732,393	12,523,058
7098.9 Total aircraft operating expenses	3,973,313,720	4,850,481,317

The employment series reports the year-end weighted average number of full-time employees in each category. Table 3-4 is a representative employment series worksheet.

Table 3-4. A Representative Employment Series Worksheet

Elements	Total: all-cargo airlines	
	1994	1995
0021.0 Employment—general management personnel	1,671	1,915
0023.0 Employment—pilots and copilots	5,725	6,673
0024.1 Employment—other flight personnel—flight operations	1,472	1,249
0024.2 Employment—other flight personnel—passenger/general services and administration	525	322
0025.0 Employment—maintenance labor	5,803	6,218
0026.0 Employment—aircraft and traffic handling personnel	456	874
0026.1 Employment—general aircraft and traffic handling personnel	1,487	1,739
0026.2 Employment—aircraft control personnel	838	1,066
0026.3 Employment—passenger handling personnel	183	77
0026.4 Employment—cargo handling personnel	9,526	12,512
0028.1 Employment—trainees and instructors	480	408
0031.0 Employment—record keeping and statistician personnel	3,006	2,643
0033.0 Employment—traffic solicitors	4,027	4,246
0099.1 Employment—other personnel	5,066	5,904
0099.2 Employment—transport-related	72,602	72,928
0099.0 Employment—total weighted average current year employment	112,867	118,774

The aircraft fleet inventory data identify the individual aircraft comprising each carrier's year-end 1995 fleet. For each aircraft, the database contains observations regarding the operator, airframe age, and current engines. Table 3-5 is a sample of observations from the fleet data worksheet.

Table 3-5. Representative Aircraft Fleet Data

Carrier	Manufacturer	Type	Model	Year of first delivery	Engine maker	Engines	Serial number
Federal Express	Boeing	727	727-100C	1966	PW	JT8D-7	19109
Federal Express	Boeing	727	727-100C	1966	PW	JT8D	19110
Federal Express	Boeing	727	727-100C	1966	PW	JT8D-7B	19136
Federal Express	Boeing	727	727-100C	1966	PW	JT8D-7B	19137
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19193
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19194
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19197
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19198
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19199
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19201
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19202
Federal Express	Boeing	727	727-100C	1966	PW	JT8D	19298
Federal Express	Boeing	727	727-100C	1966	PW	JT8D	19299
Federal Express	Boeing	727	727-100C	1966	PW	JT8D	19300
Federal Express	Boeing	727	727-100C	1967	PW	JT8D	19301
Federal Express	Boeing	727	727-100C	1967	PW	JT8D-7B	19356
Federal Express	Boeing	727	727-100C	1967	PW	JT8D	19360

In addition to historic data, the database also contains projections for future cargo traffic, costs, and revenues at the world and U.S. levels. These forecasts comprise the first two worksheets of the database and are labeled *World Forecast Analysis* and *United States Forecast Analysis*, respectively. The analysis that generated the forecasts is discussed in Chapter 7.

The third worksheet, labeled *F41 EQP Analysis*, contains the equipment-level analysis for the U.S. all-cargo industry, which is drawn from the Form 41 filings. For each type of equipment in the all-cargo fleet, the worksheet computes various network, fleet, operating cost, service, and other productivity statistics on an annual basis from the underlying raw Form 41 traffic and financial data. The statistics are designed to capture the use and underlying productivity of each type of equipment. The equipment types are arranged in sections following down the rows of the worksheet with a summary of all equipment types as the first section and a residual type as the last. Across the columns, the equipment operating data are further divided into Form 41 reporting groups I, II, and III.

The fourth worksheet, labeled *F41 AC Analysis*, contains the carrier-level analysis for the U.S. all-cargo (AC) industry. The worksheet computes a set of network, fleet, operating cost, revenue, service, and other productivity statistics on an annual basis for each all-cargo carrier. The statistics are designed to capture the network, fleet, and cost structure of each carrier. The individual carrier sections are organized across the columns of the worksheet beginning with row 50. In addition, separate sections summarizing all specified carriers, express operations, and non-express operations are organized across the columns of the worksheet beginning with row 1. Similarly, the fifth worksheet, labeled *F41 PC Analysis*, contains the carrier-level analysis for the U.S. passenger-cargo (PC) industry. Both the organization of the worksheet and the types of statistics computed are nearly identical to those of the all-cargo industry. Table 3-6 presents a representative portion of the *F41 AC Analysis* worksheet.

Table 3-6. A Representative Analysis Worksheet

Category	Total: all-cargo airlines	
	1994	1995
Network statistics		
Average stage length	669.8	819.1
Available ton miles/departure	31,453	33,884
Fleet statistics		
Aircraft years	1,138	1,054
Available ton miles/aircraft day	47,846	58,629
Available ton miles/block hour	16,450	17,817
Productivity statistics		
Revenue ton miles/employment	105,379	115,836
Departures/aircraft day	1.521	1.730
Available ton miles/gallon fuel	11.91	12.06
Revenue statistics		
Cargo revenue/cargo revenue ton miles (nominal)	1.137	$1.090
Cargo revenue/cargo revenue ton miles (real 1995 $)	1.106	$1.090
Cost statistics		
Direct operating costs/available ton miles (nominal)	0.223	$0.249
Direct operating costs/available ton miles (real 1995 $)	$0.230	$0.249
Flight operating costs/available ton miles (nominal)	$0.133	$0.141
Flight operating costs/available ton miles (real 1995 $)	$0.137	$0.141
Pilot/co-pilot costs/block hour (nominal)	$605.13	$697.70
Pilot/co-pilot costs/block hour (real 1995 $)	$622.28	$697.70
Fuel costs/gallon (nominal)	$0.518	$0.520
Fuel costs/gallon (real 1995 $)	$0.453	$0.520
Maintenance costs/block hour (nominal)	$1,003	$1,137
Maintenance costs/block hour real 1995	$1,057	$1,137
Capital costs/aircraft day (nominal)	$3,709	$4,920
Capital costs/aircraft day (real 1995 $)	$3,781	$4,920
Indirect costs/available ton miles (nominal)	$0.396	$0.388
Indirect costs/available ton miles (real 1995 $)	$0.407	$0.388
Service statistics		
Load factor	57.55%	59.76%
Schedule available ton miles/total available ton miles	66.56%	62.07%
Cargo revenue/total revenue	96.88%	97.53%

The sixth worksheet, labeled *F41 United States Traffic Summary*, contains a cargo traffic summary for U.S. registered air carriers; it is drawn from the Form 41 raw traffic data. The specified carriers of this study account for over 96 percent of the total 1995 U.S. registered air cargo RTMs. Total specified traffic is divided between all-cargo operations and passenger-cargo operations. All-cargo operations accounted for 56 percent of 1995 total RTMs. Each industry group is further divided into industry subgroups as defined by all-cargo express operations, all-cargo nonexpress operations, passenger operations with dedicated all-cargo aircraft, and passenger operations with belly cargo only.

The seventh worksheet, labeled *ICAO Traffic*, contains annual scheduled traffic series for the largest 25 international cargo carriers. These 25 carriers account for over 71 percent of the total world-scheduled traffic as measured by RTK. Carrier traffic is divided along two dimensions: domestic versus international and freight versus mail. Individual carrier observations are arranged in sections following down the rows of the worksheet with the columns containing the several divisions of the total traffic data. In addition, each carrier's share of the world-scheduled cargo market, as measured by RTK, is calculated.

The eighth worksheet, labeled *ICAO Financial*, contains ICAO annual financial series for these same 25 carriers. The reporting of financial statistics by individual carriers to ICAO is far less consistent than for other types of ICAO statistics. As a result, there is a significant amount of missing observations in the *ICAO Financial* worksheet. However, there is no evidence that reported data are in any way incorrect. The worksheet is organized with carrier observations grouped across the columns. Wherever possible, the traffic series and the financial series are combined to calculate per-unit operating costs in the last several rows of this worksheet.

The ninth and tenth worksheets, labeled *ACAS Fleet United States* and *ACAS Fleet ROW*, contain detailed information regarding aircraft fleet inventories for the United States and the ROW geographic regions. The data are sorted by carrier and contain an observation for each aircraft in the carrier's fleet at year-end 1995. The data fields available include manufacturer, type, model, serial number, registration number, year of first delivery, number of seats, engine type, and country of registration. The data source is the *AVSOFT ACAS Fleet Information System*.

The remaining worksheets comprise the raw data from the Form 41 Reports, which is used to calculate the carrier- and equipment-level analysis statistics. For each level of analysis (equipment, all-cargo, and passenger-cargo), there are separate worksheets containing raw data regarding traffic, statement of operations, Groups II and III operating costs, Group I operating costs, operating costs by objective groups, operating costs by functional group, and employment series. In addition, there are three worksheets containing economic data on price indices that are used to convert nominal costs into real costs. The final two data worksheets contain the historical series used to estimate U.S. and world cargo demand for the cargo forecasts. An additional worksheet describes the procedures required to update the database.

USE OF THE DATABASE

The primary use of the Air Cargo Operating Cost Database is to calculate the individual components of direct operating costs associated with air cargo operations. The database has been designed to examine these cost components on a per-unit basis of costs per ATM. However, the database can easily be modified to reflect an alternate cost basis.

The first step in examining the cost components is to select the appropriate level of aggregation. For the U.S. geographic region there are several options including equipment-level analysis for a particular type of equipment, carrier-level analysis for a particular carrier, industry-level analysis for either all-cargo airlines or passenger-cargo airlines, and any of four subindustry-level analyses. The next step is to select the *Analysis* worksheet from the Database that corresponds to the desired level of aggregation. Each *Analysis* worksheet contains the direct operating cost components and a variety of other useful cost and productivity statistics.

In addition to the capabilities described above, the analysis worksheets of the database offer the flexibility to compute additional statistics or modify existing calculations. To compute a new statistic, simply insert a blank row in a suitable position on the *Analysis* worksheet and use the Excel formula capabilities to reference the appropriate cells in the raw Form 41 data worksheets. To modify an existing calculation, simply edit the cell containing the calculation using Excel's formula and editing capabilities.

UPDATING THE DATABASE

The database is designed so that additional years of data can easily be added to the existing series. The first step in adding additional years of data is to insert one column for each year of data to be added after the last observation of each carrier (or grouping of carriers) on both the raw Form 41 data and corresponding analysis worksheets. For example, to add 1996 data to the existing database, one column must be inserted after each carrier's 1995 column on both the raw Form 41 data and analysis worksheet. Next, copy the additional year's raw data directly from Form 41 output into the relevant row of the inserted column. Care must be taken to ensure that the new data are aligned in the appropriate row, since the Form 41 output tends to have missing rows. The final step is to copy the formula for each row of the analysis worksheet into the inserted columns.

Chapter 4
United States Air Cargo Industry Analysis

INTRODUCTION

This chapter examines the context in which air cargo operations are conducted. First, we delineate three categories of cargo carriers according to the level of passenger service provided and the equipment used for cargo operations. Within each category, we further delineate groups of carriers according to the size of their operating revenues. We use the standard Department of Transportation definitions of Groups I, II, and III carriers. Within each category and group, we present a series of carrier-specific summary statistics that are intended to capture fleet-wide operating characteristics with regard to traffic, capacity, operating revenue, direct operating cost, fleet composition, and network structure.

Since a carrier's fleet generally is composed of several types of aircraft equipment, the summary statistics regarding direct operating cost should be interpreted with caution. These statistics represent fleet-wide weighted averages and may not accurately convey the operating costs of any one particular type of aircraft, but reflect the operating costs to serve the particular market segment that the carrier serves. In the case of carriers with both passenger and cargo operations, the cost statistics are further confounded by issues regarding the allocation of joint production costs to each activity. A more accurate measure of individual aircraft operating costs is calculated by isolating the traffic and costs attributable to each type of equipment. This analysis is presented in Chapter 5.

An additional complication arises from the fact that individual Form 41 reports do not include traffic that is subcontracted to other carriers. Thus, the revenue and cost statistics may not fully reveal the scope of a carriers integrated transportation network.

RECENT INDUSTRY HISTORY

The arrival of the Boeing 747 jumbo jet has been both a boon and a bane to the air cargo business. They were a boon because as all-cargo aircraft they provided the capacity to carry both large containers and over 100 tons per trip. But they were also a bane because the capacity available in the bellies of passenger aircraft could accommodate most of the air cargo tonnage available, and—by virtue of the byproduct nature of space—at a considerably lower cost than dedicated freighter aircraft. The combination of expanded belly capacity and lower freight rates permitted by deregulation proved to be the death knell for freighter operations by the U.S. passenger airlines. TWA operated its last freighter in December 1978, followed in later years by American, United, and Pan Am. Today, Northwest and United are the only two of the originally certified carriers to operate freighter aircraft.[1] During 1997, United added 2 McDonnell Douglas 10-30 freighters to its operation. As none of the existing all-cargo aircraft were retired, these aircraft should be thought of as an addition to meet the expected increase in the demand for cargo—services, a clear sign of future growth in the industry.

After most U.S. carriers phased out their operations of freighters, the promotion of air cargo devolved upon the freight forwarders, who had been the airlines' best customers. Some of the largest forwarders, such as Emery, Burlington Air Express and Airborne, later began to fly their own aircraft to provide the cargo lift they needed, at the times of day they needed it, and they became major cargo carriers in their own right.[2]

CARRIER DELINEATION

Using the *AvSoft ACAS Fleet Inventory System*, we identified all of the United States registered carriers having at least one dedicated all-cargo aircraft. This initial set consisted of 29 carriers. We subsequently eliminated 6 carriers that had not filed Form 41 reports with the Department of Transportation.[3] We supplemented the remaining 23 carriers by adding all Group III passenger carriers and Group II passenger carriers with well established cargo operations. The result is a set of 34 carriers that are included in the study.

Our next step was to delineate the set of carriers according to the level of passenger operations provided and the equipment employed for cargo operations. From this delineation, three categories of cargo carriers emerge:

- Carriers specializing exclusively in cargo operations
- Carriers with both passenger and cargo operations having dedicated all-cargo aircraft
- Carriers with both passenger and cargo operations having no dedicated all-cargo aircraft.

The 20 named carriers of the first category account for 56.1 percent of the 1995 U.S. flag cargo traffic as measured by RTMs.[4] The second category consists of three carriers and accounts for 9.7 percent of 1995 U.S. RTM traffic. The third

[1] Wells, pp. 360–361.

[2] Wells, p. 361.

[3] The excluded carriers are USA Jet Airlines, Omni Air Express, Ryan International Airlines, Trans Continental Airlines, Million Air, and Airborne Express.

[4] U.S. flag cargo traffic is defined as any traffic handled by carriers of U.S. registry. The data source for the total U.S. flag traffic is *The Boeing World Air Cargo Forecast 1996–1997*.

group consists of 11 air carriers and accounts for 30.7 percent of total United States flag RTM traffic. Thus, the carriers specified by this study account for 96.5 percent of the total U.S. traffic. The remaining traffic is transported by smaller predominately passenger service operations.

Within each category, we further delineated the carriers according to the magnitude of their operating revenues. We employed the standard Department of Transportation definitions of Groups I, II, and III, which are summarized in Table 4-1. In addition, the standard Department of Transportation definitions of the operating entities are also used. They are shown in Table 4-2.

Table 4-1. Department of Transportation Group Definitions

Group number	Operating revenues
III	Over $1 billion
II	Over $100 million to $1 billion
IA	Over $20 million to $100 million
IB	Under $20 million

Table 4-2. Operating Entities

Code	Operating entities	Definition	Service
D	Domestic	All operations within and between the 50 states of the United States (except Intra-Alaska), the District of Columbia, the Commonwealth of Puerto Rico, the United States Virgin Islands, and Canadian transborder operations	Scheduled, Nonscheduled
L	Latin America	Latin American operations within and between the Caribbean (including Bermuda and Guianas), Mexico, and South/Central America	Scheduled
A	Atlantic	Atlantic operations excluding Bermuda	Scheduled
P	Pacific	Pacific operations include the North/Central Pacific, South Pacific (including Australia), and the Trust Territories	Scheduled
I	International	Nondomestic operations	Nonscheduled

The delineation of carrier types is important because each type of operation is expected to have a different set of operating characteristics, revenue structure, and cost composition. In the case of passenger carriers with cargo operations, the distinction is also important in determining the allocation of costs between passenger and cargo activities. Table 4-3 shows the U.S. carriers included in the study, and it identifies the carrier’s category and revenue group.

Table 4-3. United States Flag Carriers Included in the Database

Airline	Group	Cargo or passenger	All-cargo aircraft	Mixed use	Operating entity
Air Transport International	II	Cargo	X		D, A
Alaska Airlines	III	Passenger		X	D, L
Aloha Airlines	II	Passenger		X	D, L
America West	III	Passenger		X	D, L
American Airlines	III	Passenger		X	D, P, L, A
American International Airways	II	Cargo	X		A, D, I
Amerijet International	IA	Cargo	X		D, L
Arrow Air	IA	Cargo	X		D, L
Atlas Air	II	Cargo	X		I
Challenge Air Cargo	II	Cargo	X		L
Continental Airlines	III	Passenger		X	D, P, L, A
Continental Micronesia	II	Passenger		X	P
Delta Airlines	III	Passenger		X	D, A, L, P
DHL	II	Cargo	X		D, A, L
Emery Worldwide	II	Cargo	X		D, I
Express One International	IA	Cargo	X		D, I
Evergreen	II	Cargo	X		D, I
Federal Express	III	Cargo	X		D, P, A, L
Fine Airlines	IA	Cargo	X		D, I
Florida West Airline	IB	Cargo	X		D, I
Hawaiian Airlines	II	Passenger		X	D, P
Kitty Hawk	IA	Cargo	X		D, L
Northern Air Cargo	IA	Cargo	X		D
Northwest Airlines	III	Passenger	X	X	D, P, A
Polar Air Cargo	II	Cargo	X		A, P, D, L
Southern Air Transport	II	Cargo	X		D, I
Southwest Airlines	III	Passenger		X	D
Sun Country Airlines	II	Cargo	X		D, I
Tower Airlines	II	Passenger		X	A
TransWorld Airways	III	Passenger		X	D, A
United Airlines	III	Passenger	X	X	D, P, A, L
UPS	III	Cargo	X		D, A, P, L
USAirways	III	Passenger		X	D, A, L
Zantop International	IA	Cargo	X		D

ALL-CARGO CARRIER ANALYSIS

We begin our carrier-level analysis with the carriers engaged exclusively in cargo operations. Since the aircraft of these carriers are not used in the joint production of passenger and cargo service, the calculation of direct operating costs attributable to cargo operations is straightforward.

United States Group III Carriers

The Group III carriers are the largest and most well recognized of the all-cargo carriers. The entire category is composed of only two carriers, Federal Express and United Parcel Service (UPS). Although these carriers certainly compete against one another in the market for small package time-critical deliveries, closer analysis reveals fundamental differences in their operating philosophy and customer base.

Federal Express specializes in express (one and two day) delivery of letters and other small packages. These are usually business-related or high-priority personal correspondence with a high time value. UPS specializes in shipping small to medium size packages to both business and personal customers. Each carrier operates an enormous fleet of ground vehicles for the initial collection and terminal distribution services. However, UPS operates a diverse integrated transportation network of which air cargo is only a small portion. In 1996, for example, air cargo revenues accounted for only 7.9 percent of total revenue for UPS, but 95.2 percent for Federal Express. A set of summary statistics highlighting other differences is shown in Table 4-4.

Table 4-4. Summary Statistics for Group III All-Cargo Air Carriers

Carrier	Statistic	1991	1992	1993	1994	1995
United Parcel Service	Operating profit (×$1,000)	39,777	14,681	59,653	76,121	52,107
	Average stage length	850	880	875	853	1,629
	Total available freight ton miles	3,578,192	3,824,351	4,213,109	5,188,131	5,823,729
	Total freight revenue ton miles	882,490	2,143,819	2,492,496	2,928,162	3,348,010
	Total mail revenue ton miles	0	0	0	0	0
Federal Express	Operating profit (×$1,000)	320,603	269,753	449,390	599,497	580,915
	Average stage length	550	543	536	538	551
	Total available freight ton miles	7,230,908	7,113,400	7,014,051	7,678,681	8,365,806
	Total freight revenue ton miles	4,108,710	4,211,929	4,179,177	4,738,093	5,069,889
	Total mail revenue ton miles	88,659	71,057	52,959	51,512	49,839

In addition to the discrepancies in terms of operating revenues and profits, there are other striking differences between the two carriers. One significant observation is the difference in average stage length. This can explained in terms of the differences in the additional infrastructures of the two firms. UPS uses a trucking network for a large portion of its nonexpress operations. Therefore, the aircraft network is specifically tied to its express operations. It can be characterized as hub and spoke, with aircraft connecting the hubs and a van/truck network servicing the hub spokes.[5] Federal Express, on the other hand, maintains a multiple hub and spoke network without a nationwide trucking system. Instead, the spokes of the Federal Express network are flown by a fleet of smaller turboprop aircraft. In addition, a large portion of the UPS hub operations are outsourced. Therefore, the statistics associated with that portion of its operations are not included in the table.

Tables 4-5 and 4-6 present descriptive statistics of the carrier in the aircraft fleet. The fleet of Federal Express has more than 2.5 times that of UPS. This discrepancy consists almost exclusively of the fleet of small single-engine turboprop Cessna aircraft. It is clear that the aircraft of each carrier’s fleet are considerably older than those of passenger carriers. This observation results from the fact that a substantial majority of the freighters are converted from retired passenger aircraft. The UPS aircraft average more than 20 years of age, while the total for Federal Express is slightly above 14 years. Again, this comparison may be somewhat misleading since the Federal Express fleet includes the Cessna aircraft. When these aircraft are removed from the analysis, the Federal Express average aircraft age increases to 20 years, which is identical to the UPS fleet.

Table 4-5. United Parcel Service Fleet Analysis

Manufacturer	Equipment	Number	Average age
Boeing	727-1	51	30.18
Boeing	727-2	8	18.75
Boeing	747	15	25.67
Boeing	757	55	5.67
Boeing	767-3/4	5	2.00
Boeing totals		134	17.87
McDonnell	8-71	24	29.08
McDonnell	8-73-F	28	28.25
McDonnell totals		52	28.63
Fairchild	227	11	14.00
Fairchild totals		11	14.00
Grand Total		197	20.50

[5] In essence, UPS maintains two parallel hub-to-hub networks, with one using aircraft-to-ship packages from hub to hub and the other using trucks.

Table 4-6. Federal Express Fleet Analysis

Manufacturer	Equipment	Number	Average age
Airbus	A300-600	13	2.36
Airbus	A310-600	23	12.45
Airbus totals		36	7.41
Boeing	727-1	68	30.74
Boeing	727-2	90	17.90
Boeing	747-2/3	6	17.68
Boeing totals		164	23.29
Cessna	C-208	250	7.46
Cessna totals		250	7.46
Fairchild	F-27	31	24.00
Fairchild totals		31	24.00
McDonnell	DC-10-1	13	21.62
McDonnell	DC-10-3	21	18.18
McDonnell	MD-11	15	7.64
McDonnell totals		49	14.96
Grand total		530	14.16

The final statistic presented is the calculation of direct operating cost for each air carrier. The results are summarized in Table 4-7. The DOCs for Federal Express generally exceed those of UPS by a modest margin. Two likely contributing factors to this discrepancy. First, the Federal Express data include the operations of the small Cessna aircraft while the UPS data does not. The fact that smaller turboprop aircraft generally have much lower productivity than large jet aircraft certainly puts upward bias on the direct operating costs of Federal Express. This issue is explored in more detail in the equipment-level analysis of Chapter 5.

Table 4-7. Group III All-Cargo Direct Operating Costs per ATM

Carrier	1991	1992	1993	1994	1995
United Parcel Service	$0.268	$0.255	$0.229	$0.209	$0.207
Federal Express	$0.296	$0.284	$0.282	$0.268	$0.274

A second contributing factor to the cost discrepancy is likely to be the difference in the proportion of revenues derived from express service between the two carriers. If express service is more costly to provide than nonexpress service, then we would expect the carrier with a higher proportion of express service to have higher costs. Since express traffic is not explicitly reported on Form 41, this hypothesis is difficult to confirm directly. However, an examination of the revenue yield for each carrier confirms that Federal Express obtains considerably more revenue per revenue ton mile of traffic than UPS. Since the charges for express service generally are more than non-express service, this fact supports the hypothesis.

United States Group II Carriers

The U.S. Group II all-cargo set consists of the 10 carriers who are listed in Table 4-8. The members of this group offer both scheduled and unscheduled services and operate in a wide variety of geographical locations. Table 4-8 presents some descriptive statistics. The most obvious feature of the summary statistics is the tremendous variation in average stage length from a minimum of 387 miles to a maximum of 2,291. In addition, the proportion of total traffic due to mail operations varies from zero to 22 percent.

Table 4-8. 1995 Summary Statistics for Group II All-Cargo Carriers

Carrier	Operating revenues (×$1,000)	Operating profit or loss (×$1,000)	Average stage length	Available cargo ton miles (×1,000)	Total freight revenue ton miles	Total mail revenue ton miles
Air Transport International	130,608	11,986	1,164	778,439	422,668	0
American International Airways	369,636	504	842	1,333,464	605,184	26,224
Atlas Air	145,065	34,796	2,291	57,991	48,239	0
Challenge Air Cargo	108,236	-162	1,267	374,420	171,371	2,112
DHL	958,668	22,000	387	50,453	323,098	4,728
Emery Worldwide	296,414	16,000	781	1,335,060	727,454	208,050
Evergreen	219,775	4,464	972	663,992	382,917	22,208
Polar Air Cargo	234,758	13,000	2,272	1,051,091	761,494	0
Southern Air Transport	175,746	11,910	1,337	742,204	601,249	4,067
Sun Country Airlines	202,199	1,465	1,053	14,636	36	252

Tables 4-9 and 4-10 present summary statistics regarding the aircraft fleet of the Group II all-cargo carriers. Although the size of the fleet varies widely between the carriers, one feature common to all carriers is the relatively high average aircraft age. The average aircraft age across all Group II cargo carriers exceeds 26 years. In fact, only a single carrier (Challenge Air Cargo) operates any cargo aircraft (3 B-757s of its fleet of 4) under 10 years of age. Furthermore, only one additional carrier (Atlas Air) operates aircraft (3 B-747Fs of its fleet of 13 B-747Fs) in the range of 10 to 15 years of age. Not surprisingly, more than 75 percent of the Group II all-cargo fleet is composed of converted passenger aircraft. Of these, almost one-half are converted Boeing aircraft. It should also be noted that there are no Airbus aircraft in use by these carriers. This fact is not surprising given the relatively high average cargo aircraft age and the relatively low numbers of older Airbus equipment.

Table 4-9. Size and Age of U.S. Group II All-Cargo Carriers

Carrier	Number of aircraft	Average age
Air Transport International	1	29.00
American International Airways	45	27.84
Atlas Air	13	19.00
Challenge Air Cargo	4	12.50
DHL	28	27.64
Emery Worldwide	60	28.87
Evergreen	20	26.95
Polar Air Cargo	12	26.83
Southern Air Transport	23	25.52
Sun Country Airlines	2	22.00
Summary	208	26.81

Table 4-10. Manufacturer Splits of U.S. Group II All-Cargo Carriers

Carrier	Boeing converted passenger	Boeing original freighter	MDC converted passenger	MDC original freighter	Other converted passenger
Air Transport International			1		
American International Airways	21		8	12	4
Atlas Air		13			
Challenge Air Cargo	4				
DHL	20			7	1
Emery Worldwide	25		17	18	
Evergreen	9	2	9		
Polar Air Cargo	12				
Southern Air Transport	4		4		15
Sun Country			2		
Totals	95	15	41	37	20

The breakout between Boeing and McDonnell Douglas aircraft is shown in Tables 4-11 and 4-12. One-half of the specified carriers operate fleets of more than one manufacturer. It is tempting to conclude that this implies that operating advantages derived from commonality are relatively minor.[6] However, one issue that may be relevant for Group II carriers is the lack of available financial resources to purchase the optimal aircraft for the specified network. Because of

[6] This is to be expected as with a small number of aircraft, specific crew and equipment can be assigned to specific routes as long as utilization is high. Thus, large aircraft/crew combinations can be matched to those large volume routes while small aircraft/crew combinations can be matched to other routes.

this possibility, it may be inappropriate to conclude that aircraft in use represent the carriers first choice in terms of operating characteristics. Rather, because of cash flow limitations, carriers may be choosing the best aircraft from those that they can afford.

Table 4-11. Boeing Aircraft in Use by United States Group II All-Cargo Carriers

Model	707-3C	727-100	727-200	747-100	747-200/300	747-200C	747F	757
Air Transport International								
American International Airways		2	13	4	2			
Atlas Air							13	
Challenge Air Cargo	1							3
DHL		11	9					
Emery Worldwide		25						
Evergreen				7	2	2		
Polar Air Cargo				12				
Southern Air Transport					4			
Sun Country Airlines								
Totals	1	38	22	23	8	2	13	3

Table 4-12. McDonnell-Douglas Aircraft in Use by United States Group II All-Cargo Carriers

Model	DC-8-52	DC-8-5F	DC-8-6 series	DC-8-6F	DC-8 -7 series	DC-8-7F	DC-8-9 series	DC-10-30
Air Transport International			1					
American International Airways	1	10	7	2				
Atlas Air								
Challenge Air Cargo								
DHL						7		
Emery Worldwide		2	9	8	8	8		
Evergreen			1				8	
Polar Air Cargo								
Southern Air Transport						4		
Sun Country Airlines								2
Totals	1	12	18	10	8	19	8	2

The direct operating costs for Group II carriers are shown on the basis of DOC per available ton mile in Table 4-13. Again, there is a wide range between the lowest cost carrier and the highest. Furthermore, it is important to recognize that even if two carriers have similar DOCs, there may be large differences in fleets and operating strategy. For example, Challenge Air Cargo and Polar Air Cargo have nearly identical DOCs. However, while Polar Air Cargo operates a fleet of 12 converted Boeing 747-100 aircraft in a network with an average stage length in excess of 2,200 miles, Challenge Air Cargo operates a fleet of three Boeing 757-200 converted aircraft and one 707-300 in a network with an average stage length of just over 1,200 miles. Thus, there are numerous combinations of aircraft and network characteristics that yield similar operating costs.

Table 4-13. DOC/ATM for U.S. Group II All-Cargo Carriers

Carrier	1991	1992	1993	1994	1995
Air Transport International	0.318*	0.109	0.102	0.105	0.133
American International Airways	0.201	0.240	0.213	0.215	0.192
Atlas Air					1.610*
Challenge Air Cargo	0.162	0.157	0.153	0.155	0.136
DHL			0.438	0.374	0.375
Emery Worldwide		0.163	0.169	0.121	0.372
Evergreen	.443	0.425	0.208	0.202	0.168
Polar Air Cargo				0.148	0.134
Southern Air Transport	0.336	0.386	0.267	0.176	0.203
Sun Country Airlines	0.588	0.594	0.535	0.493	0.463

*Note: Because the carrier was not in operation for the entire year indicated, the cost statistic should be interpreted with extreme caution. Substantial bias may result from capital costs being allocated to less than a year's output

United States Group I Carriers

The U.S. Group I all-cargo set consists of eight carriers, which are listed in Table 4-14. All of the specified carriers except Florida West are Group 1A carriers (operating revenue between $20 million and $100 million per year). Each of the specified carriers offer both scheduled and unscheduled service in the domestic U.S. market, but not all offer international service. Summary statistics for the United States Group I all-cargo carriers are presented in Table 4-14.

The most apparent observation is the operating losses generated by three of the eight carriers. Interestingly, the four carriers with the lowest operating profit (highest losses) are also the carriers with the highest average stage length. One possible explanation is that these firms are attempting to compete directly with larger, more well-established Group II carriers. Alternatively, the loses may reflect the inability of the small carriers to access the financial resources to acquire larger aircraft, which may be optimal for the longer stage lengths. For all but a single carrier (Northern Air Cargo), the contribution of mail to total revenue ton miles is insignificant.

Table 4-14. 1995 Summary Statistics for U.S. Group I All-Cargo Carriers

Carrier	Operating revenues (×$1,000)	Operating profit or loss (×$1,000)	Average stage length	Available freight ton miles (000)	Total freight revenue ton miles	Total mail revenue ton miles
Amerijet International	52,000	11,000	592	1,333,464	605,184	26,224
Arrow Air	51,000	-9,955	1,084	246,686	147,296	0
Express One International	96,000	6,473	723	211,523	132,457	0
Fine Airlines	84,000	399	1,108	275,557	166,104	970
Florida West	8,821	-1739	1,440	56,916	34,146	0
Kitty Hawk	58,000	5,446	451	59,536	41,149	953
Northern Air Cargo	47,000	8,724	320	47,512	13,890	12,252
Zantop International	24,000	-10,788	765	57,648	12,190	989

Descriptive statistics regarding the aircraft fleets for Group I carriers are presented in Tables 4-15 and 4-16. The fleets vary in total size from 2 to 29 aircraft but are consistently older than those of other cargo carriers. In fact, the average aircraft age across all the Group I carriers exceeds 34 years. One-half of the carriers operate a fleet of aircraft from more than one manufacturer, while two carriers operate exclusively Boeing aircraft and two operate exclusively McDonnell Douglas aircraft. The 37 aircraft not included in Table 4-16 are 10 CV-600 operated by Kitty Hawk and the mixed fleet of Zantop International, which is composed of 17 L-188A, 9 CV-640, and 1 Beechcraft turboprop.

Table 4-15. Size and Age of U.S. Group I All-Cargo Carriers

Carrier	Number of aircraft	Average age
Amerijet International	12	26.75
Arrow Air	8	30.00
Express One International	16	29.00
Fine Airlines	12	31.25
Florida West	2	29.00
Kitty Hawk	22	34.86
Northern Air Cargo	15	42.07
Zantop International	29	38.62
Summary	116	34.28

Table 4-16. Fleet Composition of U.S. Group I All-Cargo Carriers

Carrier	Boeing 707-C	Boeing 727-100	Boeing 727-200	MDC 6A, B	MDC 8-5F	MDC 8-6F	MDC 8-6 series	DC-9-15F
Amerijet International		6	6					
Arrow Air						3	5	
Express One International		6	10					
Fine Airlines					9		3	
Florida West	1					1		
Kitty Hawk			7					5
Northern Air Cargo			1	14				
Zantop International					2			
Totals	1	12	24	14	11	4	8	5

Table 4-17 presents the direct operating costs on a per-available ton mile basis for the Group I all-cargo carriers. Again, there is a wide range between the lowest cost carriers and the highest. Strangely, the lowest cost carriers are also the least profitable. Although this observation appears to be a contradiction, there is a logical explanation. Recall that costs are measured on the basis of capacity as measured by available ton miles. Revenue, however, is derived on the basis of employed capacity as measured by revenue ton miles. Thus, if the utilization rate, measured by the weight load factor, is low, then the carrier could be unprofitable even as costs remain low.

Table 4-17. DOC/ATM for United States Group I All-Cargo Carriers

Carrier	1991	1992	1993	1994	1995
Amerijet International	$0.201	$0.240	$0.213	$0.215	$0.192
Arrow Air	0.170	0.143	0.142	0.167	0.194
Express One International				0.405	0.324
Fine Airlines					0.228
Florida West	0.156	0.110	0.141	0.181	0.129
Kitty Hawk					0.494
Northern Air Cargo	0.605	1.225	0.536	0.533	0.536
Zantop International	0.339	0.429	0.566	0.568	0.493

All-Cargo Aircraft from Passenger Carriers Analysis

The next category of air carriers considered is the category of passenger airlines with dedicated all-cargo aircraft. Currently, this category includes only three air carriers: United Airlines, Northwest Airlines, and Tower Air. Because of the integrated nature of these operations, the following cargo analysis attempts to isolate the effects of those aircraft within the context of their total fleets.

As of year-end 1995, Northwest Airlines operated a dedicated cargo fleet of 8 B747-F aircraft and a total passenger fleet of 380 aircraft. The dedicated cargo aircraft range in age from 10 to 22 years. Remarkably, the 8 dedicated cargo aircraft accounted for just over 56 percent of Northwest’s 1995 cargo revenue ton miles.

At year-end 1995, United Airlines operated a dedicated all-cargo fleet of 6 aircraft and a total passenger fleet of 575 aircraft. The dedicated cargo fleet consists of 2 converted 30-year-old B727-200s, 1 29-year-old converted 737-200, and 3 22-year-old 747-SP. At the same time, Tower Air operated 2 28-year-old B747-100F and a total passenger fleet of 17 aircraft. Unfortunately, in the case of United Airlines and Tower Air, the Form 41 reports are not sufficiently detailed to determine the proportion of total traffic accounted for by the dedicated all-cargo fleet.

Summary ratios regarding these three carriers are reported in Table 4-18. In the case of Northwest Airlines, the Form 41 reports contain sufficient detail to determine the direct operating costs for the dedicated cargo fleet independent of the passenger operations. Thus, the reported cost statistics apply only to the eight dedicated all-cargo aircraft. However, for both United Airlines and Tower Air, dedicated cargo operations cannot be separated and the cost calculations are subject to the joint production cost-allocation issues discussed in Chapter 2. The approach taken is to allocate costs incurred in the joint production of passenger and cargo service in proportion to the contribution to the carrier’s total revenue. At the industry level, cargo revenues average 1/20th of the passenger revenues.

Table 4-18. 1995 Summary Statistics for Cargo Aircraft in Passenger Fleets

Carrier	Cargo revenue/ total revenue	Cargo RTM/ total RTM	Cargo ATM/ total ATM	DOC/ATM	Cargo revenue /cargo RTM
United	0.054	0.089	0.033	$0.049	0.335
Northwest	0.088	0.264	0.381	$0.116	0.335
Tower	0.045	0.168	0.300	$0.030	0.387
Totals	0.050	0.156	0.299	$0.054	0.363

PASSENGER CARRIER ANALYSIS

The next category considered is the passenger carriers who do not use dedicated all-cargo aircraft. These carriers exclusively employ vacant capacity in the lower hold of passenger aircraft to transport revenue cargo. This category includes the 12 carriers specified in Table 4-19. Again, the issue of allocation of joint production costs introduces uncertainty into the problem of accurately determining the costs of cargo operations. The approach taken is to allocate joint production costs between passenger and cargo operations according to the contribution to total revenue. The statistics that specify the allocation are shown in

Table 4-19. The carriers United Airlines and Tower Air are also included in the analysis of this section, since it is not possible to isolate their dedicated all-cargo operations.

Table 4-19. 1995 Summary Statistics for Belly Cargo Passenger Carriers

Carrier	Cargo RTM (×1,000)	Cargo ATM (×1,000)	Passenger revenue (×$1,000)	Freight revenue (×$1,000)	Operating profit (×$1,000)
Alaska	75,486	436,980	958,411	59,098	72,424
America West	99,090	474,675	1,442,864	22,770	154,732
American	2,075,310	8,363,030	13,325,908	515,570	967,820
Continental	458,777	1,172,529	4,354,185	109,865	238,200
Delta	1,411,551	5,031,428	11,385,903	376,530	1,038,427
Northwest	2,253,541	5,392,359	7,761,950	615,203	910,224
Southwest	74,277	1,011,809	2,760,760	39,936	308,548
TWA	439,118	1,465,060	2,836,368	81,322	36,956
United	2,258,628	6,782,172	13,027,398	542,646	831,937
US Airways	262,917	1,937,649	6,267,762	79,499	234,651
Aloha	9,789	30,170	178,391	25,963	-9,262
Continental Micronesia	101,614	331,089	657,388	33,378	128,256
Hawaiian	48,183	188,152	297,527	12,981	2,060
Tower	48,665	325,498	271,378	5,362	13,516
All carriers	7,314,740	27,224,744	57,492,865	1,899,558	4,924,369

The productivity statistics shown in Table 4-20 present the statistical underpinnings of this industry analysis. The cargo load factor is quite low reflecting the fact that lower hold capacity is severely underutilized. The industry average is 27 percent and ranges from a low of 14 percent (US Airways) to a high of 42 percent (Northwest Airlines) if we include dedicated all-cargo aircraft, or 39 percent (Continental Airlines) if such traffic is excluded. It is tempting to conclude that the load factor statistics indicate that cargo is a minor concern for passenger carriers. However, the load factors also reflect the fact that cargo can only be transported to destinations that happen to coincide with scheduled passenger service. In addition, it is important to recognize that the load factor is computed on the basis of weight. Often times, however, cargo capacity may fill up on the basis of volume before it approaches the weight capacity limitations. Therefore, the weight load factor may not accurately reflect the true utilization of the cargo capacity.

Table 4-20. 1995 Productivity Statistics for Belly Carrying Passenger Carriers

Carrier	Cargo load factor	Cargo rev./ total revenue	Cargo RTM/ total RTM	Cargo ATM/ total ATM	DOC per ATM	Cargo rev./ cargo RTM
Alaska	0.173	$0.078	0.081	0.239	$0.094	$1.114
America West	0.209	$0.030	0.069	0.196	$0.039	$0.448
American	0.248	$0.048	0.168	0.350	$0.031	$0.322
Continental	0.391	$0.036	0.114	0.178	$0.065	$0.358
Delta	0.281	$0.045	0.142	0.279	$0.043	$0.380
Northwest	0.418	$0.088	0.264	0.381	$0.055	$0.335
Southwest	0.073	$0.023	0.031	0.218	$0.028	$0.886
TWA	0.300	$0.048	0.149	0.277	$0.046	$0.326
United	0.333	$0.054	0.168	0.300	$0.049	$0.335
US Airways	0.136	$0.024	0.064	0.248	$0.034	$0.584
Aloha	0.324	$0.148	0.123	0.215	$0.581	$3.167
Continental Micronesia	0.307	$0.068	0.177	0.311	$0.050	$0.493
Hawaiian	0.256	$0.049	0.118	0.287	$0.048	$0.347
Tower	0.150	$0.045	0.089	0.330	$0.030	$0.387
Averages	0.269	$0.045	0.139	0.287	$0.042	$0.371

THE UNITED STATES POSTAL SERVICE

The United States Postal Service (USPS) is a significant force in the air cargo industry. Although the USPS owns no aircraft of its own, it leases space on both domestic and international flights as part of the mail delivery system. In 1995, the USPS leased space on 74 commercial airlines (up from 65 in 1994) to deliver more than 2.5 billion pounds of domestic mail. Of the 56,000 flights available daily, the USPS uses 15,000 of them. This domestic air transportation cost $1.58 billion in 1995. Another $265 million was spent for international air transportation, with United States flag carriers receiving $217 million and $48 million going to foreign-owned carriers.

Twenty-three of these 74 commercial carriers are included in this study.[7] These carriers account for $1.23 billion of the $1.58 billion in USPS's domestic air transportation costs (almost 80 percent).[8] Ten airlines handle 80 percent of this volume while 5 carriers receive more than 70 percent of the revenues (United, Emery, Delta, American, and Northwest-in descending order). These 5 carriers are also the only carriers to receive more than 10 percent of the mail revenues. Two additional carriers receive at least 5 percent of the mail revenues, USAirways and

[7] The missing carriers are the non-Group III carriers who do not own any cargo aircraft. This list would include national carriers such as Air Wisconsin and Horizon Air, as well as regional carriers such as AV Atlantic and Executive Airlines.

[8] The Air Transport Association lists 1995 domestic mail revenues as $1.05 billion and 1995 international mail revenues as $216 million for its members. If this is correct, the total domestic mail revenues sum to $1.266 billion, which is very close to the $1.232 billion calculated here. In this case, the listed carriers account for more than 97 percent of the domestic total.

TWA. When added to the first 5, these top 7 carriers account for more than 80 percent of the mail revenues.

On average, the carriers derive less than 1.5 percent of their operating revenues from mail service. However, smaller carriers tend to have a greater proportion of revenue derived from mail service. At one extreme are Emery, Northern Air Cargo, and Evergreen—for which the proportion of total revenue from mail totals 69, 41, and 15 percent, respectively. The average for Group III carriers is 1.12 percent. The highest percentage among Group III carriers is 1.89 at TWA, which is very near the average of 1.94 percent for the all-cargo carriers. The summary statistics are shown in Table 4-21.

The implication of these data is that most carriers use mail service as a way of filling excess cargo capacity. The rates are not highly profitable but when daily capacity is viewed as a perishable product, it represents an easy revenue stream. This is the rule for most carriers, with Emery, Northern Air Cargo, and Evergreen being the exceptions. A significant portion of their revenues and profits and, therefore, route structure and operations, are tied to mail service. For these carriers, the USPS is viewed as a “primary” customer as opposed to a customer simply purchasing excess capacity.

Table 4-21. Summary Statistics for U.S. Mail Services

Carrier	Group	1995 operating revenue (×$1,000)	1995 mail revenue (×$1,000)	1995 domestic market shares mail revenue	Mail rev./ operating revenue
Passenger cargo operations					
Alaska Airlines	III	1,162,878	20,173	1.6%	1.73%
Aloha Airlines	II	213,689	5,041	0.4%	2.36%
America West	III	1,561,849	21,655	1.8%	1.39%
American Airlines	III	15,610,201	152,406	12.4%	0.98%
Continental Airlines	III	4,919,025	54,311	4.4%	1.10%
Continental Micronesia	II	785,590	16,715	1.4%	2.13%
Delta Airlines	III	12,557,276	160,023	13.0%	1.27%
Hawaiian Airlines	II	3,724,677	346,904	0.3%	1.07%
Northwest Airlines	III	8,908,851	136,047	11.0%	1.53%
Southwest Airlines	III	2,873,482	25,889	2.1%	0.90%
Tower Air	II	490,473	0	0.0%	0.00%
Trans World Airways	III	3,280,888	61,847	5.0%	1.89%
United Airlines	III	14,894,761	214,350	17.4%	1.44%
USAir	III	6,984,876	74,151	6.0%	1.06%
Subtotal		74,590,743	946,332	76.8%	1.27%

Table 4-21. Summary Statistics for United States Mail Services (Continued)

Carrier	Group	1995 operating revenue (×$1,000)	1995 mail revenue (×$1,000)	1995 domestic market shares mail revenue	Mail rev./ operating revenue
All Cargo Operations					
Air Transport International	II	130,608	0	0.0%	0.00%
American International Airways	II	369,636	0	0.0%	0.00%
Amerijet International	IA	51,959	304	0.0%	0.59%
Arrow Air	IA	51,112	30	0.0%	0.06%
Atlas Air	II	141,066	0	0.0%	0.00%
Challenge Air Cargo	II	108,236	1,202	0.1%	1.11%
DHL	II	958,668	5,249	0.4%	0.55%
Emery Worldwide	II	296,414	203,067	16.5%	68.51%
Express One International	IA	9,623	0	0.0%	0.00%
Evergreen	II	219,775	33,182	2.7%	15.10%
Federal Express	III	9,825,586	22,105	1.8%	0.22%
Fine Airlines	IA	83,612	0	0.0%	0.00%
Florida West Airlines	IB	8,821	0	0.0%	0.00%
Kitty Hawk	IA	57,506	1,586	0.1%	2.76%
Northern Air Cargo	IA	47,498	19,318	1.6%	40.67%
Polar Air Cargo	II	234,758	0	0.0%	0.00%
Southern Air Transport	II	175,747	0	0.0%	0.00%
Sun Country Airlines	II	202,199	0	0.0%	0.00%
UPS	III	1,629,607	0	0.0%	0.00%
Zantop International	IA	24,478	0	0.0%	0.00%
Subtotal		14,713,520	286,044	23.2%	1.94%
Group I subtotal		421,221	21,239	1.7%	5.04%
Group II subtotal		4,673,762	268,181	21.8%	5.74%
Group III subtotal		84,209,280	942,957	76.5%	1.12%
Total		89,304,263	1,232,376	100.0%	1.38%

Chapter 5
United States Equipment-Level Analysis

Whereas the analysis in the previous chapter focused on the fleet-wide operations of individual carriers, this chapter investigates the industry-wide operations of specific aircraft types. The main advantage of this equipment-level approach is the elimination of inaccuracies from variation in productivity characteristics across equipment types within the same carrier. However, the equipment-level approach introduces its own inaccuracies from variations across carriers operating the same equipment. Nevertheless, the equipment-level approach is preferred to the carrier-level approach because the variation in productivity across equipment types for a given carrier is larger than the variation across carriers for a given aircraft type.

Because the Form 41 reports for passenger carriers are not sufficiently detailed to isolate cargo operations, we constrain the equipment-level analysis to the fleets of cargo-only carriers and the dedicated all-cargo aircraft of Northwest Airlines. Thus, the issue of cost allocation between passenger and cargo operations is not a limitation on the equipment-level analysis. However, for some equipment types, the DOT Form 41 traffic and cost reports do not distinguish between all-cargo aircraft originally delivered as freighters and those that were converted from passenger operations. Since the performance characteristics of the two may differ, an additional degree of uncertainty is introduced in the Form 41 data.

The underlying goal of the equipment analysis is to determine the direct operating costs for each type of equipment and subsequently identify the set of lowest cost aircraft. This efficient set will then determine the productivity envelope that any new design must meet.

The remainder of this chapter proceeds as follows. First, we present an overview of the cargo-only fleet and then examine the proportion of revenue traffic attributable to each aircraft type. Then we examine the most prolific aircraft types in more detail. Changes in aircraft productivity statistics are examined across the 5-year period 1991 through 1995. This analysis ultimately leads to the calculation of direct operating costs for each equipment type. Next, we investigate the relationship between equipment-level DOC and average stage length. The result is the identification of an efficient set of aircraft that depends upon the average stage length desired.

OVERVIEW OF EQUIPMENT TYPES

A wide variety of aircraft exist in the cargo-only fleet. Table 5-1 details the equipment types and presents several descriptive statistics. By convention, the aircraft types with the "-F" extension represent aircraft that were originally delivered as freighters. Conversely, all-cargo aircraft without the "-F" extension were converted from passenger aircraft. Clearly, the most numerous aircraft in the fleet are the Boeing 727, Cessna C-208, and combined DC-8 series.

Table 5-1. Fleet Equipment-Level Mix

Aircraft type	Number	Avg. year of entry	Avg. age (Sept. 97)	Standard deviation of age
A300-600	13	1994	3.21	0.52
A310-2CF	23	1983	13.88	0.81
B-707-3C	5	1965	31.95	3.49
B-727-1	200	1966	31.15	1.11
B-727-2	142	1976	21.42	5.03
B-727-200	7	1972	25.04	3.50
B-737-2	3	1969	28.75	0.00
B-737-4	1	1993	4.75	0.00
B-737-5	1	1992	5.75	0.00
B-747	22	1971	26.57	1.59
B-747-1	4	1970	27.00	0.96
B-747-100	12	1970	27.58	0.58
B-747-2	4	1978	19.25	3.11
B-747-2/3	12	1975	22.17	3.12
B-747-F	13	1978	19.75	4.97
B-757	58	1991	6.51	2.90
B-767-3	5	1995	2.75	0.00
Beechcraft C90	1	1982	15.75	0.00
Bell-20A	1	1975	22.75	0.00
C-208	250	1989	8.21	2.74
CV-600	6	1948	49.25	0.84
CV-640	13	1954	43.06	3.75
MD-11	15	1992	5.22	1.25
DC-10-1	13	1975	22.37	2.72
DC-10-3	22	1978	18.93	4.03
DC-10-30	2	1975	22.75	2.83
DC-6A	14	1954	43.32	2.06
DC-6B	4	1954	43.00	2.22
DC-8-52	1	1966	31.75	0.00
DC-8-5F	23	1965	32.75	1.83
DC-8-61	8	1967	30.00	1.39
DC-8-61F	1	1968	29.75	0.00

Table 5-1. Fleet Equipment-Level Mix (Continued)

Aircraft type	Number	Avg. year of entry	Avg. age (Sept. 97)	Standard deviation of age
DC-8-62	16	1968	29.13	1.67
DC-8-63	2	1969	28.25	0.71
DC-8-6F	13	1968	29.21	2.44
DC-8-71	32	1967	29.84	0.73
DC-8-71F	1	1969	28.75	0.00
DC-8-73CF	1	1970	27.75	0.00
DC-8-73F	45	1968	28.82	0.75
DC-8F-5	3	1963	34.42	2.08
DC-8F-62	1	1967	30.75	0.00
DC-9-15	10	1967	30.65	0.32
DC-9-15F	5	1967	30.55	0.45
DC-9-30	6	1968	29.42	0.52
F-27	32	1973	24.75	6.67
FH-227	11	1983	14.75	0.00
L-1011	4	1980	17.75	0.82
L-188A	17	1959	38.75	0.61
L-322E	15	1970	27.62	3.27
Total	1,113	1976	21.35	11.10

From the average aircraft age statistics, it is clear that the DC-8 and Boeing 727-100 series aircraft are likely to be retired from the fleet in the near future. Technologically, these aircraft are representative of past generations of passenger aircraft. Conversely, the youngest aircraft types represent the future of air cargo operations. These include the Airbus A300-600 series, the MD-11, and the Boeing 757 and 767-3 aircraft.

In the interest of brevity, we further restrict our equipment analysis to the predominant aircraft during calendar year 1995 as measured by either the number of aircraft in use or the total revenue traffic transported.[1] We used a cutoff of 20 aircraft years of use or 500 million revenue ton miles. The 13 indicated aircraft highlighted with bold typeface in Table 5-2 and depicted in Figure 5-1 represent only 57 percent of the total all-cargo aircraft in use during 1995 but they account for 82 percent of the all-cargo revenue ton miles. Thus, the calculation of DOC and other productivity measures for these aircraft represent a substantial majority of the system-wide operating characteristics. These aircraft, therefore, represent the minimum operating standard that any new all-cargo aircraft design must meet. Finally, for the sake of comparison, the cargo capacities of the individual cargo aircraft are shown in Table 5-3.

[1] Our measure of the number of aircraft in use during a calendar year is the concept of aircraft years. One aircraft year is one aircraft in service for 365 days.

Table 5-2. Types of Aircraft and Utilization Analysis of the U.S. Flag Cargo Fleet

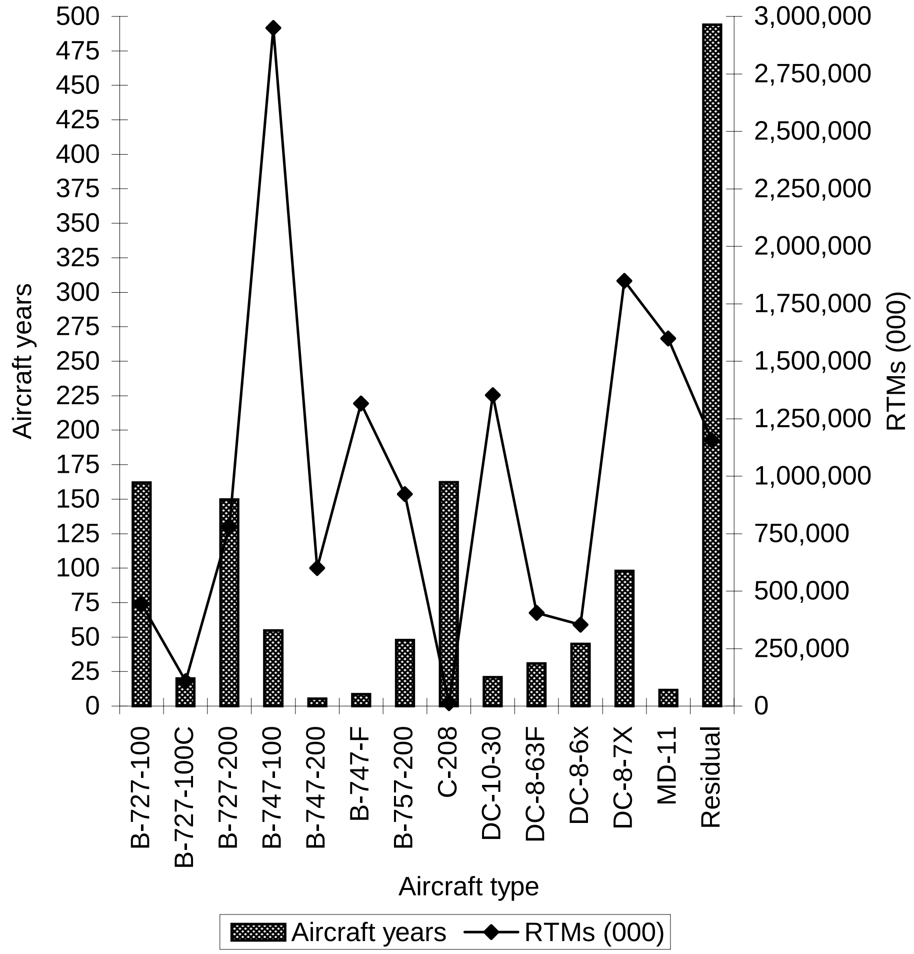
Aircraft name*	1995 aircraft years	1995 RTMs (000)
Lockheed-1011	1	11,871
Airbus-300	9	301,454
Airbus-310	11	179,132
Cessna-208	162	12,503
Lockheed-188	5	8,964
MD-11	11	1,599,150
Douglas-10-30	20	1,352,743
Douglas-10-10	11	411,024
Douglas-9-30	1	19,363
Douglas-9-15F	10	8,340
Douglas-8-73F	15	283,058
Douglas-8-7X	97	1,849,430
Douglas-8-63F	30	404,939
Douglas-8-6X	45	353,208
Douglas-8-50F	16	254,143
Douglas-6	14	24,457
Boeing-707-300C	3	109,831
Boeing-727-100	162	443,516
Boeing-727-100C	20	108,535
Boeing-727-200	150	781,933
Boeing-747-100	55	2,949,550
Boeing-747-200/300	5	600,649
Boeing-747-F	8	1,316,289
Boeing-757-200	48	922,069
Boeing-767-300/ER	1	78,426
Residual	494	1,154,822

*Note: Aircraft with bold typeface account for 82 percent of the all-cargo revenue ton miles.

Table 5-3. Cargo Capacity of Freighter Aircraft

Name	Type	Cargo capacity (lbs.)
Boeing 727-200F	Narrow body turbofan	62,000
Boeing 737-200	Narrow body turbofan	35,170
Boeing 757-200F	Narrow body turbofan	85,770
DC-8-63F	Narrow body turbofan	109,217
DC-9-30F	Narrow body turbofan	41,500
A300-600F	Wide body turbofan	112,760
Boeing 747-200C	Wide body turbofan	228,500
Boeing 747-200F	Wide body turbofan	245,300
Boeing 747-400F	Wide body turbofan	268,300
Boeing 767-300F	Wide body turbofan	228,500
DC-10-30CF	Wide body turbofan	177,000

Figure 5-1. Utilization by Aircraft Type for 1995



FLEET-WIDE ANALYSIS

The fleet-wide data in Table 5-4 show an undeniable historic increase in stage length, block hours, ATM/departure, cargo RTM, cargo ATM, and load factor. In short, over the past 5 years, cargo aircraft are flying longer, farther, and are more fully loaded than in previous years. However, the DOC per ATM does not exhibit a downward trend. The increasing factors of stage length, block hours, and load factor may lead to a declining operating cost per ATM over time. In this case, the measure of increasing ATM/departure implies that larger (and usually more fuel-inefficient) aircraft are being added to the fleet. The increasing trend in aircraft years (an aggregate measure of number of aircraft in service) prior to 1995 confirms this. This can be attributed to more aircraft being added to the fleet to service new demand. The decrease in aircraft years and DOC in 1995 is most likely the result of a more efficient use of the existing fleet occurring at the level of the firm.

Table 5-4. Summary Statistics, Fleet-Wide, at the Equipment Level

Parameter	1991	1992	1993	1994	1995
Stage length	992	1,375	1,299	1,379	1,402
Block hours	1,863,568	2,086,085	2,215,843	2,373,026	2,523,961
ATM/departure	40,593	60,591	60,412	62,938	67,427
Cargo RTM (millions)	8,191	10,355	11,458	13,548	15,541
Cargo ATM (millions)	26,709	28,825	29,955	32,989	36,067
Load factor	30.67	35.93	38.25	41.07	43.09
Aircraft years	863	1,063	1,183	1,417	1,412
DOC/ATM	0.16926	0.14613	0.15162	0.17020	0.12294

AIRCRAFT ANALYSIS

This section analyzes the 13 all-cargo aircraft (or equipment) types. Five years worth of historical statistics are presented regarding the operating characteristics of each aircraft, the number of aircraft in use, and the direct operating costs per available ton mile. Compound annual growth rates are computed for selected statistics.

Boeing 727 Series

The Boeing 727 series is the primary aircraft choice in the short haul, all-cargo aircraft market. This series, which consists of the -100, -100C/QC, and -200 models, has the greatest number of aircraft in the fleet. The equipment-level summary statistics for each aircraft model are shown in Tables 5-5, 5-6, and 5-7 respectively.

Table 5-5. Equipment-Level Analysis: Boeing 727-100

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	525	519	561	551	552	1.01
ATM/departure	11,187	11,128	11,634	11,369	11,368	0.32
Aircraft years	122.8	158.7	166.4	210.4	162.0	5.70
ATM/gallon fuel	6.619	7.454	6.931	6.521	6.666	0.14
Total RTMs (000s)	411,915	446,109	480,854	504,577	443,516	1.49
Percent of airline total	5.03	4.31	4.20	3.72	2.85	-10.7
Load factor	56.1	56.2	56.9	56.6	54.8	-0.47
Scheduled ATM/total ATM	78.0	78.9	94.7	89.2	83.1	1.27
DOC/ATM	0.721	0.704	0.639	0.610	0.679	-1.19

Table 5-6. Equipment-Level Analysis: Boeing 727-100C/QC

Parameter	1992	1993	1994	1995	Compound annual % change
Stage length	718	686	451	447	-11.2
ATM/departure	14,017	13,461	8,898	8,746	-11.1
Aircraft years	0.5037	0.9993	27.093	20.038	151.1
ATM/gallon fuel	6.0783	5.9539	5.0839	5.2403	-3.64
Total RTMs (000's)	49,501	109,040	101,360	108,535	21.69
Percent of airline total	0.48	0.95	0.75	0.70	9.89
Load factor	63.44	65.87	63.70	64.97	0.60
Scheduled ATM/total ATM	0.00	0.00	0.54	2.14	
DOC/ATM	0.2393	0.3210	0.3289	1.0351	44.21

Table 5-5 indicates that the operating characteristics of the 727-100 model have remained remarkably constant over the past 5 years. These statistics attest to the renowned reputation of the 727-100 as a steady performer. The total number of aircraft in service was steadily rising prior to 1994 but has since declined during 1995. The fact that the percentage of traffic carried has declined over the 5-year period indicates that growth in the number of 727-100s has failed to keep pace with industry-wide growth. This is not unexpected for an aircraft of considerable age, which was last produced almost 20 years ago.

The Boeing 727-100C/QC is the convertible version of the 727-100, which may be outfitted for cargo or passenger service, or some combination of both. From the Form 41 statistics, it would appear that the performance characteristics of the -100C/QC series differs considerably from the standard -100 series. However, such differences also reflect differences in ownership, utilization, and network. Furthermore, the discrepancies may be exaggerated in the earlier years because of the small number of C/QC aircraft. The 1995 observation for DOC per ATM is an anomaly caused by charges to retire several aircraft and should not be treated as representative.

The Boeing 727-200 is a stretched derivative of the -100 series with a 50 percent increase in both passenger and lower hold cargo capacity. As a result, the 1995 RTMs for the -200 series are almost double those of the -100 series even though the number of aircraft years is approximately the same. Like the other two aircraft in this series, it is a short-haul aircraft, whose stage length is decreasing and simultaneously driving down the ATM/departure ratio. The fuel efficiency is marginally increasing, although its magnitude is much higher than the -100 series due to, for the most part, its larger size. Its RTMs are increasing but not at a rate equal to industry growth; so its percentage of the total is dropping. The load factor is marginally decreasing while the ATM ratio is dropping even faster. The DOC per ATM ratio is marginally increasing, but at a rate much less than would be normally expected for the drop in stage length. The 1995 DOC/ATM compares quite favorably with the other models.

Table 5-7. Equipment-Level Analysis: Boeing 727-200

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	773	732	669	640	560	-7.74
ATM/departure	22,778	21,445	19,320	18,304	15,790	-8.75
Aircraft years	55	76	83	121	149	28.29
ATM/gallon fuel	8.80	10.28	9.05	8.06	7.58	-3.66
Total RTMs (000's)	558,003	663,920	712,451	820,191	781,933	8.80
Percent of airline total	6.81	6.41	6.22	6.05	5.03	-7.29
Load factor	61.3	59.3	57.8	57.4	55.1	-2.63
Scheduled ATM/total ATM	97.5	95.5	98.9	91.2	85.0	-3.37
DOC/ATM	0.4399	0.4456	0.4561	0.4089	0.4804	2.23

Boeing 747

The Boeing 747 equipment is a series of three aircraft that are the major long-haul carrier of the fleet. Although there are multiple derivatives in the 747 type, the three most important for the cargo industry are the original -100 series, the extended range -200 series, and the companion freighter version. More recently, however, the 747-400F has been gaining in popularity. The equipment-level summary statistics for each aircraft type are shown in Tables 5-8 to 5-10, respectively.

Table 5-8. Equipment-Level Analysis: Boeing 747-100

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	2,479	2,206	2,766	2,845	2,223	-2.69
ATM/departure	271,947	237,009	296,401	292,491	244,448	-2.63
Aircraft years	2.218	3.291	10.22	12.41	31.03	93.40
ATM/gallon fuel	12.85	10.72	11.59	12.80	12.79	-0.12
Total RTM (000's)	122,942	103,956	331,824	933,942	1,650,009	91.40
Percent of airline total	18.6	6.8	17.1	31.4	38.3	19.79
Load factor	61.3	62.3	44.4	58.3	64.4	1.24
Scheduled ATM/total ATM	0.00	0.00	34.4	57.7	47.6	
DOC/ATM	0.5941	0.4244	0.1032	0.1079	0.1031	-35.46

Table 5-9. Equipment-Level Analysis: Boeing 747-200

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	2,106	1,937	1,880	2,028	2,193	1.02
ATM/departure	24,333	223,986	228,056	243,876	216,733	72.76
Aircraft years	11.80	8.92	6.40	5.27	5.45	-17.56
ATM/gallon fuel	14.24	17.22	16.60	14.86	12.16	-3.87
Total RTMs (000's)	1,156,970	878,562	569,333	568,411	600,649	-15.12
Percent of airline total	14.13	8.48	4.97	4.20	3.86	-27.70
Load factor	55.8	59.4	55.6	56.4	70.0	5.83
Scheduled ATM/total ATM	63.7	68.1	50.7	44.7	40.5	-10.70
DOC/ATM	0.2099	0.2122	0.2103	0.2085	0.2773	7.21

Table 5-10. Equipment-Level Analysis: Boeing 747F

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	2,210	2,218	2,212	2,241	2,265	0.62
ATM/departure	234,389	235,219	235,261	239,070	239,989	0.59
Aircraft years	7.99	8.02	7.99	7.99	8.60	1.83
ATM/gallon fuel	13.080	13.480	13.428	13.373	13.207	0.24
Total RTMs (000's)	1,070,121	1,128,354	1,172,575	1,224,797	1,316,289	5.31
Percent of airline total	13.06	10.90	10.23	9.04	8.47	-10.3
Load factor	69.04	70.30	73.08	76.81	76.89	2.73
Scheduled ATM/total ATM	96.54	99.35	99.67	99.30	96.49	-0.01
DOC/ATM	0.1468	0.1304	0.1244	0.1216	0.1668	3.35

In terms of RTMs, the -100 series is the workhorse of the cargo fleet. Although it is only the sixth highest in aircraft years (or equivalent number of aircraft), it is by far the leader in RTMs. The stage length is over 2,200 miles, although it has been decreasing over the past 5 years. The increase in aircraft years has been matched by the increase in RTMs indicating that the utilization remains relatively constant. This one aircraft type accounted for almost 40 percent of the airline total RTMs in 1995. Its load factor has been marginally increasing while the share of total traffic derived from scheduled operations averages about 50 percent. The DOC per ATM is just above $0.10, which reflects the tremendous returns to scale in aircraft size.

The -200 series is the extended range version of the original -100 series. Its average stage length and fuel efficiency numbers match that of the original, but all other summary statistics differ. The ATM per departure ratio, aircraft years, and total RPM are all lower. The overall volume of traffic handled by the -200 series had been falling prior to 1994 but has rebounded slightly in

1995. This decline in traffic is the result of declining numbers of -200 aircraft in the fleet. The load factor is quite high, but the drop in ATM ratio suggests a transition from primarily scheduled to nonscheduled service, which is usually accompanied by a transfer of operations to a lower DOT revenue group. The DOC/ATM has been double that of the -100 series for most of the past 5 years, with the exception of 1995 when there was a jump to $0.28 per ATM. However, because of the small number of aircraft in the fleet, these statistics should be interpreted with caution.

Boeing 757-200

The Boeing 757 represents a relatively new narrow body design. Deliveries of this passenger aircraft type began in 1982. Its equipment-level summary statistics are shown in Table 5-11. Its stage length has been relatively constant over the past 5 years, hovering near the low end of the long-haul range. Its ATM/departure rate, fuel efficiency, and load factor also have remained relatively constant over this period. Its ATM/departure is about 50 percent higher than the Boeing 727 series.

Table 5-11. Equipment-Level Analysis: Boeing 757-200

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	808	765	791	853	819	0.34
ATM/departure	35,318	33,586	35,214	38,009	36,435	0.78
Aircraft years	11.92	25.12	38.08	54.47	47.91	41.59
ATM/gallon fuel	15.59	15.99	16.14	16.60	16.31	1.14
Total RTMs (000's)	232,770	506,101	648,415	814,126	922,069	41.08
Percent of airline total	2.84	4.89	5.66	6.01	5.93	20.21
Load factor	53.6	55.9	54.9	54.3	52.6	-0.47
Scheduled ATM/Total ATM	38.7	35.3	100.0	78.7	53.8	8.58
DOC/ATM	0.4145	0.2273	0.2058	0.1909	0.2075	-15.89

The statistics for the freighter are much closer to the -100 series than the -200 series. Both stage length and ATM/departure are quite similar. The number of aircraft years are substantially less than the -100 but more than the -200. Fuel efficiency is somewhat lower. The total RTMs are the 5th highest in the fleet while the aircraft years are 13th, which is expected of the long haul leader. The high percentage of traffic derived from scheduled operations suggests a usage that is almost exclusively scheduled service. The fuel efficiency is lower than the other two models. This may be explained by the difference in construction techniques used in the original freighter and the modified passenger versions. This is an old aircraft that is slowly losing RTMs to other aircraft. Although the aircraft years have remained relatively constant and the total RTMs have increased, they have not increased at the rate equal to industry growth. Hence the percentage of the airline total is dropping. Finally its DOC/ATM lies between that of the -100 series and the -200.

Douglas DC-8 Series

The DC-8-6X series is the amalgamation of 26 converted passenger aircraft, with an average age of 30 years. They are the narrow body aircraft with the largest capacity. Its equipment-level summary statistics are shown in Table 5-12. The rapid increase in aircraft years indicate that large numbers of the aircraft have been put into usage within the past few years. Both the ATM per departure ratio and the average stage length reflect the fact that these newly added aircraft are being flown on relatively shorter routes. The total number of RTMs flown has increased. This fact, in conjunction with the drop in stage length, has placed negative pressure on the fuel efficiency measure. The increase in RTMs has not kept pace with the overall growth of the industry, resulting in a declining share of the industry total. The load factor has been trending down and is now less than 50 percent. It is primarily used to service nonscheduled demand, which in part, explains the high variation in the data. The DOC per ATM is increasing as the aircraft years grow.

Table 5-12. Equipment-Level Analysis: Douglas DC-8-6X Series

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	1584	760	828	913	1063	-9.49
ATM/departure	70,401	31,933	33,925	37,558	43,125	-11.53
Aircraft years	4.89	24.12	21.79	35.09	37.00	65.85
ATM/gallon fuel	9.30	8.29	8.33	9.10	6.48	-8.64
Total RTMs (000's)	74,898	255,311	243,050	265987	265,761	37.25
Percent of airline total	11.4	16.6	12.5	8.9	6.2	-14.12
Load factor	64.4	60.7	61.3	52.5	49.1	-6.56
Scheduled ATM/total ATM	21.8	0.0	5.5	4.8	11.3	-15.15
DOC/ATM	0.4951	0.0706	0.0871	0.1301	0.1669	-23.80

The DC-8-7X series is the next generation of the DC-8-6X series. Since it is technically newer, it should have a lower DOC, all else constant. The summary statistics are shown in Table 5-13. The stage length has declined slightly over the past few years as has the ATM/departure and the DOC/ATM ratios. The aircraft years have almost doubled over the period of interest while the fuel efficiency has remained unchanged, implying that large numbers of the aircraft have been added to the cargo fleet, but they have been added and used in a manner consistent with the previous usage pattern. The total RTMs flown have increased more than 3.5 times, and this rate has been above the industry-wide growth in cargo; so its share of the industry total has been increasing. The load factor has seen a small but steady growth rate while the scheduled

ATM ratio has fluctuated. The decline in the DOC/ATM has been relatively constant, implying that the aircraft are being used more efficiently over time.

Table 5-13. Equipment-Level Analysis: Douglas DC-8-7X Series

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	1,197	1,167	1,099	992	1,167	-0.63
ATM/departure	59,549	59,417	55,116	53,366	58,314	-0.52
Aircraft years	49.1	80.6	101.1	121.6	97.9	18.83
ATM/gallon fuel	12.42	12.53	11.94	11.65	12.54	0.24
Total RTMs (000's)	534,641	1,017,718	1,222,373	1,530,928	1,849,430	36.38
% of airline total	6.5	9.8	10.7	11.3	11.9	16.32
Load factor	52.1	54.6	59.5	58.4	58.9	3.11
Scheduled ATM/total ATM	13.2	37.6	89.0	64.3	46.3	36.85
DOC/ATM	0.504	0.250	0.214	0.189	0.186	-22.06

The DC-8-63F is the freighter version of the DC-8-63. The comparisons between the two are not valid due to vast differences in numbers and usage. The summary statistics are shown in Table 5-14. The average stage length and ATM/departure ratio have been declining steadily at nearly the same rate. The aircraft years have been fluctuating but the trend is definitely increasing. This fact might result from the fact that many aircraft have come into service in such a short time period. This rapid ramp up may have precluded the matching of aircraft with optimal routes. This hypothesis is supported by the increase in fuel efficiency in spite of declining stage length and ATM/departure. RTMs have increased almost fourfold over the same time frame. This rate exceed the overall industry growth rate and causes the percentage of traffic attributable to the aircraft type to rise. The load factor has been increasing, while the scheduled ATM ratio has dropped to under 10 percent. Consistent with a drop in stage length and ATM per departure, the DOC/ATM has increased by 50 percent over the same period.

Table 5-14. Equipment-Level Analysis: Douglas DC-8-63F Series

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	1,747	875	1,027	1,062	953	-14.06
ATM/departure	90,739	43,971	49,085	51,108	45,783	-15.72
Aircraft years	0.9883	16.205	17.861	46.652	30.803	136.28
ATM/gallon fuel	11.952	9.9553	9.5608	10.818	9.6037	-5.32
Total RTMs (000's)	105,689	376,418	515,324	452,817	404,939	39.91
% of airline total	1.29	3.63	4.50	3.34	2.61	19.26
Load factor	53.04	60.95	63.98	59.91	59.86	3.07
Scheduled ATM/total ATM	29.55	2.57	7.26	5.81	9.46	-24.78
DOC/ATM	0.1587	0.0894	0.1082	0.1354	0.2310	9.84

Douglas DC-10-30

The DC-10-30 is one of the smaller wide-body aircraft in terms of cargo capacity. Although there are only 20 aircraft in the fleet, they accumulate a disproportionate share of the RTMs. The summary statistics are shown in Table 5-15. Although the stage length and ATM per departure ratios have been marginally decreasing, the DC-10 consistently operates in the mid long-haul range. Fuel efficiency has been decreasing, which is consistent with the drop in stage length. The traffic flown by the DC-10 series has steadily increased at a rate below the industry average. The result is that the percentage of total traffic attributable to the DC-10-30 has declined. The load factor has been relatively constant at about 60 percent, which can be expected when the scheduled ATM ratio is above 90 percent. The DOC/ATM has been stable over this period at about $0.19.

Table 5-15. Equipment-Level Analysis: Douglas DC-10-30

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	1,762	1,780	1,768	1,600	1,581	-2.67
ATM/departure	153,733	154,033	152,124	137,466	134,675	-3.25
Aircraft years	15.52	17.65	17.92	18.64	20.91	7.74
ATM/gallon fuel	15.68	18.56	17.24	15.36	15.09	-0.96
Total RTMs (000's)	1,201,303	1,392,305	1,287,743	1,181,688	1,352,743	3.01
% of airline total	14.7	13.5	11.2	8.7	8.7	-12.24
Load factor	60.4	61.8	60.9	60.4	59.8	-0.25
Scheduled ATM/total ATM	93.5	97.0	98.6	98.6	98.6	1.33
DOC/ATM	0.1978	0.1746	0.1947	0.1917	0.1886	-1.19

McDonnell Douglas MD-11

The MD-11 is the workhorse of the cargo fleet. Both the stage length and ATM/departure ratio is at the far end of the long-haul market. Since the aircraft type is relatively new, the aircraft years have been steadily increasing, which reflects new aircraft added to the fleet. Of special note is that this aircraft is now being delivered almost exclusively in a cargo, rather than passenger, version. The fuel efficiency has been relatively constant over the period of interest. The RTMs flown have increased by more than 13-fold while the 15 aircraft account for slightly more than 10 percent of the fleet total RTMs. The load factor is consistently in the mid to high 60th percentile, which is highly correlated to the scheduled ATM ratio of above 99 percent. The summary statistics are shown in Table 5-16.

Table 5-16. Equipment-Level Analysis: MD-11

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	2,225	2,145	2,200	2,280	2,384	1.75
ATM/departure	221,594	213,318	218,459	225,806	235,673	1.55
Aircraft years	1.44	4.02	8.02	11.58	11.56	68.26
ATM/gallon fuel	19.39	22.76	21.19	18.87	18.94	-0.59
Total RTMs (000's)	122,962	412,625	1,030,372	1,613,890	1,599,150	89.90
% of Airline total	1.50	3.98	8.99	11.91	10.29	61.84
Load factor	64.4	64.3	64.2	69.6	68.1	1.40
Scheduled ATM/total ATM	100.0	100.0	99.2	99.8	99.95	-0.01
DOC/ATM	0.170	0.1696	0.1425	0.1417	0.1527	-2.66

Cessna C-208

The Cessna C-208 is something of an anomaly in this analysis. It is a turboprop aircraft operated exclusively by Federal Express and performs a major function of their spoke service. This aircraft enables them to offer express services to a wide area that could not be serviced by road vehicles in the same time span. The summary statistics are shown in Table 5-17. They are all relatively unchanged over the period of interest. This is due to the standardization of the network functions that these aircraft serve. The stage length is theoretically below the short-haul limit because the distance of 150 miles could be easily covered by trucks in areas where the road networks are good. The available ton miles are also extremely low, reflecting both the stage length and the characteristics of the goods being shipped. The fuel efficiency is by far the worst in the fleet, and is, in fact, lower than some forms of ground transport. Its RTM growth almost matches that of the industry, leaving its industry total almost unchanged over the period of interest. Its load factor is marginally increasing—the outcome of increased RTM growth while not increasing the equipment type. The scheduled ATM ratio is 100 percent and the DOC per ATM is at an industry high of near $2.50.

Table 5-17. Equipment-Level Analysis: Cessna C-208

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	149	144	147	146	147	-0.34
ATM/departure	262	252	256	255	257	-0.48
Aircraft years	138.95	149.77	149.86	150.80	162.24	3.95
ATM/gallon fuel	2.34	2.44	2.48	2.40	2.52	1.87
Total RTMs (000's)	10,492	11,393	11,894	12,185	12,503	4.48
% of airline total	0.15	0.13	0.13	0.12	0.12	-5.43
Load factor	39.4	42.7	43.0	44.2	44.6	3.15
Scheduled ATM/total ATM	100	100	100	100	100	0.00
DOC/ATM	2.3446	2.4403	2.4807	2.4004	2.5239	1.86

Fleet Residual

The last aircraft type to be analyzed will be the residual category. This equipment type represents the combined data for all equipment types except those listed in Table 5-2. The size of the residual gives an indication of the nature and the structure of the rest of the industry. The size indicates that a significant portion of the cargo fleet is composed of a wide variety of aircraft, each used in small numbers. This implies that certain operating principles, typically associated with efficient operation of passenger operations, are not in effect. An example of such would be commonality costs, or the added costs of training and maintenance associated with owning multiple types of aircraft.

The summary statistics are shown in Table 5-18. Its stage length places it in the mid short-haul range, with an average almost exactly the same as the U.S. domestic passenger fleet. The ATM per departure ratio is declining with a relatively constant stage length implying that the cargo capacity of the aircraft being added to the fleet is smaller than what currently exists. These smaller aircraft are also more fuel inefficient, which is reflected in the data. There is growth in the fleet occurring as the aircraft years have risen an average of almost 5 percent over the past 5 years. The residual equipment types are increasing in total RTMs, but, in reality, the RTM per aircraft year is declining. The RTMs flown is marginally increasing but well below the industry growth rate. This implies that the new mixed equipment types are more likely to be used on short-haul routes. The load factor is showing steady growth, but it is more likely to be due to the smaller aircraft size; as it is definitely not due to ATM growth. The scheduled ATM ratio is increasing, implying that the aircraft are targeted to specific scheduled markets. The DOC per ATM is marginally increasing but fluctuating, probably as a result of the smaller aircraft added to the fleet.

Table 5-18. Equipment-Level Analysis: Residual Aircraft

Parameter	1991	1992	1993	1994	1995	Compound annual % change
Stage length	789	822	771	755	747	-1.36
ATM/departure	23,467	23,282	21,075	20,339	19,650	-4.34
Aircraft years	389	406	447	472	494	6.16
ATM/gallon fuel	8.80	7.69	7.73	7.61	7.35	-4.40
Total RTMs (000's)	1,083,977	1,144,804	1,251,547	1,268,354	1,154,822	1.60
% of airline total	13.2	11.1	10.9	9.4	7.4	-13.47
Load factor	53.5	54.0	55.7	56.1	57.6	222.12
Scheduled ATM/total ATM	81.8	94.9	96.3	94.7	97.9	4.59
DOC/ATM	0.2496	0.2778	0.2638	0.2463	0.2639	1.40

Group-Level Analysis

The group-level analysis summarizes the equipment-level information at a higher level of aggregation. This data represent the average per group. The summary data are shown in Tables 5-19 through 5-21. The average stage length increases as the group revenues increase, but over time is increasing for Group III carriers and declining for the others. Block hours flown are increasing for Group II carriers but decreasing for Group I carriers. The ATM/departure ratio is increasing for both Group II and Group III carriers, implying that larger aircraft and/or longer stage lengths are being flown. Both cargo RTMs and ATMs are increasing in all three groups, with the statistics for Group III being an order of magnitude less than those of Group I and Group II. The load factor is also increasing in each group, with the largest gains occurring in the Group III airlines. Aircraft years is also increasing in each group, with Group II showing the largest percentage gains. The range of the DOC per ATM for each group is similar. Group III and Group II show a fluctuating but downward trend over the past 5 years, while Group I shows a fluctuating but upward trend over the same period.

Table 5-19. Summary for Group III Carriers

Parameter	1991	1992	1993	1994	1995
Stage length	749	771	768	756	847
Block hours	1,682,137	1,867,816	1,889,819	1,957,110	2,042,244
ATM/departure	28,263	28,737	28,425	28,646	29,034
Cargo RTM (millions)	659	1,537	1,946	2,974	4,311
Cargo ATM (millions)	1,775	2,664	3,722	5,310	6,841
Cargo load factor	37.15	57.68	52.28	56.00	63.02
Aircraft years	781	942	978	1,049	1,005
DOC/ATM	0.27491	0.26118	0.25181	0.23630	0.24315

Table 5-22 shows the growth rates as a whole and for each group. For the industry as a whole, all of the key parameters are increasing (except DOC per ATM, which is decreasing), which is a sign of increasing growth in the industry. Group II carriers have reaped a disproportionate amount of the growth in terms of stage length, block hours, ATM/departures, cargo RTMs, cargo ATMs, and load factor. Group II carriers have experienced the same percentage growth in cargo ATMs but not load factors. They have also seen the largest drop in DOC per ATM in spite of a more than 50 percent increase in aircraft years.

Table 5-20. Summary for Group II Carriers

Parameter	1991	1992	1993	1994	1995
Stage length	880	846	652	724	775
Block hours					
ATM/departure	34,960	35,672	25,539	31,643	37,525
Cargo RTM (billions)					
Cargo ATM (billions)	1,774,925	2,664,296	3,721,960	5,310,461	6,841,192
Load factor	49.90	60.84	57.46	59.29	63.26
Aircraft years	38	91	156	296	298
DOC/ATM	0.3078	0.2408	0.1751	0.1669	0.2290

Table 5-21. Summary for Group I Carriers

Parameter	1991	1992	1993	1994	1995
Stage length	738	824	737	739	649
Block hours	98,171	52,258	75,739	86,424	91,845
ATM/departure	23,528	28,644	25,939	24,957	20,674
Cargo RTM (billions)	319	489	276	595	527
Cargo ATM (billions)	633	997	836	838	902
Load factor	50.43	49.07	33.06	70.99	58.43
Aircraft years	45	29	49	72	108
DOC/ATM	0.2195	0.2029	0.1968	0.2164	0.2588

Table 5-22. Compound Annual Percentage Growth Rates

Parameter	All	Group III	Group II	Group I
Stage length	7.16	3.12	-3.13	-3.16
Block hours	6.25	4.97		-1.65
ATM/departure	10.68	0.68	1.79	-3.18
Cargo RTM (billions)	13.67	59.93		13.37
Cargo ATM (billions)	6.19	40.11	40.12	9.26
Load factor	7.04	14.12	6.11	3.75
Aircraft years	10.35	6.51	67.34	24.47
DOC/ATM	-6.19	-3.02	-7.13	4.20

SUMMARY

The equipment-level summary is shown in Table 5-23. Aggregate and comparative analysis of the various equipment types are most easily visualized by the yield curves show in Figures 5-2 through 5-4. The curve is first used to identify efficient and inefficient usage of aircraft in terms of utilization. Once the efficient set is identified, those aircraft become the benchmark that any new design must exceed.

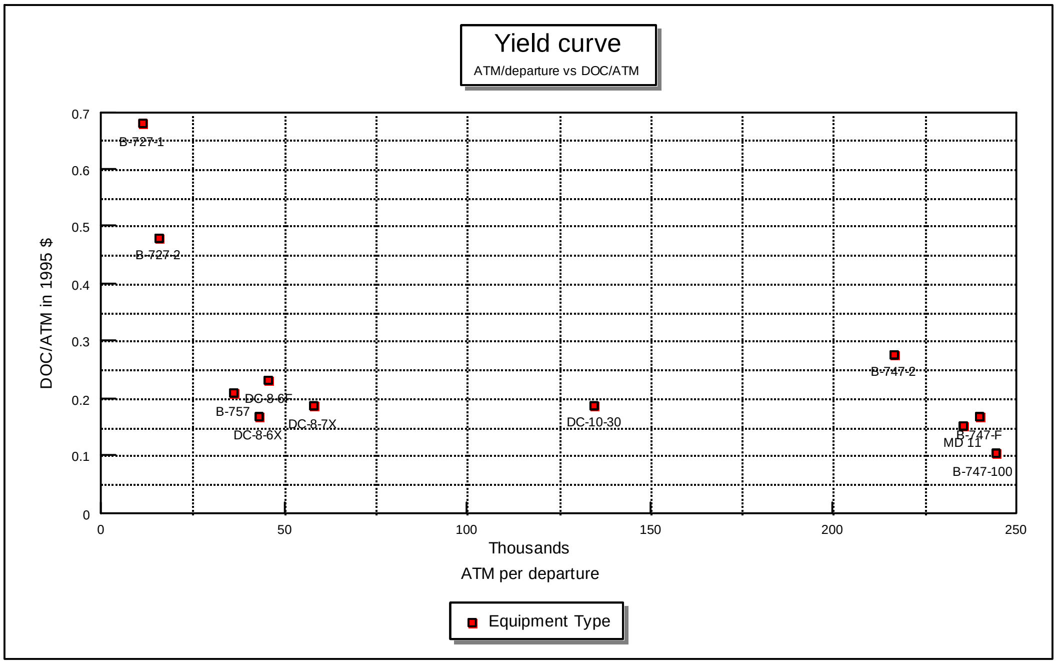
The second curve shows the DOC per ATM against stage length. Again the curve shows declining costs as stage length increases. When the efficient set is defined as the least cost for a given stage length, the efficient set is composed of C-208, B-727-2, B-757-200, DC-8-6X, DC-10-30, B-747-100, and the MD-11. Its efficient frontier is estimated by the following equation:

DOC/ATM = 749.85 stage length $^{-1.169}$ with an R^2 of 0.95. [Eq. 5-1].

Table 5-23. Equipment-Level Summary

Aircraft type	Body type	Aircraft years	Approximate capacity (lbs.)	DOC/ATM in 1995	Stage length	ATM/ departure	RTMs (000s)
B-727-100	Narrow	162.0	24,000	$0.679	552	11,368	443,516
B-727-200	Narrow	149.7	38,000	$0.480	560	15,790	560
B-747-100	Wide	31.03	119,000	$0.103	2,223	244,448	2,223
B-747-200	Wide	5.45	228,000	$0.277	2,193	216,733	2,193
B-747-F	Wide	8.6	245,000	$0.167	2,265	239,989	2,265
B-757-200	Narrow	47.9	67,000	$0.208	819	36,435	819
C-208	Prop	162.2	5,000	$2.520	147	257	147
MD-11	Wide	11.6	80,100	$0.153	2,384	235,673	2,384
DC-10-30	Wide	20.91	67,000	$0.187	1,581	134,675	1,581
DC-8-6X	Narrow	24	40,000	$0.167	1,063	43,125	1,063
DC-8-63F	Narrow	30.8	109,000	$0.231	953	45,783	953
DC-8-7X	Narrow	97.9	40,000	$0.186	1,167	58,314	1,167

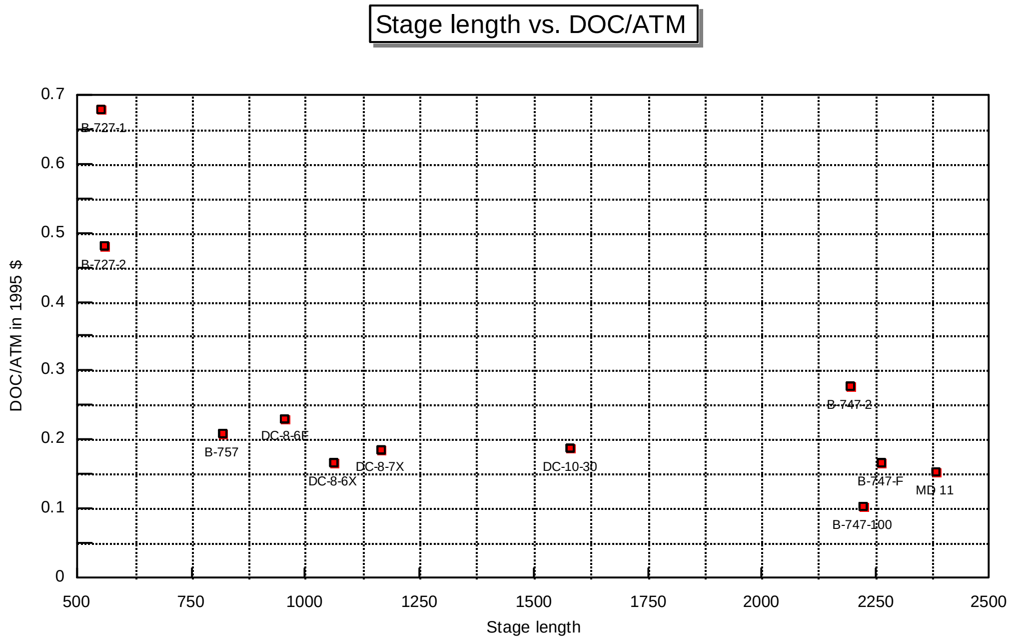
Figure 5-2. Capacity Yield Curve



The third curve shows the DOC per ATM against ATM per departure. This is a representation of the cost based on capacity and stage length. Like the others, it exhibits declining cost as the explanatory variable increases. When the efficient set is defined to include both capacity and distance, the set of efficient equipment types is composed of C-208, B-727-1, B-727-2, B-757-200, DC-8-6X, DC-10-30, and the B-747-100. Its efficient frontier is defined by the following equation:

DOC/ATM = 37.566 ATM/departure $^{-.4702}$ with an R^2 of 0.93. [Eq. 5-2].

Figure 5-3. Stage Length Yield Curve



The last measure (Figure 5-4) examines capacity utilization by cargo capacity and a load factor calculated by revenue ton mile per aircraft year divided by available ton mile per departure. This provides a measure of load that incorporates a measure of the number of aircraft used in the process.

The graph shown in Figure 5-5 shows excess capacity at all levels. This means that theoretically, a significant portion of new demand could be served with the existing cargo fleet increasing its load factor as opposed to adding new aircraft.

Figure 5-4. ATM per Departure Yield Curve

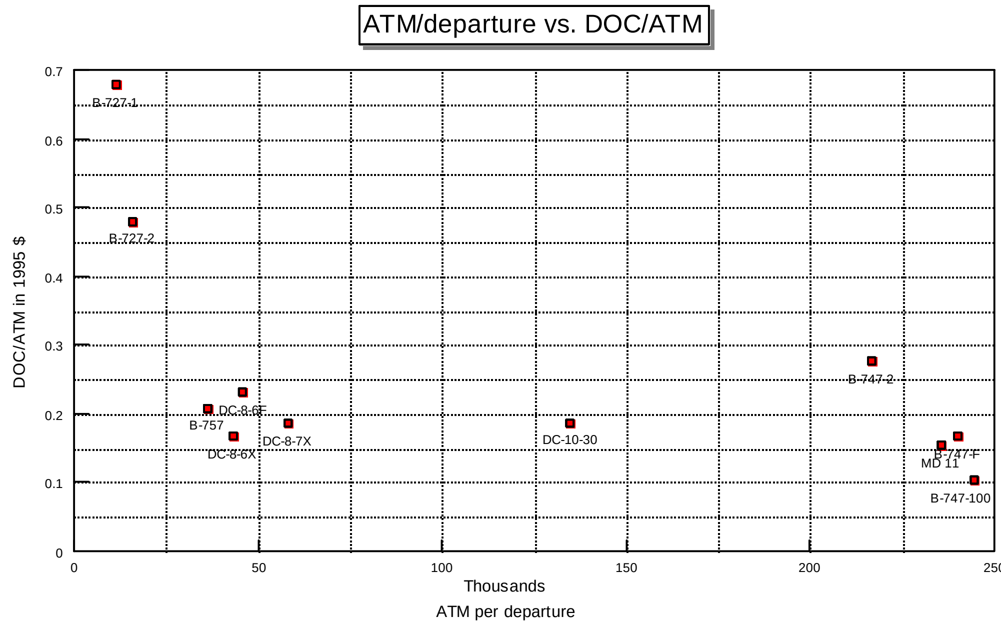
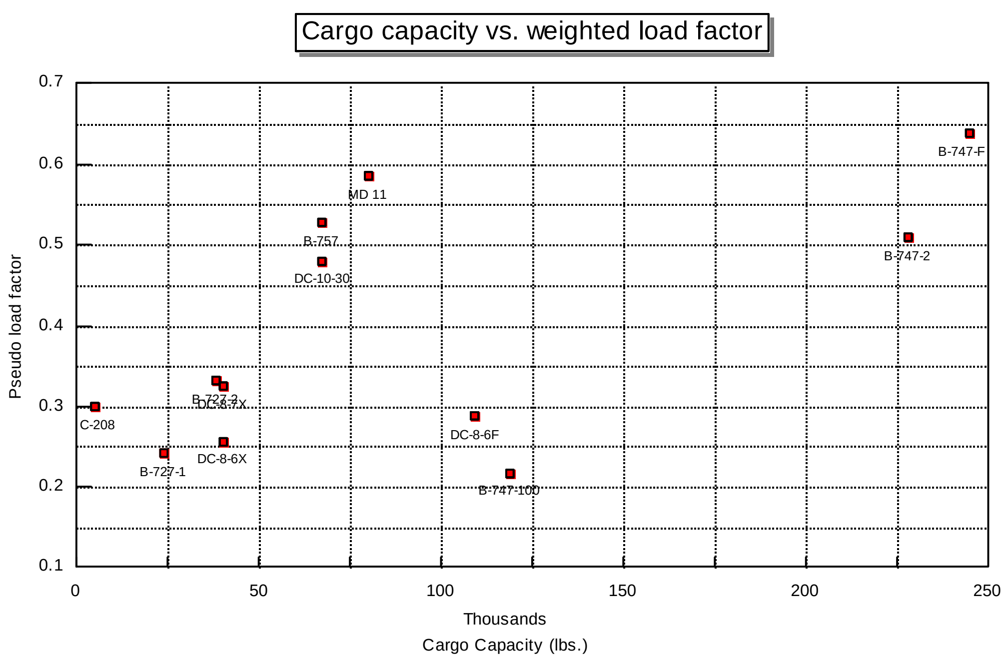


Figure 5-5. Excess Capacity by Equipment Type



Chapter 6
International Air Cargo Fleet Analysis

The international analysis is based on a collection of data published by the International Civil Aviation Organization (ICAO). Because ICAO exercises no regulatory authority over member carriers, the reporting of statistics for some carriers is not always consistent through time.[1] The database consists of the top 25 scheduled international carriers ranked by 1994 total freight and mail revenue tonne kilometers. This list includes 6 U.S. carriers and 19 foreign carriers.[2] The foreign carriers are listed in Table 6-1, and their summary statistics are presented in Table 6-2.

Table 6-1. International Carriers Included in the Database

Airline	Flag country	1995 operating revenues ($000)	Equivalent group
Air Canada	Canada	2,531,880	III
Air France	France	6,509,843	III
Alitalia	Italy	4,403,955	III
All Nippon Airways	Japan	8,738,910	III
British Airways	United Kingdom	10,410,628	III
Cathay Pacific	Hong Kong	3,696,734	III
El Al	Israel	*	
JAL	Japan	10,883,319	III
KLM	Netherlands	5,546,008	III
Korean Air Lines	Korea	4,362,823	III
Lufthansa	Germany	*	
Malaysia Airlines	Malaysia	*	
Nippon Cargo	Japan	533,276	II
Quantas	Australia	*	
Saudia	Saudia Arabia	*	
SIA	Singapore	4,440,124	III
Swissair	Switzerland	3,482,011	III
Thai Airways	Thailand	2,926,058	III
Varig	Brazil	3,411,104	III

*Note: Carriers not reporting traffic and operating statistics for 1995.

[1] This is true for several carriers in the study including El Al, Lufthansa, Malaysia Airlines, Quantas, and Saudia.

[2] The U.S. carriers, Federal Express, United Parcel Service, Delta, United, Northwest, and American were not included here because they were analyzed previously.

Table 6-2. Summary Statistics for International Carriers

Airline	Scheduled freight revenues ($000)	Scheduled mail revenues ($000)	Unscheduled freight revenues ($000)	Total cargo revenues ($000)	Percent cargo revenue of total
Air Canada	198,676	21,483	3,159	223,318	8.8
Air France	1,149,205	73,680	10,659	1,233,544	18.9
Alitalia	344,708	60,947	0	405,655	9.2
All Nippon Airways	510,736	114,384	0	625,120	7.2
British Airways	819,657	60,141	0	879,798	8.5
Cathay Pacific	718,224	29,344	0	747,568	20.2
El Al	*	*	*	*	*
JAL	1,357,773	141,756	70,317	1,569,846	14.4
KLM	990,603	46,562	0	1,037,165	18.7
Korean Air Lines	930,265	25,042	36,177	991,484	22.7
Lufthansa	*	*	*	*	*
Malaysia Airlines	*	*	*	*	*
Nippon Cargo	475,593	13,460	837	489,890	91.9
Quantas	*	*	*	*	*
Saudia	*	*	*	*	*
SIA	886,477	25,920	0	912,397	20.5
Swiss Air	448,561	25,505	55	474,121	13.6
Thai Airways	401,217	18,011	229	419,457	14.3
Varig	591,230	63,215	21,460	675,905	19.8

*Carriers not reporting traffic statistics for 1995.

All the specified carriers except Nippon Cargo would be considered Group III carriers if registered in the United States. Interestingly, all except Nippon Cargo are also predominately passenger carriers. The top 25 international carriers account for 71.63 percent of the world's total scheduled revenue tonne kilometer traffic for 1994. The 19 foreign registered carriers account for 48.86 percent of the world total, while the 6 U.S. carriers account for 27.77 percent. The remaining traffic is accounted for by smaller carriers of both U.S. and foreign registry.

Foreign carriers generally represent the dominant passenger service provider for their respective country of registration. A handful are still held under at least partial state ownership. All of these carriers specialize in international traffic between their country of registration and other nations. In addition, foreign flag carriers, which continue to operate cargo services with dedicated freighters and combi-aircraft, have been far more aggressive than U.S. carriers in promoting air cargo.[3] Thus, it is not surprising that they account for such a substantial portion of the total world cargo traffic. The result is that foreign passenger carriers have a much larger portion of their total operating revenues derived from cargo operations than do U.S. carriers. Excluding Nippon Cargo, the ratio of cargo revenues to operating

[3] Wells, page 361.

revenues range from a low of 7.2 percent for All Nippon Airways to a high 22.7 percent for Korean Air Lines.

The passenger and cargo fleet inventory counts are shown in Tables 6-3 and 6-4. The most obvious observation is that the foreign passenger and cargo fleets tend to be younger than the U.S. fleets. This fact results from a variety of factors. The first is that, over the past decade, the growth of the international air transportation industry generally has exceeded that of the U.S. industry. As a result, the foreign carriers have been purchasing new aircraft more quickly than the US carriers. Therefore, a larger portion of the international carrier's fleets have been purchased fairly recently. A second factor is the tendency of European air carriers to favor newer aircraft on the basis of environmental impact. Some airports in Europe have established noise regulations more stringent than U.S. and ICAO regulations. A third factor is the availability of government subsidized capital resources for foreign air carriers to procure new aircraft. Thus, the major foreign carriers generally are not constrained to purchase used equipment.

Table 6-3. International Passenger Fleet Counts

Airline	Number of aircraft	Average age of aircraft	Standard deviation of the aircraft age
Air Canada	127	14.85	10.42
Air France	162	12.92	7.51
Alitalia	149	11.21	7.29
All Nippon Airways	126	9.45	4.79
British Airways	253	11.82	6.17
Cathay Pacific	59	11.10	7.74
El Al	24	14.79	8.12
JAL	129	12.71	6.87
KLM	78	9.67	4.95
Korean Air Lines	108	10.24	6.67
Lufthansa	211	8.73	3.99
Lufthansa Cargo	16	19.13	7.64
Malaysia Airlines	89	6.64	4.06
Nippon Cargo	7	11.57	3.31
Quantas	93	10.19	4.50
Saudia	71	17.93	4.69
SIA	75	7.99	3.94
Swissair	68	9.35	4.73
Thai Airways	79	9.56	5.10
Varig	80	14.39	7.60
Summary	2004	11.24	6.78

Table 6-4. International Cargo Fleet Counts

Airline	Number of cargo aircraft	Average age of aircraft	Standard deviation of the aircraft age
Air Canada	0	-	-
Air France	23	22.00	7.59
Alitalia	2	17.50	0.71
All Nippon Airways	0	-	-
British Airways	5	19.00	2.35
Cathay Pacific	6	9.67	5.82
El Al	4	20.75	4.86
JAL	8	17.25	4.20
KLM	4	13.50	1.00
Lufthansa	12	14.17	5.84
Lufthansa Cargo	16	19.13	7.64
Malaysia Airlines	3	12.67	7.51
Nippon Cargo	7	11.57	3.31
Quantas	1	27.00	0.00
Saudia	3	16.00	11.27
SIA	7	7.29	5.28
Swissair	3	12.00	3.46
Thai Airways	5	16.00	6.40
Varig	10	22.60	8.15
Summary	137	16.96	7.40

The average aircraft age differences between foreign and U.S. aircraft is even more pronounced for cargo-only aircraft. Only four of the foreign carriers have fleets with an average age of more than 20 years, while seven have fleets that average less than 15 years of age. Both Singapore International Airlines and Cathay Pacific operate fleets with an average aircraft age of less than 10 years. This is certainly an indication that most of these cargo aircraft were purchased new.

Table 6-5 dissaggregates the fleet inventory data by manufacturer. As in the U.S. case, Boeing holds the dominant market share at 68 percent. Fokker follows next with just above 10 percent. McDonnell Douglas and Airbus follow respectively with just under 10 percent of the aircraft each. Interestingly 8 of the 19 foreign carriers operate all-cargo equipment exclusively from a single manufacturer. Specializing in the aircraft of a single manufacturer may help lower costs by requiring a smaller inventory of spares, and considerably less extensive crew and maintenance training.

Table 6-5. Cargo Aircraft Count by Manufacturer

Airline	Airbus	Boeing	Douglas	Fokker	Other	Totals
Air Canada						0
Air France	2	11		10		23
Alitalia		2				2
All Nippon Airways						0
British Airways					5	5
Cathay Pacific		6				6
El Al		4				4
JAL		8				8
KLM	4					4
Korean Air Lines	2	14	2			18
Lufthansa	1	9	2			12
Lufthansa Cargo		11	5			16
Malaysia Airlines		3				3
Nippon Cargo		7				7
Quantas				1		1
Saudia		1	1	1		3
SIA		7				7
Swissair			1	2		3
Thai Airways	3	2				5
Varig		8	2			10
Totals	12	93	13	14	5	137

Table 6-6 further dissagregates the Boeing aircraft by model and series. The oldest aircraft in the international fleet is the 727-100C, with an average age of almost 30 years. These aircraft are the most likely candidates for retirement from the fleet. The newest aircraft in the fleet also happens to be Boeing aircraft, the 747-400F. The 747-400F has an average age of less than 4 years. Table 6-7 presents the corresponding data for the other manufacturers. The DC-8 series and the F-27 series are nearly as old as the 727-100C and would also be expected to retire from the fleet in the near future.

In terms of operating cost data, the statistics available for international carriers are considerably less detailed than for U.S. carriers. It is possible to compute direct operating costs at the carrier level, but the necessary data for equipment level costs are unavailable. Therefore, the DOC carrier-level costs are subject to all of the issues discussed in Chapter 4. In addition, the costs also reflect geographic and political idiosyncrasies of the international community. For European carriers in particular, average stage lengths are considerably longer than for major U.S. carriers. This fact is most likely the result of well-established rail alternatives, which compete directly with air service over shorter distances.

Table 6-6. Equipment-Level Fleet Composition of Boeing Cargo Aircraft

Model	Type	Number	Average age	Total
727				9
	100C	5	29.80	
	200	4	20.75	
737				11
	200	1	13.00	
	300F	3	8.33	
	300QC	7	10.86	
747				73
	100F	2	22.00	
	200B	3	11.67	
	200BPC	3	17.00	
	200C	1	25.00	
	200F	43	15.05	
	200FM	15	15.93	
	400F	6	3.50	
Summary		93	15.14	93

The DOC/ATM calculations are presented in Table 6-8. The absence of all- cargo aircraft for the carrier fleets of Air Canada and All Nippon Airways indicates that the cost calculations reflect belly-hold cargo only.[4] The cost calculations for the other carriers, however, reflect a mixture of all-cargo and belly-hold service.

Table 6-7. Equipment-Level Fleet Composition by Other Manufacturers

Manufacturer	Model	Type	Number	Total	Average age
Airbus	A300			7	18.43
		B2	1		
		B4-103	2		
		B4-203	1		
		C4	1		
		F4	2		
	A310			5	12.80
		203	4		
		304	1		
Douglas	DC 10			4	18.50
		10-30	2		
		10-30F	2		
	DC 8			6	29.33
		72	1		
		73AF	2		
		73CD	3		

[4] Alternatively, it is possible that these carriers outsource all-cargo service from other air carriers.

Table 6-7. Equipment-Level Fleet Composition by Other Manufacturers (continued)

Manufacturer	Model	Type	Number	Total	Average Age
	MD-11	F		2	6.50
	MD-80	81		1	16.00
Fokker	F27			11	29.00
		500	10		
		600	1		
	F100			2	10.00
Lockheed	L1011			3	20.33
		200	1		
		50	2		
Brad	DHC	6	1		10.00
		7	2		17.00
Summary			44	44	20.82

Table 6-8. DOC/ATM at the International Carrier Level

Airline	1991	1992	1993	1994	1995
Air Canada	0.2306	0.2067	0.1792	0.1373	
Air France	0.3547	0.4093	0.3156	0.2884	
Alitalia		0.4204	0.3660		
All Nippon Airways		0.4777	0.5094	0.4388	
British Airways	0.2579	0.2251	0.2210	0.2320	
Cathay Pacific		0.2483	0.2578	0.2560	
El Al					
JAL	0.3924	0.3871	0.4270	0.4446	
KLM					
Korean Air Lines				0.1770	
Lufthansa	0.4523		0.3589	0.3686	
Malaysia Airlines	0.3160			0.3410	
Nippon Cargo		0.2772	0.2877	0.2875	0.3098
Quantas	0.3032	0.2387	0.2403		
Saudia			0.1818		
SIA	0.2650	0.2331	0.2336	0.2336	
Swissair	0.4645			0.3584	
Thai Airways	0.3842	0.3570	0.3678	0.3678	
Varig	0.2626	0.3201		0.4044	
Fleet-wide					

Chapter 7
Future Air Cargo Industry Analysis

This chapter outlines the methodology used to construct the analytical models used to estimate the key air cargo parameters under study as well as their implications. This set of key parameters includes air cargo traffic volume in terms of RTMs and ATMs, as well as the DOC.

METHODOLOGY

The general approach taken was to model historical changes in cargo traffic demand as a function of changes in real income, as measured by gross domestic product (GDP), and changes in real cargo yield. This approach was employed separately for both the United States and the entire world. From these econometric models, we then projected changes in cargo traffic demand forward from the 1995 baseline statistics. The result is a 20-year forecast for both world and U.S. carrier cargo traffic. From this traffic forecast, we then derived the number and composition of the cargo aircraft fleet for each region under a variety of assumptions regarding changes in the industry load factor. The result is a set of two projections for each region that form an upper and lower bound on the likely size of the future air cargo fleet.

The first step was to collect historical data regarding cargo traffic, freight yield, and income for each of the two regions over the 16-year period 1980 to 1995. In order to capture both the volume and the distance components of cargo shipments, we selected RTMs—or alternatively RTKs for the world region—as our measure of cargo traffic. The world cargo RTKs are derived from ICAO-published traffic statistics and include both scheduled and nonscheduled revenue traffic. Similarly, we aggregated U.S. cargo RTMs from individual carriers' Form 41 reports and included both scheduled and nonscheduled traffic.

We used the average yield for scheduled freight (measured in constant U.S. dollars per RTK) as our measure of fare yield for the world region.[1] Similarly, we used the average yield (measured in constant U.S. dollars per RTM) as our measure of fare yield for the U.S. region.[2] In addition, for the U.S. region, we made a distinction between observations preceding the initiation of express service with regard to real yield. The rationale is to allow for the possibility that the relation-

[1] World average scheduled freight yield statistics are published in *Civil Aviation Statistics of the World* by ICAO.

[2] U.S. average freight yield was explicitly calculated from the Form 41 revenue and traffic series.

ship between yield and traffic volume was altered by the introduction of express service.

To measure world income we used the total GDP (measured in constant U.S. dollars) of the 29 members of the Organization of Economic Cooperation and Development (OECD). These nations comprise the largest market economies in the world and account for the vast majority of international trade. Finally, we used real GDP to measure income for the U.S. region.

Next we constructed an econometric model of cargo demand for each region. Formally the models for the world and U.S. regions are represented respectively by

$$q_t^W = D_t^W(y_t^W, p_t^W)$$

$$q_t^{US} = D_t^{US}(y_t^{US}, p_t^{US}, x_t^{US}),$$

where q_t^i is cargo traffic in region *i* at time *t*; y_t^i is real income in region *i* at time *t*; p_t^i is real yield in region *i* at time *t*; and x_t^{US} is real yield after the initiation of express service in the United States. To correct for the possibility of serial correlation in the data, we employed an autoregressive model with two lags of the error terms. We used a log-log specification so that the coefficients may be interpreted as elasticities. The overall fit of the econometric models is quite good with coefficients of determination (adjusted R-square) of 0.974 and 0.986 for the world and U.S. regions, respectively. The econometric results are presented in Table 7-1.

Table 7-1. Demand Variables

Region	Variable	Name	Coefficient	T-ratio
World	Real income	LNGDP	2.4562	11.97
	Real yield	LNYIELD	-0.0534	-0.43
United States	Real income	LNGDP	2.3639	5.22
	Real yield	LNYIELD	-0.1080	-1.13
	Real yield (express)	LNXPRESS	-0.2582	-2.24

From the econometric results, we constructed an analytic model to forecast changes in cargo demand for each of the two regions. To predict demand, the model starts with actual cargo traffic for calendar year 1995 and changes it over time based on the estimated demand function coefficients and assumptions regarding explanatory variables. The equation for predicting annual changes in demand is

$$\%\Delta RTM = \sum_{i=1}^{3} \beta_i \%\Delta X_i \ , \qquad \text{[Eq. 7-1]}$$

where the β_i are the coefficients estimated from the econometric model and the X_i are the explanatory variables. Due to the logarithmic structure of the statistical model, the coefficients are interpreted as elasticities. For example, the coefficient of 2.4562 on world income means that a 1 percent increase in GDP raises the demand for air cargo by 2.4562 percent.

The baseline assumptions regarding changes in real income and real fare yield are drawn from assumptions published in *The Boeing World Air Cargo Forecast*. These assumptions are summarized in Table 7-2.

Table 7-2. Baseline Assumptions

Region	Variable	Annual growth rate
World	Real income	3.00%
	Real yield	-1.00%
United States	Real income	2.30%
	Real yield	-1.00%

Starting with 1995 traffic totals, and applying the assumptions of Table 7-2 to the coefficients of Table 7-1, we generated forecasts of cargo traffic for each region for the 20-year period 1996 through 2015. We project that world cargo traffic will grow at an annual rate of 7.25 percent, which is well within the range of 4.5 percent to 8.1 percent projected by Boeing for the same time period. Furthermore, we project that U.S. flag cargo traffic will grow at an annual rate of 5.8 percent, which is very near the Boeing projection of 5.5 percent growth over the same period. Combining the traffic projections with the assumed changes in cargo yield, we also estimate cargo revenues for the carriers of each region. This analysis also was conducted separately for each region and is described in the following two sections.

UNITED STATES ESTIMATES

As stated above, the key driver for growth in the air cargo industry is the long-term growth in GDP. The predicted U.S. real GDP growth rate of 2.3 percent translates to a 5.8 percent annual increase in RTMs flown by the U.S. fleet over the 20-year forecast period. The RTM growth in conjunction with changes in the real yield drive the revenue growth, which in this case, equals an annual increase of 4.75 percent. The combination of the RTMs and the load factor then drive the ATMs. The annual data is shown are Table 7-3.

Table 7-3. U.S. Cargo RTM and ATM Estimates for 1995 to 2015

Year	U. S. flag RTMs (billions)	U.S. flag ATMs (billions)	DOC (cents/ATM)
1995	23.9	57.7	31.12
1996	25.2	61.0	30.81
1997	26.7	64.6	30.50
1998	28.3	68.3	30.19
1999	29.9	72.3	29.89
2000	31.6	76.5	29.59
2001	33.5	80.9	29.30
2002	35.4	85.6	29.00
2003	37.5	90.6	28.71
2004	39.6	95.8	28.43
2005	41.9	101.4	28.14
2006	44.4	107.3	27.86
2007	46.9	113.5	27.58
2008	49.7	120.1	27.31
2009	52.6	127.0	27.03
2010	55.6	134.4	26.76
2011	58.8	142.2	26.50
2012	62.2	150.4	26.23
2013	65.9	159.2	25.97
2014	69.7	168.4	25.71
2015	73.7	178.2	25.45
Annualized compound growth rate	5.80%	5.80%	1.00%

WORLD ESTIMATES

GDP is also the key industry driver at the international level. For this analysis, the U.S. data were subsumed in the world data. The methodology is exactly the same as before, with the sole difference being values of the key parameters. Here, the worldwide GDP growth rate is set to 3 percent, which translates to an annualized RTM growth rate of 7.25 percent and an annualized cargo revenue increase of 6.18 percent. The summary data are shown in Table 7-4.

The demand projections presented in Tables 7-3 and 7-4 are the primary determinants of the size and composition of the future cargo fleet. Chapter 8 presents our analysis of the fleet required to service this projected demand.

Table 7-4. Worldwide Cargo RTM and ATM Estimates for 1995 to 2015

Year	Worldwide RTMs (billions)	Worldwide ATMs (billions)	DOC (cents/ATM)
1995	64.0	112.2	25.00
1996	68.7	120.4	24.75
1997	73.6	129.1	24.50
1998	79.0	138.5	24.25
1999	84.7	148.5	24.01
2000	90.9	159.3	23.77
2001	97.5	170.8	23.53
2002	104.5	183.2	23.30
2003	112.1	196.5	23.06
2004	120.2	210.8	22.83
2005	129.0	226.0	22.61
2006	138.3	242.4	22.38
2007	148.3	260.0	22.16
2008	159.1	278.9	21.93
2009	170.6	299.1	21.71
2010	183.0	320.8	21.50
2011	196.3	344.1	21.28
2012	210.5	369.0	21.07
2013	225.8	395.8	20.86
2014	242.2	424.5	20.65
2015	259.8	455.3	20.44
Annualized compound growth rate	7.25%	7.25%	1.00%

Chapter 8
The Supply and Demand for Cargo Aircraft

The calculation of cargo aircraft DOC answers the first question regarding the transport cost of the existing fleet. This calculation also determines the economic operating range that any new design for an all-cargo aircraft would have to meet. Another fundamental question is the determination of the potential market size for an all-cargo aircraft. This chapter examines the market size question by combining the demand for new cargo aircraft derived from the future estimates of RTM growth with projections for cargo aircraft supply.

We first examine the baseline supply and demand requirements for U.S. cargo aircraft and then examine the requirements for the international fleet. Next, we examine the projected growth in demand for cargo aircraft due to growth in the air cargo industry. The difference between the supply and demand for cargo aircraft is represented by a shortfall in the number of cargo aircraft required. This chapter describes the methodology and presents our projections for the requirements of both the U.S. and international cargo fleets.

INTRODUCTION

In the absence of any growth in worldwide cargo demand, baseline demand and supply for cargo aircraft would still exist. The driving force behind this baseline demand is the need to replace cargo aircraft retired due to old age. Similarly, the baseline supply of cargo aircraft is driven by the retirement cycle of older passenger-carrying aircraft. This baseline supply of converted passenger aircraft represents the most important competition for any new all-cargo design.

The prospects for phenomenal growth in world cargo demand underlie the spirit of optimism with regard to the future of air cargo transport. Since the average fleet replacement rate, which is given by the inverse of the average aircraft life span, is just above 2 percent per year, the prospects for a new all-cargo aircraft in the absence of demand growth are dismal. However, additional aircraft acquired to meet new demand growth can effectively double, triple, or even quadruple the aircraft fleet requirements above the replacement rate.

Another important issue is the historical tendency of cargo operators to purchase a large portion of their aircraft fleet as converted passenger aircraft as opposed to new all-cargo aircraft. This trend is not surprising given the high acquisition costs of new aircraft and the difficulty of securing financial resources by smaller carriers. As a result, the supply of used passenger aircraft must be treated as an important limitation on the prospects for a new all-cargo design.

BASELINE DEMAND FOR UNITED STATES CARGO AIRCRAFT

The baseline demand for U.S. cargo aircraft is simply the replacement schedule of older all-cargo aircraft due to retirement. We calculate the retirement schedule using the Air Carrier Investment Model (ACIM), which was previously developed by the Logistics Management Institute for NASA under Aviation System Analysis Capability (ASAC) funding.[1] This ACIM analysis assumes a useful lifetime of 35 years for cargo aircraft and examines the 19-year period from 1997 through 2015.[2]

The analysis must also be adjusted for the impact of the Federal Aviation Administration's (FAA's) Airport Noise and Capacity Act of 1991. The effect of this "noise law" is to remove all Stage 2 aircraft from the U.S. fleet by year-end 1999.[3] This can be done by replacement, reengining, or hushkitting. Because of the high costs of these programs and their relatively short remaining life, older Stage 2 cargo aircraft will most likely be replaced.[4] Newer Stage 2 cargo, however, would be more likely to qualify for either reengining or hushkitting. Our analysis assumes that all Stage 2 aircraft are retired or converted in equal increments before year-end 1999.

The impact of the noise regulations can be determined from the data presented in Table 8-1. The cargo aircraft needed for replacements of Stage 2 cargo aircraft is 123. The cargo aircraft needed for replacements of Stage 3 cargo aircraft is 179. Therefore, a total of 302 cargo aircraft is the baseline U.S. demand. The newer Stage 2 cargo aircraft (those with an expected retirement year of 2005 or later) will be re-engined or hushkitted and then returned to the cargo fleet. This total is 55. Thus, the U.S. demand for replacement cargo aircraft is 247 aircraft (302-55) over the 19-year period of interest, an average of between 12 and 13 aircraft per year. Unfortunately, this demand does not occur on a steady basis. More than 27 percent of the demand occurs during the 1997 to 1999 time frame as a direct result of the noise law, and almost 75 percent of it will have occurred by 2005. This front-loading effect may have a negative impact on any long-term all-cargo aircraft development programs because a large portion of the demand may have already passed prior to initial production.

[1] The ACIM calculates a retirement age for each cargo aircraft by assuming that each cargo aircraft is retired after 35 years of service. The retirement year of each cargo aircraft in the fleet is calculated then summed over the retirement year to get the number of cargo aircraft retired per year.

[2] The assumption of 35 years of useful life is a conservative estimate in the sense that many cargo aircraft are retired at a later age.

[3] See Appendix A for definitions of terms related to noise regulations.

[4] The older Stage 2 cargo aircraft would have to be replaced because the discounted cost of the hushkit plus a replacement aircraft at the end of its lifetime is higher than the discounted cost of the replacement aircraft purchased in the year of forced retirement.

Table 8-1. Baseline Demand/Retirement Schedule for the U.S. Cargo Fleet

Year	Without noise law			With noise law		
	Stage 2 aircraft	Stage 3 aircraft	Totals	Stage 2 aircraft	Stage 3 aircraft	Totals
1997	0	0	0	41	0	41
1998	0	0	0	41	0	41
1999	0	0	0	41	0	41
2000	3	0	3	0	0	0
2001	13	0	13	0	0	0
2002	22	15	37	0	15	15
2003	23	38	61	0	38	38
2004	7	39	46	0	39	39
2005	0	23	23	0	23	23
2006	0	7	7	0	7	7
2007	0	15	15	0	15	15
2008	0	2	2	0	2	2
2009	0	5	5	0	5	5
2010	9	10	19	0	10	10
2011	7	8	15	0	8	8
2012	4	1	5	0	1	1
2013	3	4	7	0	4	4
2014	13	2	15	0	2	2
2015	19	10	29	0	10	10
Totals	123	179	302	123	179	302

BASELINE SUPPLY FOR UNITED STATES CARGO AIRCRAFT

The baseline supply for U.S. cargo aircraft is the retirement of passenger aircraft due to old age. Again, we use the ASAC ACIM to calculate the retirement schedule of passenger aircraft for the period 1997 to 2015. Specifically, the ACIM calculates a retirement age for each passenger aircraft according to the year of production and the body type of the aircraft. This retirement schedule becomes the baseline supply for cargo aircraft.

Again, the analysis must be adjusted for the impact of the noise regulations. The effect of the noise law is to remove all Stage 2 aircraft from the U.S. flying fleet by the end of 1999. As for cargo aircraft, this can be accomplished by replacement, reengining, or hushkitting. The older Stage 2 passenger aircraft will be replaced by new Stage 3 passenger aircraft, thus freeing up the supply of aircraft for cargo conversion. Newer Stage 2 passenger aircraft will be either reengined or hushkitted, then returned to the passenger fleet. All of the retiring Stage 3 passenger aircraft are eligible for cargo conversion. The retirement schedules are shown in Table 8-2.

Table 8-2. Baseline Supply/Retirement Schedule for the U.S. Passenger Fleet

Year	Without noise law			With noise law		
	Stage 2 aircraft	Stage 3 aircraft	Totals	Stage 2 aircraft	Stage 3 aircraft	Totals
1997	11	0	11	220	0	220
1998	6	0	6	215	0	215
1999	45	0	45	254	0	254
2000	27	0	27	0	0	0
2001	50	0	50	0	0	0
2002	34	0	34	0	0	0
2003	53	0	53	0	0	0
2004	97	0	97	0	0	0
2005	103	0	103	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	81	4	85	0	4	4
2010	63	29	92	0	29	29
2011	35	64	99	0	64	64
2012	30	83	113	0	83	83
2013	38	84	122	0	84	84
2014	7	163	170	0	163	163
2015	9	172	181	0	172	172
Total	689	599	1,288	689	599	1,288

There is a stratification in value among the retiring passenger fleet that will affect the number of passenger-to-cargo conversions. The newer Stage 2 aircraft will be highly valued by the passenger aircraft side of the market because their usefulness can be extended relatively cheaply by either re-engining or hushkitting. It is unlikely that any of these aircraft will be available for cargo conversions over the period of interest. Thus, these aircraft comprise the set currently being either re-engined or hushkitted, as the replacement for the older Stage 2 passenger aircraft. Because the Stage 3 aircraft are a relatively new technical design, they are not scheduled to begin retirement for at least another 10 years. However, when they do become available, they will become the most highly desired as the only cost is purchase price plus cargo conversion (assuming of course, that a Stage 4, or equivalent, noise law is not in effect).

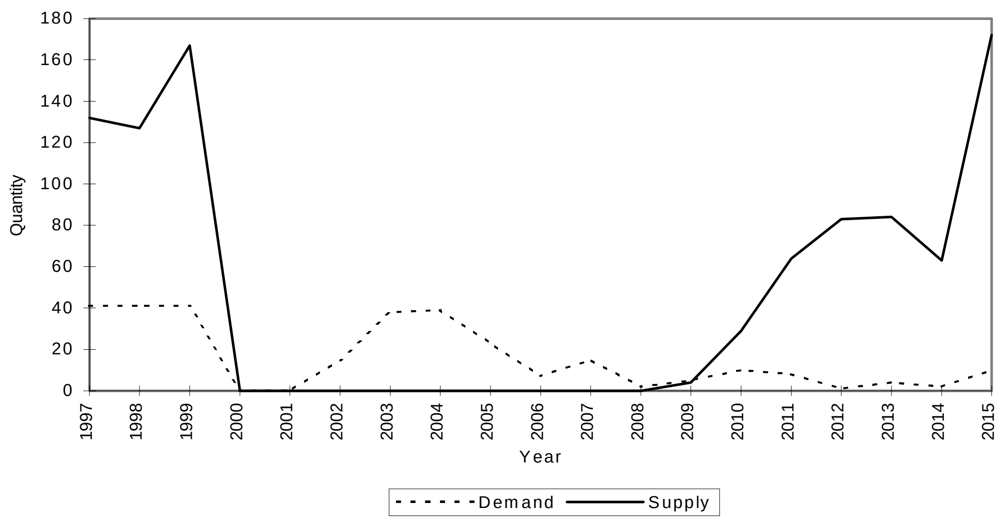
The ACIM model predicts that the 263 Stage 2 aircraft with expected retirement dates after 2006 will remain in the passenger fleet, while the 426 older Stage 2 aircraft will be eligible for engine stage upgrades, then cargo conversions. These data are shown in Table 8-3. The combined supply and demand graphs are shown in Figure 8-1. In sum, the total supply is more than three times that of the total demand. However, the combination of the noise law and the introduction of Stage 3 aircraft into the fleet produces a bimodal distribution for aircraft supply.

The result is a loading of aircraft supply during the periods 1997–1999 and 2009-2015.

Table 8-3. Likely Passenger-to-Cargo Conversion Pool

Year	Stage 2 passenger aircraft	Stage 3 passenger aircraft	Cargo eligible Stage 2 passenger aircraft	Total cargo eligible aircraft
1997	220	0	132	132
1998	215	0	127	127
1999	254	0	167	167
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	0	0	0	0
2008	0	0	0	0
2009	0	4	0	4
2010	0	29	0	29
2011	0	64	0	64
2012	0	83	0	83
2013	0	84	0	84
2014	0	163	0	163
2015	0	172	0	172
Totals	689	599	426	1,025

Figure 8-1. Baseline Supply and Demand for Cargo Aircraft



At the same time, the demand distribution shows less variation, but it certainly is not uniform. The impact of the noise law produces a similar spike in the supply of aircraft during the period 1997 to 1999. During the period between 2002 and 2009 the baseline demand is projected to exceed the baseline supply. However, this result assumes that none of the excess supply from the period before 1999 will be available to satisfy demand. Allowing for this possibility, the demand is easily satisfied. A similar situation is projected to occur between 2010 and 2015 as the first of the Stage 3 passenger aircraft are retired.

The conclusions that can be drawn from the baseline supply and demand are two-fold. First, a major portion of the baseline demand is likely to be met by the supply of converted passenger aircraft. In fact, the excess supply is so large that further price reductions in retired passenger aircraft can be expected. This fact further detracts from the attractiveness of new all-cargo aircraft. Second, the net effect of the retirement schedule upon the industry DOC is ambiguous. As aircraft age, all else constant, DOCs tend to increase as a result of higher maintenance costs. However, the price reductions derived from the excess supply of aircraft will work to lower the capital cost portion of the DOC. Depending upon which effect is dominant, we may observe increasing or decreasing operating costs. Unambiguously, however, the impact of Stage 3 aircraft entering the all-cargo fleet after 2009 will cause DOCs to decline. This result is driven by the superior operating characteristics of Stage 3 aircraft.

BASELINE SUPPLY AND DEMAND FOR THE INTERNATIONAL FLEET

This same analysis can be applied to the international fleet. The baseline supply of aircraft eligible for conversion to cargo aircraft is driven by the retirement schedule of the passenger fleet. It is found by calculating the expected retirement year for each aircraft in the fleet. Because the ACIM International Modules have yet to be released, we use the assumption that all international passenger aircraft have a useful life of 30 years. The retirement schedule is shown in the first column of Table 8-4. Over the period 1996 to 2015, a total of 668 passenger aircraft are expected to be retired. Because of more stringent European noise regulations, a large portion of this fleet already has met the Stage 3 noise requirements.[5]

The baseline demand for cargo aircraft for the international fleet is calculated in the same manner as for the domestic fleet. Cargo aircraft are assumed to be retired after 35 years of use. This retirement schedule makes up the baseline demand, or the number of replacement aircraft needed in the absence of demand growth. The

[5] The European noise law is technically known as the European Community Directive. Because Europe is composed of sovereign countries, the European equivalent of the FAA does not exist. Instead, advisory guidelines have been issued. These guidelines are de facto law because a large portion of the major European airports deny access, either outright or by time of day, to Stage 2 aircraft on the basis of environmental or noise concerns.

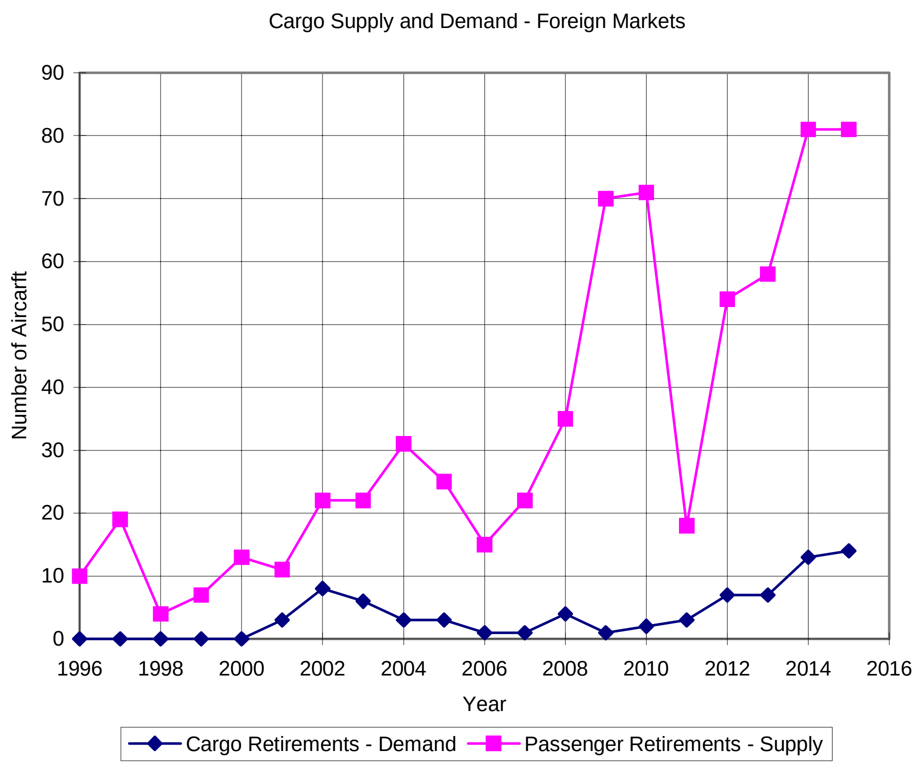
retirement schedule and types of aircraft are shown in the last four columns of Table 8-4. The total cargo aircraft required for replacement purposes between 1997 and 2015 number just 76. This number represents just four aircraft per year, which is well within the available supply. While this does not equal the total international demand, it is representative of the needs of the major airlines, which are those carriers most likely to purchase new cargo aircraft.

Table 8-4. Expected Yearly Retirements of the Current International Fleet

Year	Number of expected passenger aircraft	Number of expected cargo aircraft	Cargo aircraft type	Cargo aircraft type	Cargo aircraft type
1996	10	0			
1997	19	0			
1998	4	0			
1999	7	0			
2000	13	0			
2001	11	3	3 B-727-100C		
2002	22	8	6 F-27-500	2 DC-8-73	
2003	22	6	4 DC-8	2 F-27-500	
2004	31	3	2 B-727-100C	1 B-747-100F	
2005	25	3	3 F-27		
2006	15	1	1 B-747-200F		
2007	22	1	1 B-747-200C		
2008	35	4	2 DC-10-30	1 B-747-200F	1 A-300
2009	70	1	1 B-727-200		
2010	71	2	1 B-747-200F	1 L-1011-50	
2011	18	3	2 A-300	2 L-1011	
2012	54	7	3 B-747-200F	3 B-727-200	1 A-300
2013	58	7	6 B-747	1 A-300	
2014	81	13	11 B-747	1 L-1011-200	1 DC-10-30F
2015	81	14	12 B-747-200	2 DHC-7-110	
Totals	668	76			

As in the U.S. case, the supply of used passenger aircraft far exceeds that of demand for replacement cargo aircraft. This is pictured in Figure 8-2. However, one issue that might bolster demand for new cargo aircraft is the predisposition of international carriers to purchase new equipment.

Figure 8-2. International Baseline Supply and Demand for Cargo Aircraft



DEMAND FOR CARGO AIRCRAFT TO MEET RTM GROWTH

The number of aircraft needed to meet future RTM growth is derived from the demand estimates discussed in Chapter 7. However, the results are presented in this section for the sake of continuity.

Methodology

The gross changes in the cargo fleet inventory are driven by changes in RTM traffic. The change in the cargo fleet is calculated under two opposing sets of assumptions. This methodology produces a range of aircraft required to service the projected demand.[6] The additional cargo aircraft needed are calculated by dividing the yearly increase in RTMs by the average RTMs per aircraft of the previous year. This series forms an upper bound on the number of aircraft required to service the growth in demand because the growth in cargo aircraft exactly matches the growth in RTM traffic.

[6] This analysis also includes an implicit assumption that the ratio of belly cargo remains unchanged.

Alternatively, the lower bound is found by the same method, but with ATM substituted for the RTM. The two calculations are linked by the change in the cargo load factor. As the cargo load factor increases, less cargo aircraft are needed to meet the demand, so the additional cargo aircraft needed under the ATM calculation decreases. These two methods account for productivity changes, as reflected in the RTMs, ATMs, and load factor, in both the current cargo fleet and the future cargo fleet.

The specific changes in the cargo fleet composition are driven by two fundamental factors. The first is the rate of increase in wide body aircraft over narrow body aircraft. This shift occurs as the strategic response to shrinking airport capacity at key airports worldwide. The second factor represents the same strategic response as the first, but at the aircraft level rather than the airport level. This is the shift occurring between small versus medium payload for narrow body aircraft and medium versus large payloads for wide body aircraft.[7] This shift represents an aircraft economy of scale in light of additional RTM growth.

This method also guides the analytical model that allocates the additional cargo aircraft to the cargo fleet. The first assumption is that all-cargo aircraft retired because of either old age or the noise law are replaced by aircraft from the same body-payload class. Therefore, all the effects of the changing cargo fleet are captured by the set of cargo aircraft added to meet the new RTM growth. For each year, the number of cargo aircraft added to meet RTM growth is initially allocated to each of the four body-payload classes by its proportion from the previous year. Each allocation per body-payload class is first corrected to account for the shift between wide body and narrow body aircraft, and then within each body class, it is adjusted for the shift from smaller payload to larger payload.

United States Fleet Projections

The assumptions of the model include a real United States GDP annual growth rate of 2.3 percent and an annual real yield decline of 1 percent. The net effect on the United States air cargo fleet is a maximum increase of 2,351 aircraft over the 20-year forecast period, or an average of almost 118 aircraft added per year. This study estimates that 1,092 of these aircraft will be narrow body jet aircraft, 574 will be wide body jet aircraft, and 1,014 will be propeller or turbo propeller aircraft. The yearly inventory totals of the upper bound calculation are shown in Table 8-5. This is the limiting case as the growth rate of the fleet exactly matches the RTM growth.

[7] The industry standard definitions are in use here: (1) narrow body, small payload aircraft are those with a payload capacity of less than 60,000 lbs.; (2) narrow body, medium payload aircraft are those with a payload capacity from 60,000 lbs. to 120,000 lbs.; (3) wide body, medium payload aircraft are those with a payload capacity of 70,000 lbs. to 140,000 lbs.; and (4) wide body, large payload aircraft are those with a payload capacity of more than 140,000 lbs.

Table 8-5. Base Case: Yearly Inventory and Composition of U.S. Cargo Fleet

Year	Inventory	Aircraft added cargo fleet	Narrow body, small payload	Narrow body, medium payload	Wide body, medium payload	Wide body, large payload	Other
1995	1,125		410	225	80	82	328
1996	1,190	65	437	228	88	90	347
1997	1,259	69	466	232	96	99	367
1998	1,332	73	496	235	105	107	388
1999	1,410	77	528	239	114	117	411
2000	1,492	82	562	243	124	127	435
2001	1,578	87	598	248	135	138	460
2002	1,670	92	636	252	146	149	487
2003	1,767	97	676	257	158	161	515
2004	1,869	103	718	262	170	173	545
2005	1,978	108	763	268	183	187	577
2006	2,092	115	811	273	197	201	610
2007	2,214	121	861	279	212	216	645
2008	2,342	128	914	286	227	232	683
2009	2,478	136	971	293	244	248	723
2010	2,622	144	1,030	300	261	266	764
2011	2,774	152	1,093	307	280	285	809
2012	2,935	161	1,160	316	299	304	856
2013	3,105	170	1,231	324	320	325	905
2014	3,286	180	1,305	333	342	348	958
2015	3,476	191	1,384	343	365	371	1014
Total		2,351	974	118	285	289	686

A more realistic case would allow an increase in the load factor, so that a portion of new growth is handled by the more efficient use of the current fleet. An annual increase in the cargo load factor of 2 percent reduces the cargo aircraft needed by slightly more than a third. The results for this case are shown in Table 8-6. The U.S. cargo ATMs, RTMs, and DOCs for this case are shown in Table 8-7.

The combination of increases in RTMs and the changing composition of the fleet implies that the percentage of RTMs flown by aircraft type also will change. This change represents a strong proxy for changes in the origin and destination of cargo demand arising from changes in regional GDP. This result arises because of the correlation between the distance between the origin and destination and the type of aircraft chosen for that route. The data for the base case are summarized in Table 8-8. The percentage of RTMs flown by narrow body aircraft will drop from the current level of approximately 31 percent to slightly over 25 percent in 2015. Conversely, the percentage of RTMs flown by wide body aircraft will increase to slightly over 73 percent from its current level of almost 67 percent over the same period.

Table 8-6. Case 2: Yearly Inventory and Composition of U.S. Cargo Fleet

Year	Inventory	Aircraft added cargo fleet	Narrow body, small payload	Narrow body, medium payload	Wide body, medium payload	Wide body, large payload	Other
1995	1,125		410	225	80	82	328
1996	1,167	42	427	227	85	87	340
1997	1,211	44	446	229	90	93	353
1998	1,258	47	465	232	96	98	367
1999	1,308	50	486	234	102	104	381
2000	1,361	53	508	237	109	111	397
2001	1,416	56	531	240	115	118	413
2002	1,475	59	555	242	122	125	430
2003	1,537	62	581	246	130	133	448
2004	1,603	66	608	249	138	141	467
2005	1,673	70	637	252	146	149	488
2006	1,747	74	668	256	155	158	509
2007	1,825	78	700	260	165	168	532
2008	1,907	83	734	264	175	178	556
2009	1,994	87	770	268	185	189	581
2010	2,087	92	809	273	196	200	608
2011	2,185	98	849	278	208	212	637
2012	2,288	103	892	283	221	225	667
2013	2,397	109	937	289	234	238	699
2014	2,513	116	985	294	248	253	733
2015	2,636	123	1,036	301	263	268	768
Total		1,511	626	76	183	186	440

The data for the Case 2, with the increasing load factor, is shown in Table 8-9. Here, the percentage of RTMs flown by narrow body aircraft will drop from the current level of approximately 31 percent to just over 21 percent in 2015. Conversely, the percentage of RTMs flown by wide body aircraft will increase to slightly over 77 percent from its current level of almost 67 percent over the same period. The implication is that the growth is slightly biased toward the wide body aircraft.

Table 8-7. Case 2: U.S. Cargo RTM and ATM Estimates for 1995–2015

Year	U.S. RTMs (billions)	U.S. ATMs (billions)	DOC (cents per ATM)
1995	23.90	57.70	31.12
1996	25.20	59.80	30.81
1997	26.70	62.00	30.50
1998	28.30	64.40	30.19
1999	29.90	66.80	29.89
2000	31.60	69.20	29.59
2001	33.50	71.80	29.30
2002	35.40	74.50	29.00
2003	37.50	77.30	28.71
2004	39.60	80.20	28.43
2005	41.90	83.20	28.14
2006	44.40	86.30	27.86
2007	46.90	89.50	27.58
2008	49.70	92.80	27.31
2009	52.60	96.30	27.03
2010	55.60	99.90	26.76
2011	58.80	103.60	26.50
2012	62.20	107.40	26.23
2013	65.90	111.50	25.97
2014	69.70	115.60	25.71
2015	73.70	119.90	25.45
Annualized compound growth rate	5.80%	3.73%	-1.00%

Table 8-8. Base Case: Percentage RTM Flown by Body/Payload Type of U.S. Cargo Aircraft

Year	% RTM narrow body, small payload	% RTM narrow body, medium payload	% RTM wide body, medium payload	% RTM wide body, large payload	% RTM other
1995	10.22	20.89	16.01	51.60	1.28
1996	10.13	20.33	16.33	51.92	1.28
1997	10.04	19.78	16.66	52.24	1.28
1998	9.95	19.22	16.98	52.57	1.28
1999	9.86	18.66	17.31	52.89	1.28
2000	9.77	18.10	17.63	53.21	1.28
2001	9.68	17.55	17.96	53.53	1.28
2002	9.59	16.99	18.28	53.86	1.28
2003	9.50	16.43	18.60	54.18	1.28
2004	9.41	15.88	18.93	54.50	1.28
2005	9.32	15.32	19.25	54.82	1.28
2006	9.23	14.76	19.58	55.15	1.28
2007	9.14	14.21	19.90	55.47	1.28
2008	9.05	13.65	20.22	55.79	1.28
2009	8.96	13.09	20.55	56.11	1.28
2010	8.88	12.53	20.87	56.44	1.28
2011	8.79	11.98	21.20	56.76	1.28
2012	8.70	11.42	21.52	57.08	1.28
2013	8.61	10.86	21.85	57.40	1.28
2014	8.52	10.31	22.17	57.73	1.28
2015	8.43	9.75	22.49	58.05	1.28

Table 8-9. Case 2: Percentage RTM Flown by Body/Payload Type of U.S. Cargo Aircraft

Year	% RTM narrow body, small payload	% RTM narrow body, medium payload	% RTM wide body, medium payload	% RTM wide body, large payload	% RTM other
1995	10.22	20.89	16.01	51.60	1.28
1996	10.13	20.47	16.26	51.85	1.28
1997	10.05	20.06	16.51	52.10	1.28
1998	9.96	19.64	16.77	52.35	1.28
1999	9.88	19.22	17.02	52.60	1.28
2000	9.79	18.80	17.27	52.85	1.28
2001	9.71	18.39	17.52	53.10	1.28
2002	9.62	17.97	17.78	53.35	1.28
2003	9.54	17.55	18.03	53.61	1.28
2004	9.45	17.13	18.28	53.86	1.28
2005	9.37	16.72	18.53	54.11	1.28
2006	9.28	16.30	18.78	54.36	1.28
2007	9.19	15.88	19.04	54.61	1.28
2008	9.11	15.46	19.29	54.86	1.28
2009	9.02	15.05	19.54	55.11	1.28
2010	8.94	14.63	19.79	55.36	1.28
2011	8.85	14.21	20.04	55.61	1.28
2012	8.77	13.79	20.30	55.86	1.28
2013	8.68	13.38	20.55	56.11	1.28
2014	8.60	12.96	20.80	56.36	1.28
2015	8.51	12.54	21.05	56.61	1.28

International Fleet Projections

The international air cargo fleet is split between U.S. and foreign ownership at a ratio of almost 60 to 40. The higher worldwide real GDP annual growth rate of 3.0 percent reflects the relatively large increases occurring in economies much smaller than that of the United States. Also of note is the initial worldwide cargo load factor of 57 percent, which is almost a third larger than the U.S. load factor of 41 percent. These two factors combine to form an extremely optimistic estimate of future cargo aircraft demand. Such factors lead to an estimate composed of an increase of 5,540 aircraft over the 20-year period of interest. This is equal to an average annual increase of 7.25 percent per year, or an average of 277 aircraft added to the worldwide fleet. For the foreign carriers, this is equal to an additional 3,189 cargo aircraft, with an average annual increase of 9.04 percent per year or an average of approximately 160 cargo aircraft per year. These data are shown in Table 8-10.[8]

Table 8-10. Base Case: Yearly Inventory Count of the International Cargo Fleet

Year	Worldwide inventory	Foreign cargo fleet	Cargo aircraft added to the foreign cargo fleet
1995	1,812	687	
1996	1,943	753	66
1997	2,084	825	72
1998	2,236	903	78
1999	2,398	988	85
2000	2,572	1,080	92
2001	2,758	1,180	100
2002	2,958	1,289	108
2003	3,173	1,406	118
2004	3,403	1,534	128
2005	3,650	1,672	138
2006	3,915	1,822	150
2007	4,199	1,985	163
2008	4,503	2,161	176
2009	4,830	2,352	191
2010	5,180	2,558	207
2011	5,556	2,782	224
2012	5,959	3,024	242
2013	6,391	3,286	262
2014	6,855	3,569	283
2015	7,352	3,876	307
Totals	5,540	3,189	

As before, a more realistic estimate would have the cargo load factor increasing so that a portion of the new RTM growth is filled by the more efficient use of the current fleet. A modest annual increase of 2.0 percent to the load factor is assumed. As before, this cuts the number of additional cargo aircraft needed by more than a third. The summary inventory data for this case is shown in Table 8-11 and the worldwide ATM, RTM, and DOC trends for this case are shown in Table 8-12.

[8] No attempt has been made to segment the international fleet as was done with the U.S. cargo inventory.

Table 8-11. Case 2: Yearly Inventory Count of the International Cargo Fleet

Year	Worldwide inventory	Foreign cargo fleet	Cargo aircraft added to the foreign cargo fleet
1995	1,812	687	
1996	1,905	738	51
1997	2,004	792	54
1998	2,107	848	56
1999	2,215	907	59
2000	2,329	969	62
2001	2,449	1,033	64
2002	2,575	1,100	67
2003	2,708	1,171	70
2004	2,848	1,244	74
2005	2,994	1,321	77
2006	3,148	1,402	80
2007	3,311	1,486	84
2008	3,481	1,574	88
2009	3,660	1,666	92
2010	3,849	1,762	96
2011	4,047	1,863	100
2012	4,256	1,968	105
2013	4,475	2,077	110
2014	4,705	2,192	115
2015	4,948	2,312	120
Totals	3,136	1,695	

Future Worldwide Supply and Demand for Cargo Aircraft

The worldwide demand for cargo aircraft is found by summing the baseline demand and the demand to meet RTM growth across both the U.S. and foreign fleets. In this analysis, we chose to use the conservative growth in demand, which is consistent with a 2 percent annual increase in the load factor. The result is a total market size of 3,514 cargo aircraft. The yearly and cumulative demand is shown in Table 8-13.

Although the total aircraft requirements may appear to be substantial, these cargo aircraft actually are spread across four jet types and the general class of turboprop aircraft. Applying the ratios of the new aircraft added to the U.S. fleet to the worldwide demand leads to the allocation of those 3,514 cargo aircraft to each of the 5 aircraft types. Specifically, 1,633 narrow body aircraft are needed with 1,456 of them falling in the small payload category and the other 177 belonging to the medium payload category. The wide body class totals 859 aircraft, with 426 of them being medium payload and the other 433 belonging to the large payload class. Finally, we project 1,023 cargo aircraft in the residual category primarily composed of turboprop aircraft. These data are shown in Table 8-14.

Table 8-12. Case 2: Worldwide Cargo RTM and ATM Estimates for 1995 to 2015

Year	Worldwide RTMs (billions)	Worldwide ATMs (billions)	DOC (cents/ATM)
1995	64.0	112.2	25.00
1996	68.7	118.6	24.75
1997	73.6	125.3	24.50
1998	79.0	132.4	24.25
1999	84.7	139.9	24.01
2000	90.9	147.8	23.77
2001	97.5	156.2	23.53
2002	104.5	165.1	23.30
2003	112.1	174.4	23.06
2004	120.2	184.3	22.83
2005	129.0	194.8	22.61
2006	138.3	205.8	22.38
2007	148.3	217.5	22.16
2008	159.1	229.8	21.93
2009	170.6	242.8	21.71
2010	183.0	256.6	21.50
2011	196.3	271.2	21.28
2012	210.5	286.5	21.07
2013	225.8	302.8	20.86
2014	242.2	319.9	20.65
2015	259.8	338.1	20.44
Annualized compound growth rate	7.25%	5.67%	-1.00%

The worldwide supply of cargo aircraft comes from two sources: the converted used passenger aircraft and the purchased-as-new cargo aircraft. The worldwide supply of cargo conversion-eligible passenger aircraft is shown in Table 8-15. There are a total of 1,693 such aircraft, which means that there is a minimum demand for 1,821 (3,514–1,693) additional cargo aircraft. Assuming the same worldwide proportions as the U.S. fleet, these 1,821 new cargo aircraft are spilt out by 856 narrow body cargo aircraft, 438 wide body aircraft, and 528 turboprops. The narrow body aircraft are split 765 to 91 into the small payload and medium payload classes, while the wide body aircraft are split evenly between the medium payload and the large payload classes, each with 219 aircraft. These data are shown in Table 8-16.

Table 8-13. Total Cargo Aircraft Demand 1996 to 2015

Year	U.S. baseline	U.S. growth	Foreign baseline	Foreign growth	Total
1996	0	42	0	51	93
1997	41	44	0	54	139
1998	41	47	0	56	144
1999	41	50	0	59	150
2000	0	53	0	62	115
2001	0	56	3	64	123
2002	15	59	8	67	149
2003	38	62	6	70	176
2004	39	66	3	74	182
2005	23	70	3	77	173
2006	7	74	1	80	162
2007	15	78	1	84	178
2008	2	83	4	88	177
2009	5	87	1	92	185
2010	10	92	2	96	200
2011	8	98	3	100	209
2012	1	103	7	105	216
2013	4	109	7	110	230
2014	2	116	13	115	246
2015	10	123	14	120	267
Totals	302	1,511	76	1,625	3,514

Table 8-14. Percentage of Cargo Aircraft by Body/Payload Type

Cargo aircraft	Narrow body, small payload	Narrow body, medium payload	Wide body, medium payload	Wide body, large payload	Other
Percentage of cargo aircraft	42%	5%	12%	12%	29%
Number	1,456	177	426	433	1,023

This analysis assumes that supply and demand need to be met on an aggregate basis. A more accurate approach balances supply and demand on a yearly basis. This is shown in Table 8-17. In this approach, the demand for cargo aircraft must be met in the year it occurs, first by converted passenger aircraft and then by new cargo aircraft. Supply is not constrained to be used in the year it occurs and can be carried over to meet future demand. Using this framework, there is a minor difference of one aircraft (1820 versus 1821), and a slight difference in the demand profile from years 1997 to 2000.

Table 8-15. Supply of Cargo Conversion-Eligible Passenger Aircraft

Year	U.S. Stage 3 passenger aircraft	U.S. Stage 2 passenger aircraft	Foreign passenger aircraft	Totals
1996	0	0	10	10
1997	0	132	19	151
1998	0	127	4	131
1999	0	167	7	174
2000	0	0	13	13
2001	0	0	11	11
2002	0	0	22	22
2003	0	0	22	22
2004	0	0	31	31
2005	0	0	25	25
2006	0	0	15	15
2007	0	0	22	22
2008	0	0	35	35
2009	4	0	70	74

Implicit in this analysis is the assumption that all carriers will both desire and be financially able to purchase new cargo aircraft. This assumption may be strong for the available evidence. Table 8-18 shows the number of new cargo aircraft purchased, both domestically and internationally, over the period 1985 to 1995. The foreign carriers have averaged almost 10 new cargo aircraft per year, with a low of 3 in 1991 and a high of 17 in 1988. Similarly the U.S. carriers have purchased an average of just above 12.5 new cargo aircraft per year, with a low of 2 in 1989 and a high of 25 in 1995. These numbers warrant a closer look at the market size for new cargo aircraft.

Table 8-16. Minimum Number of Cargo Aircraft by Body/Payload Type

Cargo aircraft	Narrow body, small payload	Narrow body, medium payload	Wide body, medium payload	Wide body, large payload	Other
Percentage of cargo aircraft	42%	5%	12%	12%	29%
Number	765	91	219	219	528

Table 8-17. Yearly Demand for New Cargo Aircraft

Year	Cargo aircraft demand	Passenger aircraft supply	Excess demand	Excess supply	New cargo aircraft needed
1996	93	10	83		83
1997	139	151		12	0
1998	144	131	13		1
1999	150	174		24	0
2000	115	13	102		78
2001	123	11	112		112
2002	149	22	127		127
2003	176	22	154		154
2004	182	31	151		151
2005	173	25	148		148
2006	162	15	147		147
2007	178	22	156		156
2008	177	35	142		142
2009	185	74	111		111
2010	200	100	100		100
2011	209	82	127		127
2012	216	137	79		79
2013	230	142	88		88
2014	246	244	2		2
2015	267	253	14		14
Totals	3,514	1,693	1,856		1,820

Table 8-18. Worldwide Sales of New Cargo Aircraft

Year	Foreign	United States	Total
1985	9	11	20
1986	15	13	28
1987	13	10	23
1988	17	14	31
1989	15	2	17
1990	12	10	22
1991	3	14	17
1992	6	11	17
1993	5	10	15
1994	8	19	27
1995	6	25	31
Totals	109	139	248
Average	9.91	12.64	22.55

THE MARKET FOR NEW CARGO AIRCRAFT

The estimated yearly demand for new cargo aircraft is well above the historical buying patterns of new cargo aircraft. The reason for this gap and possible solutions are discussed in this section.

The relatively low sales of new cargo aircraft reflect both the role of cargo within the air transportation system and the financial and economic status of the carriers. For most major U.S. flag carriers, cargo represents a minor portion of the revenue stream, and it is usually carried in the belly of passenger aircraft. Cargo represents a type of ancillary revenue for these carriers. Two of the three major U.S. carriers with large cargo operations (Northwest and United) have done so by limiting their all-cargo operations to specialized cargo aircraft operating on specific high-demand routes (e.g., Northwest's fleet of Boeing 747-Fs operating on the U.S. to Tokyo route). The major increases in purchases occurring in 1995 and 1996 represent both major and minor carriers seeking to emulate this strategy in light of the expected cargo growth.

Other U.S. passenger carriers, who may be able to afford the purchase of new cargo aircraft, have not done so. The major reason is that they wish to focus on their core strengths, primarily on serving the expected increases in the passenger market while limiting cargo activity to the portion of the excess belly capacity that can be sold.

The largest new additions to the foreign cargo fleet occurred over the period 1986 to 1990. One explanation for the somewhat lower than expected new cargo aircraft demand is that of regulation. With routes and tariffs defined and controlled, there may be extraordinary lags in adding cargo capacity to meet the demand due to the lack of competitive pressures. The European continent is at the beginning of a period of deregulation in most of its major industries. As with the period of airline deregulation in the United States, one should expect capacity to be added to their air transportation system, with the inevitable shake-out period following.

The role of aircraft capital costs are critical to the success of this industry. Smaller passenger and all-cargo carriers may not wish to pay the huge capital costs associated with owning new all-cargo aircraft. For some carriers, cargo is only profitable by owning older aircraft, where the effects of the capital costs have been minimized. The Industry Analysis Chapter shows that without significantly improved balance sheets, some of these smaller cargo carriers will not be able to purchase new cargo aircraft. Unfortunately, improved balance sheets and large profits will undoubtedly attract new competitors to the marketplace, forcing a status quo type of equilibrium, where a set of carriers consistently generate above normal profits, another set barely break even, and a third set consistently lose money and exit the marketplace.

Almost all aircraft fleet projections assume that capital will be available for the purchase of future demanded aircraft. Over the next decade, the expected increase in passenger and cargo traffic and the resulting aircraft purchases may very well test that assumption. Capital markets will have to be expanded or the aircraft manufacturers will be forced to become financiers also. Of course, the price of capital will vary by purchaser, with the most profitable customers buying with lower costs of capital. This does not bode well for most of the Groups I and II cargo carriers.

Closely related to the issue of capital is that of capacity. There are effectively two manufacturers of large commercial transport aircraft in the world. They will supply the bulk the new passenger aircraft to be demanded over the next 20 years.

They also will be expected to supply the cargo aircraft as well. It is currently unclear how and where they will expand their operations to add the capacity to produce all of the desired aircraft on an efficient and cost-effective basis.

As the demand for both cargo and passenger aircraft increases, there is a set of natural responses that should occur. The first is that prices for new aircraft, of both types, will rise. If the demand for aircraft is greater than the manufacturers' ability to produce, in the very short run, there will be spot shortages of particular types of aircraft. Additionally one would expect to see an increase in aircraft prices and the emergence of a priority ordering system in which preferred customers are satisfied first.

One potential solution to the supply-demand gap in cargo aircraft is an increase in cargo-carrying capacity without increasing the number of cargo aircraft. This is likely to be the first response of the current crop of all cargo carriers.

The first way of increasing cargo capacity is derived from passenger aircraft. Because the passenger traffic is relatively large compared with cargo traffic, the relatively smaller increase in passenger traffic brings large increases to industry-wide belly cargo volume. An increasing portion of the new demand can be served by the belly carrying cargo aircraft, thus, lowering the demand for new cargo aircraft further. Furthermore, since some passenger carriers do not effectively use that belly cargo space, it could be sold or contracted to either other carriers or to a *virtual* cargo airline.

A similar increase in effective capacity can be found by increasing the cargo load factor. As seen in the analysis, relatively small increases in the cargo load factor can have a huge effect on the number of new cargo aircraft purchased. It is expected that those cargo carriers with little or no profits would find ways to better utilize their current capacity before purchasing additional, either new or used, cargo aircraft.

However, this method also has some important limitations. First note that all cargo traffic statistics are reported on the basis of weight as opposed to cubic volume. Because most cargo shipped via air has a high value-to-weight ratio, air cargo has the propensity to "cube out" before it "weighs out." Essentially, this means that the volume of the cargo hold is filled before the weight capacity of the aircraft is reached. This fact explains a portion of the low load factors associated with the cargo industry. Cargo traffic, like passenger traffic, may also have an optimal load factor of less than 100 percent. This phenomenon occurs in passenger traffic because customers are increasingly harder to serve, take longer to board and depart, and are leaving aircraft more irritable and more willing to fly on another carrier. There also may be an equivalent effect for cargo traffic, where large tonnage requires special handling, loading, and balancing requirements along with extra loading and unloading time.

The last method to increase capacity is to purchase additional aircraft. It is conceivable that new capacity will be added by the addition of new entrants in the air cargo industry as opposed to existing carriers. Just as the abandonment of freighters by the major carriers produced an opportunity for the freight forwarders to become cargo carriers, the next opportunity will be had by those well-financed transport companies looking at expansion into the air cargo market. They are then able to operate an integrated and combined shipping network under one organization, offering integrated rail, truck, air, and ocean services.

In the final analysis, 1,800 aircraft, spread across five aircraft types, is not a large enough market to support five new all-cargo aircraft designs. Because the bulk of the demand is in the narrow body, small payload aircraft type, under normal passenger market conditions, this would be enough demand for a new or derivative passenger aircraft. But this is the cargo market, a secondary market to most major U.S. carriers, and it is populated by carriers of varying degrees of experience and even wider varying degrees of profitability. While a combination of new engine technology and modern design may be able to construct an airplane to adequately cover both ends of the narrow body cargo market, the likely buyers have not historically exhibited the willingness to purchase large numbers of any size aircraft and are much more likely to exercise a wide range of tactics to increase capacity before purchasing new aircraft.

Chapter 9

Summary and Conclusions

This final section presents the summary and conclusions of this work. It is centered around two themes: the use of the Air Cargo Operating Cost Database and the market for an all-cargo aircraft.

The Air Cargo Operating Cost Database was formally presented in Chapter 3 and used throughout in the analyses presented in subsequent chapters. The database contains a mix of historical data and future estimates that describe the state of the air cargo industry. It has been used to determine the DOC/ATM of the air cargo industry, at the carrier level, at the industry level, and most importantly, at the equipment level. In addition, a set of tradeoff curves that translate specific operating and design parameters, such as stage length and capacity to DOC/ATM, for the current cargo fleet have been calculated. This curve forms the basis for calculating future cargo operating costs of the next generation of cargo aircraft, be they a new design or converted passenger aircraft. The database can be modified so that the capital costs can be increased to reflect either the resale costs of the next generation of converted passenger aircraft or the full cost of the purchase price of a new all-cargo aircraft. The calculation of this tradeoff curve determines the minimum DOC/ATM for any specified parameter, for any type of aircraft. The tradeoff curve is not a static one, but changes as large numbers and types of cargo aircraft enter and exit the fleet. The curve also is dependent on how the particular cargo aircraft are used, which is a function of the carriers.

Using conservative estimates, the worldwide inventory of cargo aircraft is expected to grow to approximately 4,950 aircraft as a result of cargo traffic generated from a worldwide GDP annual growth rate of 3 percent and an annual RTM growth rate of 7.25 percent. This translates to 3,500+ cargo aircraft being added to the current fleet. Almost 1,700 of these aircraft will come from the ranks of the older, converted, and possibly upgraded passenger aircraft fleets. This leaves the possible new cargo aircraft sales at around 1,825 aircraft. These new cargo aircraft sales will occur across five different aircraft types with the breakout being 760 narrow body, small payload cargo aircraft; 90 narrow body, medium payload cargo aircraft; 225 wide body, medium payload cargo aircraft; 225 wide body, large payload cargo aircraft; and 525 turboprop aircraft. Advances in engine technology and aircraft design may be sufficient to collapse those five sales segments into the following three: 850 narrow body cargo aircraft, 450 wide body cargo aircraft, and 525 turboprop aircraft.

From a manufacturer's perspective, any of those three segments is large enough to justify a targeted aircraft, assuming it was a passenger aircraft. Unfortunately, the cargo market has not historically purchased large numbers of new aircraft. The reasons run the gamut from poor balance sheets to cheap substitutes in the form of used converted passenger aircraft. The first response of most carriers will not be the purchase of new cargo aircraft, but the better utilization of current capacity or the purchase of excess belly-hold capacity from the passenger carriers. The last strategic response will be the purchase of new cargo aircraft by both existing carriers and new entrants to the air cargo industry. Increased efficiencies in both the use of the current cargo fleet and the belly-carrying capacity of the expanding passenger fleet will drive the number of new cargo aircraft sales to less than 1,825.

Bibliography

American Airlines. *A New Method for Estimating Current and Future Transport Aircraft Operating Economics*. NASA-CR-145190, NASA Langley Research Center, Hampton, Va. March 1978.

Andrastek, Donald. *Study of Aircraft Operating Economics*, Volume 1. NASA-CR-137685, NASA Ames Research Center, Mountain View, Ca. January 1976.

Baughcum, Steven, et al. *Stratospheric Emissions Effects Database Development*. NASA Contractor Report 4592, NASA Langley Research Center, July 1994.

Beeks, Anne and Michael Draper. Department of Decision Support, Royal Dutch Airlines. *Strategic Cargo Division Developments*. Presented at the 33rd Annual AGIFORS Conference, Chicago, Il. October 10, 1993-October 14, 1993.

Beradino, Frank and Earl Bomberger. *Stage II Versus Stage III*. Airline Business, pp. 108-113. September 1990.

Boeing Commercial Airplane Group. *World Air Cargo Forecast: 1994*. Seattle, Washington. July 1994.

Boeing Commercial Airplane Group. *World Air Cargo Forecast: 1995*. Seattle, Washington. August 1995.

Boeing Commercial Airplane Group. *World Air Cargo Forecast: 1996-1997*. Seattle, Washington. October 1996.

Bronfenbrenner, Martin, Werner Sichel and Wayland Gardner. *Economics*. Houghton Mifflin Company, Boston, Ma. 1984.

Data Base Products, Inc. *B43 Inventory of Airframes and Aircraft Engines*. Dallas, Texas. December 31, 1996.

Data Base Products, Inc. *Form F41 Financial Reporting Manual*. Dallas, Texas. May, 1993.

Data Base Products, Inc. *Form F41 Airline Financial Statistics, 1974-1996*. Dallas, Texas. June 1996.

Hendricks, Greg and Raja Kasilingam. American Airlines Decision Technologies. *Cargo Revenue Management at American Airlines Cargo*. Presented at the

33rd Annual AGIFORS Conference, Chicago, Il. 1 October 10, 1993-October 14, 1993.

International Air Transport Association. *Freight Forecast: 1995-1999*. Geneva, Switzerland. September 1995.

International Air Transport Association. *World Air Transport Statistics. No. 40*. Geneva, Switzerland. June 1996.

International Civil Aviation Organization. *Civil Aviation Statistics of the World: 1992*. Document No. 9180/18. Montreal, Canada. February 1994.

International Civil Aviation Organization. *Civil Aviation Statistics of the World: 1993*. Document No. 9180/19. Montreal, Canada. February 1995.

International Civil Aviation Organization. *Civil Aviation Statistics of the World: 1994*. Document No. 9180/20. Montreal, Canada. February 1996.

International Civil Aviation Organization. *Civil Aviation Statistics of the World: 1995*. Document No. 9180/21. Montreal, Canada. February 1997.

International Civil Aviation Organization. *Traffic: Commercial Air Carriers 1990-1994*. Series T No. 54, Digest No. 421. Montreal, Canada. June 1995.

International Civil Aviation Organization. *Traffic: Commercial Air Carriers 1988-1992*. Series T No. 52, Digest No. 400. Montreal, Canada. June 1993.

Johnson, Vicki. *Life Cycle Cost in the Conceptual Design of Subsonic Commercial Aircraft*. Ph.D. Dissertation, University of Kansas, Kansas. May 1989.

Lewis, Dale. *Freight Mode Choice: Air Transport versus Ocean Transport in the 1990's*. Flight Transportation Laboratory, Massachusetts Institute of Technology. December 1994.

Nicholson, Walter. *Microeconomic Theory*. The Dryden Press, Chicago, Ill. 1985.

Shubik, Martin. *Game Theory in the Social Sciences, Concepts and Solutions.* The MIT Press, Cambridge, Ma.1982.

U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1996*. Washington, D.C. 1996.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Transportation Statistics Annual Report 1996*. Washington, D.C. 1996.

Wells, Alexander. *Air Transportation: A Management Perspective.* Wadsworth Publishing, Belmont, Ca. 1994.

Wingrove, Earl. *Working Paper on Economic Models and Databases*. Unpublished LMI Report. McLean, Va. March 1994.

Appendix A
Glossary

This appendix contains standard industry definitions for terms used in the study. The source of the definitions is NASA's Aviation System Analysis Capability (ASAC) Quick Response System (QRS).

Airborne hours—Aircraft hours flown computed from the moment an aircraft leaves the ground during takeoff until it touches the ground during landing.

Air cargo—Subset of total cargo that is transported by aircraft.

Aircraft days—The number of days that aircraft, owned or acquired through rental or lease, are in the possession of the reporting air carrier and are available for service in the reporting carrier's routes. This definition includes days that aircraft are in overhaul or temporarily out of service due to schedule cancellations.

Aircraft miles flown—The great circle distance for each flight stage actually completed, whether or not performed in accordance with the scheduled pattern.

Available load—Represents the maximum salable load. It is the gross takeoff weight minus the aircraft empty weight, less the sum of all justifiable aircraft equipment and the operating load (consisting of minimum fuel load, oil, flight crew, steward's supplies, etc.).

Available seat mile (ASM)—One available seat transported one mile. Available seat miles are computed by multiplying the aircraft miles flown on each flight stage by the number of available seats.

Available ton mile (ATM)—One ton of available load transported one mile. Available ton miles are computed by multiplying the aircraft miles flown on each flight stage by the tons of available load.

Available ton miles per departure—Total available ton miles divided by scheduled and nonscheduled departures. Available ton miles per departure measures a combination of the aircraft size and length of its flight stages.

Available ton miles per gallon fuel—Total available ton miles divided by total fuel consumed. Available ton miles per gallon fuel is one measure of aircraft fuel efficiency.

Available tonne kilometer (ATK)—One tonne of available load transported one kilometer. Available tonne kilometers are computed by multiplying the aircraft kilometers flown on each flight stage by the tonnes of available load. One available tonne kilometer equals 0.685 available ton miles.

Average aircraft age—The difference between the year of the data and the year of initial delivery of the airframe.

Average stage length—Total aircraft miles flown divided by the total number of departures performed. Average stage length measures the average distance flown per flight segment.

Block hours—The time computed from the moment the aircraft first moves under its own power for purposes of flight at the originating airport until it comes to rest at the destination airport.

Cargo—Goods transported by ship, aircraft, truck, or other vehicle.

Cargo available ton miles—One ton of available cargo load transported one mile. Cargo available ton miles are computed by subtracting one-tenth of the available seat miles (one passenger equals 200 pounds by convention) from the total available ton miles.

Cargo available ton miles per total available ton miles—Cargo available ton miles divided by total available ton miles. Ratio measures the percentage of a carrier's traffic capacity, by weight, which is reserved for cargo.

Cargo revenue—Revenue category consisting of scheduled and nonscheduled freight and mail revenues.

Cargo yield—Cargo revenues divided by the sum of scheduled and nonscheduled cargo revenue ton miles. Ratio measures the average revenue collected for a ton mile of revenue cargo traffic.

Cargo revenue per total revenue—Cargo revenue divided by the sum of cargo revenue and passenger revenue. Ratio measures the percentage of total revenue attributable to cargo operations.

Cargo revenue ton miles—One ton of revenue cargo transported one mile. Cargo revenue ton miles are computed by subtracting one-tenth of the available revenue passenger miles (one passenger equals 200 pounds by convention) from the total revenue ton miles. Equivalently, cargo revenue ton miles are computed as the sum of freight and mail revenue ton miles.

Cargo revenue ton miles per total revenue ton miles—Cargo revenue ton miles divided by the sum of cargo and passenger revenue ton miles. Ratio measures, by weight, the percentage of total traffic that is attributable to cargo operations.

Cargo load factor**—**The sum of scheduled and nonscheduled mail revenue ton miles and scheduled and nonscheduled freight revenue ton miles divided by the sum of scheduled and nonscheduled cargo available ton miles.

Carrier group**—**A Department of Transportation delineation of air carriers according to the criteria of operating revenue. Group III carriers are those carriers with operating revenues exceeding $1 billion. Group II carriers are those carriers with operating revenues between $100 million and $1 billion. Group IA carriers are those carriers with operating revenues between $20 and $100 million. Group IB carriers are those carriers with operating revenues of less than $20 million. Group delineation is independent of the type of service provided by the carrier.

Direct operating cost (DOC**)—**A cost category consisting of flight crew costs (salaries, benefits, pensions, payroll taxes, and other personnel, professional, and training expenses); fuel and oil costs (including taxes); maintenance costs (including maintenance overhead); insurance and injuries, loss, and damage charges; aircraft rentals; and flight equipment depreciation and amortization charges.

Direct operating costs per available ton mile**—**Direct operating costs divided by total available ton miles. Ratio measures the average cost of transporting one ton mile of available capacity.

Flight equipment**—**Property and equipment of all types and classes used in the in-flight operations of aircraft. It includes airframes and unamortized airframe overhauls, aircraft engines and unamortized aircraft engine overhauls, improvements to leased flight equipment, airframe parts and assemblies, aircraft engine parts and assemblies, and other parts and assemblies.

Flight stage**—**The operation of an aircraft from takeoff to landing.

Flying operations costs**—**Expenses incurred directly in the in-flight operation of aircraft and expenses attached to the holding of aircraft and aircraft operational personnel in readiness for assignment to in-flight status.

Freight**—**Subset of air cargo that includes all property, other than mail.

Freight revenue**—**A revenue category consisting of revenues derived from scheduled and nonscheduled freight transportation.

Freight revenue ton miles**—**One ton of revenue freight transported one mile. Freight revenue ton miles are calculated by multiplying the aircraft miles flown on each flight stage by the tons of revenue freight traffic transported on that aircraft.

Indirect operating cost (IOC**)—**A cost category consisting of expenses incurred for passenger service, aircraft and traffic service, promotion and sales, general and administrative, depreciation and amortization of nonflight equipment, and transport related costs.

Kilometer—One metric kilometer (1,000 meters). One kilometer equals 0.6214 statute miles.

Mail—Subset of air cargo that consists exclusively of letters and small packages transported under contract from United States and foreign mail service organizations.

Mail revenue—A revenue category consisting of revenue exclusively from the transportation of United States and foreign mail service organizations.

Mail revenue per total revenue—Mail revenue divided by the sum of cargo revenue and passenger revenue. Ratio measures the percentage of total revenue attributable to mail.

Mail revenue ton miles—One ton of revenue mail transported one mile. Mail revenue ton miles are calculated by multiplying the aircraft miles flown on each flight stage by the tons of revenue mail traffic transported on that aircraft.

Mile—One statute mile (5,280 feet).

Noise stage—The 1977 amendment to Part 36 of the Federal Aviation Regulations established the noise designations for civil turbojet and transport category aircraft as Stage 1, Stage 2, or Stage 3. Aircraft that could not meet the original noise standards, issued in 1969, were designated as Stage 1. Examples of Stage 1 aircraft include the Boeing 707, 720, and early 727 and 737 models; the Douglas DC-8 and early DC-9 models; and the BAC 1-11. Aircraft that met the 1969 standards were designated as Stage 2. Examples of Stage 2 aircraft include the Boeing 747, Douglas DC-10, and Lockheed L-1011 models along with later versions of the 727, 737, and DC-9 models produced after 1974. Aircraft that meet the more stringent noise standards adopted in 1977 are designated Stage 3. Stage 3 models include the Boeing 757, 767 and 777; Douglas MD-80; and Fokker F-100 models.

Operating cost per available seat mile—Total operating expense divided by the sum of scheduled and nonscheduled available seat miles.

Operating cost per available ton mile—Total operating expense divided by the sum of scheduled and nonscheduled available ton miles.

Operating profit or loss—Total operating revenue minus total operating expense. Operating profit excludes income tax expense; nonoperating income and expense (capital gains and losses, interest income, and gains and losses from foreign exchange); and expenses resulting from discontinued operations, extraordinary items, and accounting changes.

Passenger load factor—Revenue passenger miles divided by available seat miles.

Passenger revenue—Revenue category consisting of revenue generated from the transportation of passengers by air, including infants transported at reduced fares, berth charges, surcharges for premium service, and other passenger-related revenues.

Passenger weight—For the purpose of Form 41 reporting, a standard weight of 200 pounds per passenger (including all baggage) is used for all civil operations and classes of service.

Revenue passenger—Person receiving air transportation from the air carrier for which remuneration is received by the air carrier.

Revenue passenger mile (RPM)—One revenue passenger transported one mile. Revenue passenger miles are computed by multiplying the aircraft miles flown on each flight stage by the number of passengers transported on that aircraft.

Revenue ton mile (RTM)—One ton of revenue traffic transported one mile. Revenue ton miles are computed by multiplying the aircraft miles flown on each flight stage by the tons of revenue traffic transported on that aircraft.

Revenue tonne kilometer (RTK)—One tonne of revenue traffic transported one kilometer. Revenue tonne kilometers are computed by multiplying the aircraft kilometers flown on each flight stage by the tonnes of revenue traffic transported on that aircraft. One revenue tonne kilometer equals 0.685 revenue ton miles.

Scheduled available ton miles per total available ton miles—Total scheduled available ton miles divided by the sum of scheduled available ton miles and nonscheduled available ton miles. Ratio measures the percentage of a carrier's traffic capacity, by weight, which is comprised of scheduled service.

Ton—A short ton (2,000 pounds).

Tonne—One metric ton (1,000 kilograms). One tonne equals 1.102 short tons.

Total operating expense—A cost category consisting of expenses incurred for flying operations, maintenance, passenger service, aircraft and traffic service, promotion and sales, general and administrative, depreciation and amortization, and transport-related costs. Total operating expense is the sum of direct and indirect operating expenses.

Total operating revenue—A revenue category consisting of passenger revenue, mail and freight revenue, charter revenue, and other revenues.

Weight load factor—The sum of scheduled and nonscheduled mail revenue ton miles, scheduled and nonscheduled freight revenue ton miles, and one tenth of the scheduled and nonscheduled passenger miles (one passenger equals 200 pounds by convention) divided by the sum of scheduled and nonscheduled available ton miles.

Appendix B
Department of Transportation Form 41 Schedules

The Form 41 schedule data are composed of a series of reports that document the financial and operational status of the individual carriers. This large set of data allows for an unsurpassed level of industry and firm analyses. The individual schedules and their reporting frequencies are shown in Table B-1. Then, for each schedule used explicitly for the study, Tables B-2 through B-5 enumerate the individual account elements.

Table B-1. Form 41 Financial Schedules

Schedule	Title	Period
A	*Certification*	Quarterly
B-1	*Balance sheet*	Quarterly
B-12	*Statement of cash flows*	Quarterly
B-43	*Inventory of airframes and aircraft engines*	Annually
B-7	*Airframe and aircraft engine acquisitions and retirements*	Quarterly
P-1	*Interim income statement*	Monthly
P-1.2	*Statement of operations*	Quarterly
P-2	*Notes to RSPA Form 41 report*	Quarterly
P-5.1	*Aircraft operation expenses-Group I carriers*	Quarterly
P-5.2	*Aircraft operating expenses-Group II carriers*	Quarterly
P-6	*Aircraft operating expenses by objective groupings*	Quarterly
P-7	*Aircraft operating expenses by functional groupings*	Quarterly
P-10	*Employment statistics by labor category*	Annually
P-12	*Fuel consumption by type of service and entity*	Monthly
T-100	*Traffic and segment (origin and destination)*	Monthly
T-2	*Traffic, capacity, and operations*	Quarterly

Table B-2. Lines of Schedule P-1.2, Statement of Operations

Category	Account number	Elements
Operating revenue	3901.1	Passenger revenue—first class
	3901.2	Passenger revenue—coach
	3905.0	Mail
	3906.1	Property—freight
	3906.2	Property—excess passenger baggage
	3907.1	Charter-passenger
	3907.2	Charter—freight
	3919.1	Reservation cancellation fees
	3919.2	Miscellaneous operating revenues
	4808	Public service revenues—subsidy
	4898	Transport—related revenues
	4999	Total operating revenues
Operating expense	5100	Flying operations
	5400	Maintenance
	5500	Passenger service
	6400	Aircraft and traffic servicing
	6700	Promotion and sales
	6800	General and administrative
	7000	Depreciation and amortization
	7100	Transport—related expenses
	7199	Total operating expenses
	7999	Operating profit or loss
Non-operating income/expense	8181	Interest on debt and capital lease
	8182	Other interest expense
	8185	Foreign exchange gains/losses
	8188.5	Capital gains
	8188.6	Capital losses
	8189	Other income and expense
	8199	Non-operating income/expense
	8999	Income before income taxes
Income taxes	9100	Income taxes
	9199	Income after income tax
Discontinued operations	9600	Discontinued operations
Extraordinary items	9796	Extraordinary operations
	9797	Taxes for extraordinary items
Accounting changes	9800	Accounting changes
Net income	9899	Net income

Table B-3. Lines of Schedule P-5.1, Aircraft Operation Expenses—Group I Carriers

Category	Account	Elements
Flying operations	3	Pilot and copilot salaries/benefits
	4	Aircraft fuel and oil
	5	Other flying operations
	6	Total flying operations (less rental)
Maintenance expense	7	Maintenance-flight equipment
	8	Depreciation and rental-flight equipment
	9	Total direct expense
Indirect expense	11	Flight attendant salaries/benefits
	12	Traffic-related expense
	13	Departure-related expense
	14	Capacity-related expense
	15	Total indirect expense
Total operating expense	16	Total operating expense

Table B-4. Lines of Schedule P-5.2, Aircraft Operating Expenses - Group II Carriers

Category	Account	Elements
Flying operations	23	Pilots and copilots
	24	Other flight personnel
	28.1	Trainees and instructors
	36	Personnel expense
	41	Professional and technical fees
	43.7	Aircraft interchange charges
	45.1	Aircraft fuel
	45.2	Aircraft oil
	47	Aircraft rental
	53	Other supplies
	55.1	Insurance purchase—general
	57	Employee benefits and pensions
	58	Injuries, loss and damage
	68	Taxes—payroll
	69	Taxes—other than payroll
	71	Other flying operations expense
	5199	Total flying operations expense
Maintenance-flight equipment	25.1	Labor—airframes
	25.2	Labor—aircraft engines
	43.1	Airframe repairs
	43.2	Aircraft engine repairs
	43.7	Aircraft interchange charges
	46.1	Maintenance materials—airframe
	46.2	Maintenance materials—engines
	72.1	Airworthiness allowance-airframe
	72.3	Airframe overhauls deficit
	72.6	Airworthiness allowance—engines
	72.8	Aircraft engine overhauls deficit
	78	Total direct maintenance—flight equipment
	79.6	Applied maintenance burden—flight equipment
	5299	Total flight equipment maintenance
Net obsolescence	7073.9	Obsolescence and deterioration
Depreciation-flight equipment	75.1	Depreciation—airframes
	75.2	Depreciation—aircraft engines
	75.3	Depreciation—airframe parts
	75.4	Depreciation—aircraft engine parts
	75.5	Depreciation—other flight equipment
	76.1	Amortization—capital leases
Total aircraft operating expense	7098.9	Total aircraft operating expense

Table B-5. Lines of Schedule P-6, Aircraft Operating Expenses by Objective Grouping

Category	Account	Element
Salaries	3	General management personnel
	4	Flight personnel
	5	Maintenance labor
	6	Aircraft and traffic handling
	7	Other personnel
	8	Total salaries
Related fringe benefits	10	Personnel expense
	11	Employee benefits and pensions
	12	Payroll taxes
	13	Total-related fringe benefits
Materials purchased	16	Aircraft fuel and oil
	17	Maintenance material
	18	Passenger food
	19	Other materials
	20	Total materials
Services purchased	22	Advertising and other promotion
	23	Communication
	24	Insurance
	25	Outside flight equipment maintenance
	26	Traffic commissions—passenger
	27	Traffic commissions—cargo
	28	Other services
	29	Total services
Landing fees	30	Landing fees
Rentals	31	Rentals
Depreciation	32	Depreciation
Amortization	33	Amortization
Other	34	Other
Transport-related expense	35	Transport-related expense
Total operating expense	36	Total operating expense

Appendix C
Review of Previous Work

In the course of the research effort outlined in this report, several previously published studies were reviewed. Three of these studies were sufficiently relevant to merit attention in this appendix. These studies include *Freight Mode Choice: Air Transport Versus Ocean Transport in the 1990's*, *The Study of Short-Haul Aircraft Operating Economics* and *A New Method for Estimating Current and Future Transport Aircraft Operating Economics*.

Freight Mode Choice: Air Transport Versus Ocean Transport in the 1990's examines the factors affecting the choice of transport mode between ocean-going vessels and aircraft. The factors studied include interest charges on goods in transit, losses to cargo in transit, and both ordering and transportation costs. The result is an integrated logistics model in which the shipper chooses the mode of transportation to maximize the net benefits of transport. Because the focus is on ocean shipping, however, the analysis is implicitly restricted to international cargo.

The volume of goods shipped by air is less than 1 percent of the weight of those shipped by water and 4 percent of the volume of goods shipped by containers. One interesting comparison is that the highest cost per ocean ton-mile is still 3.5 times lower than the lowest cost per air ton-mile. This measure defines the fundamental tradeoff in air versus ocean shipping, that of price versus time. Ocean shipping is relatively cheap but time-consuming, conversely air shipping is relatively expensive but quick. The market-observed dividing point in the tradeoff seems to be around a value of $10 value per cubic foot (cubic-value density).

The Study of Short-Haul Aircraft Operating Economics presents an attempt to develop an operating cost model for short-haul aircraft. Although the report is somewhat dated, the formulation and analysis techniques employed are still valid. The model is populated with airline operating data from 1971 to 1973 taken from the Civil Aeronautics Board Form 41. Definitions for short-haul DOC and IOC are given and cost estimating relationships (CERs) determined. The DOC CERs were based on 18 variables in the categories of flight crew, fuel, oil, taxes, insurance, flight equipment maintenance, and flight equipment depreciation. The IOC CERs were based on eight variables in the categories of passenger service, aircraft and traffic servicing, promotion and sales, ground property and equipment, general and administrative, and amortization.

A New Method for Estimating Current and Future Transport Aircraft Operating Economics presents a methodology by which the operating costs associated with variations in aircraft designs and technology characteristics can be assessed. It is essentially the precursor of the Flight Optimization System (FLOPS) model and several components of the ASAC system. The most relevant portion of this report is the definitions and components of the cost categories included in direct and indirect operating costs.

Appendix D

Environmental Analysis—Noise

Environmental concerns regarding noise pollution have become a major concern during the past several decades. The noise level produced by an aircraft engine is primarily determined by the equipment age and the thrust output. As engine technology has progressed, the noise impact of engines has declined significantly. Therefore, the latest engine designs produce substantially less noise for a given level of thrust. Such advancements are incorporated into the air transport fleet as new aircraft are purchased to replace existing aircraft or meet additional growth. As older aircraft are retired or modified, the average level of noise impact per aircraft declines over time. However, this natural rate of decline in noise emissions generally occurs quite slowly.

To speed the noise-reduction process, the governments of the United States and the European Union have adopted laws restricting the operations of older aircraft. These laws mandate the elimination or modification of aircraft engines produced during the 1970s and early 1980s by the year 2000 (2002 for Europe). Such aircraft are known as Stage 2 aircraft.[1] The specific timetable for operations in the United States consists of four milestones with the possibility for one waiver. Two of the milestones have already occurred. The remaining milestones are as follows:

- *Tier 3*—Reduce the inventory of Stage 2 aircraft 75 percent by year-end 1998 or increase the total percentage of Stage 3 aircraft to 75 percent by year-end 1998.
- *Tier 4*—Reduce the inventory of Stage 2 aircraft 100 percent by year-end 1999 or increase the total percentage of Stage 3 aircraft to 100 percent by year-end 1999.
- *Waiver*—If the total percentage of Stage 3 aircraft is at least 85 percent by 1 July 1999, a waiver to delay the Tier 4 deadline to year-end 2003 can be requested.

The European community has produced a broader set of regulations that accomplish the same goal, but allow the carriers more flexibility in terms of the timing.

[1] Aircraft currently in production use engine technology defined by Stage 3.

The European Community directive consists of the following components:

- Chapter 2 aircraft older than 25 years by April 2002 must be eliminated or modified.[2] The elimination is not to exceed 10 percent of the base fleet in any year.
- Chapter 2 aircraft less than 25 years of age are exempt until April 2002.
- Chapter 2 multi-aisle aircraft are exempt until April 2002.
- No additional Chapter 2 aircraft may be registered in European nations.
- Chapter 2 aircraft from developing nations are exempt beyond 2002 providing Chapter 3 compliancy plans are in force.

The noise regulations of both the European community and the United States allow for the retrofitting of Chapter 2 aircraft with Chapter 3-compliant engines. The retrofit may take the form of a Chapter 3 hushkit, or an entirely new Chapter 3 engine.

These noise regulations are of particular importance to the air cargo industry for several reasons. First, because cargo aircraft tend to be older than passenger aircraft, they are more likely to come under the jurisdiction of the noise regulations. Second, because the majority of air cargo operations are conducted during evening and nighttime hours, the public perception of cargo operations is particularly sensitive to the noise impact. Thus far, cargo carriers have favored the use of hushkits to achieve Stage 3 compliance.

[2] Chapter 2 and Chapter 3 noise designations are the international community counterparts of Stage 2 and Stage 3 designations, respectively.

Appendix E

Environmental Analysis—Emissions

The constituents of aircraft engine exhaust are known to affect both the atmospheric chemistry (i.e., ozone) and the general climate. The phenomenal growth of aviation has resulted in concerns that these emissions may already be large enough to have caused significant environmental damage or that they will do so in the future.

Aviation today is responsible for about 3 percent of worldwide carbon dioxide (CO_2) produced by burning carbon-based fuels and about 4 percent within the United States. The worldwide figure could grow to as large as 10 percent by the year 2050, depending upon many factors associated with economic growth. Aircraft emissions of NO_x account for similar percentages.

The growth rate of U.S. fuel aviation use is three times that of motor fuels. Current usage by subsonic aircraft is 134 billion kilograms with 70 percent of that total, 93.8 billion kilograms, used by scheduled jet and turboprop aircraft carrying both passengers and cargo. Without the introduction of the High Speed Civil Transport (HSCT), usage is expected to grow to 304 billion kilograms with 84 percent of that total, 255.36 billion kilograms, used by scheduled jet and turboprop aircraft carrying both passengers and cargo.[1]

Emission types and levels are also linked to the amount of fuel burned so that any changes in either engine design or fuel composition leading to greater efficiency also will result in emission reductions. A simple analysis would assume that the portion of emissions arising from cargo aircraft are proportional to their numbers in the fleet or block hours flown. This calculation most likely understates the true impact because older aircraft produce a disproportionate amount of the emissions.

First of all, the variance in the distribution of the age of the aircraft in use is much wider. Since the aircraft are relatively expensive, they, along with their old design engines remain in service much longer. This serves to flatten the age distribution of aircraft in use in general, but it also flattens and shifts the averages higher for cargo aircraft because they tend to be used longer than passenger aircraft and tend not to be purchased new. This effect almost overrides the changes in engine design that have resulted in improvements on an individual aircraft basis, but only in

[1] The first three paragraphs are adapted from the "Atmospheric Effects of Aviation Project" presentation at the World Aviation Congress, October 24, 1996 in Los Angeles, California. Presenters included Dr. Randall Friedl and Mr. Howard Wesoky of NASA Headquarters and Dr. Richard Sloarski of NASA Goddard Space Flight Center.

small incremental improvements in the fleet as a whole. Furthermore, the generational improvements in aircraft engine design tend to cut emissions in the 20 percent to 40 percent range, this coupled with the aircraft added to meet growing demand means that the level of atmospheric emissions will rise, only the rate will be lowered.

Appendix F

Design Options for an All-Cargo Aircraft

The possibility of a commercial all-cargo aircraft allows for several new design considerations. Historically, new freighter aircraft have been adapted from either passenger or military aircraft designs. This method allows for a lower cost per aircraft since the development cost of a derivative design is considerably lower than an all new design. However, the resulting aircraft design may not be optimal from the standpoint of cargo-only operations.

Freighter derivatives from passenger aircraft may be suboptimal designs for cargo operations because the aircraft are originally designed to carry passengers. Similarly, military transport aircraft generally are designed to carry large, heavy equipment and often have operating characteristics well beyond the requirements for commercial transport.

A variety of design options are available for an all-cargo aircraft. They do not emphasize speed but maximize the cost savings associated with cargo. The main design areas include the fuselage design, cargo door placement, engine choice, and engine placement.

Current passenger fuselage design is based on the tradeoff of speed and fuselage width. The design of the Concorde represents the far end of that spectrum. An all-cargo aircraft could be the other end. Designed to fly slower, it could be built on a much wider fuselage or even a less aerodynamic and noncircular fuselage. The cargo door placement represents another key design change. Passenger aircraft are designed for the ingress and egress for passengers at terminals. Without this concern, the cargo door(s) placement, as well as wing and engine placement, becomes much less constrained. Cargo doors could be placed for the ease of loading and unloading cargo meaning a requirement of some combination of multiple-side doors, rear loading via the tail section, or front loading via the nose cone. The aircraft itself could sit closer to the ground making loading and unloading easier.

The choice of engines for an all-cargo aircraft also may be different. Efficient engines, such as turboprops or inducted prop fans, that provide more internal noise may be used in the absence of passengers. A combination of engine choice and fuselage design could be used to alleviate the “cubing out” problem. This occurs when aircraft payload capacity is reached in volume but not in weight. The fuselage could be expanded to hold more volume, but relatively little additional weight, and the engines could be chosen to maximize the fuel efficiency of that configuration.

Appendix G
Air Transport Association

The Air Transport Association (ATA) is the primary trade organization for the U.S. airlines. The purpose of the ATA is to support and assist its member carriers by promoting the air transport industry and the safety, cost-effectiveness, and technological advancement of its operations; advocating common industry positions before state and local government; conducting designated industry-wide programs, and ensuring governmental and public understanding of all aspects of air transport. Today, the ATA has 21 U.S. airline members and 3 foreign flag carrier associate members. In 1995, the ATA member air carriers, as shown in Table G-1, accounted for 91 percent of the total passenger traffic (in RPMs) and 96 percent of the total cargo ton miles recorded by U.S. air carriers.[1]

Table G-1. Air Transport Association Members

Members	
Alaska Airlines	Hawaiian Airlines
Aloha Airlines	KIWI International Airlines
America West	Midwest Express Airlines
American Airlines	Northwest Airlines
American Trans Air	Polar Air Cargo
Continental Airlines	Reeve Aleutian Airways
Delta Airlines	Southwest Airlines
DHL Airways	Trans World Airlines
Emery Worldwide United Airlines	United Parcel Service
Evergreen International Airlines	US Airways
Federal Express	
Associate members	
Air Canada	KLM—Royal Dutch Airlines
Canadian Airlines International	

In addition, the ATA also publishes *The Annual Report of the United States Scheduled Airline Industry*, which highlights significant facts and figures drawn from all areas of the industry. These data include financial statistics, domestic and international traffic statistics for both cargo and passenger operations, safety statistics, and individual airline and aircraft operating statistics. In addition to the members, the statistics include data from the airlines listed in Table G-2.

[1] Taken from the Air Transport Association home page at http://www.air-transport.org/member_1.htm.

Table G-2. Airline Revenues

Majors	Nationals	
Annual revenues over $1 billion	Annual revenues of $100 million to $1 billion	
Alaska Airlines	Air Wisconsin	Kiwi
America West	Aloha	Mark Air
American Airlines	American International	Mesa
Northwest Airlines	American Trans Air	Midwest Express
Continental Airlines	Arrow	Morris
Delta Airlines	Atlantic Southeast	Private Jet
Southwest Airlines	Business Express	Reno Air
Trans World Airlines	Carnival	Simmons
United Airlines	Continental Express	Southern Air
United Parcel Service	Continental Micronesia	Sun Country
Federal Express	DHL Airways	Tower Air
US Airways	Emery	Trans State
	Evergreen	USAirways Shuttle
	Hawaiian	World Airways
	Horizon Air	

Regionals		
Annual Revenues under $100 million		
Air South	Airtran	Air Transport
Amerijet	Atlas Air	AV Atlantic
Buffalo	Capitol Air	Casino Express
Challenge Air Cargo	Eagle Airlines	Eastwind
Empire	Executive Air	Express One
Fine Airlines	Florida West	Frontier
Grand	Great Americans	International Cargo Express
Kitty Hawk	MGM Grand	Miami Air
Midway	Million	Nations Air
North American	Northern Air	Paradise
Patriot	Polar Air	Reeve
Rich	Ryan International	Sierra Pacific
Spirit Air	Sportsflight	Sun Jet
Tatonduk	Trans Air Link	Trans American
Trans Continental	Tristar	UFS, Inc.
Ultrair	USAfrica	USA Jet
Valujet	Vanguard	Viscount
Western Pacific	Worldwide	Zantop

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The United State, and much of the industrialized world, is in the midst of a tremendous period of growth in air traffic services. One section that has experienced particularly strong growth is the air cargo industry. Over the past 10 years, world-wide air cargo traffic has grown at an average annual rate 8.6 percent. Furthermore, it is generally accepted that his phenomenal growth in air cargo traffic will continue through at least the year 2005. Such sustained growth will undoubtedly impact the demand for cargo aircraft. A primary motivation for this study is to address the questions of how large this impact on demand for cargo aircraft will be, and what proportion of the demand for cargo aircraft is likely to be satisfied by new cargo aircraft.

To assist NASA in the analysis of these and related issues, we built a set of integrated mathematical models that (1) estimate the direct operation costs associated with air cargo operations, (2) predict the future volume of air cargo traffic, and (3) estimate the future fleet sizes and composition necessary to meet the predicted growth rates.

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