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Applying Portfolio Theory to Protect Airline Profits Through Optimal Resource Allocation

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ABSTRACT

The objective of this empirical research is to develop a new approach to resource allocation by employing a risk mitigation model using portfolio theory in which diversification is used to minimize risk. This multi-objective optimization model is intended to enable airline managers to make strategic international route planning and resource allocation decisions based on conflicting objectives: maximize earnings, minimize risk, and minimize bottom-side financial losses due to unexpected industry disruption. First, a portfolio of available seat miles distributed to global regions is determined using the Mean-Variance approach, followed by a second portfolio approach, the Mean-Value-at-Risk (VaR) approach. Lastly, a comparison is made between the results of the two approaches and between the results of the two approaches and actual airline operating profits.

INTRODUCTION

The U.S. global airline industry is characterized by highly cyclical and inconsistent operating profits, razor thin profit margins and unimpressive passenger yields. The industry is routinely affected by uncertain financial, economic, political and environmental crises that are nearly impossible to predict. Furthermore, the air transport industry operates under a maze of government regulation and bilateral agreements that severely limit operational and strategic flexibility. Many agreements place limits on access to airports, routes and capacity. Because of the lack of flexibility and constrained strategic options pertaining to global resource allocation, global airlines are vulnerable to volatile passenger demand and revenue fluctuations that are due to uncertain global financial crises, changes in political power and regulation, meteorological and environmental disasters, and terrorism. The ability for airlines to quickly adjust capacity or realign their international route networks is constrained and costly. Major financial losses occur if seat capacity is not aligned with demand; thus, it is crucial that airline managers allocate seats to international regions taking into account the realities of uncertainty and inflexibility.

OVERVIEW OF AIRLINE INDUSTRY MISFORTUNES

Airline passenger demand, when disrupted without warning, causes financial hardship to the airlines. In the past the global airline industry has been affected by a range of events including financial, economic, political, meteorological, pandemic, and terrorism crises. Severe acute respiratory syndrome (SARS), Avian influenza (bird flu), H1N1 (swine flu), the September 11 attacks, increased security requirements, volcanic ash, and regional and global economic crises have all contributed to decreased passenger demand and revenues. Airlines stand to lose millions, if not billions of dollars from events that are largely outside the control of airline managers.

The following examples underscore the array of events in which significant real losses can occur and the severity of these losses. In a March 2003 report by Air Transport Association (2003) referring to the 1990-1991 Gulf War, ATA stated in the four years it took the airlines to recover from the war the airline industry lost over $13 billion, eliminated 25,000 jobs and seven large and medium-sized airlines were forced into bankruptcy, four of which liquidated.

Airline financial declines occurred due to world economic recessions including, but not limited to U.S. recessions in 1990-1991, 2001, and 2008-2009; Argentina's financial collapse in the years 1999 through 2003; and Japan's decade long economic difficulty starting with its stock market losing value in 1990, land prices collapsing in 1992, regional banks struggling in 1994, large banks teetering on the edge of bankruptcy in 1997 and a major credit crunch occurring in 1998. Japan again ran into economic difficulty in 2001 and 2008.

A political scenario unfolded in February 2006 and again in September 2008 when National Civil Aviation Institute of Venezuela, the country's aviation agency, informed

American Airlines, Continental Airlines and Delta Air Lines that the number of their flights to and from Venezuela would be drastically reduced or all together eliminated.

In March 2003 the World Health Organization (2003) issued emergency travel recommendations to alert health authorities, physicians and the traveling public to a worldwide health threat. The earliest cases of SARS were found in Singapore, Hanoi, Hong Kong, Taiwan, Beijing, Shanghai, Toronto and the Chinese province of Guangdong. By the time SARS was under control globally in August 2003, it had spread to 30 countries with more than 8,000 patients diagnosed and caused 774 deaths (WHO, 2003). Furthermore, Centers for Disease Control and Prevention (CDC) had advised that travelers should postpone their trips not only to Hong Kong but to all of China, Singapore, and Vietnam. April 2009 travel to Mexico was hampered when CDC recommended that U.S. travelers avoid non-essential travel to Mexico. By June 2009, 62 countries officially reported 17,410 cases of influenza A (H1N1) infection, resulting in 115 deaths.

In April 2010 volcanic ash from Iceland's Eyjafjallajokull glacier drifted southeast toward northern Europe, approximately 1,200 miles away. Because of the catastrophic impact volcanic ash has on aircraft systems and engines, authorities in Britain, Ireland, Denmark, Norway, Sweden and Belgium closed their airspace. During the seven day period in which air traffic was affected, over 100,000 flights were cancelled culminating in a $1.7 billion revenue loss from scheduled air service (IATA 2010).

Terrorism has had and continues to have increasing profound effects on all forms of transportation, public or otherwise. Rising costs for transportation companies and public commissions countering security threats and fluctuations in passenger demand are two adverse effects due to terrorism. In 2004, Madrid, Spain train bombings killed 191 and injured more than 1,800 people. In 2005, London's public transport system was affected by terrorism when 56 people were killed and another 700 people were injured when bombs went off on London Underground trains and a double-decker bus. September 11, 2001 the United States saw an estimated 5,000 people killed or injured and a shutdown of its entire air traffic control system. According to the Air Transport Association (2009), airlines lost approximately $1.4 billion in revenue during the four-day shutdown of the U.S. national aviation system following the September 11, 2001 terrorist attacks. Airline revenues declined seven percent as a result of the attacks.

Air transport is affected by meteorological phenomena and its financial impact can be enormous. Hurricanes, tropical storms, snow storms, freezing rain, and flooding all contribute to airlines' bottom line being impacted from lost revenue and additional expenses. Two separate snowstorms in 2010 clearly demonstrate the financial impacts of meteorological events. Airlines are expected to report a loss of an estimated $150 million due to a December 2010 snow storm in the Northeastern section of the United States. Continental Airlines alone lost $25 million in revenue due to a February 2010 snowstorm.

U.S. airline industry operating profits have varied considerably over the years and have been a major concern in recent years (Figure 1). In a GAO (2005) report, United States Government Accountability Office stated that U.S. legacy air carriers have lost $28 billion from year 2001 through year 2004. GAO (2005) further states the number of bankruptcy filings since U.S. airline deregulation in 1978 stands at 160, including 20 since 2000. Many of the filings were made by small airlines. However, the number of bankruptcy filings by airlines with assets over $100 million has had a marked increased. Of the 20 bankruptcy filings since 2000, ten have had assets over $100 million, nearly equivalent to the number of large airline bankruptcy filings over the previous 22 years.

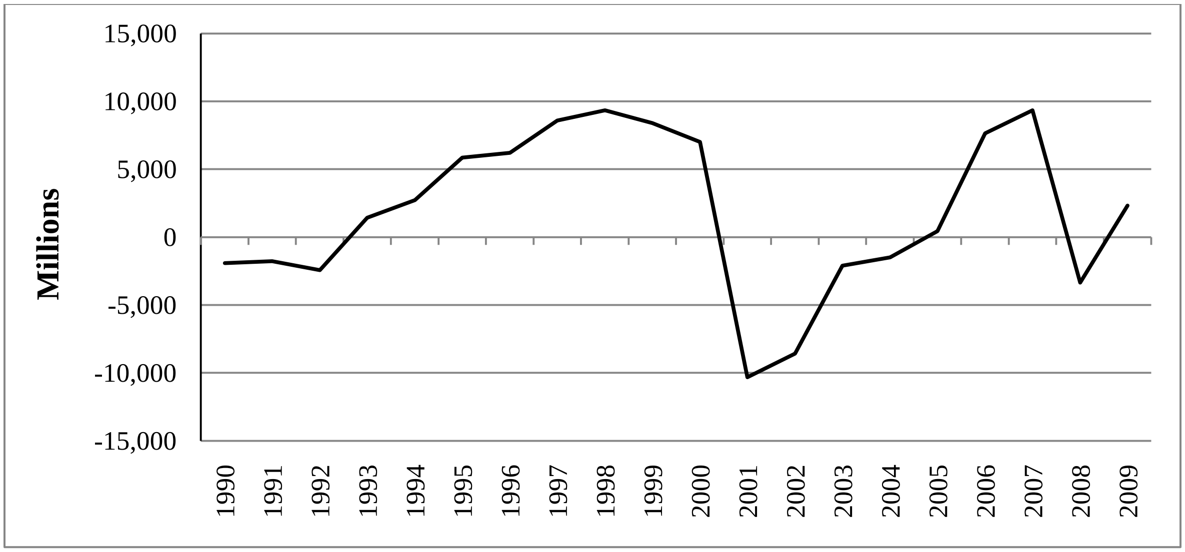

Figure 1. U.S. Airline Industry Operating Profit 1990-2009 (Source: Form 41, Schedule P-12, Bureau of Transportation Statistics, 2010).

METHODS AND SCOPE OF RESEARCH

A portfolio of available seat miles (ASM) to global regions is determined using three approaches. The first approach uses the Mean-Variance method. The expected value (mean) and covariance matrix is computed using the historical operating profit margin of a specified airline and region combination for the period of 1990-2005. These values are then used in a portfolio optimization model to allocate ASMs to three global regions. Next, a second portfolio approach is used by which the Mean-Variance method is slightly modified and is now called the Mean-VaR (Value-at-Risk) approach. This approach is similar to the Mean-Variance approach; the difference being value at risk is used as the risk measure.

This research is limited to six U.S. global airlines: American Airlines, Continental Airlines, Delta Air Lines, Northwest Airlines, United Air Lines and US Airways. Although the models in this research are developed for the U.S. global airlines, the processes and procedures can easily be replicated to develop usable models for global airlines in other regions of the world. Given that this research is viewed from the strategic management level, a five-year vantage point and longer, it is not concerned with operational or tactical timelines that are much shorter. The three international regions are defined in this research as Europe, Latin America and Asia/Pacific regions.

The data for this research is primarily obtained from The Research and Innovative Technology Administration, Bureau of Transportation Statistics, from within the U.S. Department of Transportation. Yearly data was collected between the time periods 1990-2009. Data includes Air Carrier Financial Reports (Form 41 Financial Data), which consists of air carrier operating revenues and operating expenses. Air Carrier Summary Data (Form 41 and 298C Summary Data) consists of non-stop segment and on-flight market data reported by air carriers and includes geographical regions in which an air carrier operates and the number of available seat miles (ASMs) and revenue passenger miles (RPMs) in each region of operation.

RESEARCH CONTRIBUTIONS

Previous research has been conducted on international routes and global networks using econometric models pertaining to consumer welfare, competition and ticket prices. Multi-objective optimization models have been developed to optimize routes, frequency and aircraft selection focusing more towards the operational and tactical planning stages. Route and network profitability models based on expected demand, contribution margin and costs have been published in limited quantity.

To our knowledge, alternative long-term strategic route planning based on diversification has not been previously researched or implemented in practice. Taking a long-term diversification approach, airlines might limit the bottom-side effects when encountering global passenger demand reductions and consequently, return to profitability more quickly during recovery periods. Furthermore, the allocation approach proposed in this research is based on the specific data of a particular airline and the regions in which that airline operates. This research uses disaggregate airline data for developing the optimization decision making models.

Moreover, this research focuses on a region of interest and not individual routes or city pairs as previous research has shown.

Taking into account that changing international destinations is restrictive, costly, and time-consuming, the airline industry operates under razor thin margins. Additionally, unpredictable global events hamper airline profitability; a strategic long-term international destination region portfolio model is developed following the practice of diversification, similar to risky stock allocation in financial portfolio management. The model will help managers determine the concentration in which the airline allocates its resources to that region based on conflicting objectives: to maximize earnings and to minimize the risk of financial operating losses. Finally, managers will be able to determine which regions are prone to abrupt passenger revenue and expenses movement and will identify those regions that must be supplemented with additional revenue streams or cost controls.

It is evident that managers of global airlines must make varied decisions regarding resource allocation, route planning and operations at the strategic, operational and tactical levels; therefore, multiple data sources and models should be applied to provide adequate decision-making guidance to airline managers. The models developed in this research will aid in airline management decision making pertaining to asset allocation to global regions taking into account uncertain events limiting the downside effects and volatility of passenger demand and revenue reductions.

GLOBAL AIRLINE INDUSTRY GROWTH TRENDS

World scheduled revenue traffic (domestic and international combined) has shown moderate growth during the period from 1990 to 2008 (Table 1). During three periods between 1990 and 2008 (the periods of 1990-1993, 2001-2002 and 2008) passenger demand showed declines. These declines coincided with recessions in the three periods, war in the early 1990s and early 2000s, and terrorism in the early 2000 period. The airline industry was already showing signs of decline in 2000 however; the September 11, 2001, terrorist attacks accentuated the declines.

Table 1. Development of World Scheduled Revenue Traffic, 1990-2008.

Year	Passengers (millions)	Percent Change	Revenue Passenger-km (billions)	Percent Change
1990	1,165		1,894	
1991	1,135	-2.6	1,845	-2.6
1992	1,146	0.9	1,929	4.5
1993	1,142	-0.3	1,949	1.1
1994	1,233	8.0	2,100	7.7
1995	1,304	5.7	2,248	7.1
1996	1,391	6.7	2,432	8.2
1997	1,457	4.7	2,573	5.8
1998	1,471	1.0	2,628	2.1
1999	1,562	6.2	2,798	6.5
2000	1,674	7.2	3,038	8.6
2001	1,655	-1.1	2,966	-2.4
2002	1,627	-1.7	2,957	-0.3
2003	1,665	2.3	2,998	1.4
2004	1,888	13.4	3,445	14.9
2005	2,022	7.1	3,720	8.0
2006	2,128	5.2	3,940	5.9
2007	2,281	7.2	4,228	7.3
2008	2,271	-0.4	4,282	1.3

Source: International Civil Aviation Organization

In the period 1995-2008 international scheduled revenue traffic grew at a faster rate than the overall world scheduled revenue traffic (Table 2). On one occasion in this time period international traffic showed a greater decline than the total world traffic. In 2001 the international passenger-kilometers showed a decline of -3.6% from 2000 to 2001 contrasting the -2.4% decline in total world traffic from 2000 to 2001.

Table 2. Development of International Scheduled Revenue Traffic of ICAO Contracting States, 1995-2008.

Year	Passengers Millions	Percent Change	Revenue Passenger-km (Billions)	Percent Change
1995	375	8.1	1,249	9.3
1996	412	9.9	1,380	10.5
1997	438	6.3	1,468	6.3
1998	458	4.6	1,512	3.0
1999	493	7.6	1,622	7.3
2000	542	9.9	1,790	10.4
2001	536	-1.1	1,726	-3.6
2002	547	2.1	1,736	0.5
2003	561	2.6	1,738	0.1
2004	647	15.3	2,015	15.9
2005	705	9.0	2,199	9.2
2006	761	7.9	2,365	7.5
2007	836	9.9	2,551	7.9
2008	866	3.6	2,639	3.4

Source: ICAO Air Transport Reporting Form A; ICAO estimates for non-reporting States

Regional differences occur in the number of total passenger-kilometers and share of world traffic. In 1985 as shown in Table 3, North America led with a 41.5 percent share followed by Europe with a 31.4 percent share, and the Asia/Pacific region was third with a 16.3 percent share. Latin America, the Middle East, and Africa, in that order, have a much smaller share of the world's passenger-kilometers. Since 1985, there has been a shift in distribution of the world's passenger-kilometers. Although the top three regions are ranked in the same order, the percentage of share has changed. In 2005, European and North American regions both lost market share while the Asia/Pacific region obtained a 26.0 percent share of the world's passenger-kilometers. The Middle East region has taken over the fourth position from Latin America with a 4.5 percent share. The Asia/Pacific region passenger growth can be attributable in part to China's economic growth along with an increase in per capita income and resultant larger "middle class" demographic segment.

The international share of the world's passenger-kilometers follows a different pattern. In 1985 Europe led with a share of 36.4 percent of the international passenger-kilometers, Asia/Pacific was next with 25.5 percent and North America was third with 21.1 percent. North America's ranking third in international passenger-kilometers when it ranked first in total passenger-kilometers is attributable to North America's large base of domestic traffic. In 2005 the Asia Pacific, Europe and Middle East regions all gained in their share of international passenger-kilometers; the remaining regions lost market share. Asia/Pacific region growth can be attributable to its increase in global trade and economic activity, while the Middle East region's increase can be attributable to the region's economic activity, its region's air carriers expanding and using the region's hub airports as transshipment points for passengers travelling internationally between Eastern and Western hemisphere destinations.

Table 3. ICAO Contracting States Air Traffic Forecasts, Regions of Airline Registration (1985–2025).

Scheduled services by region of airline registration	Actual 1985	Actual 2005	Forecast 2025	Average annual growth rate (percent)		Regional share of world traffic (percent)		
				1985–2005	2005–2025	1985	2005	2025
TOTAL Passenger-kilometers (billions)								
Africa	36.7	84.8	230	4.3	5.1	2.7	2.3	2.5
Asia/Pacific	222.3	967.4	2,980	7.6	5.8	16.3	26.0	32.5
Europe	428.2	1,004.9	2,350	4.4	4.3	31.4	27.0	25.6
Latin America and Caribbean	68.3	159.2	410	4.3	4.8	5.0	4.3	4.5
Middle East	42.7	168.9	520	7.1	5.8	3.1	4.5	5.7
North America	567.4	1,334.5	2,690	4.4	3.6	41.5	35.9	29.3
INTERNATIONAL Passenger-kilometers (billions)								
Africa	28.5	72.2	205	4.8	5.4	4.8	3.3	3.3
Asia/Pacific	150.3	622.5	2,100	7.4	6.3	25.5	28.3	33.7
Europe	214.4	865.9	2,160	7.2	4.7	36.4	39.4	34.7
Latin America and Caribbean	36.5	95.1	260	4.9	5.2	6.2	4.3	4.2
Middle East	35.1	152.5	480	7.6	5.9	6.0	6.9	7.7
North America	124.5	389.2	1,020	5.9	4.9	21.1	17.7	16.4

Source: ICAO Outlook for Air Transport to the Year 2025, Copyright September 2007.

LIBERALIZATION OF AIR TRANSPORT

Despite of the fact that many liberalization agreements have been reached over the years, most international markets remain regulated. After reviewing 2,299 Air Service Agreements in ICAO and WTO databases, Piermartini and Rousova (2008) indicated that regulations on route entry, pricing, capacity and cooperative arrangements are frequently imposed. They found that even in routes currently being served, 40% of them permit single designation only. That is, only one airline from each country is allowed to serve those routes. Even if the bilateral markets have been deregulated, there are usually limitations imposed with a third country, such as limitations imposed on beyond rights by the Fifth Freedom. These restrictions are likely to create substantial welfare loss. Numerous studies have established that liberalization has brought significant welfare gains worldwide. InterVISTAS (2006) estimated that liberalizing only 320 bilateral agreements of the existing thousands would create 24.1 million full-time jobs and generate an additional $490 billion in GDP. This corresponds to an economy almost the size of Brazil (Li, Lam, et al. 2010).

Even with the potential for remarkable welfare gains, negotiation of liberalizing Air Service Agreements is usually a lengthy negotiating process, even among countries that are of like minds and similar objectives. Governments seldom approve substantial regulatory changes all at once. Instead, progressive liberalization strategies are regularly utilized. Regulators either remove various restrictions gradually, or progressively increase the upper limits on the number of destinations served and the number of airlines allowed to serve these markets. Like most international treaties, such progressive liberalization of air service agreements has been conducted under the principle of achieving reciprocal fairness instead of maximizing social welfare. There is a need to quantify the effects of alternative liberalization policies, and to develop a methodology with which regulators can develop optimal policies in a liberalizing airline market (Li, Lam, et al. 2010).

PORTFOLIO THEORY INTRODUCTION

Risk, reward and diversification are central to the discussion of portfolio theory. Portfolio theory, first introduced by Markowitz (1952), has its roots in investments of risky securities or assets. However its use has expanded to other sectors including the public sector, retail, real estate, healthcare and energy sectors, among others. Prior to Markowitz, investors built portfolios viewing risk and reward of individual securities. Investors would analyze individual securities based on the potential of maximizing returns and minimizing risks and then would combine theses securities together into a portfolio. This led to the possibility of developing a portfolio of securities that were from the same industry, ignoring diversification. Markowitz's approach is to view the overall risk-reward characteristics of the portfolio which led to diversification. That is to say, by adding a risky asset to an existing investment portfolio can reduce the overall exposure to risk if the returns to the new asset are not correlated with assets that are already in the portfolio (Shiell, et al. 2009). It is theoretically possible to eliminate portfolio risk with risky securities (assets) that are perfectly negatively correlated. In actuality, it is not possible to reduce all risk but the principle of reducing risk through diversification is the foundation of modern portfolio theory.

PORTFOLIO RISK

To understand portfolio risk-reward completely it is necessary to first discuss risk further. Many definitions of risk abound, one such definition is the chance that some unfavorable event will occur. Risks in individual asset returns have two components, (1) systematic risks, also called market risk, are common to many assets and (2) non-systematic risks, which are specific to individual assets. Systematic risks are those factors that affect most firms such as war, recession, inflation and high interest rates. Non-systematic risks affect individual companies that are random events such as lawsuits, labor strikes, winning or losing major contracts, or successfulness of major marketing programs and other events that are unique to a particular company (Brigham and Houston 2004). The difference in the two types of risks involves the ability to diversify them. Systematic risks are non-diversifiable while non-systematic risks are diversifiable. Thus, investors who hold diversified portfolios instead of single assets eliminate non-systematic risks. Using portfolio theory it is possible to allocate resources among varying domains considering both risk and return.

MEAN-VARIANCE APPROACH

Markowitz (1952) developed the Mean-Variance approach to portfolio formation for risky assests such as stocks or equities. Later this approach has been applied to portfolio formation with non-risky assets such as treasuries. One of the shortcomings of the Mean-Variance approach is that it treats upside and downside risks the same. Investors are not interested in upside risk. Unexpected upside gains in stock returns is seen as a positve outcome.

The Mean-Variance approach maximizes the ratio between the sum of expected means and sum of variances. In the presence of two criteria there is not a single optimal solution or portfolio, but a set of optimal portfolios, the so-called efficient portfolios, which trade off between risks and return (Pindoriya, Singha and Singh 2010).

The Mean-Variance approach typically is solved in order to minimize the variance and is done following these three steps: (1) estimate the expected return and covariance, (2) optimize the problem to create the efficient frontier, and (3) select a point or group of points on the efficient frontier (Fabozzi, Huang and Zhou 2010).

MEAN-VALUE AT RISK

J.P.Morgan/Reuters (1996) introduced Value-at-Risk publically in 1995 providing data on variances and covariances from various security and asset classes that it had used internally to manage risk. It titled the service "RiskMetrics" and used the term Value-at-Risk to describe the risk measure. Value-at-Risk is an established measure of risk in financial service firms such as banks, investments firms and pension funds where a liquidity crisis due to a low-probability catastrophic occurrence creates a major loss of capital. Value-at-Risk has also been used by non-financial service firms as well. Value-at-Risk can be specified for an individual asset, a portfolio of assets or for an entire firm, thus risk can be analyzed using Value-at-Risk for competitive and firm specific risks or for large investment projects.

Value-at-Risk focuses on downside risk and potential losses and measures the potential loss in value of an asset or portfolio over a defined period of time for a given confidence interval. J.P.Morgan/Reuters (1996) states, "Value-at-Risk is a measure of the maximum potential change in value of a portfolio of financial instruments with a given probability over a pre-set horizon. VaR answers the question: how much can I lose with x [percent] probability over a given time horizon." Value-at-Risk (VaR) can be further explained as a number that represents the potential change in a portfolio's future value. This change depends on the time horizon over which the portfolio's change in value is measured and the "degree of confidence" chosen by the risk manager.

J.P.Morgan/Reuters (1996) further states that VaR calculations can be performed without using standard deviation or correlation forecasts though the primary reason for choosing to use standard deviations (volatility) is the strong evidence that the volatility of financial returns is predictable. As a result, if volatility is predictable, forecasts using this predictable volatility make sense to predict future values of the return distribution.

The three common methods of computing VaR include the historical simulation method, the variance-covariance method or analytic method, and the Monte Carlo simulation method. The historical method assumes that past data will represent the future and that the sample obtained is representative of the population, while the variance covariance method assumes normal distribution. The Monte Carlo or simulation method is similar to the historical method except that the analyst chooses the statistical distribution and parameters. This paper used the variance-covariance method since the normality tests revealed normal distribution.

PORTFOLIO OPTIMIZATION MODEL DEVELOPMENT

Introduction

As previously stated, a portfolio of available seat miles is determined through two approaches. First, the Mean-Variance approach is used followed by the Mean-Value-at-Risk approach. In the Mean-Variance approach and the Mean-VaR approach, the mean or expected value of historical operating profit margin is used. In both approaches, operating profit margin is determined for six U.S. global airlines in each global region of operation: Europe, Latin America and Asia/Pacific.

Next, a multi-objective optimization problem is formulated, where a minimum variance portfolio achieves maximum effect of diversification. The problem is typically formulated as a single objective optimization problem solving for minimum variance, which will result in an expected return with the least risk. This model extends the risky asset portfolio typically associated with financial investments to the airline industry.

The rationale behind developing the multi-objective optimization problem using portfolio theory stems from the volatility of airline revenues and passenger demand. Taking the view that a portfolio approach through diversification reduces the variability of revenue due to the variability of passenger demand, removing some of the volatility helps to better manage profits and losses. Predictable cash flows allow airlines to borrow funds at more favorable rates and to reinvest in their companies to remain competitive.

The models seek to solve two objectives by combining them into one optimization formulation: objective (1) is to maximize expected value of a portfolio of operating profit margins and objective (2) is to minimize the variance of the portfolio of operating profit margins.

This type of problem has been solved using linear, nonlinear and goal programming techniques. Classical Mean-Variance portfolio optimization problems have been solved using quadratic programming with the help of risk aversion factors (Pindoriya, Singha and Singh 2010). As such, this model will be solved using quadratic programming.

The focus of this research is limited to six U.S. global passenger airlines (legacy air carriers): American Airlines, Continental Airlines, Delta Air Lines, Northwest Airlines (before it merged with Delta Air Lines in 2008), United Air Lines and US Airways. This research narrows its focus to passenger revenue and expenses, excluding revenue and expenses related to the carriage of cargo and mail, and miscellaneous revenue obtained from ticket cancellation and change fees, baggage fees and onboard food service sales. The process, procedures, and models developed in this research are flexible in that they can be modified to include weights for decision maker preferences and risk appetite, as well as the ability to be applied to global airlines from other regions of the world.

Data Source

Data for the variables in Table 4 are collected for the years 1990-2009 and include Europe, Latin America and Asia/Pacific regions. The U.S. Domestic region is excluded since the focus of this research is determining a portfolio of international markets. Data for the period 1990-2005 are used for the analysis using the Mean-Variance and Mean-VaR methods while data for the periods 2006-2009 are used to validate the effectiveness of the models.

Table 4. Data Sources of Variables.

Variable	Data Source
Revenue Passenger Miles (RPM)	Bureau of Transportation Statistics Schedule T2, Air Carrier Summary: U.S. Air Carrier Traffic And Capacity Statistics by Aircraft Type
Passenger Revenue	Bureau of Transportation Statistics Form 41, Schedule P-12
Operating Costs*	Bureau of Transportation Statistics Form 41, Schedule P-7
Operating Profit/Loss	Bureau of Transportation Statistics Form 41, Schedule P-12 and P-7
Available Seat Miles	Bureau of Transportation Statistics Schedule T2, Air Carrier Summary: U.S. Air Carrier Traffic And Capacity Statistics by Aircraft Type

* See Table 5 below for explanation of costs

Available Seat Miles include both scheduled and non-scheduled passengers (charter); passenger revenue includes revenue from scheduled passenger service and charter passengers. Revenue from passenger baggage fees, freight, mail, reservation cancellation fees, and other miscellaneous fees are not included. These additional revenue streams vary widely and could adversely distort the results of this study. By eliminating these revenue streams it is now possible to isolate airline financial operating performance from passenger carrying operations and whether passenger operations are sufficient for airline financial sustainability. Total operating costs as shown in Table 5 include those cost associated with operating passenger flights. Operating costs that have been excluded include those that are related to cargo and transport costs.

Table 5. Operating Expenses and Definitions.

Cost	Definition
Flying Operations	Expenses incurred directly in the in-flight operation of aircraft and expenses related to the holding of aircraft and aircraft operational personnel in readiness for assignment for an in-flight status. Includes flight crew and fuel costs.
Maintenance	All expenses, both direct and indirect, specifically identifiable with the repair and upkeep of property and equipment.
Passenger Service	Cost of activities contributing to the comfort, safety, and convenience of passengers while in flight or when flights are interrupted. Includes salaries and expenses of flight attendants and passenger food expenses.
Aircraft And Traffic Servicing	Compensation of ground personnel, in-flight expenses for handling and protecting all non-passenger traffic including passenger baggage, and other expenses incurred on the ground to (1) protect and control the in-flight movement of the aircraft, (2) schedule and prepare aircraft operational crew for flight assignment, (3) handle and service aircraft while in line operation, and (4) service and handle traffic on the ground after issuance of documents establishing the air carrier's responsibility to provide air transportation.
Promotion And Sales	Cost incurred in promoting the use of air transportation generally and creating a public preference for the services of particular air carriers. Includes the functions of selling, advertising, and publicity, space reservations, and developing tariffs and flight schedules for publication.
General And Administrative	General costs not associated with any particular activity.
Depreciation And Amortization	Capital Costs of airline assets, mainly aircraft, spread over expected lifetime.

Source: Air Carrier Financial Reports (Form 41 Financial Data) Schedule P-12, (Belobaba, Odoni and Barnhart 2009)
*Transport Related Expenses are not included and have been removed from Total Operating Expenses since these are payments paid to regional airline partners for providing regional air service and are not considered. Cargo related expenses are not included since cargo revenues were not included in the analysis.

Mean-Variance Model

Schefczyk (1993) presents a new approach for measuring operational performance of international airlines. Evaluating the performance of international airlines from published financial information is difficult for a variety of reasons. First, most airlines lease a substantial fraction of their aircraft. Second, different accounting and taxation rules in various countries result in different impacts of leased assets on profit and balance-sheet information, and third, financial reporting requirements vary from one country to the next. Schefczyk (1993) proposed non-financial data used in "Data Envelopment Analysis" as a technique to analyze and compare operational performance of airlines.

In light of this, for this research operating profit margin was chosen as the metric to measure due to its usefulness in providing information for investors to determine the quality of a company when looking at the trend in operating margin over time and to compare with industry peers. Operating profit margin ratio analysis measures a company's operating efficiency and pricing efficiency with its ability to control costs. A higher operating profit margin indicates that a company has lower fixed costs and/or a higher gross margin, or the company is increasing sales faster than costs, which gives management more flexibility in determining prices. Although not a perfect measure (financial ratios rarely are), operating profit margin is a better metric because it excludes company accounting policies, which affect gross profit margin and net profit margin. Company policies regarding depreciation, taxes and interest paid affect many financial ratios and using these ratios could misrepresent specific airline results and disguise true results when comparing between airlines and regions in which they operate.

Some of the drawbacks of operating profit margin are that companies can artificially enhance it by excluding certain expenses or improperly recording inventory. Moreover, revenues may also be erroneous by recording unshipped products or recording sales into a different period than when sales actually occurred. Since the U.S. airline industry is regularly scrutinized and is required to submit financial and operating results, these drawbacks do not appear to be a serious concern. Table 6 shows descriptive statistics for operating profit ratio for the period 1990-2005 for each of the six U.S. global airlines and to the regions in which they operate.

Since one of the research objectives is to analyze passenger revenue and an airline's operating profit, revenue included in the analysis is only from passengers in scheduled and non-scheduled service and in connection with ticket purchases. Revenue from passenger baggage fees, freight, mail, reservation cancellation fees and other miscellaneous fees is not included. By disaggregating revenue streams and not including revenue from other sources, the analysis will enable an airline's management to gain insight into whether revenue from ticket sales is sufficient to sustain operations or whether a focus on additional revenue streams is necessary. Total operating expenses as shown in Table 5 include those cost associated with operating flights and those that relate to carrying passengers. Operating expenses that have been excluded include those expenses related to cargo and transport costs. The excluded costs are cargo traffic expense, cargo reservation expense, cargo advertising expense and transport expense. Cargo related expenses are not included since cargo revenues are not included in the analysis and transport related expenses are not considered since these are payments paid to regional airline partners for providing regional air service.

Cost and expense terms are commonly used interchangeably and are in need of clarification. In accounting, the term expense means a cost that has been used up while a company is doing its main revenue-generating activities. A cost may or may not be an expense and is regarded as the price of an asset. This paper uses the term expense as accountants do, meaning that a cost has been used.

The passenger revenue generated by regional air service is not reported as passenger revenue from international travel in this analysis, thus including transport related expenses would inflate an airline's expenses without offsetting this rise with corresponding revenue from these transactions.

Table 6. Descriptive Statistics Operating Profit Margin 1990-2005.

Operating Profit Ratio	N	Mean	Variance	Std Dev	Min	Max
American Airlines Europe	16	-0.0067	0.0052	0.0720	-0.1566	0.0962
American Airlines Latin America	16	0.0111	0.0043	0.0657	-0.1363	0.1166
American Airlines Pacific	16	-0.0825	0.0218	0.1476	-0.3136	0.2775
Continental Airlines Europe	16	0.0560	0.0053	0.0731	-0.1007	0.1534
Continental Airlines Latin America	16	0.0368	0.0037	0.0605	-0.0697	0.1561
Continental Airlines Pacific	12	0.0227	0.0321	0.1792	-0.2507	0.3137
Delta Air Lines Europe	16	-0.1237	0.0175	0.1325	-0.3758	0.0681
Delta Air Lines Latin America	16	0.0151	0.0067	0.0818	-0.1430	0.1395
Delta Air Lines Pacific	16	-0.2373	0.0222	0.1491	-0.6759	-0.0287
Northwest Airlines Europe	16	0.0336	0.0102	0.1011	-0.2125	0.1699
Northwest Airlines Pacific	16	-0.2166	0.0197	0.1405	-0.4188	-0.0502
United Air Lines Europe	16	-0.0903	0.0168	0.1296	-0.3776	0.0785
United Air Lines Latin America	14	-0.1342	0.0255	0.1596	-0.5296	0.0191
United Air Lines Pacific	16	-0.1116	0.0261	0.1615	-0.4835	0.1122
US Airways Europe	16	-0.0497	0.0148	0.1217	-0.2651	0.1400
US Airways Latin America	16	-0.0931	0.0346	0.1860	-0.4731	0.1264

Source: Author's Calculations

Operating profit in this paper is calculated by passenger revenues less operating expenses. Operating profit margin calculated using equation *(1)* can be negative if operating profit is negative when a loss has occurred.

$$OpPr = \frac{x-y}{x} \qquad (1)$$

where *OpPr* is operating profit margin, *x* is passenger revenue and *y* is operating expense.

The portfolio model formulation is discussed next. The expected return of a portfolio is given by:

$$E(R_p) = \sum_{i=1}^{n} \mathrm{w}_i \, E(R_i) \qquad (2)$$

where $E(R_i)$ is the expected return of seats allocated to region i, w_i is the weight associated with seats allocated to region i, and n is the number of regions.

The variance or risk of the portfolio is given by:

$$\sigma_p^2 = \sum_{i=1}^{n} w_i^2 \, \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2 \, w_i w_j \, \sigma_{ij}$$

$$= \sum_{i=1}^{n} w_i^2 \, \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2 \, w_i w_j \, \sigma_i \sigma_j r_{ij} \qquad (3)$$

where σ_p^2 is the portfolio variance, w_i is the weight associated with seats allocated to region *i*, σ_i^2 is the variance of returns from seats allocated to region *i*, σ_i is the standard deviation of returns from seats allocated to region *i*, σ_{ij} is the covariance of returns from seats allocated to region *i* and *j*, and r_{ij} is the correlation of returns from seats allocated to region *i* and *j*.

A covariance matrix is developed from the operating profit margin expected values for each airline in each region. Using these values, an optimization model is used to determine the optimal ASM allocation to the European, Latin American and Asia/Pacific regions. For the optimization model region 1 is designated as the Atlantic region, 2 is the Latin America region and 3 is the Asia/Pacific region.

Modifying equations *(2)* and *(3)* of the general formulation of portfolio return and variance, equations *(4)* and *(5)* are formulated using operating profit margin as a proxy for the expected value of the return for allocated seats.

$$EV(opr_p) = \sum_{i=1}^{3} \mathrm{w}_i \, opr_i \qquad (4)$$

$EV(opr_p)$ is the expected value of the portfolio of operating profit margin; w_i is the weight associated with region i, and opr_i is operating profit margin in region *i*.

$$\sigma^2(opr_p) = \sum_{i=1}^{n} w_i^2\, \sigma^2\,(opr_i) + \sum_{i=1}^{n}\sum_{j=i+1}^{n} 2\, w_i w_j\, cov\,(opr_i, opr_j) \qquad (5)$$

$\sigma^2(opr_p)$ is the variance of the portfolio operating profit margin; w_i is the weight associated with operating profit margin in region i , $\sigma^2\,(opr_i)$ is the variance of operating profit margin from region i, $cov\,(opr_i, opr_j)$ is the covariance matrix of operating profit margin from region *i* and *j*.

Mean-Value at Risk (VaR) Model

The Mean-VaR model is similar to the Mean-Variance model with a minor formulation modification. Using the same expected values and covariance matrix as the Mean-Variance model, the Mean-VaR formulation uses Value-at-Risk (VaR) as the measure of risk, instead of variance. When minimizing variance in the optimization models both, extreme profits and losses are minimized. Managers are not concerned with unexpected extreme gains, only losses. VaR minimizes the losses or bottom side risk beyond a certain probability and ignores extreme gains. The .05 level is used to determine VaR; however any level can be used by the risk manager.

The change in portfolio variance is dependent on the size and value of the position holdings, the variance of the holdings and correlations between those positions and can be described by the following standard formula, which is equivalent to equation *(3)*.

$$\sigma^2\, portfolio = x_1^2\,\sigma_1^2 + x_2^2\,\sigma_2^2 + x_3^2\,\sigma_3^2 + 2x_1x_2\rho_{12}\,\sigma_1\,\sigma_2 + 2x_1x_3\rho_{13}\,\sigma_1\,\sigma_3 + 2x_2x_3\rho_{23}\,\sigma_2\,\sigma_3 \qquad (6)$$

Taking the square root of the variance to obtain standard deviation σ, Value-at-Risk is found from the following equation:

VaR=1.65*$\sigma\, portfolio$ if 5 percent probability (.05 level) is used. *(7)*

A property of the normal distribution is that observations or data points less than or equal to 1.65 standard deviations below the mean occur five percent of the time.

PORTFOLIO OPTIMIZATION MODEL

This model solves for w_i , the percentage of total available seat miles allocated to each region (Europe, Latin America, and Asia/Pacific). This model is performed six times, once for each airline.

The proposed multi-objective model formulation for the Mean-Variance approach using equations *(4)* and *(5)* is as follows:

Objective 1: $maximize = [\, EV(\sum_{i=1}^{3} \mathrm{w}_i \, opr_i \,)]$ *(8)*

Objective 2: $minimize = \left[\, \sigma^2\left(\sum_{i=1}^{n} w_i^2 \, \sigma^2 \, (opr_i) + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2 \, w_i w_j \, cov \, (opr_i, opr_j)\right)\right]$ *(9)*

Combing equations *(8)* and *(9)* to formulate equation *(10)*, the optimization model minimizes variance :

$$minimize = \left[- \left[\, EV\left(opr_p\right)\right] + \left[\, \sigma^2\left(opr_p\right)\right]\right] \quad (10)$$

Equation *(11)* adds weights to $EV\left(opr_p\right)$ and $\sigma^2\left(opr_p\right)$ which enable the risks taker to adjust the emphasis and tolerance on risk. Theoretically, taking higher risks should provide higher returns.

$$minimize = \left[- \alpha\left[\, EV\left(opr_p\right)\right] + (1-\alpha)\left[\, \sigma^2\left(opr_p\right)\right]\right] \quad (11)$$

subject to:

$\sum_{i=1}^{3} w_i = 1, \;\; w_i \geq 0$

where $EV\left(opr_p\right)$ is the expected value of the portfolio of operating profit margin and i is the region 1, 2 and 3, w_i is the weight associated with region *i*, and opr_i is operating profit margin in region *i*. $\sigma^2\left(opr_p\right)$ is the variance of the portfolio operating profit margin and *i* = region 1, 2 and 3 and *j* = region 2 and 3, w_i= decision variables, percentage of total available seat miles allocated to a region, where *i* = region 1, 2, and 3 and α is the weight associated with the tolerance for risk.

The formulation for the Mean-VaR approach is similar to the Mean-Variance and is shown starting with equation *(12*). The objective is to maximize the value not at risk. The proposed multi-objective model formulation for the Mean-Variance approach using equations *(4)* and *(5)* is as follows:

Objective 1: $maximize = [\ EV(\sum_{i=1}^{3} \mathrm{w}_i\ opr_i\ )]$ *(12)*

Objective 2: $Minimize = \left[\ \sigma^2 \left(\sum_{i=1}^{n} w_i^2\ \sigma^2\ (opr_i) + \sum_{i=1}^{n} \sum_{j=i+1}^{n} 2\ w_i w_j\ cov\ \left(opr_i, opr_j\right)\right)^{.5}\right] * 1.65$ *(13)*

Combing equations *(12)* and *(13)* to formulate equation *(14)*, the optimization model minimizes variance:

$$maximize = \left[\ \left[\ EV\left(opr_p\right)\right] - \ (1.65)\left[\ \sigma\left(opr_p\right)\right]\right] \tag{14}$$

Equation *(15)* adds weights to $EV\left(opr_p\right)$ and $\sigma\left(opr_p\right)$ which enable the risks taker to adjust the emphasis and tolerance on risk. Theoretically, taking higher risks should provide higher returns.

$$maximize = \left[\ \alpha\left[\ EV\left(opr_p\right)\right] - \ (1-\alpha)(1.65)\left[\ \sigma\left(opr_p\right)\right]\right] \tag{15}$$

subject to:

$\sum_{i=1}^{3} w_i = 1, \ \ w_i \ \geq 0$

where $EV\left(opr_p\right)$ is the expected value of the portfolio of operating profit margin and *i* is the region 1, 2 and 3, w_i is the weight associated with region *i*, and opr_i is operating profit margin in region *i*. $\sigma^2\left(opr_p\right)$ is the variance of the portfolio operating profit margin and *i* = region 1, 2 and 3 and *j* = region 2 and 3, w_i= decision variables, percentage of total available seat miles allocated to a region, where *i* = region 1, 2, and 3 and α is the weight associated with the tolerance for risk.

RESULTS AND ANALYSIS

Tables 7 through 18 show each airline's actual available seat mile distribution and each airline's actual operating profit compared to the optimized allocations and the operating profit that could have been achieved with the optimized allocation. Once the analysis was completed using data from 1990-2005, the validity of the models was verified against actual airline cost per available seat mile, load factor and yield in each of the three regions for the years 2006-2009. In this analysis, the optimized allocation in percent was held constant for the years 2006-2009.

Using equation *(16)* operating profits were derived for each airline in the four years of validation.

$$Opeating\ Profit = \sum_{i=1}^{n}((x)(y) - (z)) * (a) \qquad (16)$$

where i is the region, x is load factor, y is yield, z is cost per available seat mile and a is available seat miles.

Generally, the optimized results far outperformed each airline's actual operating results. In most instances, the optimized allocation showed higher profits and reduced losses than airline actual results. Moreover, it cannot be definitively said that one approach to optimizing available seat miles is better than the other. The Mean-Variance and Mean-VaR approaches showed mixed results, though it appears that the Mean-VaR approach outperforms the Mean-Variance approach in most instances.

The Mean-VaR method has a propensity to remove available seat miles entirely from a region and such is the case with all airlines in this research except US Airways. The Mean-Variance is not quite as extreme; however both methods eliminating flying to a particular region can be attributed to the fact that in these particular regions either the operating profit margin expected value is very low, there is great variance or both. Additionally, negative correlation between regions is not sufficient to warrant allocating seats to a region where there is low expected value or a high degree of variance. American Airlines' expected value in the Asia/Pacific region was not overly excessive at -.08 compared to Delta Air Lines' -.24 or Northwest Airlines' -.22; however American Airlines has a high degree of variance in its operating profit margin in this region, which allowed for the extreme measure of removing all seats from the Asia/Pacific region.

Due to bilateral agreement restrictions, an airline that eliminates all of its flying to a region altogether or does not take advantage of its awarded landing slots, is not certain that it will be allowed to re-enter the market when it so desires. Furthermore, a global air carrier that is branded as a world airline may not deem it appropriate to remove service to a region entirely. The stigma of not serving an area may not coincide with a marketing strategy of becoming a world leader in air transport services.

Though it is not practical or ideal to remove all available seat miles from a particular region, it is practical to realign or reallocate seat miles to reduce exposure to potential risks to either protect profits or reduce the amount and severity of potential losses. Adding constraints to the optimization model, limiting the amount of reduction in available seat miles in a region, is appropriate.

Table 7 and Table 8 show that American Airlines would fare better if it eliminated Asia/Pacific flying and reallocated its seats to Latin America. The Mean-VaR approach increases Latin America flying more than the Mean-Variance Approach and as such adjusts European flying to below its allocation in the periods of 2006-2009. Operating profit and loss numbers are greatly improved with the reallocation of its seats using either approach, though the Mean-VaR approach leads to better results.

Table 7. American Airlines ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	62,592	40.07	43.37	34.06
2006	L		46.89	56.63	65.94
2006	P		13.04	0.00	0.00
2007	E	61,341	40.68	43.37	34.06
2007	L		48.30	56.63	65.94
2007	P		11.03	0.00	0.00
2008	E	61,673	39.89	43.37	34.06
2008	L		49.19	56.63	65.94
2008	P		10.92	0.00	0.00
2009	E	58,805	40.28	43.37	34.06
2009	L		48.25	56.63	65.94
2009	P		11.47	0.00	0.00

Table 8. American Airlines Operating Profit/Loss Results ($ dollars); Comparison between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	201,201,567	203,818,207	29,044,000
2007	171,999,968	192,098,265	86,165,000
2008	-663,973,102	-559,597,530	-772,632,000
2009	-824,583,128	-801,550,398	-957,893,271

Continental Airlines (Tables 9 and 10) would fare better if it too eliminated its Asia/Pacific flying and reallocated its seats to Latin America. The Mean-Variance approach in Continental's analysis increases Latin America flying more than the Mean-VaR approach and both approaches lead to lower levels of European flying. The Mean-Variance approach improves Continental Airlines financial performance more than the Mean-VaR approach, although both approaches show improvement over Continental's actual results. In 2008 Continental shifted its available seat miles away from Latin America and increased European flying, resulting in the optimized allocation and showing greater financial improvements over Continental's actual performance. In 2009 Continental realigned its available seat miles with increases in Latin America and Asia/Pacific regions. Again, the optimized results show greater financial gains in 2009.

Table 9. Continental Airlines ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	40,484	56.10	38.88	46.63
2006	L		30.16	61.12	53.37
2006	P		13.74	0.00	0.00
2007	E	43,630	58.17	38.88	46.63
2007	L		28.66	61.12	53.37
2007	P		13.17	0.00	0.00
2008	E	46,163	59.89	38.88	46.63
2008	L		27.57	61.12	53.37
2008	P		12.54	0.00	0.00
2009	E	44,899	56.01	38.88	46.63
2009	L		28.61	61.12	53.37
2009	P		15.39	0.00	0.00

Table 10. Continental Airlines Operating Profit/Loss Results ($ dollars); Comparison between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	331,115,639	326,509,839	227,363,000
2007	699,551,496	695,783,983	580,897,000
2008	474,540,321	410,632,172	231,277,000
2009	349,336,192	293,608,633	122,615,392

Tables 11 and 12 show the results for Delta Air Lines. The results are mixed. In 2006 and 2007 Delta Air Lines outperformed the optimized results, losing $75.1 million where the optimized results lost $86.8 million and $87.1 million. The next two years the Mean-VaR approach performed better than the Mean-Variance approach and Delta Air Lines’ actual performance. The Mean-Variance allocation shows that Delta would be better off reducing European flying and increasing both Latin American and Asia/Pacific flying. The Mean-VaR approach would allocate all flying to Latin America. Both optimized approaches show results with better improvements in the years 2008 and 2009; however the Mean-VaR approach with the best results is impractical since it would allocate all seats to Latin America and eliminate flying to Europe and the Asia/Pacific Region.

Table 11. Delta Air Lines ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	42,690	70.78	11.76	0.00
2006	L		26.09	74.45	100.00
2006	P		3.13	13.79	0.00
2007	E	49,279	70.45	11.77	0.00
2007	L		25.91	74.45	100.00
2007	P		3.63	13.79	0.00
2008	E	56,339	71.90	11.77	0.00
2008	L		22.51	74.45	100.00
2008	P		5.59	13.79	0.00
2009	E	55,156	69.89	11.77	0.00
2009	L		22.92	74.45	100.00
2009	P		7.19	13.79	0.00

Table 12. Delta Air Lines Operating Profit/Loss Results ($ dollars);
Comparison between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	-86,883,388	-87,135,164	-75,132,000
2007	172,873,589	218,744,525	262,707,000
2008	43,651,843	228,002,346	2,188,000
2009	-497,550,444	-290,920,288	-593,001,000

Northwest Airlines' allocation and financial results are displayed in Tables 13 and 14. Prior to Delta Air Lines acquiring Northwest Airlines, Northwest did not have a presence in Latin America, thus the analysis and results include only the Europe and Asia/Pacific regions. Resembling Delta Air Lines, the results show that Northwest should either reduce or eliminate Asia/Pacific flying. Mean-Variance allocation would keep 7.8 percent of the available seat miles in the Asia/Pacific region, while the Mean-VaR approach eliminates all flying to the region. Both methods of allocation show profound positive changes in financial operating performance for Northwest Airlines.

Table 13. Northwest Airlines ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	34,823	34.97	92.26	100.00
2006	P		65.03	7.74	0.00
2007	E	36,551	37.05	92.26	100.00
2007	P		62.95	7.74	0.00
2008	E	39,260	41.14	92.26	100.00
2008	P		58.86	7.74	0.00
2009	E	34,177	39.72	92.26	100.00
2009	P		1.66	7.74	0.00

Table 14. Northwest Airlines Operating Profit/Loss Results ($ dollars); Comparison between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	518,563,973	638,092,257	-366,057,000
2007	635,926,391	735,495,170	-74,219,000
2008	-424,281,375	-342,016,602	-967,556,000
2009	6,458,554	24,697,698	-113,834,000

Similar to the results of the other airlines, the Asia/Pacific region contains the greatest risk to positive financial operating performance for United Airlines (Tables 15 and 16). While both optimization approaches display a reduction in Asia/Pacific flying, the Mean-Variance method nearly eliminates all Latin America flying but keeps a 13.8 percent share of available seat miles in the Asia/Pacific region while the Mean-VaR approach essentially eliminates all Latin America and Asia/Pacific flying. These results indicate that the greatest downside risk lies within the Latin America region.

Table 15. United Air Lines ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	56,288	33.92	86.12	99.28
2006	L		10.02	0.13	0.00
2006	P		56.06	13.75	00.72
2007	E	57,928	35.21	86.12	99.28
2007	L		8.74	0.13	0.00
2007	P		56.05	13.75	00.72
2008	E	58,463	38.72	86.12	99.28
2008	L		8.41	0.13	0.00
2008	P		52.87	13.75	00.72
2009	E	53,404	41.28	86.12	99.28
2009	L		7.50	0.13	0.00
2009	P		51.22	13.75	00.72

Table 16. United Air Lines Operating Profit/Loss Results ($ dollars); Comparison between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	-264,394,627	-216,539,280	-479,170,000
2007	320,089,397	376,657,910	71,991,000
2008	-1,134,996,601	-1,105,788,532	-1,239,303,000
2009	-44,915,027	27,853,953	-320,906,000

US Airways' (Tables (17 and 18) available seat mile distribution and corresponding financial performance was remarkably comparable to the optimized results. This may be due to US Airways operating only to two regions, Europe and Latin America, bypassing Asia/Pacific regions. Opting out of Asia/Pacific flying, US Airways has reduced its risk of operating profit losses seen by other airlines in this research. In the years 2007-2009, the Mean-Variance method provided better results, though in 2006 Mean-VaR method provided better results. Both optimization approaches showed better results than US Airways actual results. This was accomplished through adjusting its Latin America and corresponding Europe flying. A 20.5

percent reduction in Latin America flying in 2006 resulted in an increase in operating profit of approximately $10.8 million for the airline. Meanwhile, the airline would have fared better if it had increased slightly its Latin America flying while reducing its Europe flying for the years 2007-2009.

Table 17. US Airways ASMs Actual Allocation vs. Optimized Allocation.

Year	Region	Total Actual Int'l ASMs (millions)	Total Actual Int'l ASMs per Region (Percent)	Mean Variance Allocation (Percent)	Mean VaR Allocation (Percent)
2006	E	13,430	64.88	67.61	72.07
2006	L		35.12	32.39	27.93
2007	E	14,455	70.58	67.61	72.07
2007	L		29.42	32.39	27.93
2008	E	16,064	68.40	67.61	72.07
2008	L		31.60	32.39	27.93
2009	E	17,471	68.63	67.61	72.07
2009	L		31.37	32.39	27.93

Table 18. US Airways Operating Profit/Loss Results ($ dollars);
Comparison Between Approaches and Actual Performance.

Year	Mean Variance	Mean VaR	Actual Operating Profit
2006	79,128,020	85,886,397	74,977,570
2007	-84,958,464	-89,805,067	-88,192,960
2008	-498,330,716	-502,274,711	-499,028,680
2009	-276,286,862	-282,878,661	-277,798,000

CONCLUSION

Variance and Value-at-Risk were used to measure the risk of loss to operating profits for six U.S. global airlines operating to three international regions. Historical operating profit margin was used to compute variance and Value-at-Risk. Generally, the Mean-VaR shows the best results except in the case of Continental Airlines and US Airways, where Mean-Variance has shown a propensity to be the better method. The Asia/Pacific region appears to contain the most risk and the models suggest that reductions in this region may be appropriate. US Airways available seat mile global distribution and operating profit margin most closely resemble the optimized solutions suggesting that its lack of Asia/Pacific flying could explain its optimal results.

The preponderance of expected negative profit margins would also suggest that airline executives and managers should focus more on additional revenue streams, rather than relying on passenger revenue as their main source of income. The airline industry is currently undergoing a paradigm shift and is engaged in devising alternative revenue streams.

What is unknown using variance and Value-at-Risk as risk measures is the underlying significance of the variance and VaR. Without further investigation it is not readily apparent or identifiable what the underlying causes of the variance or VaR in an airlines' operating profit margin are. Cost, load factor, yield obviously have an impact on operating profit margin, but what is not readily identifiable are the reasons behind the changes or variability in cost, load factor, or yield. Determinants affecting passenger demand and passenger revenues such as political risks, terrorism, meteorological and natural disasters, infrastructure costs, income levels, economic factors, taxes and fuel prices all have an impact on airline operating profit margins. The next step should be to identify which regions are prone to each of these determinants and to adjust capacity limiting over exposure to risk and financial losses.

Furthermore, data limitations prohibited analysis between country or city pairs. Further research conducted using operating revenues and expenses on a country pair or city pair basis could further extend insight into the risks at the disaggregate level. This would allow for resource allocation to regions within regions which could further diversify airlines' assets. Lastly, incorporating competitor response into asset reallocation decision making would take into account the expected number of competitors with which an airline could potentially compete, the expected time frame in which competitors enter or change their market positions, and the corresponding impacts to load factor and yield projections.

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