Airline Industry

Strategies, Operations and Safety

Transportation Infrastructure
Roads, Highways, Bridges, Airports and Mass Transit

Connor R. Walsh
Editor

NOVA

TRANSPORATION INFRASTRUCTURE – ROADS, BRIDGES, HIGHWAYS,
AIRPORTS AND MASS TRANSIT

AIRLINE INDUSTRY

STRATEGIES, OPERATIONS AND SAFETY

Copyright © 2011 by Nova Science Publishers, Inc.

All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic, tape, mechanical photocopying, recording or otherwise without the written permission of the Publisher.

For permission to use material from this book please contact us:
Telephone 631-231-7269; Fax 631-231-8175
Web Site: http://www.novapublishers.com

NOTICE TO THE READER

The Publisher has taken reasonable care in the preparation of this book, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained in this book. The Publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or in part, from the readers' use of, or reliance upon, this material. Any parts of this book based on government reports are so indicated and copyright is claimed for those parts to the extent applicable to compilations of such works.

Independent verification should be sought for any data, advice or recommendations contained in this book. In addition, no responsibility is assumed by the publisher for any injury and/or damage to persons or property arising from any methods, products, instructions, ideas or otherwise contained in this publication.

This publication is designed to provide accurate and authoritative information with regard to the subject matter covered herein. It is sold with the clear understanding that the Publisher is not engaged in rendering legal or any other professional services. If legal or any other expert assistance is required, the services of a competent person should be sought. FROM A DECLARATION OF PARTICIPANTS JOINTLY ADOPTED BY A COMMITTEE OF THE AMERICAN BAR ASSOCIATION AND A COMMITTEE OF PUBLISHERS.

Additional color graphics may be available in the e-book version of this book.

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Airline industry : strategies, operations and safety / editor, Connor R.
Walsh.
p. cm.
Includes index.
ISBN 978-1-61122-423-8 (eBook)
1. Airlines. 2. Aeronautics, Commercial. I. Walsh, Connor R.
HE9776.A37 2010
387.7068'4--dc22
2010037901

Published by Nova Science Publishers, Inc. † New York

TRANSPORATION INFRASTRUCTURE – ROADS, BRIDGES, HIGHWAYS, AIRPORTS AND MASS TRANSIT

TRANSPORATION INFRASTRUCTURE – ROADS, BRIDGES, HIGHWAYS,
AIRPORTS AND MASS TRANSIT

AIRLINE INDUSTRY

STRATEGIES, OPERATIONS AND SAFETY

CONNOR R. WALSH
EDITOR

Nova Science Publishers, Inc.
New York

CONTENTS

PREFACE

This book presents a comprehensive review of the strategies, operations and safety of the airline industry. Topics discussed herein include a financial history and analysis of the U.S. airline industry; outsourcing strategies of full-service airlines; measuring and benchmarking airport efficiency; service quality and internal differences among members of the airline alliances; measures used to schedule airline crew under a variable workload using fixed days on and days off patterns; and frequent flyer mile usage among passengers.

Chapter 1 - This dissertation analyzes the financial history of the U.S. airline industry from the perspectives of earnings, dividends, risk and capital structure. The airline industry is chosen because of its transition from economic regulation to competition. Within the area of earnings, the authors examine the impact of deregulation on the mean-reversion behavior of earnings documented by Fama and French (2000). Next, the author examines the impact of dividends on the variation of carriers' stock returns. Then, he extends this relation by examining the impact of specific industry characteristics, deregulation, air crashes and the events of 9/11, on both the total and market risk of the industry's stock returns. The author also examines the effect of inflation on shareholder returns using the consumer price index as a proxy. He then examines the effect of deregulation and stock returns on debt ratio behavior. Finally, he examines the relation between operating leases and operating performance.

The results suggest that deregulation has affected the magnitude and variation of earnings, but not on the mean-reversion behavior. The author also finds that stock return volatility appears to increase industry-wide following air crashes, that deregulation appears to increase the industry's total stock return risk and that 9/11 appears to have increased both the total and systematic risk of the industry. Additionally, in the presence of these risks, there does not appear to be a relation between dividends and stock return volatility. Further, there appears to be a negative relation between industry returns and the consumer price index that is robust to lagged stock returns. Within the area of capital structure, the author finds that the recently documented relation between stock returns and debt ratio behavior is not impacted by deregulation. Finally, although my results are mixed, he generally finds a negative relation between the use of operating leases and profitability.

Chapter 2 - The Airline Operations Control Centre (AOCC) of an airline company is the organization responsible for monitoring and solving operational problems. It includes teams of human experts specialized in solving problems related with aircrafts, crewmembers and passengers, in a process called disruption management or operations recovery. In this chapter the authors propose a new concept for disruption management in this domain. The organization of the AOCC is represented by a multi-agent system (MAS), where the roles that correspond to the most repetitive tasks are performed by intelligent agents. The human experts, represented by agents that are able to interact with them, are part of this AOCC-MAS supervising the system and taking the final decision from the solutions proposed by the AOCC-MAS. The authors show the architecture of this AOCC-MAS, including the main costs involved and details about how the system takes decisions. The authors tested the concept, using several real airline crew related problems and using four methods: human experts (traditional way), the AOCC-MAS with and without using quality-costs and the integrated approach presented in this chapter. The results are presented and discussed.

Chapter 3 – Over the last decade or so there has been a significant shift away from vertically integrated organisational structures and a move towards outsourcing in many industries. Outsourcing can take many different forms and go under various names such as subcontracting, contracting out or out-tasking. It is essentially a process of contracting ‘for results not people, collegiate obligations or assets. It is also nothing new - some companies have always subcontracted parts of their operations to suppliers whom, it is felt, can provide these functions more efficiently or effectively. However, since the 1990s, the trend to outsource seems to have accelerated.

Chapter 4 - This chapter refers to two main fields of aviation literature, namely the analysis of the low-cost business model and the study of dynamic pricing techniques, with respect to the case of Ryanair: the European low cost leader has developed a strictly low fare leading strategies and price formation represents a cornerstone of its success, source of debate for both academic and practitioners.

Researchers have extensively examined the cost-effective policy, which so clearly permeates the low-cost business model. Nevertheless, the success of the low-cost model is based on a fragile balance between fare levels, load factors and operating costs and the importance of the different strategic choices made by carriers suggests examining other elements of the low-cost business model. In particular, the structure of revenues and the determination of prices are nearly as important as the minimisation of costs in the equation of profits and need further investigation. Relatively few facts are known about airline price setting at the micro level and results are quite different. Differences drawn from the difficulties to take into account the micro structure of low cost pricing rather than average fare and from the limited set of available data (most of the studies limited the extension of the sample, few fixed departing data, only one departing airport, a limited set of advancing booking price offered).

In this framework this chapter aims to identify the main features of Ryanair’s business model, the competitive and the contextual factors that drive the choice of the average fares and their relative dynamics.

Chapter 5 - Airports are multidimensional organizations whose efficiency is difficult to measure on the basis of a single criterion. Differences in terminal layout, runway configurations, passengers’ origin and destination, and hub versus non-hub status all make comparisons among airports even more challenging. In a context of airline consolidation, tightening noise and environmental regulations, as well as competition for scarce resources in capacity expansion, managers find it more compelling to measure the efficiency of their airport as a whole and to benchmark it with others.

The present article will provide an introduction to two methods for measuring and comparing airport efficiency. The criterion for efficiency is the System Airport Efficiency

Rate (SAER) published daily in the Aviation System Performance Metrics (ASPM). Even though one method is parametric (Stochastic Frontier Analysis) while the other is not (Data Envelopment Analysis), they both attempt to derive an efficiency frontier that serves to define technical efficiency in the former case or an empirical technology frontier in the latter case.

This article will start with the differences between DEA and SFA, their theoretical underlining, and their limitations. Then, it will illustrate the use of both analytical methods to determine how efficiently each sampled airport utilizes its available capacity. The discussion will end with some remarks derived from the application of either model.

Chapter 6 - The Aerohemodynamics Theory is more cogent to flight nursing practice and safety in the new millennium than it was when first identified in 1983. Major advances in the commercial airline industry and military transport capabilities have challenged nursing's comprehension of physiological adaptations necessitated by the flight environment, and those challenges are significant. The airline industry transported almost two billion passengers in 2002, many with serious cardiovascular and respiratory problems. Although the incidence of death among air travelers is low (frequency of occurrence approximately 0.3-1 per 3,000,000 passengers), medical emergencies of various other etiologies are more common, occurring 1 per every 14,000-40,000 passengers. Awareness of the risks and principles of nursing that augment nursing practice at altitude is necessary both for the specialty of flight nursing, as well as for the occasional nursing traveler who might be called upon to assist in an airborne emergency. This article explores the construct and use of the Aerohemodynamics Theory, identifies research on some of the physiologic adaptations to the flight environment that nurses must recognize, and offers recommendations for education and practice by medical, nursing, and airline personnel, .for future safety considerations.

Chapter 7 - Corporate social responsibility (CSR) plays an important role in the formation of airlines' strategies due to the unique characteristics of the airline industry. Nevertheless, CSR in the airline industry has received relatively little attention from academics. The purpose of this study is to present a preliminary exploration of the CSR issues being addressed and reported by twelve major Asian airlines. This research is exploratory by nature and is based on he CSR reports published by the selected airlines and related CSR information on the company websites. The main focuses of major Asian airlines' CSR commitments and practices are identified, which will set the foundation for future enquiry and research.

Chapter 8 - The topic of global airline alliances has received much attention in the literature in recent years. The vast majority of these studies on strategic alliances are the focus upon issues relating to the organization. However, little attention to date has been paid to strategic airline alliances from the consumer perspective. This paper attempts to empirically investigate the internal differences among members of the global airline alliance from the quality of service perspective. The present study is based on a sample of the international airlines from the three major airline alliances. This research has analysed the internal differences among members of the global airline alliances from the quality of service perceived by the passengers. The alliance founding members have higher scores in the majority of service attributes than other full members. However, there are few significant differences.

Chapter 9 - Personnel costs typically are the second largest costs for airline operations after fuel costs. Since efficient crew employment can drastically reduce operational costs of airline companies, the crew scheduling problemin the airline industry has been extensively investigated in the operations research literature. This problem typically consists of assigning duties to crew members securing the safety of all flights minimizing the corresponding overall cost for personnel. Due to the typical size and complexity of the crew rostering problem, airline companies want to adopt scheduling policies that roster crew members according to fixed days on and days off patterns. However, as the distribution of work duties over the planning horizon is typically highly variable in airline operations, the scheduling according to these fixed work patterns is seriously hindered. In this chapter, the authors give an overview of different measures that help to schedule airline crew under a variable workload using fixed days on and days off patterns.

Chapter 10 - Previous research on Frequent Flyer Programs (FFP) covered various topics, from analyzing the effect of international airline alliances on domestic travel demand to th effect of airport dominance and FFP on pricing. However, one important constraint in previous empirical research on FFP is the lack of a measure of these programs at a specific time-variant route and carrier level. In this chapter the authors use a novel way to measure the extent of FFP that allows them to analyze how these programs change from route to route, across carriers and over time. The dataset, which covers the quarters from 1993.1 to 2009.3, was constructed with data obtained from the Bureau of Transportation and Statistics, and it has information on prices, proportion of frequent flyer tickets as well as various route and carrier variables. Using panel data techniques to control for unobservables along with the use of instrumental variables to control for potentially endogenous regressors, the results found are consistent with our economic model: travelers are more likely to redeem their frequent flyer miles in more expensive routes. Moreover, business travelers, who usually pay higher prices, were found to be less price sensitive than tourists when switching to buy with accumulated miles.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 1-60
ISBN: 978-1-61122-079-7

Chapter 1

A FINANCIAL HISTORY AND ANALYSIS OF THE U.S. AIRLINE INDUSTRY

Ray R. Sturm
Florida Atlantic University, Boca Raton, Florida, USA

ABSTRACT

This dissertation analyzes the financial history of the U.S. airline industry from the perspectives of earnings, dividends, risk and capital structure. The airline industry is chosen because of its transition from economic regulation to competition. Within the area of earnings, I examine the impact of deregulation on the mean-reversion behavior of earnings documented by Fama and French (2000). Next, I examine the impact of dividends on the variation of carriers' stock returns. Then, I extend this relation by examining the impact of specific industry characteristics, deregulation, air crashes and the events of 9/11, on both the total and market risk of the industry's stock returns. I also examine the effect of inflation on shareholder returns using the consumer price index as a proxy. I then examine the effect of deregulation and stock returns on debt ratio behavior. Finally, I examine the relation between operating leases and operating performance.

My results suggest that deregulation has affected the magnitude and variation of earnings, but not on the mean-reversion behavior. I also find that stock return volatility appears to increase industry-wide following air crashes, that deregulation appears to increase the industry's total stock return risk and that 9/11 appears to have increased both the total and systematic risk of the industry. Additionally, in the presence of these risks, there does not appear to be a relation between dividends and stock return volatility. Further, there appears to be a negative relation between industry returns and the consumer price index that is robust to lagged stock returns. Within the area of capital structure, I find that the recently documented relation between stock returns and debt ratio behavior is not impacted by deregulation. Finally, although my results are mixed, I generally find a negative relation between the use of operating leases and profitability.

I. INTRODUCTION

This dissertation analyzes the financial history of a single industry from the perspective of most of the major areas within the discipline of finance – those being earnings, dividends, risk and capital structure. The purpose of such an approach is to provide a solid foundation that future research can extend. Traditional finance theory states that management's primary goal is to maximize the current value of the firm's stock. This theory assumes that the stock's price accurately reflects value, suggesting a slightly modified goal of maximizing the firm's value. Since current value derives from expected future cash flows and earnings provide the best available data as to expected future cash flows. I argue that earnings are a critical area to study. Thus, earnings behavior is the first area studied in this dissertation.

Once the managers of a firm achieve positive earnings, the returns to owners will take the form of either dividends or capital gains. Hence, management's dividend policy and more specifically, the effect of that policy on the firm's stock, is of critical importance to maximize stock value. Thus, dividend policy is the next area studied after earnings. Of course, shareholder returns are enjoyed at the expense of risk. So, examining risk is the next area studied. Finally, all of the above areas result from investments that must be acquired through either internal or external capital. Therefore, capital structure is the final area studied.

Given this approach, the next decision is to choose an industry that would provide a good experimental setting. Although many industries would be good candidates, I chose the airline industry for three primary reasons. First, the industry has a long history, thereby providing a relatively large sample of time series data. Second, the industry is unique in that it has transitioned from complete economic regulation to complete competition. Since production efficiency and product quality purportedly results from competition, this industry characteristic provides an opportunity to test this proposition. Finally, although I argue that it is one of the main industries representing the American economy and lifestyle, the industry has always financially struggled. Moreover, in the absence of government financial assistance, the industry as we know it today probably wouldn't exist. This presents a question as to how the industry has been able to attract investment capital.

The primary focus of this dissertation is to begin a determination of how the economic deregulation of an industry affects the financial characteristic and behavior of that industry. A comprehensive analysis would take a career to complete, so this study just begins to lay the foundation. However, the significance of such an undertaking is clear when the government is contemplating economic regulation or deregulation of an industry. The ultimate purpose of regulation is to protect consumers, thus understanding the effect is critical when setting the policy's details. Moreover, financial managers' decisions may differ depending on the economic environment in which they operate. Forward-looking proactive managers would benefit from an understanding of how a proposed or approved change in economic regulation will affect their industry. While many studies have examined the difference between regulated and deregulated environments cross-sectionally, this dissertation appears to be one of the first to study the difference in time-series.

Within the area of earnings, prior literature documents that earnings tend to exhibit a mean-reversion behavior. This behavior is the result of changes in competition for market share. However, absent from the literature is the effect that economic regulation has on this behavior. Furthermore, prior literature suggests that the magnitude of earnings may be different due to the shift in agency oversight from government to competition. Therefore, in the area of earnings, I examine whether the magnitude of earnings appears to be different. But, my primary focus is on the changes in earnings behavior precipitated by the changes in regulation.

When setting dividend policy, prior literature suggest that mangers will behave differently based on the extent of economic regulation. The results of this is the amount of focus mangers direct towards their firm's stock when setting dividend policy. That is, regulated managers seem to place more importance on stock price than deregulated managers. However, prior literature does not address the change in importance that mangers place on their firm's stock return variability. Therefore, I examine the relation between a firm's dividend policy and the firm's stock volatility. Similarly, in Chapter 3, I study the effect that idiosyncratic risk sources have on shareholder risk in the industry.

Prior literature documents a relation between the Deregulation Act of 1978 and shareholder wealth, but does not address shareholder risk. Thus, I examine the relation between the Deregulation Act of 1978 and changes in shareholder risk. Additionally, other prior literature examines the effect of air crashes on individual carriers, but not on the industry as a whole. Hence, I examine the industry-wide effect of airline crashes on shareholder risk. Further, I examine the industry-wide effects of 9/11 on shareholder risk.

Finally, I examine capital structure behavior and the effectiveness of leasing in the industry. More specifically, optimal capital structure decisions have long been debated in the academic literature. Recently, however, capital structure has been show to vary passively with stock returns rather than actively as would be the case if managers sought a target capital structure. I analyze this relation in the airline industry, as well as examining the effect that deregulation has on the relation. In addition to capital structure behavior, I also examine the effectiveness of operating leases as a substitute for other forms of financing. Prior literature argues that leases and debt are substitutes for one another. However, prior literature does not address the more specific use of operating leases. Further, the airline industry is well-known as a frequent user of leasing arrangements in capital budgeting decisions. Therefore, I use this industry to test the relation between financial performance and the extent to which operating leases are employed.

The dissertation is organized as follows. Chapter 3 provides insight into the earnings performance and dividend policies of the airline industry. In Section A, the industry's earnings behavior is examined for mean reversion. If earnings are mean reverting, then they are at least partially predictable which carries significant implications for carrier valuation. In addition, I examine the impact of regulation on this behavior. When examining the behavior of earnings, most prior academic studies do not include utility and insurance firms because of their regulation, but do include airlines. The implications from my study suggest that past studies may be biased to the extent they do not control for airline firms during the period of regulation and that future studies should exclude them. In Section B, the dividend policies of carriers are inferred from examining the stock price variability of dividend payers. Prior studies have cross-sectionally documented the effect of regulation on dividend policy. The airline industry provides an opportunity to study the effect in time series. From my results, I infer how deregulation has affected managers' use of dividend policy to maximize shareholder wealth and minimize shareholder risk.

Chapter 4 examines the industry-level idiosyncratic risks faced by owners of airline carriers. The unique risk characteristics of this industry include the industry's economic deregulation, safety issues with respect to airline crashes and the events of 9/11. At issue is the extent to which each of these events influences the risk of owners' investments – a foundational principle in portfolio theory. In this chapter, I consider both the industry's market and total risk.

Finally, in Chapter 5, I use the unique characteristics of the airline industry to examine two capital structure issues. Recent literature has argued and documented that managers tend to allow debt ratios to vary with the firm's market value of equity rather than structuring capital in accordance with more traditional theories. Therefore, in Section A, I examine the impact of deregulation on the relation between debt ratios and the market value of equity. A significant change suggests that regulation has impacted managers' decisions with respect to capital structure. In Section B, I capitalize on the industry's notorious use of lease financing to conjecture whether there is an operational benefit to using operating leases rather than purchase arrangements. Chapter 6 provides a dissertation summary, conclusions and implications.

II. A BRIEF FINANCIAL HISTORY OF THE U.S. AIRLINE INDUSTRY

The primary focus of this chapter is to provide a brief history of the airline industry, highlighting the more important economic and financial events. In addition, the airline industry is unique in that it has experienced a transition from complete economic regulation to complete economic competition. This provides an experimental setting to test the financial effect of this transition on the industry as a whole. Therefore, the first section presents a motivation for the study.

A. The Paradox of the Airline Industry

In a socialist economic society, capital is owned collectively and decisions with respect to the allocation of capital are theoretically motivated by a concern for the needs of others. In this economic system, there is little (if any) incentive to optimize business performance which leads to an inefficient economy. By contrast, capital in a capitalist economic society is owned privately. The allocation and distribution of capital are determined by supply and demand which introduces competition into the market place. The threat posed by competitors provides a strong incentive to optimize business performance and to survive by maximizing product quality while minimizing product costs. If both of these goals are achieved and if there is a need or desire for the product in society, then capital will be transferred to the supplier.

The equilibrium of supply and demand is the mechanism by which capital is transferred and this equilibrium is determined by price. Basically, suppliers ask prices that maximize their profits while consumers pay prices that minimize their costs with respect to the product being received. If suppliers and consumers agree on a price, a mutually beneficial exchange takes place and the market clears. If they cannot agree on a price, then the market will not clear, the supplier will not be able to obtain capital and ultimately, the product will be removed from society. Therefore, if a supplier desires to acquire capital, it must offer a product at a price low enough to attract demand. But, in order to survive, it must receive a price high enough to cover its costs. If both these conditions can be met, then market equilibrium is reached, the producer will be able to survive and the product will be available to society. However, if market equilibrium cannot be achieved, then the producer cannot survive and the product will no longer be available. Hence, price is the key determinant of survivability.

The theory of market efficiency generally posits that this equilibrium price will reflect all available information about the product. As a consequence, abnormally positive profits cannot be earned in the long-term because others, having full knowledge, will enter the market and compete for market share. Of course, this increases supply which in the absence of an overwhelming increase in demand, will drive prices down thereby reducing profits. Similarly, market efficiency also implies that abnormally negative profits will not be accepted for long due to the opportunity cost of capital. That is, if a supplier cannot receive a price that provides a return greater than or equal to the opportunity cost, then the supplier will not supply the product and will instead, choose the next best alternative.

The theoretical result of market efficiency is that after adjusting for risk, all firms should earn identical profits. If a firm earns more, then competition should increase which will erode away the excess profits. If a firm earns less, then competition should decrease as existing firms exit the market and profits of the remaining firms will increase. This is the basis of economics in the marketplace and it suggests that the forces of the producer’s ability and willingness to supply a good (supply) and the consumers’ ability and willingness to purchase a good (demand) will decide which goods are present in society and at what price. At odds with these theories is the very existence of the airline industry. The airline industry as we know it today started with the Civil Aeronautics Act of 1938. Yet, despite the fact that the industry’s product is in demand and has become a necessity, the airline industry has always financially struggled and has depended on government support for survival (KPMG Corporate Finance, www.kpmg.com). Indeed, Chan (2000) documents that during the period 1989-1991, the airlines lost a total of $10 billion which drove the industry as a whole into negative cumulative profits. The industry again went into negative cumulative profits in the year 2002 (Figure 2). The legacy of the airlines seems to contradict almost all financial and economic theories, yet these airlines are still flying.

In this study, I examine the airline industry from two broad perspectives: that of the corporation and of the investor. The corporate analysis focuses on the financial performance of the airline industry as a whole in comparison to other industries; the investment analysis focuses on the stock price performance and behavior of the airline industry in comparison to other industries and the market portfolio. At issue is the industry’s ability to attract capital and create value. I address these issues by analyzing not only the key profit and/or risk sources in the industry, but also the historical contribution of airline stocks to the risk and return of investors’ portfolio. Ultimately, the findings should provide insights into the industry that will begin to help it to attract capital and create value in the future.

B. The Pre-Regulation Period (1914-1938)

The first American commercial flight occurred in 1914 when passengers paid $5.00 for an 18-mile flight along the St. Petersburg-Tampa Airboat Line (Morrison and Winston, 1995).

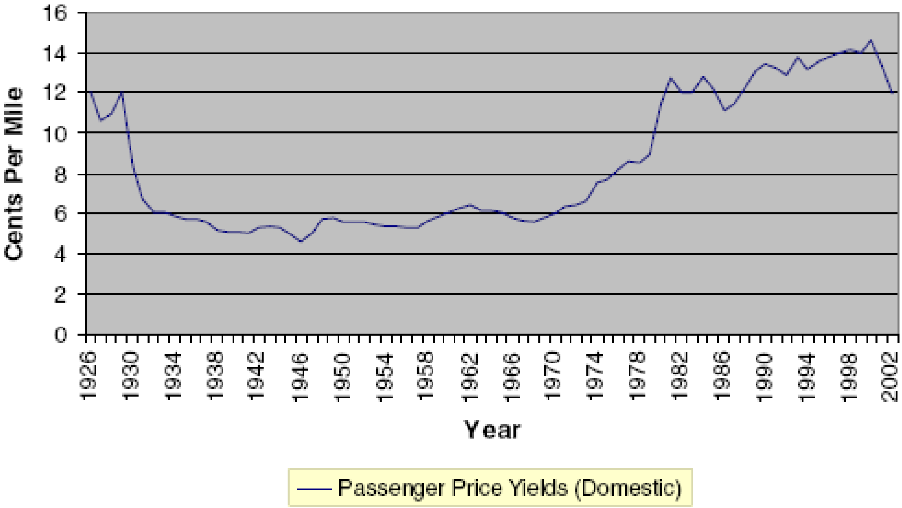
After the inaugural flight in 1914, the industry received its first major boost in 1925 when The Kelly Act of 1925 began phasing out the use of the Post Office's own aircraft for mail delivery, and began contracting the use of private aircraft (O'Conner, 2001). At that time, the post-master general began granting route authority to airlines based on their bids to provide airmail service. Airmail delivery was the primary business component of the airlines during this time and passenger service was little more than a subsidy. Hence, the post-master general was the regulator of commercial air transport. Also during this time, the Air Commerce Act of 1926 initiated the air traffic control and airport infrastructure.

By the early 1930's, the post-master general sought to develop a national air transportation system, from which the first big airlines were created – American, Eastern, United and Trans World. Because they temporarily lost their governmental contracts due to a legal charge of monopoly, none of the airlines showed a profit prior to 1938.

The airline industry has experienced at least three significant financial events in its history. The first was the enactment of the Civil Aeronautics Act of 1938 which sought to governmentally regulate the industry via restrictions on fares and routes. The second was the enactment of the Airline Deregulation Act of 1978 which phased out the Civil Aeronautics Act and allowed the forces of supply and demand through competition to set prices. Finally, the third significant event was the use of commercial aircraft to carry out one of the largest acts of terrorism in history. This event happened in New York City, New York on September 11, 2001 and delivered a devastating financial blow to the industry. For purposes of this study, these events are considered "significant" because they created a clear and definable structural break in the industry's financial time series. The effect of regulation on passenger price yields is evident from a casual observation of Figure 1; and the effects of the terrorist attacks on profits are well documented and evident from a casual observation of Figure 2. Therefore, these events form natural, convenient and obvious sub-periods in which to frame the industry's financial history.

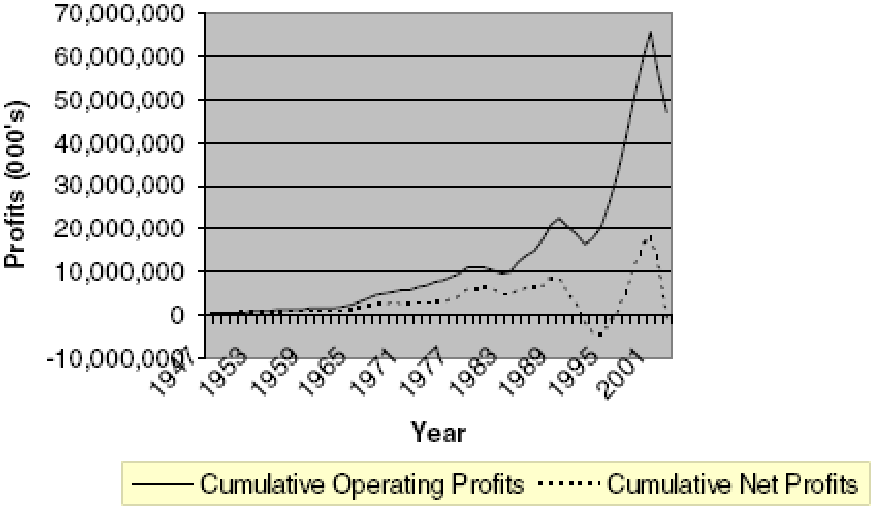
C. The Period of Regulation (1938-1978)

The Civil Aeronautics Act of 1938 became effective on August 22, 1938 and brought interstate, overseas and the international common-carrier airlines of the United States under the Civil Aeronautics Board's (CAB) direct economic regulation. Presumably, the Act's intent was to protect the consumer from exploitation by the producers. However, Jordan (1970) found that the actual result was to in effect create an airline oligopoly. That is, an oligopoly in any industry is formed so that producers as a group can charge higher prices than could be charged if they competed with each other directly. In such industries, the consumers end up paying a higher price than in industries with free competition. So an oligopoly serves to increase the industry's cost to society. By comparing airlines under CAB regulation with those outside of their regulation, this is exactly what Jordan (1970) found.



Source: The Air Transport Association of America, Inc.

Figure 1. Airline Industry (1926-2002).



Source: The Air Transportation Association of America, Inc.

Figure 2. Airline Industry Profits (1947-2002).

Figure 1 shows that during the period of regulation, passenger price yields were very steady at around 5.5 cents per mile. In addition, Figure 2 shows that the industry's profits appear to be stable with a slight growth rate. This is not surprising since, consistent with Jordan (1970), the industry was enjoying the benefits of an oligopoly via CAB regulation.

The CAB had regulatory power in the areas of entry, exit, service and price within the industry. For example, no airline could provide scheduled interstate service with an aircraft having a takeoff weight over 12,500 pounds unless specifically authorized by the CAB. Apparently, the effect of such requirements was to limit the number of aircraft in the industry to the pioneers of a specific service (trunk, local service, all-cargo and supplemental carriers).

That is, those that were the first in appeared to be effectively protected from financial distress via the CAB. Hence, there was no need for additional service.

Regulation of entry into a market

More generally, in order for an airline to be granted a certificate to enter a market, the proposed service must have been deemed required by the public convenience and necessary. Additionally, the airline was required to be "fit, willing and able" to perform the service (O'Conner, 2001). However, the issue of competitive market forces was guided by the following language:

> Competition to the extent necessary to assure the sound development of an air-transportation system properly adapted to the needs of the foreign and domestic commerce of the United States, of the Postal Service, and of the national defense.

In practice, whether competition was "necessary" was often debatable. However, during the regulated period, the CAB followed a "presumption doctrine" which tended to give increased competition the benefit of the doubt assuming that operating costs would not increase substantially. Thus, according to O'Conner (2001), there was a general trend of increased competition in most markets from 1938 – 1978.

Conversely, Edelman and Baker (1996) report that between 1938 and 1978, the CAB did not grant a single long-distance route to a new carrier despite more than 150 requests. Furthermore, Brady and Cunningham (2001) document that the CAB turned down all 94 applications for trunk common carrier authority filed between 1950 and 1975. So the actual degree of competition is unclear, but if competition did increase, it appears to have been within the smaller markets.

Regulation of exiting from a market

In addition to the entry requirements, no airline could exit the market without the CAB's authorization. As it turns out, apparently the only exits during the studied time period of 1946 – 1965 were through merger or acquisition by another certificated carrier. Together, the entry and exit requirements limited the number of carriers in existence, thereby reducing competition.

The regulation of services

With respect to the regulation of services, the CAB's power was limited. Thus, the difference in the level of service provided by the carriers was probably the most competitive area of the industry. However, for the local service providers, since prices were controlled by the CAB and the CAB issued monopoly rights in most markets, there was little incentive for these carriers to maximize the quality of their service. Of course, in this environment, the quality of the service suffered.

By contrast, the larger trunk carriers often had at least one other competitor in their market. Thus, they could compete for market share by attempting to provide a higher quality service. The competition during this era spawned the concept of "coach service", which was introduced by Capital Airlines in 1948. This resulted from the fact that some passengers would prefer to sacrifice quality in exchange for lower fares. Hence, carriers could offer two different levels of service.

The regulation of prices

The CAB had the power to regulate prices in two ways. It could either simply approve or suspend fares filed by individual carriers, or it could set exact (or maximum and/or minimum) fares that could be charged. Fares fall into one of two major categories: *general* fares and *promotional* fares. General fares are available to everyone; Promotional fares are not available to everyone and are defined by a common characteristic such as travel during certain times, round-trip tickets, members of the military, etc. If a carrier wanted to change its fares, then in general, it was required to obtain approval from CAB.

For the purpose of deciding whether or not to authorize a change in fares, the CAB did not act independently. Jordan (1970) documents that:

> The carriers also played a major role in establishing fares through the submission of tariff changes, through formal and informal discussions with the Board and its staff, trough discussions with each other as authorized by the CAB, and trough various public announcements, etc. Actually, the majority of the postwar across-the-board fare increases were precipitated by the actions of various carriers. In addition, state and local government agencies, chambers of commerce, congressional representatives, etc., have influenced the Board's decisions.

However, the general agreement among the airlines seemed to be that the new fares were more profitable for them than the old.

The beginning of deregulation

During the 1960's and 1970's, intrastate carriers were charging lower fares, but reaping higher profits than the interstate carriers under the CAB's control (Chung and Szenberg, 1996). This sparked an 8-year congressional debate that started in August 1970 (Edelman and Baker, 1996) and ultimately lead to deregulation of the industry.

During this 8-year period, the CAB was accused of protecting the airline industry from "the ugly specters of competition, efficiency and innovation." This resulted in The Aviation Act of 1975 which sought to stimulate price competition and eliminate entry into new markets. The CAB became more and more lax in their control over the industry until finally, on October 24, 1978, President Carter signed into law the Airline Deregulation Act.

D. The Post-Regulation Period (1978-2001)

The Airline Deregulation Act of 1978 was enacted in an attempt to allow the forces of competition to lower prices and increase the quality of services for consumers. The act was actually a phase-out of regulatory control over the industry by the CAB and occurred in stages during 1978 – 1985. Its major provisions were as follows (Edelman and Baker, 1996):

1. Effective December 31, 1981, the airlines assumed responsibility for determining their domestic routes and schedules.

2. On January 1, 1983, the airlines became free to set domestic fares and engage in price competition.
3. On January 1, 1985, the CAB ceased operations and the responsibility for overseeing the industry was transferred to the Department of Transportation for the period 1985-1988. After 1988, the industry was completely deregulated, oversight was transferred to the Department of Justice and airlines were subject to antitrust laws like any other industry (Singal, 1996).

So, by 1982, the industry was free from regulatory control over its entry, exit and servicing of markets and by 1984, it was free from regulatory control over its pricing.

What immediately followed over the years 1985-1987 was a dramatic decrease in competition due primarily to mergers and acquisitions, the most significant of which were as follows (O'Conner, 2001):

- American acquired the former Air California
- Delta merged with Western
- Northwest acquired Republic
- TWA acquired Ozark
- Texas Air acquired People Express and Eastern
- United acquired the Pacific Division of Pan American
- USAir acquired Piedmont and Pacific Southwest

Morrison and Winston (1995) document that the number of *effective competitors* dropped from around 11 in 1985 to around 7.75 during the period 1987-1993. Chung and Szenberg (1996) attribute this to the process of globalization. They identify two distinct periods: the "offensive stage" during the period 1985 – 1989, and the "defensive stage" during the period 1990 – 1992.

During the offensive stage, the major American carriers were financially stable, as was the overall economy. Therefore, they attempted to exploit the opportunity to expand into overseas markets. But during the defensive stage, they started incurring losses due to an economic recession and "fare wars", which provided an opportunity for foreign airlines to enter U.S. markets. In an effort to remain financially healthy, the targeted American airlines were forced to accept the acquisitions.

The result of the post-regulation competition was that by 1992, Midway, Pan Am and Eastern (three major U.S. carriers) had been liquidated and three others, America West, Continental and TWA were in bankruptcy (Chan, 2000). The problem was that many of the airlines were allowed to continue operating under a restructuring plan while at the same time enjoying the protection of bankruptcy laws. Because they only needed to cover their marginal costs to be profitable, fares could be lowered. This, of course, created downward pressure on fares for the remaining carriers, which eroded their profits. Therefore, they were criticized for exploiting the bankruptcy to laws to effectively gain a government subsidy. Also in 1992, the U.S. started seeking the so-called *open skies agreement*. This agreement allows foreign carriers access to U.S. markets provided that the governments of these countries open their markets to U.S. carriers (O'Conner, 2001; Chung and Szenberg, 1996).

Probably the most important strategy to come out of this era of competition was the so-called hub-and-spoke network. This strategy allowed airlines to reduce the number of flights necessary to cover their networks, thereby reducing their costs (Chan, 2000). For example, suppose a particular airline serviced 25 pairs of cities. In the point-to-point system, 25 planes would be necessary to service 25 routes. However, in the hub-and-spoke system, those same 25 planes could service 675 city-pairs (25 x 25 plus direct flights from 50 cities to the hub) (Robson, 1998). Therefore, in addition to lower operating costs, consumers enjoy more frequent flights and lower fares. The hub-and-spoke network also resulted in code-sharing alliances between the major carriers and commuter airlines (Chan, 2000). This resulted in the commuter airlines restructuring their routes around the hub system and therefore becoming more integrated with and dependent upon the major carriers for survival.

After 1995, the industry stabilized and the four surviving major carriers were not engaging in price wars (Chan, 2000). By 1998, a two-tier market was present: the hub-and-spoke market and the peripheral markets. The hub-and-spoke markets were serviced and dominated primarily by the major carriers while the peripheral markets were serviced by the point-to-point carriers. As Chan (2000) documents, the major carriers were able to fend off the threat of new entrants into their markets by using two strategies. The first, called "bracketing", was a direct strategy aimed at defeating specific routes. That is, if a new entrant offered to service a particular market at a discounted price, then the major airlines would drop their fares for flights departing just before and just after the new entrant's flight. All other fares would remain at the higher price. In addition to bracketing, the major carriers acquired almost all of the available slots at the nation's most important airports and refused to sell or lease them to new entrants.

The purpose of the Airline Deregulation Act of 1978 was to increase competition within the industry. Yet, that competition was effectively held at bay by the major carriers' success in defeating new market entrants through various pricing schemes. Hence, they were criticized for their pricing practices, most notable of which is the concern that they were practicing *predatory pricing*. Generally, predatory pricing is the practice of setting prices below some measure of cost for the purpose of driving competitors out of the market. Accordingly, the carrier with the largest financial resources can set prices so low that through the forces of supply and demand, their competitors will be forced to match those prices. While prices remain at this level, all of the market participants will be losing money, but the larger carrier will be able to survive longer than the new entrant because of their superior resources. Hence, after the new entrant is forced out, the larger carrier then adjusts prices back up and starts recouping its losses. However, to successfully prosecute predatory pricing, two issues must be addresses: intent and the appropriate measure of cost.

Apparently, in earlier court decisions, intent was the primary issue for determining predation and unreasonably low prices were enough to establish intent. However, more recent decisions have focused on determining whether or not the pricing decision is economically irrational. That is, it would be considered economically irrational to enter a market and remain in that market with no hope of earning profits. Of course, integral to the calculation of profits is the measure of costs, which is not purely objective. For example, Brady and Cunningham (2001) point out several measures of cost that have been identified in the literature:

- Fully allocated costs
- Average total costs
- Average variable costs
- Average incremental costs
- Average avoidable costs
- Marginal costs

Of these or combinations of these measures, there is no common agreement even within the judicial system as to which is the most appropriate measure for the purpose of determining predation. Moreover, the issue is even more complex for the airline industry because predatory pricing has been applied only to producers of goods, and not services (Brady and Cunningham, 2001). Additionally, the large fixed costs common to the airline industry make the proper matching of revenues and costs even more complex. Because of these complexities, in 1998, the Department of Transportation was not focusing on these issues specifically, but on actions that were designed to reduce competition while at the same time, result in substantially decreased revenue. So, their focus was on foregone revenue rather than the appropriate measure of cost. In their *Statement of the Department of Transportation's Enforcement Policy Regarding Unfair Exclusionary Conduct in the Air Transportation Industry*, they (Brady and Cunningham, 2001):

> Propose(s) to consider that a major carrier is engaging in unfair exclusionary practices…if, in response to new entry into one or more of its local hub markets, it pursues a strategy of price cuts or capacity increases, or both, that either (1) causes it to forego more revenue than all of the new entrant's capacity could have been diverted from it or (2) results in substantially lower operating profits-or greater operating losses-in the short run than would a reasonable alternative strategy for competing with the new entrant.

The Department of Transportation argues that such a strategy is only economically rational if it is intended to eliminate competition. Nonetheless, between about 1994 and 1998, pricing wars were largely nonexistent.

Between 1993 and 1998, the industry enjoyed increasing profits driven primarily by low labor costs, low fuel costs and a dramatic drop in orders for new aircraft. But by 1999, another major cost was facing the airlines – that of Y2K. At issue was the vast computer network which simply used two digits to identify a year. Hence, the computers could not differentiate between the years 1900 and 2000, thereby potentially causing them to crash. The International Air Transport Association (IATA) estimated that the industry would spend $2.3 billion dollars to resolve the problem. Coupled with this expense was a significant jump in labor costs that resulted from renewed labor contracts. The old contracts started expiring between 1995 and 1998 and were partially responsible for the industry's aforementioned profits. However, the renegotiated contracts drove these costs up to about 36% of revenues. Therefore, they were the highest category of costs that the airlines faced. But during this same time, fuel costs had decreased dramatically which served to at least partially offset the increased labor costs.

With fuel costs being a major cost of airline operations and fuel prices on the rise, many airlines began hedging their fuel costs by the year 2000. Most carriers used either Crude Oil or Heating Oil futures as their hedge vehicle, and the most notable airlines that began hedging were Delta, American, United and Southwest. Despite these efforts, airline profits decreased about 10% during 2000. Also prevalent in 2000 was a new wave of proposed mergers, starting with the proposed purchase of US Air by United. This deal was ultimately disapproved by the Department of Justice and with the exception of American purchasing TWA, there were no major mergers. But the industry was about to face an entirely new and unforeseeable problem.

E. The Post-Terrorist Period (2001 - Present)

On September 11, 2001, terrorists from the Al Quaida organization hijacked and successfully used three of four commercial aircraft as missiles to attack the World Trade Center towers in New York and the Pentagon in Washington. The 9/11 attacks mortally wounded the industry because it struck fear into potential passengers about the future safety of air transportation. This caused a massive decline in demand for tickets which (coupled with high operating leverage) sent the industry into financial distress. The post-9/11 period also called for a significant increase in security – yet another fixed cost to an already highly leveraged industry. Once again, the industry was forced to rely on governmental assistance for its survival.

Airline industry losses for the top 10 carriers in the year 2001 were estimated to be $7.6 billion - $1.4 billion of which was incurred just during the four days following the attack when all flights were suspended. Losses in the year 2002 were estimated to be $11.3 billion and losses for the year 2003 are estimated to be about $6.4 billion. This led to the *Air Transportation Safety and System Stabilization Act* which congress passed on September 22, 2001 to compensate airlines for the effects of 9/11. The act provided the industry with $5 billion in cash grants and in addition to other benefits, another $10 billion in loan guarantees. On November 19, 2001, the Aviation and Transportation Security Act brought the responsibility for airport security under the federal government's control. Further, a federal sky marshal program was initiated. The airlines were forced to reinforce their cockpit doors as well as purchase baggage screening machines that can cost up to $1 million each. The costs of many of the new safety requirements were borne by the industry.

During the post-9/11 period, airlines were enjoying historically low fuel costs, but historically high labor costs as a percentage of revenue. In 2001, labor costs reached 40.8% of revenues, but this was primarily driven by the decline in revenues as a result of the decline in demand. Although fuel costs were low during this time, they started rising in 2002 as war in the Middle East loomed and Venezuelan production slowed. On April 16, 2003, the *Emergency Wartime Supplemental Appropriations Act* was enacted which reimbursed carriers for security fees paid since February 2002. Even so, for the year 2003, Standard and Poors was estimating that the top 10 U.S. carriers would lose about $6.4 billion, even after considering government assistance and then lose an estimated $1.0 billion for the year 2004. Given that upward trend in losses, a profit for the year 2005 could be projected, but that is subject to considerable uncertainty.

III. EARNINGS BEHAVIOR AND DIVIDENDS IN THE AIRLINE INDUSTRY

A. Earnings Behavior in the Airline Industry

Prior literature

Basic economic theory posits that businesses earning abnormally high (or low) profits will not continue to do so in the long-run due to the forces of competition. Competition should increase or decrease in every industry as entrepreneurs search for abnormal profits and therefore enter and exit the market. This shift in competition changes the supply of products or services in the market, thereby changing prices and driving earnings toward normal returns, resulting in mean reversion. As Fama and French (2000) note, this process implies that profitability and earnings are therefore somewhat predictable. They test the hypothesis that in a competitive market, profitability is mean reverting and they provide further descriptive statistics on the behavior of profitability. More specifically, they extend mostly accounting literature that attempts to identify predictable variation in earnings and profitability. Consistent with Brooks and Buckmaster (1976), they find that changes in earnings tend to reverse from one year to the next and that large changes of either sign reverse faster than small changes. They also confirm the findings of Elgers and Lo (1994) that negative changes in earnings reverse faster than positive changes.

Following Fama and French (2000), Sarkar and Zapatero (2003) use the mean reversion properties of earnings to reformulate the “trade off” theory of capital structure. They show that there should be a negative relation between optimal leverage and earnings when earnings are mean-reverting. Pastor and Veronesi (2003) develop a simple approach to valuing stocks in the presence of learning about average profitability. Their findings are summarized as follows:

1. The Market-to-Book ratio increases with uncertainty about average profitability.
2. The Market-to-Book ratio is predicted to decline over a firm's lifetime.
3. Younger stocks and stocks that pay no dividends have more volatile returns.
4. Firm profitability has become more volatile recently.

In Fama and French’s (2000) tests, they use annual data from 1964 to 1995 excluding financial firms and utilities. These firms are excluded because they are highly regulated and “may produce unusual behavior of profitability.” Of course, this same possibility exists in the airline industry during its period of regulation, and provides the motivation for this section. Therefore, the goal of this section is to test whether earnings’ behavior is indeed different during periods of complete regulation versus periods of complete competition. Unlike other tests of the regulatory effect on earnings behavior, the airline industry provides a unique time series to test since it has transitioned from an environment of complete regulation to an environment of complete competition. Additionally, the industry is old enough to provide a sufficient sample size. The findings from this study have several implications:

1. If earnings' behavior is different between periods of regulation and competition, that information can be incorporated into policies for regulating or deregulating other industries.
2. If earnings' behavior is different, then it may be partially predictable which is valuable for analysts' estimates as well as capital budgeting decisions.
3. If the earnings' behavior of airlines during regulation is "unusual", then the results of Fama and French (2000) and others may be contaminated since their sample period presumably includes fourteen years of total airline regulation as well as four years of regulation phase-out.
4. The time-series properties of airline earnings have wide-reaching implications for firm valuation models, such as those using price-to-earnings ratios, return on equity, return an assets, earnings discount models, etc.
5. The properties of variability in earnings have implications for risk assessment and management and shareholders of airline stocks.

Descriptive statistics

To develop an understanding of the airline industry's financial health relative to other industries, I compare annual profits before taxes between various industries for the period 1987 – 2001. The comparison begins with an analysis of the broadest industry groupings, followed by a successive decomposition of the group containing air transportation. These data were obtained from the United States Department of Commerce's Bureau of Economic Analysis (BEA) and Figures 3 – 7 present the results. For each figure, the vertical axis represents the annual profits before taxes and the horizontal axis represents the calendar year in which the profits were earned. Figure 3 presents the profitability of the most general industry groupings – private industry, electronic instruments and equipment, depository and non-depository institutions, and business, miscellaneous and other services. Not surprisingly, profitability is dominated by what the BEA classifies as private industries.

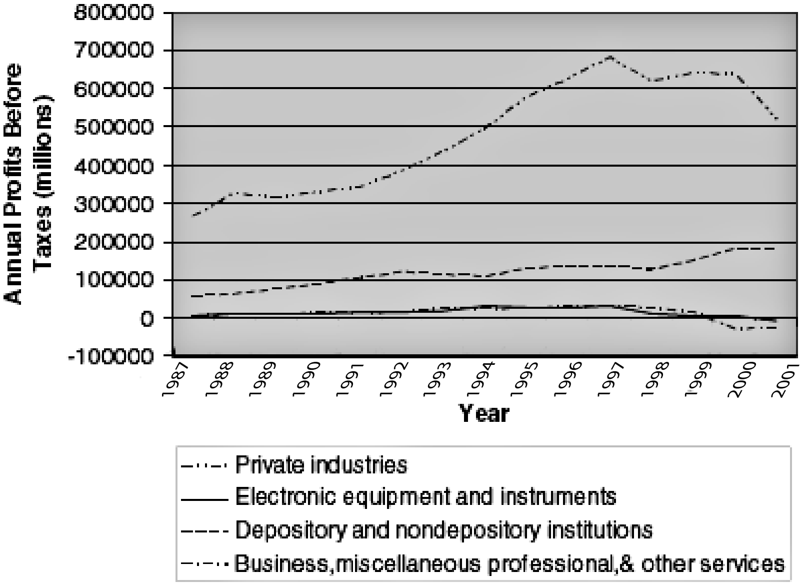


Figure 3. Profitability by Broad Industry Groups.

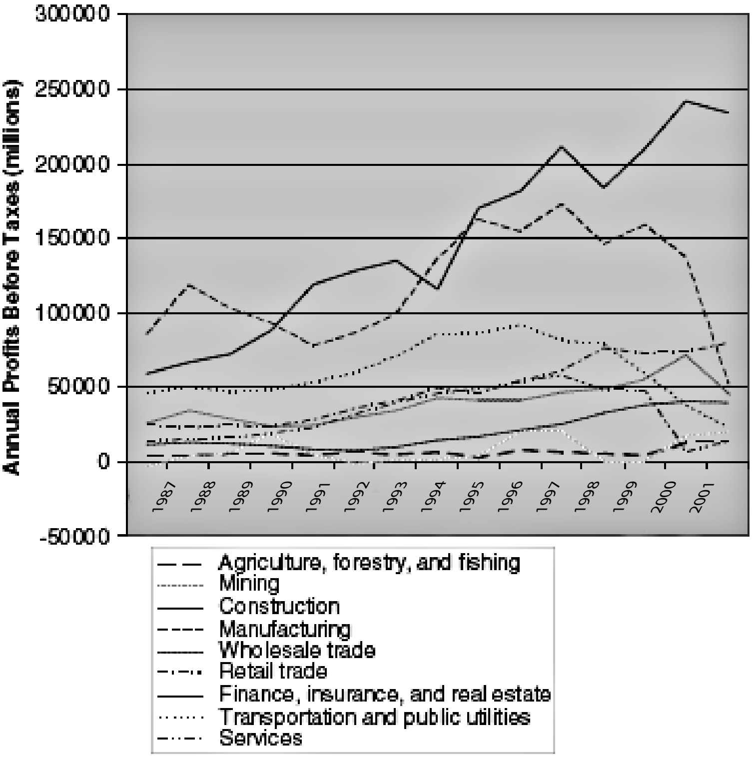


Figure 4. Profitability of Private Industry Sub-Groups.

Decomposing the private industry sector into nine subgroups yields the results presented in Figure 4. At this level, the BEA groups transportation and public utilities together, with the other groups being:

- Agriculture, Forestry and Fishing
- Construction
- Wholesale Trade
- Finance, Insurance and Real Estate
- Services
- Mining
- Manufacturing
- Retail Trade

Using these groupings, the transportation and public utilities industries generated the third largest profits of all the groups until about 1998, at which time profits dropped dramatically. Figure 5 shows that this drop was the result of a cumulative effect whereby all three sub-groupings successively became less profitable. All three had generally increasing annual profits over the period 1987 until about 1994. At that time, the communications industry was the first to become less profitable, followed by the electric, gas, and sanitary services industry grouping about a year later. Finally, the transportation industry's profits starting turning downward around 1999 – even before 9/11. However, as of 2001, the communications industry has been less profitable than the transportation industry. This is further illustrated in Figure 6 which shows the growth of each dollar in 1987 profits. Although the transportation industry is a very close second, the communication industry has lost more of its profits on a 1987 base-dollar basis than the transportation industry.

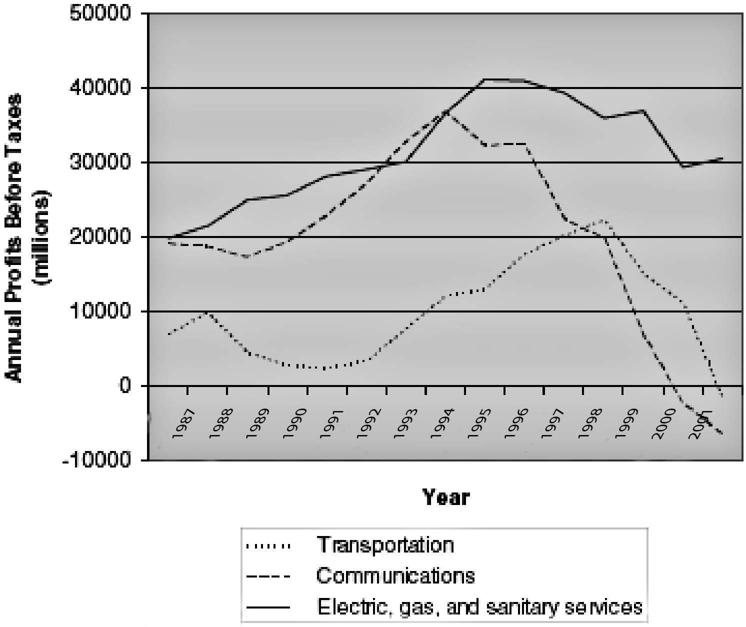


Figure 5. Profitability of Transportation and Public Utilites Industry Sub-Groups.

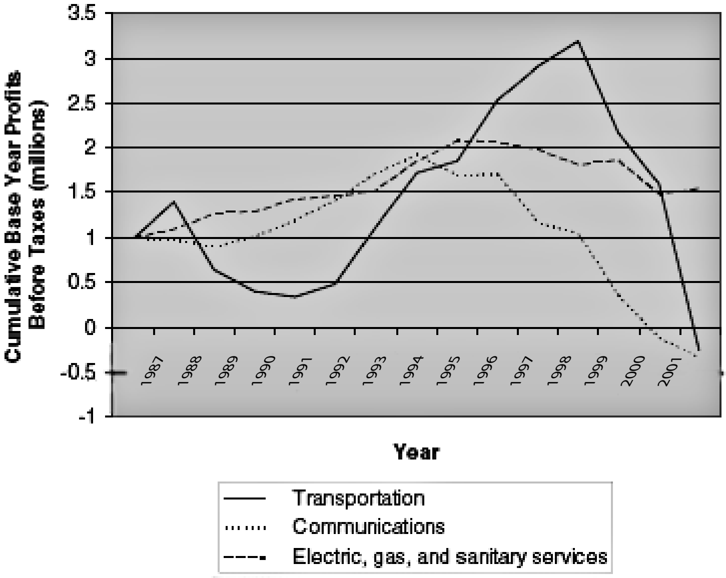


Figure 6. Cumulative Profitability of Transportation and Public Utilites Industry Sub-Groups (Base Dollar).

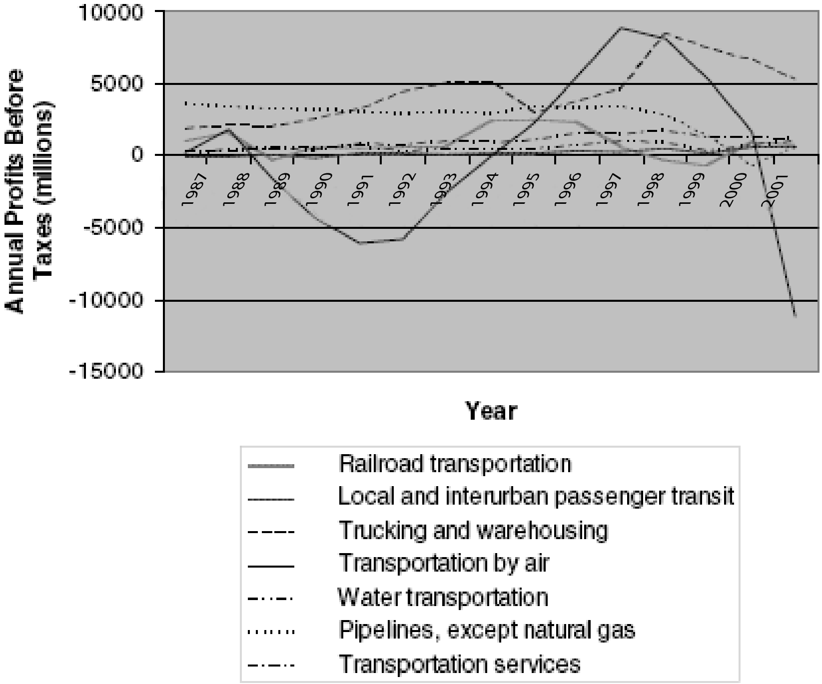


Figure 7. Profitability of Transportation Industry Sub-Groups

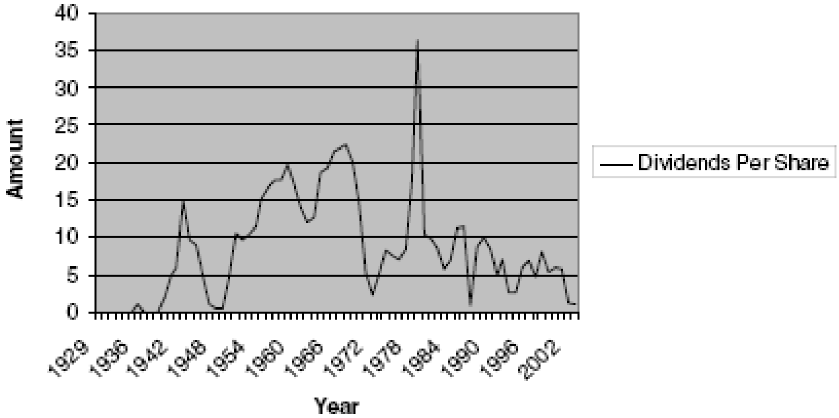


Figure 8. Ordinary Dividends Paid

Finally, Figure 7 shows the sub-groupings within the transportation industry which consist of Railroad Transportation, Local and interurban passenger transit, Trucking and warehousing, Transportation by air, Water transportation, Pipelines (except natural gas) and Transportation services. Immediately apparent is that the air transportation industry has a much greater variability in profits than the other industries. This variability has led to the air transportation industry being the least profitable transportation industry (1989-1994) to the most profitable transportation industry (1996-1997) and back to the least profitable industry (2001). Also, there is not an obvious negative correlation in profits between the air transportation industry and any other transportation industry. Hence, based on these groupings, the variability in air transportation profits does not appear to be caused by or lead to a switching effect. That is, it does not appear to be capturing the migration of travelers as they choose different modes of transportation.

Data and methodology

Following Fama and French (2000), I employ a two-stage regression to test the mean reversion behavior in earnings. Data are hand-collected from Moody's Transportation manuals for the period 1946 – 2003 for three airlines: United, American and Delta. These carriers provide the longest time series of all carriers, rendering them ideal to proxy for the effect of regulation on earning's behavior. Further, consistent with Chapter 4, using these carriers effectively controls for potential biases in earnings behavior caused by financial distress and size. More specifically, Survivorship bias has been an issue in the study of mutual fund performance in recent studies. Elton, Gruber and Blake (1996) as well as others, note that studying only surviving mutual funds introduces a positive bias into fund performance – the goal of which is generally to determine the effect on investors' wealth from the allocation of wealth to the funds. However, poorly performing funds tend to disappear from databases due to attrition or merging with other funds. Hence, to not consider the possibility that some of an investor's portfolio may have been allocated to the distressed fund is to overstate the return to investors. Unlike mutual fund studies, my purpose is not to estimate returns to investors. Rather, I am conducting a study on the behavior of earnings rather than a total *accumulation* of wealth over time. Therefore, I argue that studying the survivors should not introduce a survivorship bias into the sample.

The primary purpose of this section is to examine the difference in earnings behavior during regulation and after regulation. First, to identify variables that may proxy for macroeconomic risk factors thereby at least partially explaining earnings, correlations between earnings scaled by book value of assets and various economic proxies are estimated. The results are presented in Table 2 where:

SP_t is the S&P 500 index average monthly return at time t.
CPI_t is the Consumer Price Index average monthly change at time t.
$CRUDE_t$ is the log change in average U.S. Crude Oil prices at time t from the previous period.

SP is included to proxy for the market portfolio, CPI is used to control for cyclical business factors and CRUDE is included because fuel costs are the second largest operating expense in the airline industry. Hence, intuition suggests that profits would be sensitive to price changes in this commodity. However, the magnitude of correlation would depend on the degree of hedging by the airlines. This relationship is left for subsequent work.

From Table 2 Panel A, profits for two of the three carriers are related to S&P 500 returns, but none are related to CPI or crude oil log price changes. While the relation with the consumer price index is intuitive, the relation with crude oil price changes is not. Since fuel prices are the second largest cost to the airlines and since fuel prices are highly correlated with crude oil prices, intuition suggests that crude oil prices should directly impact profitability – although it may be mitigated by hedging activities. To investigate these relations further, cross-autocorrelations are estimated and presented in Panels B and C. The results show that two of the three carriers are related to SP at times t and t-1, and to CPI and CRUDE at time t-2. Hence, these are the four variables chosen to estimate expected profits in the first pass regression (Equation 3). Further, the only correlation between these four variables is the cross-correlation between CPI and CRUDE (results not presented), so CRUDE is orthogonalized to control for multicollinearity.

As a preliminary test to determine if earnings are autocorrelated, a Ljung-Box test is conducted as follows:

$$LB = n(n + 2) [\Sigma \rho_k^2 / (n - k)] \qquad (1)$$

where n is the sample size and ρ_k is the autocorrelation of the kth order. This test is used primarily to determine which lags (if any) are significant. The results are presented in Table 3 and reveal that the first and second-order autocorrelations appear to be the only significant autocorrelations for most of the carriers. Hence, the Fama and French (2000) mean-reversion model (Equation 2) is modified to include the second-order autocorrelation.

Table 1. Common Earnings' Descriptive Statistics

Using annual data, this table shows descriptive statistics for the airline industry's three major carrier's common earnings divided by book value of assets. The rows in each panel show respectively the mean, standard deviation, sample size, maximum and minimum.

Panel A. Entire Period (1946 – 2003)			
	American	Delta	United
Mean	.0285	.0436	.0248
σ	.04349	.04654	.05260
n	62	55	62
Max	.14	.13	.17
Min	-.12	-.08	-.14
Panel B. Regulated Period (1946 – 1981)			
Mean	.0378	.0650	.0353
σ	.04035	.02857	.03932
n	40	33	40
Max	.14	.13	.14
Min	-.03	.01	-.04
Panel C. Phase-out Period (1982 – 1988)			
Mean	.0285	.0325	.0280
Σ	.03641	.03888	.06687
N	9	9	9
Max	.06	.07	.17
Min	-.05	-.05	-.09
Panel D. Deregulated Period (1989 – 2003)			
Mean	.0003	-.0016	-.0110
σ	.04895	.05447	.06627
n	15	15	15
Max	.06	.07	.06
Min	-.12	-.08	-.14

Table 2. Correlation Matrix

This table shows correlations for the airline industry's three major carriers' common earnings divided by book value of assets, average monthly S&P 500 returns (SP), average monthly log changes in the consumer price index (CPI) and annual log changes in Crude Oil prices (CRUDE). The first row shows the correlation and the second row shows the p-value. For all panels, the carriers' profits are at time t. For SP, CPI and Crude, the returns are at times t, t-1 and t-2 for panels A, B and C respectively. Hence, Panel A tests the cross-correlation of the carriers' profits with macroeconomic explanatory variables at time t, and Panels B and C test the cross-autocorrelations of carrier profits at time t with lead explanatory variables at times t-1 and t-2 respectively.

Panel A. Cross-correlations

	American	Delta	United	SP	CPI	Crude
American	1.00	.630 .000***	.844 .000***	.348 .006***	-.207 .119	-.120 .386
Delta		1.00	.622 .000***	.033 .808	.196 .151	.165 .233
United			1.00	.235 .066*	-.017 .902	-.057 .682
SP				1.00	-.309 .018**	-.232 .092*
CPI					1.00	.537 .000***
Crude						1.00

Panel B. First-order Cross-autocorrelations

	American	Delta	United	SP	CPI	Crude
American	1.00	.630 .000***	.844 .000***	.410 .001***	-.345 .009***	-.158 .260
Delta		1.00	.622 .000***	.148 .282	.033 .808	-.106 .448
United			1.00	.340 .007***	-.190 .158	-.119 .394
SP				1.00	-.302 .022**	-.249 .072*
CPI					1.00	.552 .000***
Crude						1.00

Panel C. Second-order Cross-autocorrelations

	American	Delta	United	SP	CPI	Crude
American	1.00	.630 .000***	.844 .000***	.201 .124	-.264 .049**	-.292 .036**
Delta		1.00	.622 .000***	.110 .425	-.090 .515	-.123 .386
United			1.00	.285 .028**	-.227 .093*	-.414 .002***
SP				1.00	-.332 .012**	-.263 .060*
CPI					1.00	.553 .000***
Crude						1.00

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

Table 3. Ljung-Box Statistics

This table shows the LB statistics from a Ljung-Box analysis of the k-order autocorrelations as follows:

$$LB = n(n + 2) [\Sigma \rho_k^2 / (n - k)]$$

where n is the sample size and ρ_k is the autocorrelation at of the kth order. The first row shows the LB statistic and the second row shows the chi-squared critical value at the .01 level.

k	American	Delta	United
1	28.29544*** 6.6349	27.62836*** 6.6349	22.13219*** 6.6349
2	11.75066*** 9.21034	11.41817*** 9.21034	2.692328 9.21034
3	1.289376 11.3449	3.468231 11.3449	2.164217 11.3449
4	.16483 13.2767	.395045 13.2767	3.518614 13.2767
5	.196431 15.0863	.107039 15.0863	1.999218 15.0863

*** indicates significance at the .01 level.

Similar to Fama and French (2000), the mean reversion hypothesis in earnings is tested by employing the following model:

$$P_{it}/A_{it} - P_{it-1}/A_{it-1} = \alpha + \beta_1[P_{it-1}/A_{it-1} - E(P_{it-1}/A_{it-1})] + \beta_2[P_{it-2}/A_{it-2} - E(P_{it-2}/A_{it-2})] + \beta_3[P_{it-1}/A_{it-1} - P_{it-2}/A_{it-2}] + \beta_4[P_{it-2}/A_{it-2} - P_{it-3}/A_{it-3}] + \varepsilon_{it} \quad (2)$$

However, based on the Ljung-Box results above, this model tests mean reversion over 2 periods rather than just one – captured by β_1 and β_2 and is estimated over the entire sampling period, as well as the regulated and deregulated sub-periods. The left-hand side of the equation represents the changes in scaled profits from time t-1 to time t. The first term on the right-hand side is the intercept, followed by the deviations of profitability from its expected values. The estimation of the expected value is explained below. The next terms on the right-hand side is the change in scaled profitability from t-2 to t-1 and from t-3 to t-2 (i.e. the lead change in scaled profitability), followed by an error term.

From above, expected profitability is estimated in a first-stage regression:

$$P_{it}/A_{it} = \theta_0 + \theta_1 SP_t + \theta_2 SP_{t-1} + \theta_3 CPI_{t-2} + \theta_4 CRUDE_{t-2} + \varepsilon_{it} \quad (3)$$

If earnings are mean-reverting, then β_2 and/or β_3 from the second-stage regression should be less than unity. Additionally, these coefficients are estimated for various periods around the transition period to deregulation, from which inferences are drawn about deregulation's effect on behavior.

To further test the difference in earnings behavior between the two regulatory periods, the following model is estimated:

$$P_{it}/A_{it} - P_{it-1}/A_{it-1} = \alpha + (\beta_1 + \beta_2 D)[P_{it-1}/A_{it-1} - E(P_{it-1}/A_{it-1})] + (\beta_3 + \beta_4 D)[P_{it-2}/A_{it-2} - E(P_{it-2}/A_{it-2})] + (\beta_5 + \beta_6 D)\,[P_{it-1}/A_{it-1} - P_{t-2}/A_{it-2}] + (\beta_7 + \beta_8 D)\,[P_{it-2}/A_{it-2} - P_{t-3}/A_{it-3}] + \varepsilon_t \tag{4}$$

where D is a dummy variable taking the value of 1 in the post-regulation period, 0 else, and all other variables are identical to those in equation (2). If earnings behavior changes during the period of deregulation, then this coefficient should be significantly different from zero.

Results

Table 1 presents descriptive statistics for the three carriers' common earnings divided by book value of assets over the entire sampling period (Panel A), and the sub-periods around the process of deregulation (Panels B – D). These statistics show that the scaled profits of the carriers dropped from about 2% - 4% during the regulated period to about -1% - 0% during the deregulated period. Further, the annual volatility of these profits increased from about 4% - 5% during regulation to about 5% - 7% during deregulation. This suggests that earnings behavior is affected by economic regulation, both in magnitude and dispersion. Table 4 presents the results of testing the effect of regulation on the mean-reversion behavior of earnings as documented by Fama and French (2000).

Table 4 presents the results of the primary test of the mean reversion in earnings – equations 2, 3 and 4. Panel A presents the results of estimating Equation 2 over the entire period and Panels B – D present the results of estimating Equation 4 over the various sub-periods. Consistent with the findings of Fama and French (2000), Panel A shows that the model specification is reasonable based on the adjusted r-squareds of .083, .152 and .039 for American, Delta and United respectively. Further, the test coefficients β_1 and β_2 are less than unity indicating mean reversion behavior – again, consistent with Fama and French (2000). Moreover, the first-order lead variable is negative for all three carriers suggesting a strong mean-reversion tendency. However, the goal of this section is to test whether economic regulation affects this behavior. Therefore, Panels B – D present the results of these tests.

Panels B – D show the dummy coefficients for the respective period, which captures the excess relation for each variable. Panel B presents the excess coefficients during the period of regulation, none of which are significantly different from zero. Panel C presents the excess coefficients during the phase-out period and show significant results for United and American airlines. However, these results must be interpreted with caution due to the small sample size of only eight years. Panel D presents the excess coefficients during the period of deregulation during which, American was the only carrier with significant results suggesting strong excess mean-reversion for the first-order lead, but reduced mean-reversion for the second-order. By contrast, the other two carriers' results are highly insignificant suggesting that economic deregulation has had no significant impact on mean-reversion tendencies. Therefore, although the results are mixed, it appears that economic deregulation has not significantly changed the mean-reversion tendency of earnings in the airline industry. This is at odds with conventional wisdom suggesting that economic regulation affects earnings behavior.

Table 4. Mean Reversion in Earnings

Using annual data, Panel A shows regression results for testing the mean reversion hypothesis in the airline industry's earnings over the entire sample period as follows:

$$P_{it}/A_{it} - P_{it-1}/A_{it-1} = \alpha + \beta_1[P_{it-1}/A_{it-1} - E(P_{it-1}/A_{it-1})] + \beta_2[P_{it-2}/A_{it-2} - E(P_{it-2}/A_{it-2})] + \beta_3\,[P_{it-1}/A_{it-1} - P_{it-2}/A_{it-2}] + \beta_4[P_{it-2}/A_{it-2} - P_{it-3}/A_{it-3}] + \varepsilon_{it}$$

where P_{it} is the common earnings of carrier i at time t, A_{it} is the book value of assets for carrier i at time t and D is a dummy variable taking the value of 1 in the post-regulation period, 0 else. Expectations are formed from a 1st pass regression as follows:

$$P_{it}/A_{it} = \theta_0 + \theta_1 SP_t + \theta_2 SP_{t-1} + \theta_3 CPI_{t-2} + \theta_4 CRUDE_{t-2} + \varepsilon_{it}$$

where SP_t is the S&P 500 index average monthly return at time t, CPI_t is the Consumer Price Index average monthly change at time t and $CRUDE_t$ is the log change in average U.S. Crude Oil prices at time t from the previous period. Panels B – D show the dummy coefficients from the following estimation:

$$P_{it}/A_{it} - P_{it-1}/A_{it-1} = \alpha + (\beta_1 + \beta_2 D)[P_{it-1}/A_{it-1} - E(P_{it-1}/A_{it-1})] + (\beta_3 + \beta_4 D)[P_{it-2}/A_{it-2} - E(P_{it-2}/A_{it-2})] + (\beta_5 + \beta_6 D)[P_{it-1}/A_{it-1} - P_{t-2}/A_{it-2}] + (\beta_7 + \beta_8 D)\,[P_{it-2}/A_{it-2} - P_{t-3}/A_{it-3}] + \varepsilon_t$$

Panel A. Entire Period (1946 – 2003)						
	Adj R2	Int	β1	β2	β3	β4
American						
Coeff	.083	-.002	-.586	.344	.208	.048
P-value		.669	.010***	.096*	.312	.769
Delta						
Coeff	.152	-.002	-1.073	.782	.807	-.056
P-value		.679	.009***	.047**	.051*	.702
United						
Coeff	.039	-.001	-.465	-.032	.118	.166
P-value		.880	.079*	.890	.573	.325
Panel B. Regulated Period (1946 – 1981)						
	Adj R2	Int	β2	β4	β6	β8
American						
Excess Coeff			.714	-.314	-.692	-.122
P-value			.141	.488	.119	.738
Delta						
Excess Coeff			.143	.090	-.143	-.223
P-value			.865	.914	.868	.495
United						
Excess Coeff			-.237	.706	.024	-.218
P-value			.685	.202	.967	.586
Panel C. Phase-out Period (1982 – 1988)						
American						
Excess Coeff			1.977	-.920	-1.248	.251
P-value			.139	.212	.230	.758
Delta						
Excess Coeff			-1.231	-1.698	-.594	.476
P-value			.383	.449	.683	.431
United						
Excess Coeff			.151	-1.515	.669	.718
P-value			.858	.021**	.393	.261

Table 4. (Continued)

Adj R2	Int	β1	β2	β3	β4	Adj R2
Panel D. Deregulated Period (1989 – 2003)						
American						
Excess Coeff			-1.210	.860	1.10	-.126
P-value			.020**	.084*	.011**	.724
Delta						
Excess Coeff			.035	-.153	.258	.172
P-value			.969	.867	.782	.615
United						
Excess Coeff			-.219	.085	.123	.146
P-value			.716	.871	.807	.705

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

Summary and implications

Fama and French (2000) document a mean-reversion tendency in earnings behavior – excluding unregulated industries because of a potential difference in behavior. In this section, using the airline industry as an experimental setting, I test whether earnings behavior is in fact affected by economic regulation. My findings suggest that airline profits are mean-reverting consistent with Fama and French (2000), but that this behavior is largely unaffected by the industry's deregulation. That is, Delta and United airlines showed no significant difference in behavior between the periods of regulation and deregulation while American Airlines did show a difference. Given that Delta and United are not just insignificant, but highly insignificant, the outlier results of American are perplexing. However, although the results are mixed, the findings do not appear to support the intuitive argument that economic regulation has an effect on earnings behavior.

B. Dividends in the Airline Industry

Prior literature

Nissim and Ziv (2001) investigate the relation between dividend changes and future profitability. They find that dividend changes provide information about the level of profitability in subsequent years and that dividend changes are positively related to earnings changes in each of the two years after the dividend change. This supports the findings of Baker (1999) who surveyed 170 senior managers of U.S. utilities and U.S. manufacturing corporations about dividend policy issues. More specifically, Baker's study examines respondents' views about four popular explanations for dividend policy – signaling, bird-in-the-hand, tax preference, and agency costs. In addition, he examines the factors that managers consider the most important in setting dividend policy. Finally, he examines whether managers' attitudes differ with respect to regulated (utilities) versus unregulated (manufacturers) firms. He finds that the signaling explanation received more support than the other explanations. Consistent with Nissim and Ziv (2001), he also finds that the most important determinants of dividend policy are the level of current and expected future earnings, as well as the pattern or continuity of dividends. The results of these factors were consistent with a similar study conducted in 1983, suggesting that the importance of the factors is stable over time.

Moyer, Rao and Tripathy (1992) examine the reasons for high dividend payout ratios and dividend yields in regulated electric utilities. They argue that the regulatory approval necessary for mergers effectively insulate the utilities from the threat of hostile takeovers. Further, they argue that the high dividend payout ratios are a mechanism by which regulated utilities force more frequent trips to the capital market. Consequently, the monitoring by the capital market substitutes for the agency control mechanisms of competition, the market for corporate control and high insider ownership. That is, they find a positive relation between dividend payout ratios and the extent of regulatory control.

Finally, Baker (1999) concludes that the factors influencing dividend policy between regulated and unregulated firms are more similar now than in the past. Also, he notes that among other factors, managers of regulated utilities firms place a higher importance on maintaining or increasing the firm's stock price than their non-regulated counterparts. Assuming that they are successful, this implies that stock price variability should be lower for regulated dividend payers than non-regulated dividend payers. This is also consistent with Moyer, Rao and Tripathy's (1992) findings that dividends are used by regulated utility firms to induce the use of capital markets. An implication of this argument is that utilities are especially cognizant of the firm's stock price – again suggesting that stock price variability should be lower in regulated environments. Because of the transition from regulation to competition, the airline industry provides a unique opportunity to test this inference. Therefore, in this section, I test the variability of stock returns for dividend payers in the airline industry. The above findings suggest that returns should be more (less) volatile during deregulation (regulation).

Methodology

The Airline Industry's ordinary dividend distribution history is obtained from the CRSP monthly database for the period 1929-2003. All firms with SIC codes of 4500, 4511 or 4512 are used and the results are presented in Table 5. To test whether stock price variability for dividend payers is different under regulation than in an unregulated environment, monthly stock return data without dividends and ordinary dividend data are obtained from the CRSP database for all firms with SIC codes of 4500, 4511 and 4512 during the period 1929 – 2003. Next, the mean and standard deviation of monthly returns for each carrier during each year are computed and the ordinary dividend amounts for each carrier are summed for each year. A carrier is classified as a dividend payer if they paid a dividend at anytime during the year.

To test the difference in volatility, a difference of means regression is employed as follows:

$$\sigma_{it} = \alpha_1 + \alpha_2 D_t + \varepsilon_t \tag{5}$$

where σ_{it} is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample for carrier i, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, and D is a dummy variable taking the value of 1 during the period of deregulation and 0 else. Several cutoff dates are used to distinguish between the two periods.

In addition, differences are computed for non-dividend payers as well as for dividend payers to control for industry-wide effects of regulatory change.

Table 5. Dividends Paid by Each Airline – 1929-2003

	N	Mean	Minimum	Maximum	Total
A C I Holdings In	9	-	-	-	-
A I A Industries	14	-	-	-	-
A M R Corp Del	510	-	-	-	-
Air California In	58	-	-	-	-
Air Methods Corp	11	-	-	-	-
Air Midwest Inc	104	0.002	-	0.100	0.250
Air One Inc	17	-	-	-	-
Air West Inc	23	-	-	-	-
Air Wisconsin Inc	59	-	-	-	-
Air Wisconsin Ser	102	-	-	-	-
Aircal Inc	35	-	-	-	-
Airlift Internati	150	-	-	-	-
Airnet Systems In	28	-	-	-	-
Airtran Holdings	42	-	-	-	-
Alaska Airgroup I	224	0.006	-	0.050	1.360
Alaska Airls Inc	274	0.003	-	0.120	0.720
Allegheny Airline	414	0.001	-	0.060	0.220
Allegis Corp	36	0.042	-	0.250	1.500
Aloha Airls Inc	51	0.011	-	0.480	0.580
Aloha Inc	33	-	-	-	-
America West Airl	166	-	-	-	-
America West Hold	84	-	-	-	-
American Airls In	1040	0.054	-	2.000	56.244
Atlanta Express A	13	-	-	-	-
Atlas Air Inc	11	-	-	-	-
Aviation Group In	50	-	-	-	-
Bonanza Air Lines	32	-	-	-	-
Braniff Airways I	720	0.026	-	0.500	18.650
Braniff Inc	68	-	-	-	-
Braniff Internati	206	0.016	-	0.110	3.240
British Airways P	203	(0.122)	9.920	2.425	24.669
Capital Airls Inc	158	-	-	-	-
Chicago & Souther	13	-	-	-	-
China Eastern Air	35	0.014	-	0.242	0.484
China Southern Ai	78	0.002	-	0.121	0.121
Command Airways I	30	-	-	-	-
Continental Air L	516	0.022	-	0.500	11.100
Continental Airli	302	-	-	-	-
Delta Air Lines I	1122	0.065	-	0.800	73.210
Eastern Air Lines	1154	0.021	-	0.500	24.500
Empire Airlines I	69	-	-	-	-

Table 5. (Continued)

	N	Mean	Minimum	Maximum	Total
Expressjet Hldgs	21	-	-	-	-
Florida Express I	30	-	-	-	-
Flying Tiger Corp	49	0.008	-	0.200	0.400
Flying Tiger Line	111	0.002	-	0.100	0.200
Frontier Airlines	217	0.004	-	0.050	0.900
Frontier Holdings	42	0.011	-	0.050	0.450
Galileo Internati	17	0.020	-	0.075	0.345
H A L Inc	110	0.002	-	0.150	0.250
Hawaiian Airlines	215	0.002	-	0.150	0.350
Hawaiian Holdings	16	-	-	-	-
Horizon Air Inds	39	-	-	-	-
Japan Air Lines L	357	0.072	-	10.670	25.619
Jet American Airl	61	-	-	-	-
Jetblue Airways C	21	-	-	-	-
K L M Royal Dutch	1680	0.053	-	3.490	88.460
Lan Chile S A	60	0.018	-	0.367	1.067
Linea Aerea Nacio	8	0.000	-	0.001	0.001
M G M Grand Inc	128	0.002	-	0.200	0.200
Mackey Airls Inc	54	-	-	-	-
Mackey Internatio	26	-	-	-	-
Metro Airlines In	54	-	-	-	-
Metromail Corp	24	-	-	-	-
Midway Airlines I	260	-	-	-	-
Mississippi Valle	17	-	-	-	-
Mohawk Airls Inc	117	-	-	-	-
N W A Inc	126	0.074	-	0.225	9.370
National Air Tran	35	-	-	-	-
National Airlines	844	0.029	-	0.300	24.700
New York Airlines	54	-	-	-	-
North Atlantic Ai	8	-	-	-	-
North Central Air	79	0.011	-	0.200	0.830
Northeast Airline	121	-	-	-	-
Northwest Airline	1036	0.044	-	0.500	45.750
Ocean Airways Inc	26	-	-	-	-
Overseas National	73	0.007	-	0.500	0.500
Ozark Air Lines I	204	0.006	-	0.150	1.150
Ozark Holdings In	28	0.013	-	0.050	0.350
P S A Inc	164	0.025	-	0.150	4.050
Pacific Air Lines	19	-	-	-	-
Pacific Northn Ai	60	0.004	-	0.125	0.250
Pacific Southwest	93	0.029	-	0.255	2.685
Pan Am Corp	176	-	-	-	-
Pan Am Corp Fla	17	-	-	-	-
Pan Amern Awys Co	266	0.041	-	1.000	11.000
Pan Amern World A	826	0.032	-	0.500	26.717

Table 5. (Continued)

	N	Mean	Minimum	Maximum	Total
Pennsylvania Cent	57	0.004	-	0.250	0.250
People Express Ai	57	-	-	-	-
People Express In	16	0.009	-	0.050	0.150
Petroleum Helicop	219	0.008	-	0.050	1.860
Piedmont Aviation	179	0.018	-	0.100	3.254
Pinnacle Airlines	2	-	-	-	-
Presidential Airw	50	-	-	-	-
Provincetown Bost	32	-	-	-	-
Regent Air Corp	9	-	-	-	-
Republic Airlines	85	0.004	-	0.200	0.300
Royale Airlines I	60	-	-	-	-
Saturn Airways In	95	-	-	-	-
Seaboard World Ai	219	0.003	-	0.100	0.600
Simmons Airlines	55	-	-	-	-
Southern Airways	79	-	-	-	-
Southwest Airline	373	0.009	-	0.120	3.521
Stateswest Airlin	33	-	-	-	-
Sun World Intl Aw	10	-	-	-	-
Texas Air Corp	240	0.004	-	0.040	1.040
Texas Internation	180	0.004	-	0.040	0.640
Tiger Internation	175	0.026	-	0.225	4.475
Trans Intl Airls	9	-	-	-	-
Trans World Airli	473	0.015	-	0.250	7.000
Trans World Airls	294	-	-	-	-
Trans World Corp	126	-	-	-	-
Transcontinental	362	0.001	-	0.250	0.500
Transworld Corp D	64	0.038	-	0.150	2.460
Transworld Corp L	8	-	-	-	-
U A L Corp	540	0.009	-	0.313	4.838
U A L Inc	639	0.040	-	0.275	25.500
U S Air Inc	80	0.009	-	0.030	0.720
U S Airways Group	166	-	-	-	-
United Air Lines	1257	0.060	-	1.500	75.225
Usair Group Inc	336	0.006	-	0.060	1.860
W T C Internation	42	-	-	-	-
Westair Holding I	44	-	-	-	-
Western Air Lines	1004	0.038	-	0.450	38.590
Wien Air Alaska I	91	0.003	-	0.100	0.280
Wien Consolidated	5	-	-	-	-
Wings West Airlin	35	-	-	-	-
Worldcorp Inc	138	-	-	-	-

First, the difference of means are analyzed for dividend payers, non-dividend payers and the entire sample using December 31, 1981 and January 1, 1989 as the cutoff dates. That is, 1929 – 1981 is considered the period of regulation and 1989 – 2003 is considered the period of deregulation. Next, to consider the possibility that information leakage would lead to different results based on different cutoff dates, I use pre-1978 data as the period of regulation. Although the first major phase of deregulation took place on December 31, 1981, the law was signed on October 24, 1978. Hence, it stands to reason that there would be transitional effects starting at this time. Similarly, the debate over deregulation began in congress during 1970 which could also lead to information leakage. Thus, the final test uses pre-1970 data as the period of regulation.

The above tests classify a carrier as a dividend payer if a dividend of any size was paid at anytime during the year. To test the influence of the dividend's size on to above results, the following regression was estimated:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_t + \varepsilon_t \qquad (6)$$

where Div_t is the sum of all ordinary dividends paid during the year t for carrier i and all other variables are consistent with equation (4).

If there is a significant difference, then it provides empirical evidence in support of Baker's (1999) survey findings. If there is not a significant difference, then it suggests that either regulated managers do not value supporting stock prices as strongly as suggested by Baker (1999), or they are not successful in doing so through dividend policy.

Results

Table 6 Panel A presents the results of the mean monthly standard deviation in stock returns using January 1, 1982 and December 31, 1988 as the cutoff dates. Chapter 4 presents the results of using other cutoff dates. The second column presents data for the entire sample and the third and fourth columns present data for dividend and non-dividend payers respectively. For the entire sample of carriers, there is clearly a significant difference in monthly standard deviations between the two periods. More specifically, the mean monthly standard deviation during the period of regulation is 11.9% while during the period of deregulation it is 3.2% higher – this difference is significant at the .01 level. Additionally, the adjusted R-Squared is 3.2%. These results suggest that deregulation has increased the volatility of carriers' stock returns and were robust with respect to Wilcoxon Signed-Rank and Kruskal-Wallis tests. However, when dividend policy is considered, the results change.

The second column presents the results for only dividend paying carriers. The findings of Baker (1999) and Moyer, Rao and Tripathy (1992) imply that consistent with the above findings, stock price variability of dividend payers should be higher during the period of deregulation. However, I find that the difference is highly insignificant, although the difference for non-dividend payers is significantly (at the .01 level) higher during deregulation by 4.3%. Together, these results suggest that the significant increase in volatility of all carriers' stock returns is entirely attributable to non-dividend paying carriers. Additionally, dividend policy appears to provide a shielding effect for carriers. That is, intuition suggests that the increased stock return volatility reflects the increased risk carriers face when they are no longer enjoying the benefits associated with economic regulation. However, not only do the owners of dividend paying carriers suffer increased risk in their portfolios, but consistent with the findings of Baker (1999), the volatility of returns for dividend payers is considerably lower than for non-dividend payers. For dividend payers during regulation, the average monthly standard deviation was 10.6% while for non-dividend payers, it was 13.0%. During deregulation, volatility increased to 17.3% for non-dividend payers and *decreased* to 10.5% for dividend payers.

Panel B of Table 6 presents the results of using December 31, 1977 as the cutoff date for the period of regulation – these results are very similar to the results in Panel A. However, the results of Panel C suggest that the above unclear results may suffer from some information leakage. When the period of regulation is cutoff at January 1, 1970, there is a significant (.01 level) increase in stock return volatility for dividend payers. Specifically, the volatility is 9.1% prior to 1970 and 10.5% after 1988 with 3% of the variability in volatility explained by the deregulation dummy variable.

Table 6. The Effect of Regulation and Dividends on Stock Return Volatility

This table presents the results of the following difference of means regression:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \varepsilon_t$$

where σ_t is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, and D is a dummy variable taking the value of 1 during the period of deregulation and 0 else. Pre and post refer to the cutoff dates used to define the period of regulation and deregulation respectively. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	Entire Sample	*Dividend Payers*	*Non-Dividend Payers*
Panel A. Pre 1982, Post 1988			
Adj. R-Sq	.032	-.002	.044
n	1141	481	660
α_1	.119	.106	.130
p-value	*.000****	*.000****	*.000****
α_2	.032	-.001	.043
p-value	*.000****	*.843*	*.000****
Panel B. Pre 1978, Post 1988			
Adj. R-Sq	.043	.000	.053
n	1007	410	597
α_1	.114	.101	.126
p-value	*.000****	*.000****	*.000****
α_2	.037	.004	.047
p-value	*.000****	*.353*	*.000****
Panel C. Pre 1970, Post 1988			
Adj. R-Sq	.068	.030	.065
n	767	328	439
α_1	.103	.091	.115
p-value	*.000****	*.000****	*.000****
α_2	.048	.014	.057
p-value	*.000****	*.001****	*.000****

Table 7. The Effect of Regulation and Dividend Size on Stock Return Volatility

This table presents the results of the following difference of means test:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_t + \varepsilon_t$$

where σ_t is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, D is a dummy variable taking the value of 1 during the period of deregulation and 0 else, and Div_t is the total amount of dividends paid during year t. Pre refers to the cutoff dates used to define the period of regulation. The period of deregulation is 1989 – 2003. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	Pre 1982	*Pre 1978*	*Pre 1970*
Adj. R-Sq	.069	.077	.091
n	1141	1007	767
α_1	.128	.124	.115
p-value	*.000****	*.000****	*.000****
α_2	.027	.031	.040
p-value	*.000****	*.000****	*.000****
α_3	-.015	-.016	-.014
p-value	*.000****	*.000****	*.000****

Table 7 presents the results of deregulation's effect on stock return volatility when controlling for dividend size. Unlike the above results, all of the results are statistically significant at the 0.01 level regardless of the cutoff dates used. In sum, stock return volatility appears to increase with a transition to a deregulated economic environment, but the magnitude of that increase appears to be inversely related to dividend size. In other words, the larger the dividend amounts, the smaller the increase in stock return volatility. Taken together, the results presented in Tables 6 and 7 provide evidence that both the use and size of dividends serves to stabilize the volatility of the carrier's stock returns.

Summary and implications

Baker (1999) surveyed 170 senior managers and found that the signaling hypothesis was the most important determinant for setting dividend policy. Further, he finds managers of regulated utilities place a higher importance on maintaining or increasing stock price than do managers of non-regulated utilities. This is consistent with Moyer, Rao and Tripathy's (1992) findings that dividends are used by regulated utility firms to induce the use of capital markets. In this section, I extend these findings by testing the relation between dividend policy and shareholder risk.

Using monthly data for all airlines over the period 1929 – 2003, I find generally that dividend payers' stock return volatility is not significantly impacted by deregulation while non-dividend payer's stock return volatility is significantly impacted. More specifically, I find an inverse relation between the dividend size and the increased volatility in stock returns associated with deregulation. These findings are consistent with prior literature suggesting that regulated managers more actively attempt to affect stock prices through dividend policy than their non-regulated counterparts. Hence, owners of dividend paying carriers appear to incur lower portfolio risk than owners of non-dividend paying carriers.

IV. THE RISKS OF AIRLINE OWNERSHIP

The Capital Asset Pricing Model (CAPM) distinguishes between two general sources of risk – specific and systematic. According to the CAPM, systematic risk is the only concern to investors in a well-diversified portfolio and is proxied for using returns on the market portfolio. But, these broad classifications overlook the sources of risk unique to an industry. That is, specific with respect to the industry and systematic with respect to the individual firms within the industry. Therefore , in this chapter, I add to the literature by empirically testing several potential sources of risk specific to the airline industry and systematic to individual carriers. These sources are:

1. The industry's shift from regulation to deregulation. Under regulation, the government closely monitors the industry's financial health. This predicts that the risk to shareholders should be less in a regulated environment than under competition.
2. The demand for airline services is highly sensitive to safety concerns. Therefore, I hypothesize that there should be a relation between airline crashes and the risk faced by shareholders.
3. Similar to airline crashes, the industry was forced to endure the consequences of the events from 9/11. I suggest that this event created a large amount of uncertainty as to the industries future cash flow stream. However, as time passes from 9/11 and in the absence of future terrorist attacks – particularly those using airliners, this uncertainty should diminish. Therefore, I hypothesize that shareholder risk increased dramatically immediately following the 9/11 event.
4. Adding to the risk of the 9/11 attacks is the argument that the event helped to push the country further into the recession that had already begun. In addition, intuition suggests that the services provided by airlines are to a greater or lesser extent, a luxury. To the extent that they are a luxury, economic resources transferred to the industry will be highly sensitive to demands on those same resources from necessities. Accordingly, changes in economic conditions should explain a significant portion of the carriers' cash flows and changes in cash flows should be discounted by stock prices. This follows from the argument that the customers of airlines can be divided into three broad categories: recreational travelers, business travelers and freight shippers. Recreational travelers clearly will not transfer resources to the industry during bad times. Instead, they will either choose a substitute product or simply not travel. Business travelers are more likely to travel during bad times, but could still choose substitute products. Similarly, shippers could choose substitute products or not ship, but their demand is probably the most necessary of the three groups. Therefore, I investigate the relation between macroeconomic variables as a proxy for business cycles and the risks faced by shareholders.

Prior Literature

Regulatory effects

Previous studies examined market effects during the deliberation stage of the Deregulation Act of 1978. Edelman and Baker (1996) studied the effect on shareholder wealth of the Act's phase-in provisions. Based on Stigler's capture theory (Stigler, 1971), the market should respond negatively to the two phase-in provisions, unless the tradeoffs are perceived to be positive. They found that the market response was positive around the phase-in provision deregulating domestic routes and schedules, but they found that the market response was negative around the phase-in provision deregulating fares. Hence, although it appears clear that changes in regulation will affect shareholder wealth, whether that effect is positive or negative is unclear. This study adds further evidence to the literature.

Inflationary and airline safety effects

Fisher (1930) pioneered the theory that returns on assets should be positively correlated with expected inflation because asset returns should compensate for inflation movements. However, many empirical studies have documented a negative relation.[1] One explanation is the *proxy hypothesis* which states that the negative relation is driven by stock prices discounting future earnings potential. By examining the extent to which various assets are hedges against inflation, Fama and Schwert (1977) find that T-bills and T-bonds were complete hedges against expected inflation, and private residential real-estate was a complete hedge against both expected and unexpected inflation. Most notably, they find a negative relation between stock returns and expected inflation. Bernard (1986) documents a negative relation between firm betas and unanticipated inflation. However, Boudoukh and Richardson (1993) find that at longer-term horizons, stock returns and inflation do appear to be positively related. Hess and Lee (1999) show that this relation varies over time between a positive and negative relation based upon supply and demand shocks. In sum, prior literature is inconclusive as to the expected relation between inflation and the effect on the airline industry. This study extends the literature by contributing evidence from the airline industry.

Bosch, Eckard and Singal (1998) examine stock market reactions to commercial air crashes to test if the cause is an expected adverse response by consumers. More specifically, they test for a switching effect whereby consumers use rival airlines, and for a spillover effect whereby the demand for all air travel is reduced. They find evidence of both effects. This study extends their work by examining the effect of not only crashes, but also the 9/11 events (the result of hijacking) on stock return variability.

Data and Methodology

To empirically test the various risks faced by airline shareholders, monthly stock data are obtained from CRSP for all firms with SIC codes 4500, 4511 or 4512. Data on airline crashes are obtained from Bosch et al. (1998) and to proxy for inflation, economic data are obtained from the Federal Reserve Bank of St. Louis (FRED II).

---

[1] For applicable references, see Boudoukh, Richardson and Whitelaw (1994).

To examine how the various events affect shareholder risk, two methods are used. First, difference of means regressions are conducted to determine if the variance of stock returns is affected by economic regulatory control, airline crashes and the events of 9/11.[2] Then, regression analysis is employed to determine how the airline's systematic risk is effected by regulatory control, airline crashes, the 9/11 events and inflationary pressures.

Difference of means regressions

Consistent with Chapter 3b, the standard deviation of monthly returns without dividends is averaged for each year for all carriers. Next, a difference of means regression is employed as follows:

$$\sigma_{it} = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_{it} + \varepsilon_t \tag{1}$$

where σ_{it} is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample for carrier i, and D is a dummy variable taking the value of 1 during the post-event period and 0 else. The periods tested are regulation, crashes and 9/11. Additionally, the findings of Chapter 3b show that return variability is partially explained by dividends. Therefore, Div_{it} is the total dividend paid for year t by carrier i.

To test the effect of 9/11 on stock return variability, the same difference of means test is employed where the dummy variable equals 1 starting with the month October 2001, 0 else. As with regulation, various pre-event periods are defined. To gain a broad perspective, first, the pre-event period is defined as April 1935 through August 2001. Then, to control for the effects of regulation, the pre-event period is defined as January 1988 through August 2001. Finally, to equate the number of time periods during the pre and post event period, the pre-event period is defined as June 1999 through August 2001.

The last analysis tests the effect of crashes on industry-wide stock return volatility. Data are collected from Bosch, Eckard and Singal (1998) and updated through 2003 from the National Transportation Safety Board. The crashes of 9/11 and the American Airlines crash in November 2001 are excluded due to the unique nature of the event. That is, all other crashes were unintentional whereas the 9/11 crashes were acts of terrorism. The American Airlines crash is excluded due to its proximity to the events of 9/11. The 1, 2 and 3 month's average variability in returns is examined using non-overlapping data. For example, a Pan Am crash occurred in July 1982 and in August 1982, so the first event is dropped and September 1982 is the +1 month. Additionally, for post-event periods greater than one month, only the non-event months are considered. For example, a crash occurred in July of 1994 followed by another one in September 1994. Thus, for the +2 event study, only August of 1994 is considered. Similarly, for the +3 event study, only August and October of 1994 is considered.

Market risk

To test the change in the industry's market risk, the carriers' stock returns are first averaged as above. Then the following model is estimated:

$$Ret_t = \alpha + (\beta_1 + D\,\beta_2)RM_t + \varepsilon_t \tag{2}$$

---

[2] The F-test is not convenient for the effects of inflationary pressures.

where Ret_t is the monthly average returns at time t and RM_t is the returns without dividends on the S&P Composite at time t. The dummy variable takes the value of 1 during the period of deregulation, 0 during the period of regulation, 1 during the post-crash period, 0 else, and1 during the post-9/11 period, 0 else.

To test the effect of inflation on shareholder returns, the following model is estimated:

$$RET_t = \alpha + \beta(INFL_{t+n}) + \varepsilon \tag{3}$$

where

RET_t is the average returns at time t

$INFL_t$ is a macroeconomic variable that proxies for the economy at time t.

These variables could be changes in CPI, t-bill rates, the spread of t-bonds over t-bills, etc.

n takes the value of -1, 0 or +1 to test cross correlation, as well as cross autocorrelation relations.

Results

Table 8 presents the results of testing the effect of regulation on return variability over various cutoff dates. The second column presents the results when the regulated period ends December 31, 1981, the third column presents the results when the regulated period ends December 31, 1977 and the fourth column presents the results when the regulated period ends December 31, 1969. For all tests, the period of deregulation begins January 1, 1989. Consistent with the finding in Chapter 3b, it appears that deregulation increases the volatility of returns regardless of the cutoff dates used. That is, shareholder return volatility increases by between 2.7% and 4.0% depending on the cutoff date employed, all significant at the .01 level. Further, there is an inverse relation between volatility and amount of dividends paid. More specifically, for every dollar of dividends paid per share, stock volatility decreases by about 1.5% (significant at the .01 level).

Table 9 presents the results of testing the effect of 9/11 on return variability. When the pre-event period is defined as April 1935 through August 2001, the standard deviation of returns is approximately 8.7%. In the post-9/11 era, this volatility almost doubles to 17%, clearly suggesting that 9/11 had a substantial impact on owners' risk. These general results also hold when only the post regulation period is considered. The third column shows that the pre-9/11, post-regulation variability in monthly returns is approximately 13.4% - increasing by 3.7% in the post-9/11 era. With significance at the .01 level, this again strongly suggests that 9/11 has had a negative impact on shareholder risk. Finally, when the pre-9/11 period is defined as June 1999 through August 2001, the volatility in returns jumps from 11.7% to 17.0% with significance at the .01 level. Taken together, all of these results provide clear evidence suggesting that the events of 9/11 have increased the volatility of stock returns to airline owners. Note also that in the presence of 9/11, the negative relation between volatility and dividends dissipates. This suggests that the previously documented negative relation may have been capturing the effect of 9/11 on carrier profits and the industry's future financial health.

Table 8. The Effect of Deregulation on Stock Return Volatility

This table presents the results of the following difference of means test:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_t + \varepsilon_t$$

where σ_t is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, D is a dummy variable taking the value of 1 during the period of deregulation and 0 else, and Div_t is the total amount of dividends paid during year t. Pre refers to the cutoff dates used to define the period of regulation. The period of deregulation is 1989 – 2003. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	Pre 1982	*Pre 1978*	*Pre 1970*
Adj. R-Sq	.069	.077	.091
n	1141	1007	767
α_1	.128	.124	.115
p-value	*.000****	*.000****	*.000****
α_2	.027	.031	.040
p-value	*.000****	*.000****	*.000****
α_3	-.015	-.016	-.014
p-value	*.000****	*.000****	*.000****

Table 9. The Effect of 9/11 on Stock Return Volatility

This table presents the results of the following difference of means test:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_t + \varepsilon_t$$

where σ_t is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, D is a dummy variable taking the value of 1 during the pre-event period and 0 else, and Div_t is the total amount of dividends paid during year t. *, **, *** indicates significance at the .01, .05 and .10 levels respectively.

	Pre = 4/35 – 8/01	*Pre = 1/88 – 8/01*	*Pre = 6/99 – 8/01*
Adj. R-Sq	.078	.045	.186
n	824	191	54
α_1	.087	.134	.117
p-value	.000***	.000***	.000***
α_2	.083	.037	.053
p-value	.000***	.004***	.001***
α_3	.000	-.005	.002
p-value	.909	.352	.884

Data on air crashes are presented in Table 10 and the results of the difference of means regression are shown in Table 11. The second column shows the results for the month immediately following an air crash including dividend amount and deregulation control variables. While the largest effect on volatility is still driven by economic deregulation, the average monthly volatility increased by about 2.3% in the month following a crash (significant at the .05 level). In the two months following a crash, the increase is 1.9% (.01 level) and in the three months following a crash, the increase is 2.0% (.01 level). Additionally, note that in the presence of crashes and regulation, dividend policy appears to have no explanatory power over stock volatility. Together, all of this suggests that Air Crashes have industry-wide effects on shareholder stock return variability.

Table 10. Air Crashes

This table shows descriptive statistics on airline crashes. Data are collected from Bosch, Eckard and Singal (1998) and from the National Transportation Safety Board. The crashes of 9/11 and the American Airlines crash in November 2001 are excluded.

Crash Month and Year	*Crash Airline*	*Number of Deaths*
December 1978	United	10
February 1979	US Air	2
May 1979	American	271
October 1979	Western	72
January 1982	Air Florida	74
January 1982	World	2
July 1982	Pan Am	145
August 1982	Pan Am	1
January 1983	Republic	1
August 1985	Delta	135
August 1987	Northwest	156
November 1987	Continental	28
December 1987	PSA	43
August 1988	Delta	14
December 1988	Pan Am	270
February 1989	United	9
July 1989	United	111
September 1989	US Air	2
December 1990	Northwest	8
February 1991	US Air	34
March 1991	United	25
March 1992	US Air	27
July 1994	US Air	37
September 1994	US Air	132
July 1996	TWA	230
August 1997	Continental	1
December 1997	United	1
June 1999	American	10
January 2000	Alaska	83
January 2003	US Airways	19

Table 11. The Effect of Air Crashes on Stock Return Volatility

This table presents the results of the following difference of means test:

$$\sigma_t = \alpha_1 + \alpha_2 D_t + \alpha_3 Div_t + \alpha_4 DReg_t + \varepsilon_t$$

where σ_t is the estimated population's standard deviation of monthly returns during year t extrapolated from the sample, α is the standard deviation of monthly returns during the period of regulation, α_2 is the excess standard deviation during the period of deregulation, D is a dummy variable taking the value of 1 during the post-event period and 0 else, Div_t is the total amount of dividends paid during year t and $DReg_t$ is a dummy variable taking the value of 1 during the period of deregulation (post 1988), 0 else. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	(0,1)	*(0,2)*	*(0,3)*
Adj. R-Sq	.224	.225	.228
n	824	824	824
α_1	.075	.075	.075
p-value	.000***	.000***	.000***
α_2	.023	.019	.020
p-value	.013**	.008***	.001***
α_3	.001	.001	.001
p-value	.475	.439	.527
α_4	.058	.058	.057
p-value	.000***	.000***	.000***

Table 12 presents the results of testing the effect of deregulation on the industry's market risk. The second column presents the results when the regulated period ends December 31, 1981, the third column presents the results when the regulated period ends December 31, 1977 and the fourth column presents the results when the regulated period ends December 31, 1969. For all tests, the period of deregulation begins January 1, 1989. Regardless of the cutoff date for determining the period of deregulation, the industry's beta during the period of regulation appears to be about 1.43 (significantly different from 1.00 at the .01 level). This provides strong evidence that the airline industry is more risky than the market portfolio. Additionally, in contrast to the results of testing the industry's total risk, market risk does not appear to change significantly with deregulation. This result is intuitive given the non-diversifiable characteristic of market risk.

Table 13 presents the results of testing the effect of 9/11 on the industry's market risk. The second column presents the results when the pre-9/11 period begins in April 1935, the third column presents the results when the pre-9/11 period only includes post-regulation data and the last column presents the results with the pre and post-9/11 periods have the same number of observations. Interestingly, the only period during which the industry's beta is significantly different from unity is when the period of regulation is included in the sample. Subsequently, the industry's market risk does not appear to be significantly different from the market portfolio. However, regardless of how the pre-9/11 period is defined, the events of 9/11 appear to have reliably increased the industry's market risk between .872 and 1.313 – all significant at the .01 level. This result is not perplexing since 9/11 had such a huge impact on the industry's financial health (see Chapter 1). With increased operating leverage, the industry's returns are much more sensitive to macroeconomic shocks.

Table 12. The Effect of Deregulation on the Industry's Market Risk

This table presents the results of the following single-index model test:

$$Ret_t = \alpha + (\beta_1 + D\,\beta_2)\,Rm_t + \varepsilon_t$$

where Ret_t is the industry mean of monthly returns during month t, α is the intercept, β_1 is the industry's market risk during the period of regulation, D is a dummy variable taking the value of 1 during the period of deregulation and 0 else. Therefore, β_2 is industry's excess market risk during the period of deregulation. Statistical tests are conducted with the null hypotheses $\beta_1 = 1.00$ and $\beta_2 = 0$. Pre refers to the cutoff dates used to define the period of regulation. The period of deregulation is 1989 – 2003. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	Pre 1982	*Pre 1978*	*Pre 1970*
Adj. R-Sq	.446	.450	.438
n	741	693	605
α	.002	.002	.002
p-value	.378	.418	.422
β_1	1.434	1.434	1.417
t-stat	6.78***	6.58***	5.71***
β_2	-.213	-.213	-.196
p-value	.119	.12	.163

Table 13. The Effect of 9/11 on the Industry's Market Risk

This table presents the results of the following single-index model test:

$$Ret_t = \alpha + (\beta_1 + D\,\beta_2)\,Rm_t + \varepsilon_t$$

where Ret_t is the industry mean of monthly returns during month t, α is the intercept, β_1 is the industry's market risk during the pre-9/11 period, D is a dummy variable taking the value of 1 during the post-9/11 period 0 else. Various pre-9/11 periods are defined to control for deregulation and to equate the pre and post event sample sizes. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	Pre = 4/35 – 8/01	*Pre = 1/88 – 8/01*	*Pre = 6/99 – 8/01*
Adj. R-Sq	.449	.465	.602
n	825	192	54
α	.002	.000	.005
p-value	.308	.956	.620
β_1	1.306	1.001	.864
t-stat	5.77***	.009	-.502
β_2	.872.	1.178	1.313
p-value	.001***	.000***	.001***

More specifically, the events of 9/11 were a combination of idiosyncratic risk to airlines and macro-economic risk to the entire economy. It is specific to the industry because the industry's primary assets were the tools by which the plan was executed; and it is a macro-factor because of the economic consequences of the country going to war. Therefore, it stands to reason that the events of 9/11 would cause not only a change in the industry's specific risk, but also a change in the industry's market risk because of the change in carriers' financial and operating leverage (see Chapter 1). Of course, this increase in risk would be mitigated by any financial assistance rendered, such as the Airline Stabilization Act which serves to reduce the uncertainty of future cash flows.[3]

Table 14 presents the results of testing the effect of airline crashes on the industry's market risk. Consistent with the above findings, the industry appears to have more market risk than the market portfolio. However, for the cumulative one, two and three months following an airline crash, the industry's beta does not appear to change significantly. Again, this is intuitive given the industry-specific nature of the event.

Table 15 presents the results of testing the effect of inflation on the stock returns to airline owners. The results when n=0 clearly suggest a negative relation between changes in CPI and shareholder returns. That is, as the cost of living increases (decreases), returns to shareholders decreases (increases). Additionally, there appears to be an inverse lead-lag relation between changes in the CPI and returns to shareholders in the one and two months following the change. The strongest effect is the month following the change. The effect is still significant two months after the change, but it begins to dissipate. This all suggests that changes in CPI cause inverse changes in airline stock returns. I argue that this result is also intuitive because most commercial air travel is more of a convenience than a necessity. Hence, economics dictates that as necessities become more expensive, luxuries are forfeited and vice versa.

Summary and Implications

In this chapter, I test the effect of deregulation, air crashes and 9/11 on the risks that airline owners face. In Chapter 3, I document a positive relation between deregulation and stock return volatility. Additionally, I find that dividend size appears to have a shielding effect on this relation. In this chapter, I extend those findings by using different cutoff dates to define the periods of regulation versus deregulation – none of which appear to diminish the relation. However, the relation is impacted by other events.

I also test the impact of 9/11 on the airline owners' risk – finding that 9/11 has increased both the total and market risks of the industry's stock. Further, in the presence of 9/11, dividend size no longer appears to shield owners from stock return volatility.

Bosch, Eckard and Singal (1998) document a switching effect by consumers following an air crash. Extending these results, I document that airline crashes appear to have an industry-wide spillover effect on stock return volatility, but not on the industry's market risk. This

---

[3] A limitation of the single-index market model is that it assumes that the market portfolio captures all of the macroeconomic risk sources and that all firms are equally sensitive to these sources. For example, if the returns for all firms in the economy are determined by sensitivity to changes in the market portfolio, inflation, terrorism, crude oil prices, etc., then each individual firm and certainly each industry would be uniquely sensitive to each of the sources. Therefore, using just the market portfolio as a proxy for all sources may cause an omitted variable bias in the results. While this hypothesis could be tested, all of the firms in this study are from the same industry and therefore, probably close to equally sensitive to the various risk sources. Thus, while the exact explanatory variables for which the market portfolio proxies are open for debate, my findings nonetheless suggest that 9/11 set off a structural break in the sensitive of carriers to certain macroeconomic risk sources. Further, these sources are effectively captured in the single-index model.

suggests that in addition to the switching effect, the industry as a whole will face increased stock volatility following an airline crash. An extension to this research could be to test the option market's efficiency in capturing this effect – work which will be saved for future studies.

Finally, I find that the industry's stock returns appear to be negatively related to the cost of living as proxied for by the consumer price index. This supports my hypothesis that air travel is largely a luxury, thereby subject to the impact of substitute products when the price of necessities increases. In sum, all of these risk sources impact airline owners and should therefore be variables in their portfolio decisions. Further, in the presence of these industry-specific sources, dividend policy appears to no longer play a role in explaining stock return volatility.

Table 14. The Effect of Air Crashes on the Industry's Market Risk

This table presents the results of the following single-index model test:

$$Ret_t = \alpha + (\beta_1 + D\,\beta_2)\,Rm_t + \varepsilon_t$$

where Ret_t is the industry mean of returns during time t, α is the intercept, β_1 is the industry's market risk during the non-crash periods, D is a dummy variable taking the value of 1 during the post-crash period 0 else. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	(0,1)	*(0,2)*	*(0,3)*
Adj. R-Sq	.442	.442	.442
n	825	825	825
α	.002	.002	.002
p-value	.359	.362	.351
β_1	1.343	1.341	1.348
t-stat	6.47***	6.31***	6.33***
β_2	-.009	.025	-.052
p-value	.977	.903	.774

Table 15. The Effect of Inflation on Shareholder Returns

This table presents the results of estimating the following single-index model:

$$Ret_t = \gamma_0 + (\gamma_1)\,CPI_{t+n} + \varepsilon_t$$

where Ret_t is the industry mean of returns during time t, γ_0 is the intercept, γ_1 is the industry's sensitivity to changes in inflation as proxied for by the consumer price index (all items). The sample period is February 1946 through November 2003. ***, **, * indicates significance at the .01, .05 and .10 levels respectively.

	n=0	*n=+1*	*n=-1*	*n=-2*
Adj. R-Sq	.008	.002	.013	.007
n	694	694	694	693
γ_0	.015	.012	.016	.015
p-value	.000***	.002***	.000***	.000***
γ_1	-1.879	-1.125	-2.284	-1.747
p-value	.009***	.117	.001***	.015**

V. FINANCING DECISIONS IN THE AIRLINE INDUSTRY

A. Leverage, Economic Regulation and Shareholder Wealth

In the Miller and Modigliani (1963) view, the tax-deductibility of interest payments is an advantage to debt financing. Given the obvious potential costs of financial distress caused by excess debt financing, the notion of a static trade-off resulted in each corporation having a unique optimal capital structure. Much work, both theoretical and empirical, has followed in an attempt to explain or guide capital structure decisions. Although several theories have emerged, clarity with respect to the drivers of capital structure decisions remains elusive. In this section, my goal is to gain insight into the use of debt by the firm. More specifically, I examine the effect of price regulation and stock returns on capital structure in an industry that has not only financially struggled for most of its history, but an industry that has relied heavily on the use of leverage (Bowen et al, 1982; Bradley et al., 1984). Because the industry relies so heavily on leverage, it follows that the incentive to find the optimal capital structure is high. That is, if such a structure is obtainable, the idea of market efficiency suggests that the airline industry should find it.

Prior literature

Since 1958, capital structure decisions have been the subject of many studies and debates.[4] Some of the more recent studies have found a relation between capital structure and profitability. For example, Panno (2003) investigates the determinants of capital structure using companies in the UK and Italy during the period 1992 – 1996. He finds that financial leverage is positively related to size and profitability and negatively related to liquidity conditions and the risk of bankruptcy. Wald (1999) examines factors correlated with capital structure in France, Germany, Japan, the UK and the US. He finds differences across countries between long-term debt/asset ratios and the firms' riskiness, profitability, size and growth. Krishnan and Moyer (1996) examine the determinants of capital structure of large corporations in industrialized countries. For the period 1988-1992, they find support for the pecking order theory of capital structure with past profitability being the major determinant of leverage. Sharma, Kamath and Tuluca (2003) revisit the capital structure decisions using the neural networks methodology. They find that non-debt tax shields and profitability are related to debt ratios, but the relation is non-linear.

However, by using the following cross-sectional regression, Welch (2004) tests the influence of stock returns on capital structure decisions:

$$ADR_{t+k} = \alpha_0 + \alpha_1 ADR_t + \alpha_2 IDR_{t+k} + \varepsilon_t (1)$$

where ADR is the actual corporate debt ratio and IDR is the implied debt ratio defined respectively as

$$ADR_t \equiv D_t / (E_t + D_t) \qquad (2)$$

---

[4] For excellent capital structure literature reviews, see Harris and Raviv (1991), Sharma, Kamath and Tuluca (2003) and others.

$$IDR_{t,t+k} \equiv D_t / (E_t * (1 + x_{t,t+k}) + D_t) \quad (3)$$

where D is the book value of debt (due to lack of availability of market value data), E is the market value of equity and x is the stock return net of dividends. If firms adjust their debt ratios to previous levels, then α_1 should be equal to unity and α_2 should be equal to zero. By contrast, if debt ratios are allowed to fluctuate with stock prices, α_1 should be equal to zero and α_2 should be equal to one. His findings support the hypothesis that debt ratios are transient, commoving with stock returns, and any managerial readjustment to previous levels is slow and modest. These findings are robust when explanatory variables from prior literature are included in the regression. He reconciles prior work with his findings by arguing that other variables have explained debt ratios primarily because they are correlated with stock returns.

Welch's (2004) findings are consistent with the survey study by Graham and Harvey (2001) who surveyed 392 CFO's about their decision to issue debt. They found that the primary factors affecting the firm's debt policy is financial flexibility and credit rating. Apparently, little attention is given to target debt ratios, prior debt levels, or other theories of capital structure. Both financial flexibility and credit rating would be affected by economic regulation because of the financial safety net (or lack thereof) provided by regulators.

Lacking from Welch's (2004) study is the influence of economic regulation on the use of debt, but others have studied this influence. For example, Dasgupta and Nanda (1993) develop a bargaining model of regulation and test it in the electric utility industry. In their model, firms can use higher debt levels to induce regulators to set higher prices for output. Moreover, this bargaining power is positively correlated with the extent of industry regulation, so that in harsher regulatory environments, firms choose higher levels of debt. They compile evidence from the electric utility industry over the period 1972-1983, providing results that are consistent with their model. Similarly, Ramesh and Moyer (1994) develop a theoretical model for the regulated electric utility industry in which managers can mitigate unfavorable regulation by increasing leverage. This model is also consistent with a positive relation between debt levels and the extent of regulation. Klein, Phillips and Shiu (2002) examined the effect of regulation on capital structure in the insurance industry. They also find evidence of a strong relation between the degree of price regulation and debt levels.[5]

These results are all consistent with Spiegel and Spulber's (1994) sequential model of regulation. In their model, they show that the firm's capital structure has a significant effect on the regulated price. Hence, the firm can use capital structure decisions as a tool for influencing the regulation process. Specifically, increasing debt increases the probability of financial distress thereby motivating regulators to increase regulated prices.

In sum, Welch (2004) found that stock returns more adequately explain capital structure changes than other previously researched variables because managers *passively* allow the structure to vary with changes in the market value of equity. However, his study does not consider the effect of regulation which has been shown to motivate managers to *actively* increase debt levels. Therefore, in this section, I study the relational change between debt ratios and stock returns in a regulated and unregulated environment. By using Welch's model, I analyze the impact of regulation on the extent to which debt ratios are allowed to vary with

---

[5] See also Bradley et al. (1984), Taggart (1985), Rao and Moyer (1994) and others.

stock returns. I hypothesize that the removal of economic regulation will increase the extent to which managers allow this variation.

Data and methodology

The airline industry is a good experimental setting in which to study these issues because in addition to being one of the most highly levered industries (Bowen et al, 1982; Bradley et al., 1984), it has transitioned from a regulated to a competitive environment. Hence, as much as is possible, all other variables can be held constant while the environment is deregulated. To help understand the history of the use of debt in the airline industry, I first investigate how debt ratios have changed over time. To avoid debt-ratio contamination issues such as higher debt ratios by carriers in financial distress, those in the early stages of their life, as well as other issues, I study the three major carriers that have survived from the beginning of regulation until the present – Delta Airlines, United Airlines and American Airlines.

Survivorship bias has been an issue in the study of mutual fund performance in recent studies. Elton, Gruber and Blake (1996) as well as others, note that studying only surviving mutual funds introduces a positive bias into fund performance – the goal of which is generally to determine the effect on investors' wealth from the allocation of wealth to the funds. However, poorly performing funds tend to disappear from databases due to attrition or merging with other funds. Hence, to not consider the possibility that some of an investor's portfolio may have been allocated to the distressed fund is to overstate the return to investors. Unlike mutual fund studies, my purpose is not to estimate returns to investors. Rather, I am conducting an event study on the impact that an event has on the use of debt - the focus of which is on representative *behavior* between periods rather than a total *accumulation* of wealth over time. Intuition suggests that new entrants and financially distressed carriers have a much greater need than financially healthy carriers to supplement or replace operating cash flows with debt proceeds. That is, the decision-making process of both new entrants and those in financial distress would be biased by a short-term goal of survival rather than a long-term goal of value maximization. Thus, I argue that these two events are highly correlated with the use of debt by managers and would thereby bias debt ratio behavior because they are not indicative of a financially stable going concern. Further, because of the ambiguity of the length of time necessary to adequately control for these two variables, I argue that the successful carriers provide the cleanest representation of the debt ratio behavior in a financially healthy carrier.

Data on total assets, PPE, total debt and long-term debt are hand collected from Moody's Transportation and Industrial manuals for the period 1938 – 2003. These data are then examined to gain insight into how they have changed over time and in particular, if they are significantly different in different eras.

First, descriptive statistics are compiled on various debt-to-asset ratios for the three airlines and for the equally-weighted average of the three airlines. Then, following Welch (2004), stock return data without dividends are compiled from CRSP for the period 1938 – 2003, and the following model is estimated:

$$ADR_{it+k} = \alpha_0 + (\alpha_1 + DREG\alpha_2)ADR_{it} + (\alpha_3 + DREG\alpha_4)IDR_{it+k} + \varepsilon_t \tag{4}$$

where consistent with Welch (2004), ADR is the actual corporate debt ratio and IDR is the implied debt ratio. However, my regression uses pooled data while he used the Fama and MacBeth procedure. Pooled data is convenient in this study due to the relatively small number of cross-sectional variables and the relatively large number of time series variables. DREG is a dummy variable taking the value of 1 during the period of regulation (1938-1981) and 0 during the period of deregulation (1989-2003). Welch's (2004) findings suggest that in the presence of IDR, the explanatory power of ADR_t over ADR_{t+k} should be insignificant. Further, prior work suggests that deregulation should decrease debt ratios. Therefore, if regulation affects the extent to which stock returns explain debt ratios, α_4 should be significantly different from zero. More specifically, I hypothesize that α_4 should be significantly positive thereby causing α_2 to be significantly negative.

Results

Table 16 presents descriptive statistics about the carriers' debt ratios over the periods of regulation, regulatory phase-out and deregulation, as well as a paired-sample difference of means test between debt ratios during periods of regulation versus deregulation. The most revealing statistics are presented in Panel D which shows the change in debt-to-asset ratios from the regulated to the deregulated economic environment. For American and United, debt ratios generally appear to decrease in the absence of regulation consistent with prior literature. However, Delta's debt ratios have increased since deregulation. Although mixed, the results generally support the hypothesis that regulation encourages the use of debt and are consistent with prior literature.

Table 17 present the results of testing the effect of stock returns on debt ratios. Observing the coefficient of the implied debt ratios (IDR) with the actual debt ratios (ADR) reveals that consistent with Welch (2004), IDR more adequately explains capital structure than past ADR – suggesting that managers passively allow capital structure to vary with the market value of equity rather than actively seeking a target capital structure. However, the goal of this section is to test the influence of economic deregulation on this relation. The results of these tests are reported in Table 18.

Table 18 shows the results of estimating Equation 4. The test statistics are α_2 and α_4 which represents the excess explanatory power of the variables under deregulation. For Delta Airlines, the IDR coefficient is positive and significant across all three lags – suggesting that market value of equity has more explanatory power over capital structure during deregulation than during regulation. More specifically, the increased explanatory power of the implied debt ratio is around 20% for all three lags. This supports the hypothesis that managers will allow capital structure to vary with stock returns more under deregulation than under regulation. However, this support is weak in light of the insignificant findings from the other two carriers.

Summary and implications

In an attempt to explain the prior capital structure literature, Welch (2004) shows that stock returns more adequately explain capital structure than traditional theories. In addition, other prior literature shows a strong positive relation between economic regulation and debt levels. In this section, I synthesize these two lines of research using the airline industry. My findings indicate that there appears to be a significant change in debt levels dependent upon the regulatory environment. For two of the three carriers studied, debt levels decreased consistent with the prior literature documenting a positive relation between debt levels and regulation. Additionally, consistent with Welch (2004), I find that the market value of equity more adequately explains changes in capital structure than does an attempt by management to seek some predetermined target level. However, the effect of deregulation on this relation is mixed.

For two of the three carriers studied, deregulation had no effect on the ability of stock returns to explain capital structure. However, the results for one carrier show an increase in explanatory power under regulation. Therefore, my findings seem to be more supportive of management allowing capital structure to vary with the market value of equity, irrespective of the regulatory environment.

Table 16. Descriptive Statistics

This table shows various debt-to-asset ratios in percentages for American Airline, United Airline, Delta and an equally-weighted average of the three. Panel A shows the ratios during the period of economic regulation, Panel B shows the ratios during the period of Deregulation and Panel C shows the results of the paired-sample difference of means test. The first row shows the mean and the second row shows the standard deviation for Panels A, B and C. In Panel D, the first row shows the difference in means and the second row shows the p-value of the difference.

Panel A. Regulation (1936 – 1981)

	American	Delta	UAL	EWA
L/T Debt to	.3130	.2072	.3088	.2821
Total Assets	.02818	.02322	.03498	.02720
Total Debt to	.5512	.3840	.5129	.4827
Total Assets	.01339	.01216	.01760	.01230
Panel B. Phase-out (1982 – 1988)				
L/T Debt to	.1530	.1895	.1428	.1618
Total Assets	.02122	.07819	.06595	.02022
Total Debt to	.4382	.4295	.5297	.4658
Total Assets	.03864	.07406	.07504	.02086
Panel C. Deregulation (1989 – 2003)				
L/T Debt to	.2176	.2287	.1710	.1968
Total Assets	.02588	.02756	.01757	.01848
Total Debt to	.4801	.5112	.5095	.5002
Total Assets	.02136	.02486	.03470	.01627
Panel D. Paired-sample Difference of Means (Panel C minus Panel A)				
L/T Debt to	-.09541	.02152	-.13785	-.08528
Total Assets	.046	.642	.002***	.034**
Total Debt to	-.07108	.12714	-.00341	.01755
Total Assets	.016**	.001***	.897	.361

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

Table 17. The Relation between Future Actual Debt Ratios (ADR) and Stock Return-Modified Debt Ratios (IDR) for the Entire Period (1963 – 2002)

This table presents the results of estimating the following model:

$$ADR_{it+k} = \alpha_0 + (\alpha_1 + DREG\alpha_2)ADR_{it} + (\alpha_3 + DREG\alpha_4)IDR_{it+k} + \varepsilon_t$$

where ADR is the actual corporate debt ratio and IDR is the implied debt ratio defined as follows:

$$ADR_t \equiv D_t / (E_t + D_t)$$
$$IDR_{t,t+k} \equiv D_t / (E_t * (1 + x_{t,t+k}) + D_t)$$

where D is the book value of debt, E is the market value of equity and x is the stock return net of dividends.
Since these estimations are across the entire sample period, the DREG dummy variable is zero. Thus, α_2 and α_4 are also zero. The second column presents the regression's adjusted r-squared and all subsequent columns present the regression coefficient in the first row and p-value in the second row.

Panel A. k=1						
	Adj R^2	α_0	α_1	α_2	α_3	α_4
American						
Coeff	.961	-.013	.438		.596	
P-value		.463	.000***		.000***	
Delta						
Coeff	.955	-.010	.343		.679	
P-value		.469	.000***		.000***	
United						
Coeff	.423	.105	.514		.257	
P-value		.136	.002***		.014**	
Panel B. k=2						
American						
Coeff	.889	-.011	.278		.752	
P-value		.768	.000***		.000***	
Delta						
Coeff	.927	-.009	.192		.827	
P-value		.630	.006***		.000***	
United						
Coeff	.818	.114	.029		.717	
P-value		.010***	.752		.000***	
Panel C. k=3						
American						
Coeff	.837	.049	.109		.789	
P-value		.317	.175		.000***	
Delta						
Coeff	.910	.004	.085		.879	
P-value		.883	.265		.000***	
United						
Coeff	.824	.088	.076		.724	
P-value		.060*	.396		.000***	

*, **, *** indicates significance at the .01, .05 and .10 levels respectively.

Table 18. The Effect of Deregulation on the Relation between Future Actual Debt Ratios (ADR) and Stock Return-Modified Debt Ratios (IDR)

This table presents the results of testing the effect of deregulation on debt ratios. The regulated period is 1963-1981 and the deregulated period is 1989-2003. The following model is estimated:

$$ADR_{it+k} = \alpha_0 + (\alpha_1 + DREG\alpha_2)ADR_{it} + (\alpha_3 + DREG\alpha_4)IDR_{it+k} + \varepsilon_t$$

Where D is a dummy variable taking the value of 1 in the post-regulation era (1989-2003), 0 else. All other variables are consistent with Table 4.2. The second column presents the regression's adjusted r-squared and all subsequent columns present the regression coefficient in the first row and p-value in the second row.

Panel A. k=1

	Adj R^2	α_0	α_1	α_2	α_3	α_4
American						
Coeff	.922	-.019	.334	.111	.684	-.064
P-value		.542	.000***	.223	.000***	.438
Delta						
Coeff	.965	-.009	.466	-.182	.525	.209
P-value		.629	.000***	.112	.000***	.033**
United						
Coeff	.875	.015	.406	-.103	.550	.098
P-value		.707	.000***	.370	.000***	.339
Panel B. k=2						
American						
Coeff	.851	-.029	.220	.075	.806	-.009
P-value		.608	.016**	.435	.000***	.942
Delta						
Coeff	.936	-.002	.263	-.115	.670	.186
P-value		.941	.050**	.350	.000***	.068*
United						
Coeff	.781	.104	.090	-.100	.676	.075
P-value		.086*	.479	.461	.000***	.499
Panel C. k=3						
American						
Coeff	.809	.032	.102	-.023	.808	.043
P-value		.708	.376	.828	.000***	.577
Delta						
Coeff	.920	.039	.047	-.025	.671	.202
P-value		.376	.774	.852	.000***	.061*
United						
Coeff	.779	.095	.048	.019	.726	-.002
P-value		.208	.740	.875	.000***	.988

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

B. Does the Use of Operating Leases Create Value?

Traditional finance theory suggests that leases and debt are substitutes for one another. Ang and Peterson (1984) first tested this theory and documented the "leasing puzzle" which was at odds with the notion of leases and debt being substitutes. Since that time, a debate has ensued, but largely absent from this debate is the issue of operating leases since the associated liabilities are not reported on financial statements. Using data from the UK, Beattie, Goodacre and Thomson (2000) attempt to measure leasing by incorporating an estimate of the liability associated with operating leases into the total lease obligations. However, they note that a major problem for such studies is the lack of transparency with respect to operating lease information. In the airline industry, this problem is mitigated because many airlines' annual reports include a table of how the aircraft in their fleet are financed. Nevertheless, my focus is not an estimate of the associated liability because consistent with FASB 13, operating leases do not constitute the purchase of an asset. Rather, my goal is to determine whether the renting (i.e. leasing under an arrangement that would qualify as an operating lease for purposes of FASB 13) of an asset creates more value than an outright purchase – regardless of the formality of the purchase. The airline industry provides a natural experimental setting for testing leasing decisions because of its continual need for high-dollar assets and its notorious use of leases to obtain aircraft for use in its operations. Additionally, the airlines' annual report contains reliable data on the financing arrangements for the aircraft in its fleet.

If a carrier finances a purchase either externally or internally, both an asset and a liability (if any) will be recorded on the financial statements. Similarly, if a carrier uses a leasing arrangement to effectively finance the purchase, such an arrangement is considered a capital lease and an asset and liability are also recorded on the financial statements.[6] By contrast, if the leasing arrangement is not effectively a purchase of the asset, then it is considered an operating lease and only an expense is recorded. Hence, in this section, I examine whether there is a systematic value advantage by the use of operating leases. To test this potential advantage, I examine the relation between the proportion of aircraft in the fleet under operating leasing arrangements and operating performance.

Data and methodology

Data are available from many of the carriers' annual reports and 10-k filings that report the number of aircraft in the fleet and how they are financed.[7] Using the carriers' annual reports, these data are collected consistent with the methods in Section A with one exception. FASB 13 was adopted in 1976 and set forth the formal accounting requirements for distinguishing between capital and operating leases. Additionally, since leasing is essentially a capital structure decision, the period of regulation may affect the leasing decision. Hence, for my time series analysis, I am only interested in data for the post-1981 period because earlier data would not be reliable due to potential inconsistencies in account methods. Also, the period 1976 – 1978 does not provide enough observations to compare regulation to

---

[6] FASB 13, which established the procedures for operating versus capital lease accounting, was adopted in 1976. Because accounting procedures prior to this time would suffer from low comparability, only post-1976 data are considered.

[7] Because not all carriers report their leasing arrangements, there is a potential bias in the data. That is, the carriers that report may be the ones reporting more favorable results. However, these tests should still pick up any meaningful relations.

deregulation, and the 1978-1981 phase-out period is not indicative of periods of regulation or competition. Further, data are only available for the last 10 years, so the period that I analyze is the years 1994 – 2003.[8] The airlines studied for this time period are Southwest, American and Delta.

For the time-series analysis on American, Delta and Southwest for the period 1994-2003, the following regression is estimated:

$$OP_{it} = \alpha + \beta_1 OLP_{it,t-1} + \beta_2 RM_t + \beta_3 CPI_t + \beta_4 CRUDE_t + \beta_5 AGE_t + \varepsilon_t \qquad (5)$$

where OP_{it} is the operating performance of carrier i at time t. Following Mikkelson, Partch and Shah (1997), operating performance is operating income before depreciation, interest, taxes and extraordinary items scaled by total end of the year assets. OLP_{it} is the percentage of the carrier i's fleet financed under an arrangement qualifying as an operating lease at time t, and $SIZE_{it}$ is the size of carrier i at time t as measured by total revenues.[9] RM_t, CPI_t, and $CRUDE_t$ control for macroeconomic variables and represent returns on the market portfolio as proxied for by the CRSP equally weighted portfolio, the log change in the consumer price index and the log change in crude oil price respectively. Finally, Mikkelson, Partch and Shah (1997) find that in addition to size, operating performance is also related to the years of operating history. Hence, AGE_t is the number of years of operating history at time t. If β_1 is significantly different from zero, it suggests that operating leases are not perfect substitutes for debt. More specifically, if the coefficient is positive (negative), then the use of operating leases creates value and is (is not) therefore preferred to financing and capital leasing arrangements.

In addition, I examine the year 2003 only for several airlines to obtain a larger cross-section of data. For this test, the following regression is estimated:

$$OP_i = \alpha + \beta_1 OLP_i + \beta_2 SIZE_i + \beta_5 AGE_t + \varepsilon_t \qquad (6)$$

where OP_i is the operating performance of carrier i as measured by operating income scaled by total assets, OLP_i is the percentage of the carrier i's fleet financed under an arrangement qualifying as an operating lease, AGE_t is the number of years of operating history at time t and $SIZE_i$ is the size of carrier i as measured by total revenues. In both estimations, if the use of operating leases adds value abnormally above (below) other financing arrangements, then the coefficient should be significantly positive (negative).

Results

Table 19 presents the correlations between all of the explanatory variables in equation 5. For Southwest Airlines, there appears to be a relation between OLP and AGE, which is not consistent with either American or Delta. Similarly, for Delta, there appears to be a relation between OLP and CPI which is not consistent with American or Southwest. However, there is a highly positive correlation between CPI and CRUDE indicating that they both proxy for

---

[8] Edgar, Moody's manuals, and the Tenkwizard site were searched. The only known data source for earlier years is Commerce Clearing House which is cost prohibitive.

[9] Although Mikkelson, Partch and Shah (1997) use total assets as their measure of size, total assets are not used here because of potential multicollinearity with OLP. Further, revenue is the traditional means by which the size of airlines are measured.

similar macroeconomic variables. Therefore, to correct for multicollinearity, orthogonalized values for CRUDE are used in equation 5, the results of which are presented in Table 20.

The second column of Table 20 presents the results of estimating equation 5 for Southwest, all of which are insignificant. Therefore, there does not appear to be a relation between the operating profits of Southwest and the use of operating leases, suggesting that operating leases are a substitute for debt. However, for American and Delta in the third and fourth columns respectively, the results are much more significant. Specifically, there appears to be an inverse relation between the use of operating leases and operating profits for both carriers – both statistically reliable at the .01 level. These results appear to indicate that the use of operating leases damages profits relative to other forms of financing. This suggests that operating leases are not a substitute for debt and may therefore be less preferred than other forms of financing. However, the results are not robust with respect to Southwest and are therefore perplexing. In an effort to gain further insight, a cross-sectional regression analysis was conducted (Table 21).

Table 19. Correlation Matrix

This table presents the correlations between the percentage of the carrier’s fleet obtained under an agreement qualify as an operating lease (OLP), the market portfolio (RM), the consumer price index (CPI), the log-change in crude oil prices (CRUDE) and the carrier’s age (AGE). The first row shows the correlation and the second row shows the p-value.

Panel A. Southwest Airlines

	OLP	RM	CPI	CRUDE	AGE
OLP		-.160 .329	.241 .251	-.073 .421	-.979 .000***
RM			-.292 .207	.032 .465	.263 .231
CPI				.624 .027***	-.300 .200
CRUDE					.016 .482

Panel B. American Airlines

	OLP	RM	CPI	CRUDE	AGE
OLP		.188 .301	-.410 .120	.025 .473	.371 .146
RM			-.292 .207	.032 .465	.263 .231
CPI				.624 .027***	-.300 .200
CRUDE					.016 .482

Panel C. Delta Airlines

	OLP	RM	CPI	CRUDE	AGE
OLP		-.105 .387	.506 .068**	.219 .271	-.342 .166
RM			-.292 .207	.032 .465	.263 .231
CPI				.624 .027**	-.300 .200
CRUDE					.016 .482

***, ** indicates significance at the .01 and .05 levels respectively.

Table 20. Time Series Analysis

This table presents the results of estimating the following model:

$$OP_{it} = \alpha + \beta_1 OLP_{it,t-1} + \beta_2 RM_t + \beta_3 CPI_t + \beta_4 CRUDE_t + \beta_5 AGE_t + \varepsilon_t$$

where OP_{it} is the operating performance of carrier i at time t, OLP_{it} is the percentage of the carrier i's fleet financed under an arrangement qualifying as an operating lease at time t, and $SIZE_{it}$ is the size of carrier i at time t as measured by total revenues. RM_t, CPI_t, and $CRUDE_t$ are the returns to the CRSP equally weighted portfolio, the log change in the consumer price index and the orthogonalized log change in crude oil price respectively.

	Southwest	American	Delta
Adj. R-sq	-.181	.899	.780
Intercept	1.325	1.442	1.295
OLP	-.991	-1.790	-1.384
	.353	.006***	.005***
RM	.006	.043	.056
	.935	.270	.322
CPI	.299	-1.342	5.609
	.904	.389	.057*
CRUDE	-.046	-.025	-.058
	.449	.458	.247
AGE	-.033	-.013	-.013
	.306	.011***	.037**

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

Table 21. Cross-Sectional Analysis

Panel A presents the correlations between the percentage of the carrier's fleet obtained under an agreement qualify as an operating lease (OLP), the carrier's size as measured by total operating revenue (SIZE) and the carrier's age (AGE). The first row shows the correlation and the second row shows the p-value. Panel B presents the results of estimating the following model:

$$OP_i = \alpha + \beta_1 OLP_i + \beta_2 OrthSIZE_i + \beta_5 OrthAGE_t + \varepsilon_t$$

where OP_i is the operating performance of carrier i as measured by operating income scaled by total assets, $OrthAGE_t$ is the orthogonalized AGE from above and $OrthSIZE_i$ is the orthogonalized SIZE variable from above.

Panel A. Correlation Matrix

	OLP	AGE	SIZE
OLP		-.543 .022**	-.493 .037**
AGE			.879 .000***

Panel B. Regression Results

	OLP	OrthAGE	OrthSIZE
Adj. R-sq	.138		
Coefficient	.074	-.004	.000
P-value	.624	.059*	.592

***, **, * indicates significance at the .01, .05 and .10 levels respectively.

Panel A of Table 21 shows the correlation matrix of the explanatory variables in Equation 6 and indicates significant multicollinearity problems. Thus, the regression results in Panel B reflect orthogonalized values of AGE and SIZE and show that the operating lease coefficient is not reliably related to operating profits. This suggests that operating leases are a substitute for debt. Together, the results from Tables 20 and Panel B of 5.6 provide inconclusive evidence whether operating leases are substitutes for debt and it is unclear whether they add excess value relative to other forms of financing.

A note on the tax consequences of debt versus operating leases

An important issue in the lease versus purchase decision is the tax consequences, especially in the airline industry given the high acquisition costs of aircraft. While a thorough analysis will be saved for future work, an identification and understanding of the issues is presented here. This presentation follows DeAngelo and Masulis' (1980) paper on leverage and dividend irrelevancy. By extending Merton Miller's seminal work in "Debt and Taxes", they generally concluded that the supply and demand-side interactions with respect to debt and dividends will reach an equilibrium robust to the tax-treatment differences. As it pertains to this section, I argue that the use of leverage versus operating leases by carriers will be in equilibrium when the tax benefits of the two are equal. While simple in concept, the indifference point's exact calculation is rather complicated. Further, the tax reform act of 1986 (as well as other tax law changes) have rendered DeAngelo and Masulis' (1980) findings much more complicated than as they were originally presented. However, the tax benefits of each can be generalized without a cumbersome examination of tax law minutia.

To carriers, the tax benefits of debt will arrive in the form of interest payments on the outstanding debt, as well as the depreciation of the capital asset – presumably aircraft. Additionally, there is either a tax benefit or an additional tax burden upon disposition of the capital asset depending on whether it was disposed of for a tax gain or loss. In comparison, operating leases are straightforward as the tax benefits of such arrangements merely arrive in the form of deduction of the lease payments. Since the asset is not capitalized, no depreciation is allowed nor is a capital gain or loss recorded upon disposition of the asset. Hence, the tax-benefit indifference point can be formulated as follows:

$$\sum_{t=0}^{n} \frac{(D_t + I_t)\,T_{ordt} - (CG_t)(T_c)}{(1 + r_{dt})^n} = \sum_{t=0}^{n} \frac{L_t T_{ordt}}{(1 + r_{Lt})^n} \tag{7}$$

where the left-hand side of the equation is the present value of the net tax-benefit of debt financing and the right-hand side of the equation is the present value of the tax benefit of operating-lease financing. In the left-hand side numerator, D_t and I_t are the amounts expensed for deprecation and interest respectively at time t. To arrive at the tax benefit, this must of course be multiplied by the tax rate on ordinary income at time t, T_{ordt}. CG_t is the excess of the net sales price over the tax basis of the property upon disposition at time t – of course, multiplied by the tax rate on capital gains at time t, T_{ct}. The numerator on the right-hand side is much easier to understand since it is simple the lease payments at time t (L_t) multiplied by the tax rate on ordinary income at time t, T_{ordt}.

Of course, these calculations are complicated by several factors – the first of which is the necessity of an accurate forecasting method for the amounts and timing of the variables. The most difficult in this case is the ultimate salvage value of the asset to be sold. Another is the forecasting of tax rates into the future. However, looking past these difficulties, there are several tax-related difficulties that complicate the calculation. First, if the asset is sold at a capital gain, there will be a tax burden. By contrast, if it is sold for a tax loss, then that loss may or may not be subject to an immediate tax benefit depending on whether there are other capital gains against which to offset the loss. If there are no other capital gains, then under current law, the loss may be carried forward for 5 years to offset other capital gains. If there are none, then it merely disappears. Consequently, not only the amount, but the timing of this cash flow is highly uncertain.

Another major source of uncertainty is the profitability of the carrier in any given year, a very real concern to the airline industry. That is, the other sources of tax benefits will be available if the corporation (assuming a subchapter C corporation) has a positive net income during the year. However, if the corporation has a net operating loss for the year, then under current law, the loss could end up being carried forward for as many as 20 years. Therefore, although the amount of these cash flows is fairly certain, the timing of the cash flows is not.

Together, the presence of capital gains/losses creates a larger uncertainty with respect to the timing and amount of tax benefits for debt financing than for operating lease financing. Accordingly, I argue that not only should the discount rate for each of these two arrangements should be different, but r_{dt} should be greater than r_{Lt}. In sum, while the tax ramifications of the decision are highly relevant, the accurate calculation of those ramifications are very complicated and perhaps, highly speculative. This could provide fertile ground for future research.

VI. SUMMARY, IMPLICATIONS AND EXTENSIONS

The airline industry has always depended on the government for its very survival. Even currently, the industry as a whole is in a cumulative financial deficit and Delta, one of the most successful carriers over the long-run, is considering bankruptcy protection. In this study, I have begun a line of research to gain insight into the industry by describing various financial characteristics from the corporate and investors' perspective, especially as it pertains to the role economic regulation has played. This regulatory change is an idiosyncratic financial characteristic of the industry and provides the common theme throughout most of my tests.

Even before economic regulation, the industry relied on the government for its survival in the form of mail delivery. At that time, airmail delivery was the carriers' primary revenue source and passenger service was merely a subsidy. However, even in its infancy, none of the major carriers were profitable prior to 1938.

In 1938, the Civil Aeronautics Act established economic regulation over the industry – specifically in the areas of ticket prices and the extent to which competition was allowed. Although most of the major carriers had at least one competitor, the only area in which they could realistically compete was in the area of services. This process spawned our modern-day difference in service known as coach versus first-class. Most of the industry-wide price increases were initiated by individual carriers and competition was limited. These two forces created an inefficient and un-innovative industry, the cost of which was borne by consumers. This was evidenced by the fact that intra-state carriers (not subject to economic regulation) were charging lower fares, but were more profitable than the larger regulated interstate carriers. This observation led to the Airline Deregulation Act of 1978.

Of course, the purpose of deregulation was to allow the struggle for survival through the forces of competition to chisel away the financial inefficiencies, thereby optimizing the quality of service and cost of that service to consumers. This precipitated many mergers and fare wars during the early stages of deregulation, resulting in the first wave of bankruptcies. These bankruptcies introduced one of the major problems to the deregulated industry – that carriers under bankruptcy protection could still compete in the market. Because of the protection provided by bankruptcy laws, the troubled carriers become cost-leaders courtesy of the government, and can therefore charge lower fares. This forces healthy carriers to lower their fares as well, the industry-wide implications of which are obvious.

Despite the problems, the industry was mostly profitable between 1993 and 1998 due in part to relatively low labor costs. During that time, labor accounted for about 34% of operating expenses. This changed around 1999 when labor unions demanded significant pay increases, driving labor costs to about 36% of all operating expenses. The renegotiated costs were apparently motivated by feelings of animosity and resentment towards management by labor. This friction is perhaps one of the primary causes of the industry's financial struggle, manifesting itself not only in direct compensation to labor, but in agency costs as well. However, research into this area will be saved for future management-oriented studies. This study focuses mostly on the impact that deregulation has had on the industry's financial health.

For several of my studies, I use three major carriers as a proxy for the industry – United, Delta and American airlines. These carriers were chosen because they have been in existence from the 1930's until the present. Interestingly, two of these carriers are now either considering bankruptcy protection, or already under such protection. I argue that using these carriers to study financial behavior avoids the potential biases present in industry-wide data with carriers in start-up, in financial distress and those exploiting bankruptcy laws. That is, I argue that using these carriers provides a more stable financial life-cycle to study.

In Chapter 3, I primarily study the effect that economic deregulation had on earning's behavior in the industry. Prior literature, most notably Fama and French (2000), documented a mean-reversion tendency in earnings behavior, thereby rendering earnings at least partially forecastable. This forecastability has wide-reaching implications for business valuation models and therefore, market efficiency. My results suggest that deregulation has affected the magnitude of earnings, but not earnings behavior per se. More specifically, I find that not only do carriers appear to be much less profitable since regulation, but the variability in earnings is much higher as well. This is consistent with the above-mentioned difference in financial heath of the industry.

In addition and consistent with prior literature, I document a mean-reversion tendency in earnings behavior. However, my results suggest that this behavior is not clearly impacted by the removal of economic regulation. Hence, it does not appear that business-valuation models necessarily need to reflect changes in economic regulation. Moreover, Fama and French (2000) and others exclude industries subject to economic regulation because earnings behavior may not be comparable to behavior in unregulated environments. While I do find a clear magnitude and dispersion difference, my findings do not support a clear and/or significant difference in behavior.

Also in Chapter 3, I examine the role that carriers' dividend policy has on stock return volatility. Prior work suggests that regulated firms use dividend policies to force more frequent trips to the capital markets. Accordingly, in a regulated environment, monitoring capital markets becomes more important than the agency control mechanism of competition. Therefore, I hypothesize that stock returns of dividend payers should be less volatile under regulation than in a deregulated environment. My results suggest that for all carriers (both dividend and non-dividend paying carriers), stock returns are more volatile in the deregulated environment. However, this increased volatility appears to be attributable exclusively to non-dividend paying carriers. That is, I find no evidence suggesting that the stock return volatility of dividend payers is different between regulated and deregulated environments. Further, I find that stock return volatility is inversely related to dividend size suggesting that dividend policy provides a shielding effect that reduces ownership risk. This initial finding, however, is more fully developed in Chapter 4.

In Chapter 4, I test the effect that three idiosyncratic sources of risk – deregulation, 9/11 and airline crashes – have on the risks of owning airline stock. Using more robust cutoff dates between regulation and deregulation and including tests of changes in market risk, my findings in Chapter 4 are consistent with those in Chapter 3. That is, returns are more volatile during deregulation than during regulation and that volatility is inversely related to dividend size. But, the role that dividend policy plays in determining stock return volatility changes in the presence of 9/11 and airline crashes.

Not surprisingly, returns appear to be more volatile since 9/11, but in the presence of 9/11, dividend policy does not appear to impact return volatility. Similarly, stock return volatility increases industry-wide immediately following an airline crash, but dividend size has no statistically significant explanatory power. Yet, the effect of deregulation remains significant. Together, my findings suggest that controlling idiosyncratic risks appears to be much more important for controlling stock risk than dividend policy. This stands to reason given the nature of these risks relative to the risks inherent to other industries. That is, these risks reflect public safety concerns of a magnitude not typical for most businesses, implying that carriers would better serve their shareholders by replacing dividend payments with additional aircraft safety controls. For future work, an interesting extension of this research could be to conduct a cross-sectional study across industries to test the relation between the explanatory power of dividends over volatility, and the extent to which unique industry risks impact public safety. I hypothesize that the more an industry's risk is related to public safety, the less of an impact dividend policy would play in explain stock return volatility.

Also in Chapter 4, I test the impact that these risks have on owner's market risk. In sum, the only event that affected market risk was 9/11. I suggest that this reflects the devastating and unprecedented impact that 9/11 had on industry profits. Hence, the increase in expenses associated with an increase in macroeconomic variables now represents a larger portion of profits than it did before 9/11.

Finally in Chapter 4, I test my "luxury hypothesis" that air travel is largely a luxury that will be replaced by substitute forms of travel as the cost of living increases. My tests support this hypothesis by documenting a negative relation between changes in the consumer price index and airline stock returns. This relation is robust to lagged stock returns, but not to lagged consumer price indices, further supporting my argument. An interesting extension of this would be to test this relation in other travel-related industries. A negative relation between the findings in this study and the future findings of that study would further strengthen my hypothesis.

Lastly, in Chapter 5, I examine the right-hand side of carriers' balance sheets by studying the impact deregulation has on debt ratios and by testing the value of using operating leases as a form of financing. More specifically, because of the industry's well-known use of lease financing, I test the relation between the use of operating leases and operating profits of airlines. Prior literature debates whether leases and debt are substitutes for each other. I contribute to this debate by conjecturing whether the use of operating leases creates abnormal value relative to other forms of financing. Although mixed, I find a negative relation between the use of operating leases and profitability – not only suggesting that operating leases do not substitute for debt, but also that the use of operating leases is associated with lower operating profits. Whether operating leases are more expensive thereby yielding lower profits, or whether less profitable carriers are forced to use operating leases is unclear. This would be an interesting extension to this study. However, in either case, my findings suggest that operating leases are sub-optimal forms of financing.

Finally in Chapter 5, I extend recent work by Welch (2004) who found that changes in firm debt ratios are more fully explained by changes in the market value of equity than by management seeking a target debt ratio. My findings support this contention, and I extend it by testing the impact that deregulation has on this relation. From prior literature in Chapter 3, managers of regulated firms more closely monitor the capital markets than their deregulated counter parts. Further, prior literature suggests that regulated managers use debt as a tool for influencing regulatory policies. Hence, I hypothesize that debt levels will be different, and that the relation between debt levels and the market value of equity will differ between periods of regulation and deregulation.

My findings support the hypothesis that debt levels should be lower during deregulation, thereby suggesting that consistent with prior literature, regulated managers use debt to influence regulatory policy. However, my findings generally do not support the hypothesis that the relation between debt ratios and the market value of equity will be different. Together with the results from Chapter 3, I find support for the notion that economic regulation effectively creates a oligopoly, resulting in a more inefficient industry as evidenced by higher debt ratios and inflated earnings – the costs of which are passed on to consumers. Said another way, these combined results suggest that during regulation, carriers increase their debt levels as a means by which they can later argue the need for higher ticket prices. Given higher earnings, this suggests a disproportionate change in expenses. My tests further suggest that when competition is introduced via deregulation, managers become more cognizant of agency costs as evidenced by lower earnings and lower levels of debt.

REFERENCES

Ang, James & Peterson, Pamela P. "The Leasing Puzzle," *Journal of Finance*, 1984, v39(4), 1055-1065.

Baker, HK & Powell, GH. "Dividend Policy Issues In Regulated And Unregulated Firms: A Managerial Perspective," *Managerial Finance*, 1999, v25(6), 1-20.

Beattie, Vivien, Alan Goodacre & Thomson, Sarah. "Operating Leases And The Assessment Of Lease--Debt Substitutability," *Journal of Banking and Finance*, 2000, v24(3,Mar), 427-470.

Bernard, Victor, L. "Unanticipated Inflation And The Value Of The Firm," *Journal of Financial Economics*, 1986, v15(3), 285-322.

Borenstein, Severin & Nancy, L. Rose. “Bankruptcy and Pricing Behavior in U.S. Airline Markets”, *The American Economic Review*, 1995, 85, 2, May 397-402.

Bosch, Jean-Claude, E. Woodrow Eckard & Singal, Vijay. "The Competitive Impact Of Air Crashes: Stock Market Evidence," *Journal of Law and Economics*, 1998, v41(2,Oct), Part 1, 503-519.

Boudoukh, Jacob & Matthew Richardson. "Stock Returns And Inflation: A Long-Horizon Perspective," *American Economic Review*, 1993, v83(5), 1346-1355.

Boudoukh, Jacob; Matthew Richardson & Whitelaw, Robert, F. "Industry Returns And The Fisher Effect," *Journal of Finance*, 1994, v49(5), 1595-1615.

Bowen, Robert, M; Lane, Daley, A. & Huber, Charles C. Jr. "Leverage Measures And Industrial Classification: Review And Additional Evidence," *Financial Management*, 1982, v11(4), 10-20.

Bradley, Michael; Jarrell, Gregg, A. & Kim, E. Han. "On The Existence Of An Optimal Capital Structure: Theory And Evidence," *Journal of Finance*, 1984, v39(3), 857-878.

Brooks, LeRoy, D & Buckmaster, Dale, A. "Further Evidence Of The Time Series Properties Of Accounting Income," *Journal of Finance*, 1976, v31(5), 1359-1373.

Dasgupta, Sudipto & Nanda, Vikram. "Bargaining And Brinkmanship: Capital Structure Choice By Regulated Firms," *International Journal of Industrial Organization*, 1993, v11(4), 475-497.

DeAngelo, Harry & Masulis, Ronald, W. “Leverage and Dividend Irrelevancy Under Corporate and Personal Taxation,” *The Journal of Finance*, 1980, v35(2), 453-464.

Eckel, Catherine; Doug Eckel & Singal, Vijay. "Privatization And Efficiency: Industry Effects Of The Sale Of British Airways," *Journal of Financial Economics*, 1997, v43(2,Feb), 275-298.

Edelman, Richard, B & Kent Baker, H. “The Impact of Implementing the Airline Deregulation Act on Stock Returns”, *Journal of Economics and Finance*, 20, 1, Spring 1996, 79-99.

Elgers, Pieter, T & H. May, Lo, "Reduction In Analysts' Annual Earnings Forecast Errors Using Information In Prior Earnings And Security Returns," *Journal of Accounting Research*, 1994, v32(2), 290-303.

Elton, Edwin, J; Gruber, Martin, J & Blake, Christopher, R. "Survivorship Bias And Mutual Fund Performance," *Review of Financial Studies*, 1996, v9(4,Winter), 1097-1120.

Fama, Eugene, F & French, Kenneth, R. "Forecasting Profitability And Earnings," Journal of Business, 2000, v73(2,Apr), 161-175. Fama, Eugene, F; William Schwert, G. "Asset Returns And Inflation," *Journal of Financial Economics*, 1977, v5(2), 115-146.

Graham, John, R & Harvey, Campbell, R. "The Theory And Practice Of Corporate Finance: Evidence From The Field," *Journal of Financial Economics*, 2001, v60(2-3,May), 187-243.

Harris, Milton & Artur Raviv. "The Theory Of Capital Structure," *Journal of Finance*, 1991, v46(1), 297-356.

Hess, PJ & Lee, BS. "Stock Returns And Inflation With Supply And Demand Disturbances," *Review of Financial Studies*, 1999, v12(5,Winter), 1203-1218.

Klein, Robert, W; Phillips, Richard, D. & Wenyan Shiu. "The Capital Structure Of Firms Subject To Price Regulation: Evidence From The Insurance Industry," *Journal of Financial Services Research*, 2002, v21(1-2,Feb), 79-100.

Krishnan, VS & Moyer, RC. "Determinants Of Capital Structure: An Empirical Analysis Of Firms In Industrialized Countries," *Managerial Finance*, 1996, v22(2), 39-55.

Mikkelson, Wayne, H; Megan, Partch & Kshitij, Shah, M. "Ownership And Operating Performance Of Companies That Go Public," *Journal of Financial Economics*, 1997, v44(3,Jun), 281-307.

Modigliani, Franco & Merton Miller. "Corporate Income Taxes And The Cost Of Capital: A Correction," *American Economic Review*, 1963, v53(3), 433-442.

Moyer, R. Charles; Rao, Ramesh & Tripathy, Niranjan. "Dividend Policy And Regulatory Risk: A Test Of The Smith Hypothesis," *Journal of Economics and Business*, 1992, v44(2), 127-134.

Nissim, Doron & Ziv, Amir. "Dividend Changes And Future Profitability," *Journal of Finance*, 2001, v56(6,Dec), 2111-2133.

Panno, A. “An empirical investigation of the determinants of capital structure: The UK and Italian experience,” *Applied Financial Economics*, 2003, v13(2), 97-112.

Pastor, L & Veronesi, P. “Stocks valuation and learning about profitability,” *Journal of Finance*, 2003, v58(5, Oct), 1749-1789, Rao, Ramesh and R. Charles Moyer. "Regulatory Climate And Electric Utility Capital Structure Decisions," *Financial Review*, 1994, v29(1), 97-124.

Sarkar, S & Zapatery, F. “The trade-off model with mean reverting earnings: Theory and empirical tests,” *Economic Journal*, 2003, v113(490, Oct), 834-860.

Sharma, Jandhyala; Kamath, Ravi & Tuluca, Sorin. “Determinants of corporate borrowing: An application of a neural network approach,” *American Business Review*, 2003, v21(2), 63-73.

Stigler, George, J. "The Theory Of Economic Regulation," *Bell Journal of Economics*, 1971, v2(1), 3-21.

Wald, John, K. "How Firm Characteristics Affect Capital Structure: An International Comparison," *Journal of Financial Research*, 1999, v22(2,Summer), 161-187.

Welch, Ivo. “Capital Structure and Stock Returns,” *The Journal of Political Economy*, 2004, v112(1), 106-132.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 61-97
ISBN: 978-1-61122-079-7

Chapter 2

AIRLINE OPERATIONS CONTROL: A NEW CONCEPT FOR OPERATIONS RECOVERY[*]

António J. M. Castro and Eugénio Oliveira
LIACC-NIAD&R, FEUP, DEI, University of Porto, Portugal

ABSTRACT

The Airline Operations Control Centre (AOCC) of an airline company is the organization responsible for monitoring and solving operational problems. It includes teams of human experts specialized in solving problems related with aircrafts, crewmembers and passengers, in a process called disruption management or operations recovery. In this chapter we propose a new concept for disruption management in this domain. The organization of the AOCC is represented by a multi-agent system (MAS), where the roles that correspond to the most repetitive tasks are performed by intelligent agents. The human experts, represented by agents that are able to interact with them, are part of this AOCC-MAS supervising the system and taking the final decision from the solutions proposed by the AOCC-MAS. We show the architecture of this AOCC-MAS, including the main costs involved and details about how the system takes decisions. We tested the concept, using several real airline crew related problems and using four methods: human experts (traditional way), the AOCC-MAS with and without using quality-costs and the integrated approach presented in this chapter. The results are presented and discussed.

1. INTRODUCTION

Control the operation is one of the most important tasks that an airline company has. It does not matter much to produce an optimal or near-optimal schedule of flights if, later, during the execution of the operational plan, the changes to that plan caused by disruptions

---

[*] Most of this chapter was written based on previous publications by the same authors, specially “A New Concept for Disruption Management in Airline Operations Control”, Proc. IMechE Part G: J. Aerospace Engineering. All papers are referenced.

are too far from the original schedule. Unfortunately, the majority of the disruptions are difficult to predict (for example, those caused by meteorological conditions or by aircraft malfunctions). Airline companies developed a set of operations control mechanisms to monitor the flights (and crewmembers) to check the execution of the schedule. During this monitoring phase, several problems may appear related with aircrafts, crewmembers and passengers [1]. According to Kohl et al. [2], disruption management is the process of solving these problems. To be able to manage disruptions, airline companies have an entity called Airline Operations Control Centre (AOCC). This entity is composed of specialized human teams that work under the control of an operations supervisor. Although each team has a specific goal (for example, the crew team is responsible for having the right crew in each flight), they all contribute to the more general objective of minimizing the effects of disruption in the airline operational plan.

In this chapter we propose a new concept for disruption management in this domain. We see the AOCC as an organization with local goals (for example, minimizing the costs with aircraft, crew and/or passengers when solving a specific disruption) but also with global goals like minimizing delays and costs in a given period of time. The objective is to make the AOCC more efficient, quicker when solving disruptions and with better global decisions and performance. We believe that human experts should be managers and not controllers. In our opinion, repetitive tasks are performed better by software agents and tasks with a high degree of uncertainty are performed better by humans. For that we propose to represent the AOCC as an organization of agents, a multi-agent system (MAS), where the roles that correspond to the most repetitive tasks are performed by intelligent agents. The human experts, represented by agents that are able to interact with them, are part of this AOCC-MAS supervising the system and taking the final decision from the solutions proposed by the AOCC-MAS.

This chapter is organized as follows: In Section 2 we present a comparative summary of related work regarding operations recovery and a brief summary of the current use of software agents' technology in other domains. Section 3 introduces the Airline Operations Control Centre (AOCC), including typical organizations and problems, the current disruption management (DM) process and a description of the main costs involved. A classification of current tools and systems is also included. Section 4 is the main section of this chapter and presents our new concept for disruption management in AOCC, including details about how we built the agent-based approach to this problem. This section presents: (i) the reasons that made us adopt the software agents and multi-agent system (MAS) paradigm; (ii) the MAS architecture including the specific agents, roles and protocols as well as some relevant agent characteristics like autonomy and social-awareness; (iii) decision mechanisms, including costs criteria and negotiation protocols and (iv) examples of the problem solving algorithms used. In Section 5 we present the experimental setup and, in Section 6, we evaluate our approach, presenting and discussing the results. Finally, in Section 7, we conclude and give some insights on the future work.

2. SUMMARY OF RELATED WORK

We have divided this section in two parts. In section 2.1 we summarize the existing work regarding operations recovery. Most of the work in this area has been done using operation research methods (OR). For the interested reader Barnhart et al., [3] gives an overview of OR air transport applications. In section 2.2 we give an incomplete and brief list of agents applied in other domains.

2.1. Operations Recovery

The goal of this section is to present a brief comparative summary of research regarding operations recovery. We also classify each work according to the dimensions they are able to deal with, that is, aircraft recovery, crew recovery or integrated recovery. We classify a work as integrated when it is able to deal with, at least, two of the dimensions (for example, aircraft and passenger or aircraft and crew). Table 1 presents a descendent chronological order of research regarding airline disruption management. Most of this information was collect from Clausen et al., [34] and from [32] and, for detailed information about each work, we recommend reading the above mentioned papers.

2.2. Other Application Domains

The agent and multi-agent paradigm has been used in several application domains, including in other air transportation problems. To the best of our knowledge and regarding the use of this paradigm to represent the AOCC as an organization of agents, we believe that we were the first to do it [12, 14].

Regarding the use of agents in other domains a very brief list follows: Jonker et al., [17] propose a multi-agent system for ATC Tower operations. In the aviation domain but in a different context, Tumer and Agogino [15] present a multi-agent system for traffic flow management. Another use of agents in the context of collaborative traffic flow management is reported by Wolfe et al., [16]. Here, agents are used to compare routing selection strategies. As a last example and in completely different domain, Quelhadj [18, 19] developed an integrated dynamic scheduling system of steel production based on the multi-agent paradigm.

As we said in the beginning of this section, the examples above are an incomplete and very brief list of the use of the multi-agent system paradigm, just to give an idea that this technology is able to deal with very complex and critical problems.

3. AIRLINE OPERATIONS CONTROL

In this section we introduce the airline operations control problem – AOCP (also known as airline disruption management problem). To contextualize, we start by briefly introducing the AOCP preceding problem known as the Airline Scheduling Problem (ASP). Then we explain what an airline operational control centre (AOCC) is and we present some typical AOCC organizations. The typical problems, the current disruption management process as well as the main costs involved are also introduced. At the end of this section we present a classification of current tools and systems.

Table 1. Comparative summary of research regarding operations recovery

Author(s)	Year	Main Strategies/Objectives	Main Model/Solver	Airc. Rec.	Crew Rec.	Integ. Rec.
Abdelghany et al. [35]	2008	Resource reschedule; Flight Cancelations; Departure delays.	Mixed integer	---	---	Yes
Zhang & Hansen [71]	2008	Ground transportation (pax)	Integer with non-linear objective function	---	---	Yes
Mei Yang [5]	2007	Flight schedule modifications	Tabu search	Yes	No	No
Zhao & Zhu [72]	2007	Surplus aircraft; Delay; Cancellations; Cost.	Grey programming; Local search heuristic.	Yes	No	No
Eggenberg et al. [45]	2007	Recovery plans; Cancellations; Flight, delay, maintenance cost.	Set partitioning; Resource constraint shortest path.	Yes	No	No
Zhao et al. [73]	2007	Flight schedule modifications; Crew, Flight delay cost; Individual roster	Grey programming; Local search heuristic.	No	Yes	No
Castro & Oliveira [12]	2007	Crew and aircraft swap, reserve crew and aircraft; Crew cost; Individual roster.	Multi-agent system; Hill Climbing and Simulated annealing.	No	Yes	No
Medard & Sawhney [74]	2007	Assumes recovery flight schedule first; Illegal crew, uncovered flights and affect crew; Individual roster.	Set covering model; Depth-first search or reduced cost column generator.	No	Yes	No
Liu et al., [50,4]	2006/8	Flight connections and swaps; Total flight delay; Cancellations; Assignment.	Multi-objective genetic algorithm (Meta-heuristics)	Yes	No	No
Bratu & Barnhart [9]	2006	Delay, cancel, assign reserve crew and aircraft	Flight schedule network	---	---	Yes
Andersson [37]	2006	Cancellations, swap and fleet swap.	Tabu and Simulated Annealing (Meta-heuristics)	Yes	No	No
Nissen & Haase [55]	2006	Assumes recovery flight schedule first; Duty-based formulation; Modifications original schedule; Individual roster	Branch-and-price; Set covering; Resource constrained shortest path.	No	Yes	No
Stojkovic & Soumis [58]	2005	Departure delays; Reserve pilots; Modifications, uncovered flights, flight delays; Individual roster	Multi-commodity network flow; Column generation.	No	Yes	No
Love et al. [51]	2005	Cancellations; Revenue minus costs	Meta-heuristics	Yes	No	No
Andersson & Varbrand [38]	2004	Cancellations, swap and fleet swap	Set packing problem with generalized upper bound (GUB) constraints; Lagrangian relaxation-based heuristic and Dantzig-Wolfe decomposition.	Yes	No	No
Abdelgahny et al., [8]	2004	Deadheading, stand-by, swap, flight delay costs; Individual roster	Mixed-integer program;	No	Yes	No

Author(s)	Year	Main Strategies/Objectives	Main Model/Solver	Airc. Rec.	Crew Rec.	Integ. Rec.
Guo [46]	2004	Assumes recovery flight schedule first; Stand-by, modifications, operating costs; Individual roster	Set partitioning problem; Column generation with LP relaxation or Hybrid heuristic based in a genetic algorithm with a local search.	No	Yes	No
Kohl et al., [2]	2004	Flight swaps, cancellations, crew swaps, stand-by, up/downgrading crew; Passenger delay costs at destination, value of passenger based on the booked fare class and frequent flyer information.	Dedicated aircraft solver (Extension Local Search Heuristic [51]); Dedicated crew solver (Differential column-generation/constraint integer problem); Dedicated passenger solver (multi-commodity flow problem); Integrated recovery layer (Intelligent messaging system).	---	---	Yes
Yu et al. [70]	2003	Cancellations; Deadheading, modifications, uncovered flight costs	Depth-first search; *CrewSolver* optimization.	No	Yes	No
Rosenberger et al., [6]	2003	Delay and cancellation	Set partitioning model; Pre-processing heuristic; CPLEX 6.0.	Yes	No	No
Andersson [36]	2001	Delay, cancel, assign reserve crew and aircraft	Flight schedule network	---	---	Yes
Bard et al. [40]	2001	Delay and cancellation	Integer minimum cost flow model with additional constraints.	Yes	No	No
Thengvall et al. [65,66]	2001/3	Cancellations; Multi-fleet; Revenue minus cost	Three mixed-integer program models.	Yes	No	No
Stojkovic & Soumis [57]	2001	Modifications, uncovered flights, flight departure delays; Individual roster	Multi-commodity network flow with additional constraints; Column generation.	No	Yes	No
Lettovsky et al. [49]	2000	Cancellation; Pairing, cancel flight costs.	Set covering with decision variables; LP Relaxation and Branch-and-Bound	No	Yes	No
Thengvall et al. [64]	2000	Cancellations, swaps, delays; Revenue minus costs	Integer programming; LP relaxation with heuristic	Yes	No	No
Luo & Yu [53]	1998	Delayed flights	Assignment problem with side constraints; Heuristic	Yes	No	No
Stojkovic et al. [59]	1998	Assumes recovery flight schedule first; Pairing, Deadheading, undercovering costs; Individual roster	Integer non-linear multi-commodity flow network problem; Columns generation, branch-and-bound.	No	Yes	No
Lettovsky [10]	1997	Cancellation, delays, equipment assignment; Maximizes total profit.	Linear mixed-integer mathematical problem; Benders decomposition.	---	---	Yes
Wei et al. [67]	1997	Assumes recovery flight schedule first; Pairing cost	Integer multi-commodity network flow problem; Depth-first search	No	Yes	No

Table 1. (Continued)

Author(s)	Year	Main Strategies/Objectives	Main Model/Solver	Airc. Rec.	Crew Rec.	Integ. Rec.
Arguello et al. [39]	1997	Cancellations; Multi-fleet; Flight route augmentation, partial route exchange; Route cost and cancellation cost	Meta-heuristics (GRASP – Greedy Randomized Adaptative Search Procedure)	Yes	No	No
Luo & Yu [52]	1997	Number delayed flights under GDP (Ground Delay Program)	Assignment problem with side constraints; Heuristic	Yes	No	No
Cao & Kanafani [41,42]	1997	Cancellations; Revenue minus costs	Minimum cost network flow; Network flow algorithms.	Yes	No	No
Yan & Tu [68]	1997	Cancellations; Multi-fleet; Costs minus revenues	Network flow model with side constraints; Lagragian relaxation with subgradient method, Lagragian heuristic.	Yes	No	No
Clarke [43,44]	1997	Cancellations; Multi-fleet; Costs minus revenues	Set partioning, Column generation, extra constraints; Tree-search heuristic and a set packing-based optimal solution.	Yes	No	No
Yan & Yang [69]	1996	Cancellations; Costs minus revenues	Minimum cost network flow; Network flow algorithms.	Yes	No	No
Talluri [60]	1996	Multi-fleet; Swaps when exchanging aircraft type.	Classifies swap opportunities; Polynomial time algorithm.	Yes	No	No
Mathaisel [54]	1996	Cancellations; Revenue loss, operating cost	Minimum cost network flow; Network flow algorithms.	Yes	No	No
Teodorovic & Stojkovic [63]	1995	Cancellation and delay minutes; Crew considerations; Minimize total passenger delays.	Heuristic.	Yes	No	No
Johnson et al. [48]	1994	Pairing, stand-by, deadheading costs; Cancellations.	Set covering problem with decision variables; *MINTO* [75] (mixed integer optimizer)	No	Yes	No
Jarrah et al. [47]	1993/6	Cancellations; Delay, swap and ferrying.	Minimum cost network flow; Network flow algorithms.	Yes	No	No
Rakshit et al. [56]	1993/6	Cancellations; Delay, swap and ferrying.	Minimum cost network flow; Network flow algorithms.	Yes	No	No
Teodorovic & Stojkovic [62]	1990	Cancellation and delay minutes	Heuristic	Yes	No	No
Teodorovic & Guberinic [61]	1984	Delay minutes	Heuristic	Yes	No	No

3.1. Airline Scheduling Problem

According to Kohl et al., [2] the scheduling process of an airline company is composed by the long and short-term phases presented in Figure 1. The scheduling process has three main dimensions or views: (1) passenger view; (2) aircraft view and (3) crew view. The first one represents the seats available to be sold to the airline customers. The other two views, represents resources that will be allocated.

Everything starts with *publishing the flights timetable* for a specific period of time (usually six months). After publishing the timetable, the *revenue management* phase starts. Here the goal is to maximize the revenue obtained selling tickets. At the same time, the scheduling of the two most important resources starts: aircrafts and crew. Regarding the aircraft, the first step is the *fleet assignment*. Here, the goal is to assign the aircraft type or aircraft fleet that will perform the flights. It is an important step because the aircraft type/fleet will define the number of available seats in each flight. Near to the day of operations, the assignment of the specific aircraft to each flight is performed. This step is known as *tail assignment*. After the fleet assignment step, it is possible to start to schedule the crew. The first step is the *crew pairing*. The goal is to define the crew duty periods (pairings) that will be necessary to cover all the flights of the airline for a specific period of time (typical one month). Having the pairings, it is possible to start the *crew rostering* step that is, assign crewmembers to the pairings. The output of this step is an individual crew roster that is distributed or published in the crew web portal. Finally and until the day of operations, it is necessary to change/updated the crew roster (*roster maintenance*), to include any changes that might appear after publishing the roster. The airline scheduling problem (ASP) is composed of all the previous phases and steps and ends some hours or days (depends on the airline policy) before the day of operation. The global objective of the ASP is to maximize the airline operating profit. For more detailed information please consult [20] specially Section 2.1 to Section 2.4.

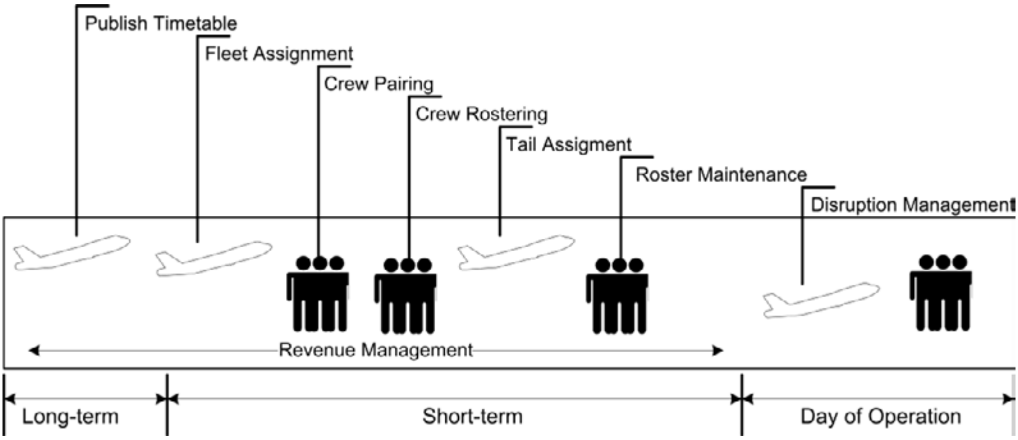


Figure 1. The airline scheduling process.

3.2. AOCC Organization

The airline operations control problem (AOCP) starts where the airline scheduling problem stops. If everything goes as planned the airline just needs to monitor the execution of the plan. Unfortunately, several unexpected events appear during this phase that can disrupt the plan. To monitor those events and solve the problems that arise from these, it is necessary to define and follow a disruption management process. Airline companies have an entity called Airline Operations Control Centre (AOCC) that is responsible for the disruption management process. There are three main types of AOCC organizations [11]:

- *Decision Centre*: The aircraft controllers share the same physical space. The other roles or support functions (crew control, maintenance service, etc.) are in a different physical space. In this type of *Collective Organization* all roles need to cooperate to achieve the common goal.
- *Integrated Centre*: All roles share the same physical space and are hierarchically dependent of a supervisor. For small companies we have a *Simple Hierarchy Organization*. For bigger companies we have a *Multidimensional Hierarchy Organization*. Figure 2 shows an example of this kind of AOCC organization.
- *Hub Control Centre (HCC)*: Most of the roles are physically separated at the airports where the airline companies operate a hub. In this case, if the aircraft controller role stays physically outside the hub we have an organization called *Decision Centre with a hub*. If both the aircraft controller and crew controller roles are physically outside the hub we have an organization called *Integrated Centre with a hub*. The main advantage of this kind of organization is to have the roles that are related with airport operations (customer service, catering, cleaning, passengers transfer, etc.) physically closer to the operation.

The organization adopted depends on several factors like airline size, airline network type (for example, hub-and-spoke) and geographic distribution of the operation, as well as, tradition and/or company culture.

In Figure 2 we present the organization of a typical *Integrated Operational Control Centre*. It is important to point out the role of the supervisor, a characteristic that makes this organization hierarchical and, also, the operation time-window that marks the responsibility boundaries of the AOCC. This operation time-window is different from airline to airline but, usually, ranges from 72 to 24 hours before to 12 to 24 hours after the day of operation.

The roles or support functions more common in an AOCC, according to Kohl et al., [2] and [11], are the following:

- *Flight Dispatch*: Prepares the flight plans and requests new flight slots to the Air Traffic Control (ATC) entities (FAA in North America and EUROCONTROL in Europe, for example).
- *Aircraft Control*: Manages the resource aircraft. It is the central coordination role in the operational control. In a disruptive situation, tries to minimize the delays by changing aircrafts and rerouting or joining flights, among other actions. Usually, uses some kind of computer system to monitor the operation that, in some cases, might

include some decision supports tools. Much more common is the use of *rules-of-thumb* based on work experience (a kind of hidden knowledge).

- *Crew Control*: Manages the resource crew. Monitors the crew check-in and check-out, updates and changes the crew roster according to the disruptions that might appear during the operation. Like the previous role, it uses some kind of system with or without decision support tools. The experience and the use of *rules-of-thumb* are still the most common decision tools. To use reserve crew and exchange crewmembers from other flights, are among the possible actions used to solve crew problems.
- *Maintenance Services*: Responsible for the unplanned maintenance services and for short-term maintenance scheduling. Changes on aircraft rotations may impact the short-term maintenance (maintenance cannot be done at all stations).
- *Passenger Services*: Decisions taken on the AOCC will have an impact on the passengers. The responsibility of this role is to consider and minimize the impact of the decisions on passengers, trying to minimize the passenger trip time. Part of this role is performed on the airports and for bigger companies it is part of the HCC organization.

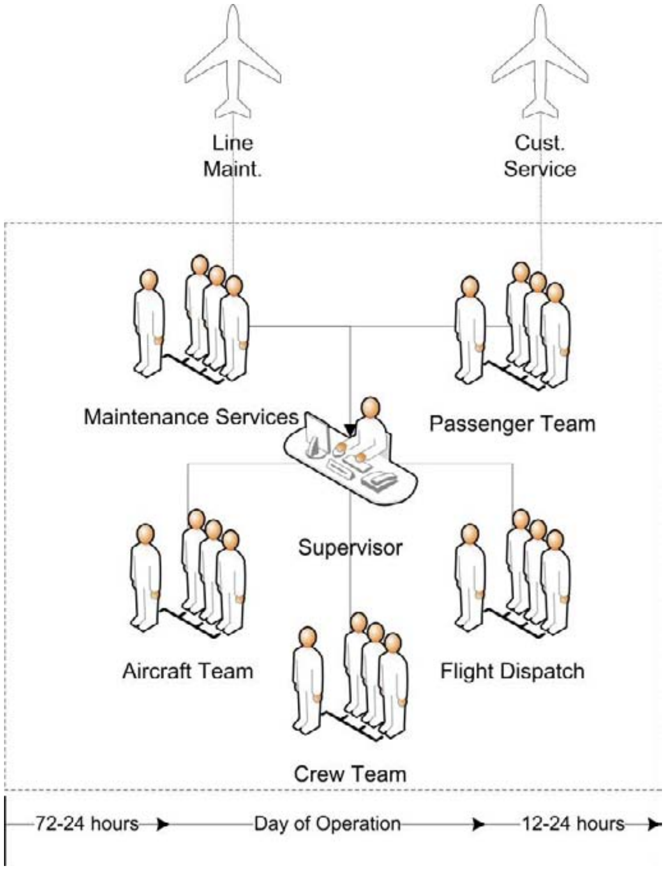


Figure 2. Integrated airline operational control centre.

3.3. Typical Problems

In the previous section we presented typical AOCC organizations and the roles that exist on those organizations. Now, it is important to understand the typical problems that appear during the execution of the airline operation. From our observations in a real AOCC, and from Kohl & Karisch [21], we found the typical problems presented in Figure 3. In this diagram we have also included the impact that each problem might have on flight arrival or departure delays as well as the relation that exist between them. The diagram also shows that the problems might propagate due to the relation between them and generate new problems on different flights. This propagation characteristic makes the problem more difficult to be solved optimally in a real time and dynamic environment, like the one we have on the AOCC. As we can see in Figure 3 there is an obvious relation between *Flight Arrival Delays* and *Flight Departure Delays*. Most of the flights are performed by aircrafts that are used in previous flights. If we have an arrival delay and the aircraft turn-around time at the airport is not enough, then, if the AOCC does not find an alternative solution, we will also have a departure delay. From the diagram we can also see that the main reasons for flight arrival delay (besides the delay on departure) are: *En-route air traffic*, *en-route weather*, *en-route aircraft malfunction* and *flight diversion*. In the previous cases and to minimize the arrival delay it is necessary a cooperation between the pilot, the AOCC and ATC. Regarding departure delays, the main reasons are: *crew delays*, *cargo/baggage loading delays* and *passenger delays* as a consequence of an *arrival delay*. Crewmembers that do not report for duty, air traffic control reasons, aircraft malfunctions and weather conditions (at departure or at arrival) are the other main reasons for departure delays.

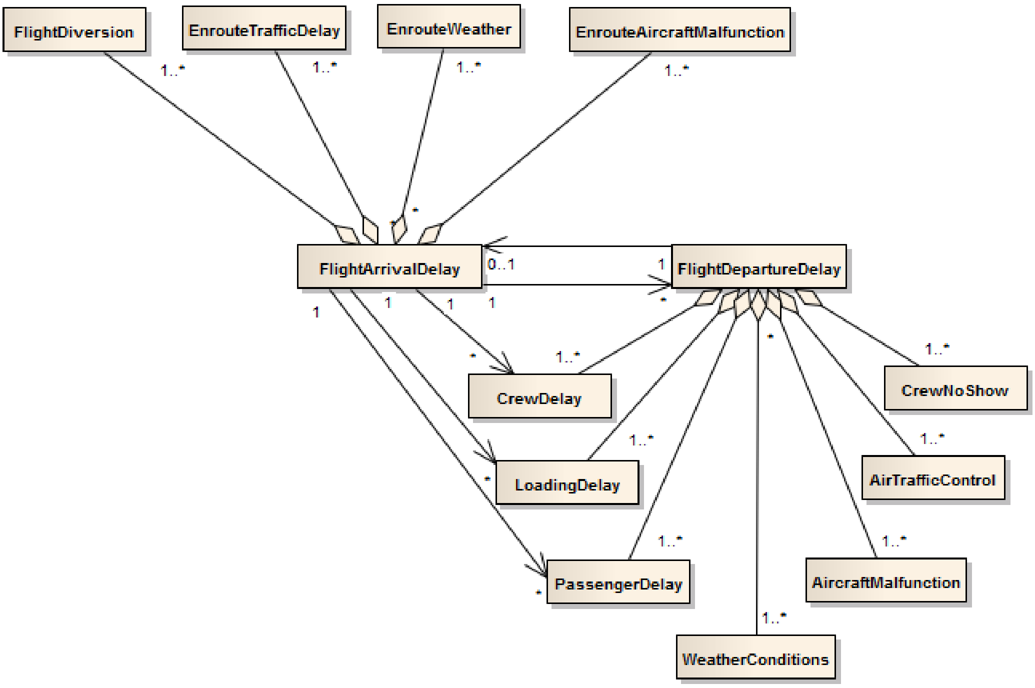


Figure 3. Typical AOCC problems and relations.

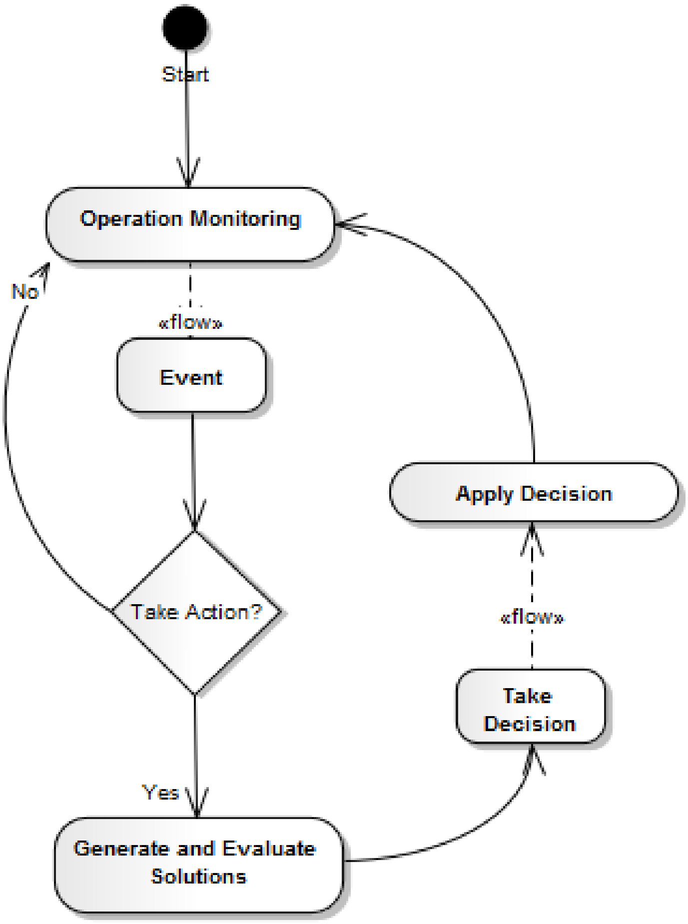


Figure 4. AOCC disruption management process.

3.4. Current Disruption Management Process

As we can see from the previous section, there are several problems that might cause flight delays. AOCCs have a process to monitor the events and solve the problems, so that flight delays are minimized with the minimum impact on passenger and, preferably, with the minimum operational cost. In Figure 4 we present the current disruption management process in use at most of the airlines. This process has five steps:

1. *Operation Monitoring*: In this step the flights are monitored to see if anything is not going according the plan. The same happens in relation with crewmembers, passenger check-in and boarding, cargo and baggage loading, etc.
2. *Take Action*: If an event happens, like for example, a crewmember is delayed or an aircraft malfunction, a quick assessment is performed to see if an action is required. If not, the monitoring continues. If an action is necessary than we have a problem that needs to be solved.

3. *Generate and Evaluate Solutions*: Having all the information regarding the problem the AOCC needs to find and evaluate the candidate solutions. Usually, a sequential approach is adopted when generating the solutions. First, the aircraft problem is solved. Then, the crew problem and finally, the passengers. It is understandable that the AOCC adopts this approach. Without good computer tools, it is difficult to take care of the problem, considering the three dimensions (aircraft, crew and passengers) simultaneously. Although there are several costs involved in this process, we found that the AOCC relies heavily on the experience of their controllers and in some *rules-of-thumb* (a kind of hidden knowledge) that exist on the AOCC.
4. *Take Decision*: Having the candidate solutions a decision needs to be taken.
5. *Apply Decision*: After the decision the final solution needs to be applied in the environment, that is, the operational plan needs to be updated accordingly.

In our opinion, this process can greatly benefit from an intelligent agent based approach to the problem, as we will explain in Section 4.

3.5. Main Costs Involved

In the step *Generate and Evaluate Solutions* of the disruption management process on the previous section, we should consider the main costs involved in generating and choosing from candidate solutions. According to our observations these are the main costs involved when generating and evaluating a solution for a specific disruption:

1. *Crew Costs:* the average or real salary costs of the crewmembers, additional work hours and perdiem days to be paid, hotel costs and extra-crew travel costs.
2. *Flight Costs:* airport costs (approach and taxing taxes, for example), service costs (cleaning services, handling services, line maintenance, etc.), and average maintenance costs for the type of aircraft, ATC en-route charges and fuel consumption.
3. *Passenger Costs:* passenger airport meals, passenger hotel costs and passenger compensations.

Finally, there is a less easily quantifiable cost that is also included: the cost of delaying or cancelling a flight from the passenger point of view. Most airlines use some kind of *rule-of-thumb* when they are evaluating the impact of the decisions on passengers. Others just assign a monetary cost to each minute of delay and evaluate the solutions taking into consideration this value. In a previous work [31, 32] we propose a different way of calculating this cost component. Section 4.5 highlights the most important parts of this approach.

3.6. Current Tools and Systems

In a previous work [11] we have classified the current tools (or systems that provide those tools) in use at AOCCs in one of these three categories:

1. Database Query Systems (DBQS)
2. Decision Support Systems (DSS)
3. Automatic or Semi-Automatic Systems (ASAS)

The *DBQS – Database Query Systems* (the most common situation at airlines) allows the AOCC human operators to perform queries on the existing databases to monitor the airline operation and to obtain other data essential for decision-making. For example, the aircraft and/or crew roster, aircraft maintenance schedule, passenger reservations, and so on. These systems are useful and relatively easy to implement and/or acquire but they have some important disadvantages, for example, to find the best solution and to take the best decision is completely dependent on the human operator. As we have explained in [11] there are two problems when airline companies use only this type of systems: (1) the solution quality is dependent on knowledge and experience of the human operator and, (2) due to the usual difficulty of the human being in leading with large volumes of data simultaneously, they do not use all the necessary information (variables) to take the best decision.

The *DSS - Decision Support Systems*, besides having the same characteristics of the DBQS, also include additional functionalities to support the human operators on the decision-making. For example, after a request made by a human operator, these systems are able to recommend the best solution to solve a problem related with a delayed aircraft. Some of them may just recommend a flight re-scheduling but others are able to justify the candidate solution as well as to present the solution cost. DSS systems eliminate some of the disadvantages of the DBQS systems. Namely, they are able to analyse large volumes of data and, because of that, propose solutions that take into consideration more information (variables). The decision-making still is on the human operator side but, now, he is able to take better decisions. Unfortunately, one of the big problems with airline companies is the absence and/or complexity of the computerized information system keeping all the operational information. These are of paramount importance for the success of the decision support tools. This problem, referred in [2] as the Data Quality and System Accessibility Problem, gains more importance when we start to implement decision support tools and/or automatic or semi-automatic systems.

The goal of the third type of systems, *ASAS – Automatic or Semi-Automatic Systems*, is to automate as much as possible the AOCC, replacing the functional part by computerized programs. Specifically, these systems try to automate the repetitive tasks and also the tasks related with searching for the best solution (problem solving). In a totally automatic system, decision-making is also taken by the system. In a semi-automatic system, the final decision is taken by the human operator. In ASAS type of systems, the AOCC does not need as much human operators as in the previous ones, to operate correctly. Usually, roles or functions related with operation monitoring, searching for solutions related with aircraft, crew or passenger problems and re-allocation of resources, are performed by specialists agents [12] replacing the human specialists. The final decision regarding the application of the solution found by these systems on the environment (for example, making the necessary changes on the airline operational plan database) depends on the human supervisor. According to [13] and [14] the agent and multi-agent systems paradigm is more appropriate to be used in this domain than any other paradigm. Our new concept for operations recovery fits in this type of systems.

4. A NEW CONCEPT FOR OPERATIONS RECOVERY

In Section 3 we introduced the Airline Scheduling Problem and the Airline Operations Control Problem (or Disruption Management Problem). We have described the AOCC organization and roles as well as the typical problems that appear during the execution of the operational plan. The disruption management process used by airlines was presented as well as the main costs involved in generating and evaluating the solutions. We have also classified the current tools and systems in three categories.

In this section we present our new concept for disruption management in the airline domain, including how we represent the AOCC using a multi-agent system (MAS), an organization of intelligent agents. To implement the MAS we have used Java[1] and JADE [22]. These tools provide the necessary development framework and runtime environment for our agents.

4.1. Introduction

Looking at the current roles in the AOCC (Figure 2), we see that some of them correspond to very repetitive tasks. For example, the *aircraft controller* (a member of the aircraft team) is constantly checking the computer system (including, e-mail, *datalink* system, telex, etc.) to see if there is any problem that might affect the departure or arrival of a flight. A similar routine regarding monitoring crewmembers is performed by the *crew controller* (a member of the crew team). When a problem is detected, the process of solving it is also very repetitive. For example, if a flight is delayed, the possible and general actions than an *aircraft controller* has to solve the problem are (the applicability of each action depends on the specific problem at hand):

1. Use an aircraft from a later flight (change aircrafts).
2. Reroute the flight (helpful when the delay is related with slots).
3. Join flights (use one aircraft to also perform the flight of the broken aircraft).
4. Freight an aircraft and crew from another company, also known as ACMI – Aircraft, Crew, Maintenance and Insurance.
5. Delay the flight.
6. Cancel the flight.

The crew controller also performs very repetitive tasks when trying to solve crew problems. For example, the general actions he can use to solve the problems are (the applicability of each action depends on the specific problem at hand):

1. Use a reserve crew at the airport.
2. Use a reserve crew that lives near the airport.
3. Use another crew from another flight.
4. Invite a day off crew.

---

[1] http://www.java.com

5. Propose to change the aircraft to a different aircraft type.
6. Proceed without the crewmember.
7. Delay the flight.
8. Cancel the flight.

Taking into consideration the above as well as the characteristics of the agent and multi-agent paradigm (see next section) we propose to represent the AOCC by a multi-agent system, replacing the monitoring, aircraft controller, crew controller and part of the passenger role, by intelligent agents as represented in Figure 5.

In this new approach, the aircraft team will be replaced by a sub-organization of agents (represented as *Aircraft Manager*). The same will happen to the crew team (represented as *Crew Manager*). Regarding the passenger services, we propose to replace by software agents the task of finding the best solutions to the problems with passengers (usually a plan of alternative flights to each disrupted passenger) and keep the other tasks to be performed at the airports by human operators (represented as *Passenger Manager* in figure 5). The supervisor interacts with the software agents through an interface agent.

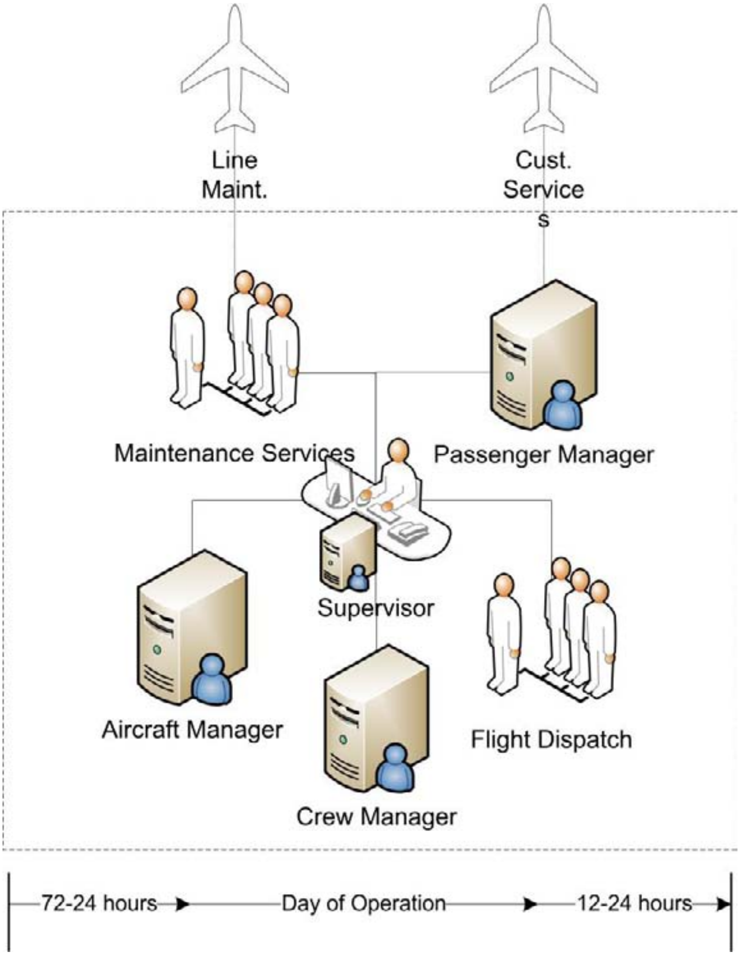


Figure 5. New concept for integrated Airline Control Centre.

4.2. Why an Agent and Multi-Agent System Paradigm?

Before presenting the architecture of our multi-agent system, it is important to point out the characteristics of this paradigm, according to [13, 23], that make us adopt it to model this problem. Table 2 summarizes the characteristics. For the interested reader, more details are available in [32], section III.

Table 2. Summary of the MAS paradigm characteristics

Characteristic	Main reason
Autonomy	Problems are modelled as autonomous interacting components. The *Crew Manager*, *Pax Manager* and *A/CManager* in figure 6 are example of that. They can choose to respond or not to the requests according to their own objectives.
Natural Metaphor	The AOCC modelled as an organization of cooperating agents is a natural metaphor.
Reactivity	Agents are able to perceive and react to the changes in their environment. The *Monitor* agent in figure 6 is an example of such an agent.
Resource Distribution	With a MAS we can distribute the computational resources and capabilities across a network of interconnected agents avoiding problems associated with centralized systems. Airline companies of some dimension have different operational bases. We use a MAS for each operational base, taking advantage of this important characteristic. Due to the *social awareness* characteristics of some of our agents (for example, *Monitoring* agent in Figure 6) they are able to distribute their tasks among other agents with similar behaviour.
Scalability and Modularity	A MAS is extensible, scalable, robust, maintainable, flexible and promotes reuse. These characteristics are very important in systems of this dimension and complexity. Our MAS is able to scale in terms of supporting more operational bases as well as in supporting different algorithms to solve specific problems.
Parallelism/ Concurrency	These characteristics are important if we want a fault-tolerant system and if we want to speed up computation. Our *Specialist* agents in figure 6 are example of that. Agents are capable of reasoning and performing tasks in parallel. This provides flexibility and speeds up computation. Our *Specialist* agents in figure 6 are examples of concurrent agents. Additionally and according to Stone & Veloso [24] "if control and responsibilities are sufficiently shared among agents, the system can tolerate failures by one or more agents". Our MAS can be totally or partially replicated in different computers. If one or more agents fail, the global objective is not affected.
Legacy Systems	Legacy systems can be wrapped in an agent layer to be able to interact with other systems. It the air transportation domain, most likely, we need to interact with older but functional systems. So, this characteristic is very important.

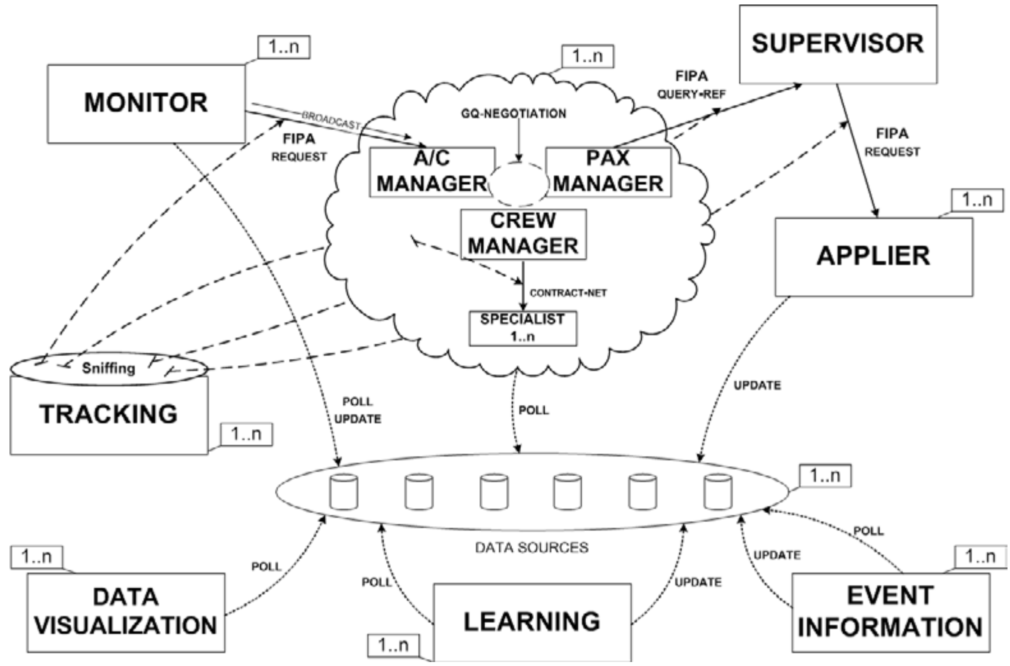


Figure 6. MAS architecture.

4.3. MAS Architecture

To develop a software system it is important to follow a methodology. Multi-agent systems are not an exception. The architecture presented here is the result of following an agent-oriented methodology, specifically an adaptation of GAIA according to [25]. The base for this architecture was the service and agent model that resulted from following the methodology.

Figure 6 shows the architecture of our multi-agent system approach. The boxes represent agents, the solid lines represent interactions between agents and the dash lines represent actions in the environment. The cloud represents the negotiation at the managers' level. In this figure we are representing only *one instance* of the system. All agents can be replicated with the exception of the *Supervisor* agent. Each agent performs one or more roles in the AOCC. The *Monitor* agent looks for events on the operational plan that may trigger any aircraft/flight, passenger and/or crew problem. This agent has *social-awareness* characteristics in the sense that it is able to recognize and interact with other agents with the same role, splitting the tasks. For example, if each monitor agent instance corresponds to a different hub, they will monitor the corresponding hub operational plan. This agent, like others in our system, is *autonomous* because it is able to consider an event as a problem only when specific conditions or characteristics are present.

The *CrewManager* and *A/CManager* agents are responsible for crew and aircraft/flight problems, respectively. They manage a team of expert agents [12] with the role of finding solutions for the problems in their area of expertise. The expert or specialist agents implement different heterogeneous problem solving algorithms and are able to run in parallel. The managers are *autonomous* because they only respond to requests related with their area of expertise. To find the best solution regarding passenger problems we have the *PaxManager*.

The agent *Supervisor* and agent *EventInformation* are the only ones that interact with a human user of the AOCC. The solutions selected by the *Supervisor* are presented to the human. Includes solution details (and the rationale behind the solution) to help the human decide and are ranked according to the criteria of the airline company. After getting approval from the human supervisor, the *Supervisor* agent requests *Applier* agent to apply it on the environment.

In figure 6, *Data Sources* represent the environment that all agents are able to observe and act upon. All the necessary information is included in the data sources. For example, company and airport information, flight schedule, aircraft and crew rosters, etc.

Additional information to support some characteristics of the MAS like learning is also included on the data sources. The *Tracking* agent supports the tracking characteristics of the system and the *Data Visualization* agent supports the visualization of the information (flight movements, delays, problems, etc.) showing what is happening at the AOCC. Figure 7 shows a partial GUI updated by the *Data Visualization* agent.

There is also a *Learning* agent that will support the advanced learning characteristics of the system (not implemented yet). In Section 7, the interested reader can find more information about the way we expect to apply learning in our MAS. Finally, the protocols we use are the following (the first three are FIPA[2] compliant ones):

- *Fipa-Request*: This protocol allows one agent to request another to perform some action and the receiving agent to perform the action or reply, in some way, that it cannot perform it. Fipa-request is used in interactions between the *Monitor* and *Crew*, *Pax* and *A/C Manager* interactions.
- *Fipa-Query*: This protocol allows one agent to request to perform some kind of action on another agent. It is used in the interactions that involve *PaxManager*, *A/CManager*, *CrewManager* and *Supervisor* agent; *Supervisor*, *Applier* and *EventInformation* agent and, finally, *EventInformation* and *Monitoring* agent.
- *Fipa-Contract.net* [29]: A simplified version of this protocol is used in the interactions between the *Managers* and the *expert/specialised* agents.
- *GQ-Negotiation*: This negotiation protocol is a generalization of the Q-Negotiation protocol as presented in [26]. We use it at the manwaer agents' level so that we can get the best integrated solution. The next section gives more information about this protocol.

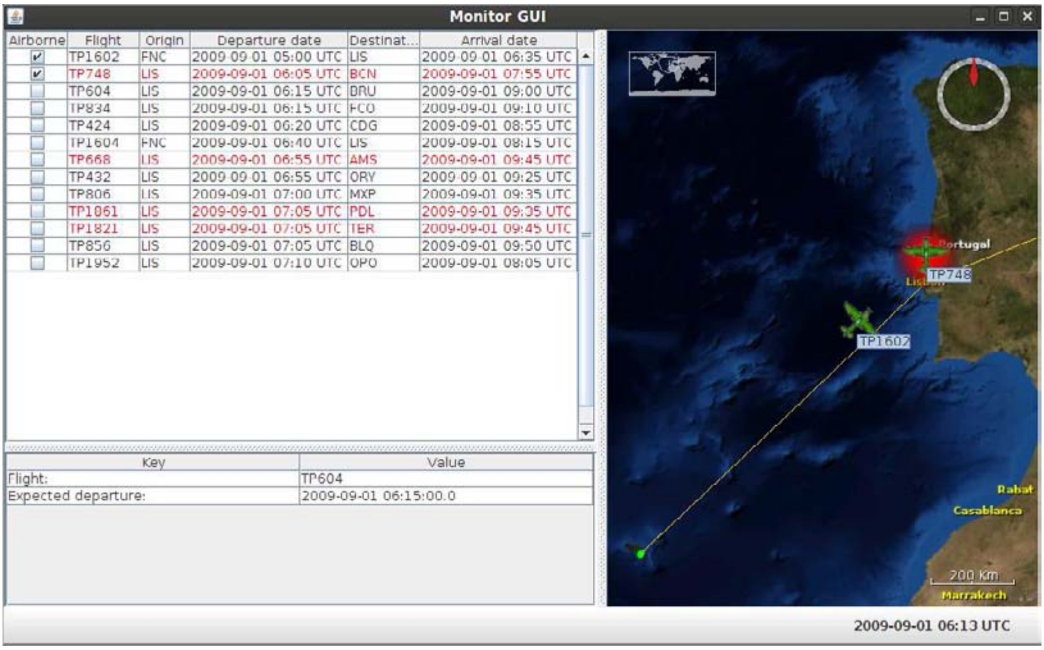
4.4. Decision Mechanisms

We use two levels of negotiation. The *Manager Agents Level*, that is, between *A/CManager*, *CrewManager* and *PaxManager*. At this level they cooperate to find an integrated solution, that is, one that includes the impact on passengers, crew and aircraft.

The *Team Level* (or *Specialist Agents Level*), that is, between each manager and the expert/specialist team agents. In the following sections we explain both decision mechanisms.

---

[2] http://www.fipa.org



Airborne	Flight	Origin	Departure date	Destinat...	Arrival date
☑	TP1602	FNC	2009-09-01 05:00 UTC	LIS	2009-09-01 06:35 UTC
☑	TP748	LIS	2009-09-01 06:05 UTC	BCN	2009-09-01 07:55 UTC
☐	TP604	LIS	2009-09-01 06:15 UTC	BRU	2009-09-01 09:00 UTC
☐	TP834	LIS	2009-09-01 06:15 UTC	FCO	2009-09-01 09:10 UTC
☐	TP424	LIS	2009-09-01 06:20 UTC	CDG	2009-09-01 08:55 UTC
☐	TP1604	FNC	2009-09-01 06:40 UTC	LIS	2009-09-01 08:15 UTC
☐	TP668	LIS	2009-09-01 06:55 UTC	AMS	2009-09-01 09:45 UTC
☐	TP432	LIS	2009-09-01 06:55 UTC	ORY	2009-09-01 09:25 UTC
☐	TP806	LIS	2009-09-01 07:00 UTC	MXP	2009-09-01 09:35 UTC
☐	TP1861	LIS	2009-09-01 07:05 UTC	PDL	2009-09-01 09:35 UTC
☐	TP1821	LIS	2009-09-01 07:05 UTC	TER	2009-09-01 09:45 UTC
☐	TP856	LIS	2009-09-01 07:05 UTC	BLQ	2009-09-01 09:50 UTC
☐	TP1952	LIS	2009-09-01 07:10 UTC	OPO	2009-09-01 08:05 UTC

Key	Value
Flight:	TP604
Expected departure:	2009-09-01 06:15:00.0

2009-09-01 06:13 UTC

Figure 7. User Interface (Partial) updated by the Data Visualization agent.

4.4.1. Manager agents level negotiation

At this level we are using a generalization of the *Q-Negotiation* protocol present in Rocha & Oliveira [**26, 27**]. Rocha & Oliveira propose a negotiation mechanism in the context of agent-based Virtual Organisation (VO) formation process, which selects the optimal group of organisations that satisfies the VO needs. In this scenario, each organisation has the objective to maximize its own profit and, for that, the negotiation process takes into account the rationality and self-interestedness of the agents. The *Q-Negotiation* includes a multi-attribute negotiation with several rounds and qualitative feedback. Additionally, the agents are able to learn (adapt) their strategies during bid formulation, due to the inclusion of a Q-Learning algorithm. According to the authors "(…) Q-Learning enables on-line learning, which is an important capability (…) where agents will learn in a continuous way during all the negotiation process, with information extracted from each one of the negotiation rounds, and not only in the end with the negotiation result". We believe that the *Q-Negotiation* protocol can be useful in our domain, given that we perform the necessary adaptation.

Figure 8 shows a simplified version of the *GQ-Negotiation* protocol (Generic *Q-Negotiation*) that results from the adaptation of Rocha & Oliveira protocol, applied to our domain.

The *Monitor* agent sends the problem to the *Supervisor* agent, including information about the dimension affected (aircraft, crew or passenger) as well as the schedule time and costs (flight, crew and passenger). The agent *Supervisor* assumes the role of *organizer* and using the information about the problem, prepares an *call-for-proposal* (cfp) that includes the problem, a range of preferred values for delay, flight costs, crew costs, passenger costs,

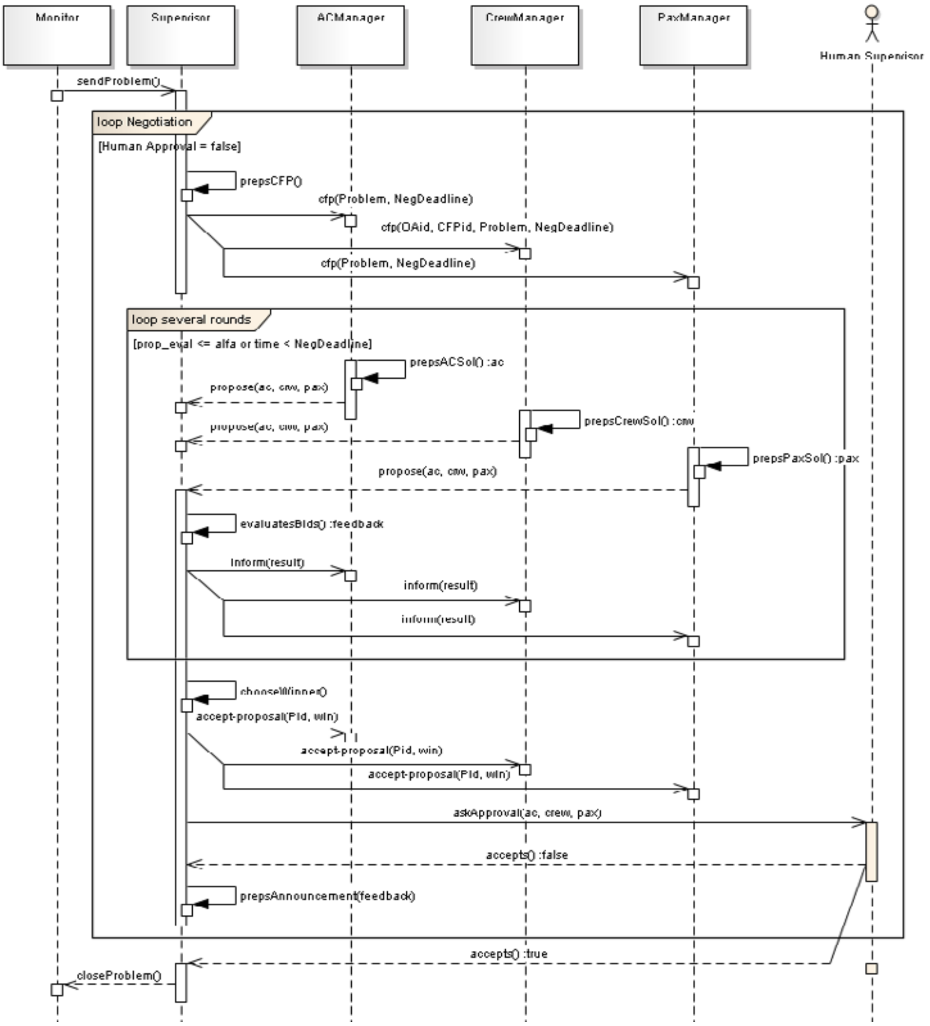


Figure 8. GQ-Negotiation Protocol (simplified version).

passenger trip time and a negotiation deadline. After the cfp, the first round of negotiation starts. The *ACManager*, *CrewManager* and *PaxManager* agents (*respondent* agents) present the proposal according to their interests. For example, the *ACManager* wants to minimize the flight costs and delay and the *PaxManager* wants to minimize the passengers trip time and cost. It is important to point out that the proposals presented by the *respondent* agents are based on the candidate solutions found by their specialist agents as explained in section 4.4.2 and 4.6. The proposals are evaluated by the *Supervisor* and qualitative feedback is sent to the *respondent* agents. At this time we use a simple function to evaluate the proposals as indicated in Equation 1.

$$ev = \frac{\alpha\left(\frac{da}{\max(DA)}\right) + \beta\left(\frac{dc}{\max(DC)}\right) + \gamma\left(\frac{tt}{\max(TT)}\right) + \frac{\delta}{3}\left(\frac{ac}{\max(AC)} + \frac{cc}{\max(CC)} + \frac{pc}{\max(pc)}\right)}{\propto + \beta + \gamma + \delta} \qquad (1)$$

In this equation *da*, *dc* and *tt*, represents the aircraft delay, crew delay and passenger trip time; *ac*, *cc* and *pc* represents the aircraft cost, crew costs and passenger cost of a specific proposal. The set of aircraft delay from all proposals is represented by *DA* and a similar approach is followed for the other equation components. Each component has a weight represented by α, β, γ and δ with values between 0 and 1.

Using the feedback, the *respondent* agents change their proposals. The bid formulation process uses a Q-Learning algorithm endowing the agent with the capability to learn on-line along the negotiation process. This loop of proposals and feedback ends when the *Supervisor* agent founds a proposal that satisfies its preferences. The *respondent* agents are informed of the result. After having the best solution, the *Supervisor* agent shows to the *human supervisor* the solution and the rationale behind it. The *human supervisor* can choose to apply it or not. If he chooses to not apply the solution, some feedback is given. For example and for a specific problem, it might be better to have lower passenger costs even if it means higher flight costs. Using this feedback, the *Supervisor* agent (the one with the *organizer* role in the negotiation process) improves the range of preferences included in the cfp and the negotiation process restarts. Before finish this section, it is important to point out that Ehlers & Langerman [28] proposed the use of an Intelligent Interface Agent that uses an hybrid approach (combination of an expert system and a Q-Learning system) to learn the preferences of the users when solving disruptions in airline schedules. Although there are some similarities (starting with the domain), we believe that our approach differs considerably. For example, we use a multi-agent system that represents the AOCC and in this context, the agents are able to negotiate and learn autonomously. There are other differences but this one, by itself and in our understanding, shows the main difference between the two approaches.

4.4.2. Team level negotiation

At the Team Level we use a fipa-contract.net [29, 30] protocol with some modifications. Figure 9 presents this protocol applied to the *CrewManager* team.

The *Monitoring* agent requests a solution to a specific problem. If the *CrewManager* agent (*organizer*) has expertise to propose a solution, he can decide to reply. For that, he issues a *cfp* (call for proposal) to start the negotiation process. On the *cfp* it is included information about the problem as well as deadlines for receiving an answer (*refuse/propose*) and for receiving the candidate solution from the *responder agent* (*CrewSimmAnneal* in the example).

The *respondent* agent answers back with *refuse* or *propose*. If he answers with *propose* it means that he will seek for a possible solution according to the *cfp* conditions. The *organizer* agent answers back with an *accept-proposal*. To speed-up the communication, it was here that we have simplified the protocol. In our approach, we do not need to select from the received answers because we want all available agents to work in parallel. That is the reason why the answer from the *respondent* agents is “yes” or “no”, meaning that they are available (or not) to seek for candidate solutions. If the *respondent* agent finishes the task with success, it will send the candidate solution included in the *inform-result* performative. If he fails, the reasons are included in a *failure* performative.

Table 3. Summary of costs involved

#	Equations	Description
2	$tc = dc + \beta qc \qquad \beta \in R, \beta \geq 0$	*Total Operational Cost (tc)* includes Direct Operational Costs (dc) and Quality Operational Costs (qc).
3	$dc = cc + fc + pc$	*Direct Operational Costs (dc)* of a specific solution are costs that are easily quantifiable and are related with the operation of the flights, namely, *Crew Costs (cc)*, *Flight Costs (fc)* and *Passenger Costs (pc)*.
4	$cc = \sum_{i=1}^{\lvert F\rvert}\sum_{j=1}^{\lvert C\rvert}(Salary_{\{i,j\}} + Hour_{\{i,j\}} + Perdiem_{\{i,j\}} + Hotel_{\{i,j\}} + Dhc_{\{i,j\}})$ $where$ $i \in F; F = \{all\ flights\ in\ solution\}$ $j \in C; C = \{all\ crewmembers\ in\ flight\}$	The *Crew Cost (cc)* for a specific flight includes the salary costs of all crew members (*Salary*), additional work hours to be paid (*Hour*), additional perdiem days to be paid (*Perdiem*), hotel costs (*Hotel*) and extra-crew travel costs (*Dhc*).
5	$fc = \sum_{i=1}^{\lvert F\rvert}(Airp_i + Service_i + Maint_i + Atc_i + Fuel_i)$ $where$ $i \in F; F = \{all\ flights\ in\ solution\}$	The *Flight Cost (fc)* for a specific flight includes the airport costs (*Airp*), i.e., charges applied by the airport operator like approaching and taxing; service costs (*Service*), i.e., flight dispatch, line maintenance, cleaning services and other costs; average maintenance costs for the type of aircraft that performs the flight (*Maint*); ATC en-route charges (*Atc*); and fuel consumption (*Fuel*), i.e., fuel to go from the origin to the destination (trip fuel) plus any additional extra fuel required.
6	$pc = \sum_{i=1}^{\lvert F\rvert}\sum_{d=1}^{\lvert D\rvert}(Meals_{\{d,i\}} + PHotel_{\{d,i\}} + Comp_{\{d,i\}})$ $where$ $i \in F; F = \{all\ flights\ in\ solution\}$ $d \in D; D = \{all\ delayed\ passengers\ in\ flight\}$	The *Passenger Cost (pc)* of the delayed passengers for a specific flight includes airport meals the airline has to support when a flight is delayed or cancelled (*Meals*), hotels costs (*PHotel*) and any compensation to the passengers according to regulations (*Comp*).
7	$qc = \alpha\sum_{i=1}^{\lvert F\rvert}\sum_{p=1}^{\lvert PP\rvert}(P_{\{p,i\}} * C_{\{p,i\}})$ $where$ $i \in F; F = \{all\ flights\ in\ solution\}$ $p \in PP; PP = \{flight\ passengers\ profiles\}$ $P = number\ of\ passengers\ of\ profile\ p$ $C = delay\ cost\ of\ each\ passenger\ on\ profile\ p$ $\alpha = coefficient\ to\ convert\ to\ monetary\ costs$	*Quality Operational Costs (qc)* of a specific solution are costs that are not easily quantifiable and are related with passenger satisfaction. The quantification of this value is very important to increase the quality level of an airline company when facing a disruption. For more information about this topic please see section 4.5 and/or consult [31, 32].

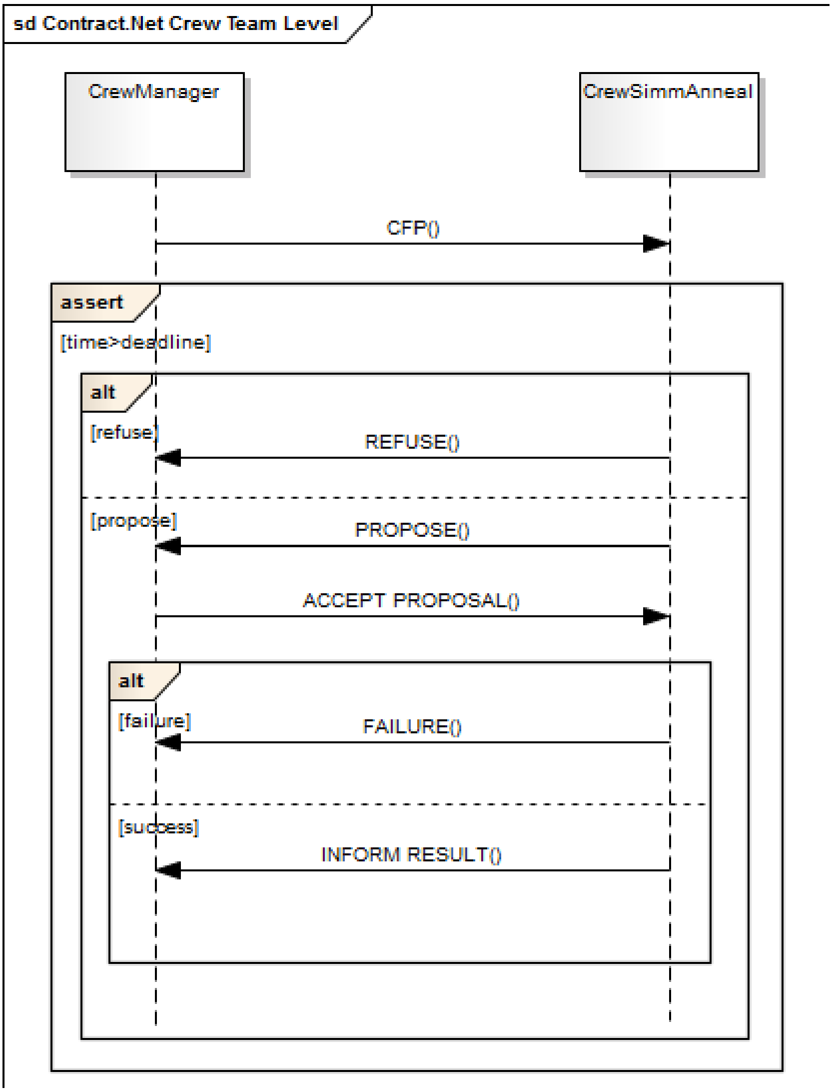


Figure 9. Contract net protocol (simplified).

After receiving all the candidate solutions, the *organizer* agent needs to select the best one. This process is explained in [32] and is based on the *Total Operational Cost* criteria. Table 3 summarizes the costs involved.

4.5. Quality Operational Costs

The Airline Operations Control Centre (AOCC) has the mission of controlling the execution of the airline schedule and, when a disruption happens (aircraft malfunction, crewmember missing, etc.) find the best solution to the problem. It is generally accepted that, the best solution, is the one that does not delay the flight and has the minimum direct operational cost. Unfortunately, due to several reasons, it is very rare to have candidate solutions that do not delay a flight and/or do not increase the operational cost. From the observations we have done in a real AOCC, most of the times, the team of specialists has to choose between candidate solutions that delay the flight and increase the direct operational costs. Reasonable, they choose the one that minimize these two values. Also from our observations, we found that some teams in the AOCC use some kind of rule of thumb or hidden knowledge that, in some cases, make them not choose the candidate solutions that minimize the delays and/or the direct operational costs. For example, suppose that they have disruptions for flight A and B with similar schedule departure time. To solve the problem, they have two candidate solutions: one is to delay flight A in 30 minutes and the other would delay flight B in 15 minutes. The direct operational costs for both candidate solutions are the same. Sometimes they would choose to delay flight A in 15 minutes and flight B in 30 minutes. We can state that flights with several business passengers, VIP's or for business destinations correspond to the profile of flight A in the above example. In our understanding this means that they are using some kind of quality costs when taking the decisions, although not quantified and based on personal experience. In our opinion, this knowledge represents an important part in the decision process and should be included on it.

4.5.1. Quantifying Quality Costs

To be able to use this information in a reliable decision process we need to find a way of quantifying it. What we are interested to know is how the delay time and the importance of that delay to the passenger are related in a specific flight. It is reasonable to assume that, for all passengers in a flight, less delay is good and more is bad. However, when not delaying is not an opinion and the AOCC has to choose between different delays to different flights which one should they choose? We argue that the decision should take into consideration the passenger's profile(s) of the specific flight and not only the delay time and/or operational cost. For quantifying the costs from the passenger point of view, we propose the following generic approach:

1. Define the existing passenger profile(s) in the flight.
2. Define a delay cost for each passenger in each profile.
3. Calculate the quality costs using the previous steps.

Most likely, every airline company will have a different method to *define the passenger profile* in a specific flight. Most of the airlines will just consider one or two profiles (for example, business and economy). To get the number of passengers that belong to these profiles is very easy. Airline companies can use the flight boarding information to calculate this number.

Most of the airline companies will choose to use a fixed *delay cost value to each passenger of each profile*. These numbers can reflect the perception of the costs from the point of view of the company or can result from a statistical analysis of the company information. In our opinion and that *is one of the main contributions of our approach*, we think that this cost should be calculated from the passenger point of view. This implies to use a formula to calculate the costs of each profile that represents this relation. Giving the above we believe that the quality costs should result from the relation between the number of passenger profiles in the flight and the delay cost for each passenger *from their point of view*, expressed by Equation 7 in Table 3.

4.5.2. Airline example

The final goal in this real example is to be able to have passenger profiles to every flight in the company, regarding the *delay cost from the point of view of the passengers*. To get this information, we have done a survey to several passengers on flights of the airline company. Besides asking in what class they were seated and the reason for flying in that specific flight, we asked them to evaluate from 1 to 10 (1 – not important, 10 very important) the following delay ranges (in minutes): less than 30, between 30 and 60, between 60 and 120, more than 120 and flight cancellation. From the results we found the passenger profiles in Table 4.

For the profiles in Table 4 to be useful, we need to be able to get the information that characterizes each profile, from the airline company database. We found that we can get the number of passengers of each profile in a specific flight from the boarding database, using the information in Table 5.

Besides being able to get the number and characterization of profiles from the survey data, we are also able to get the trend of each profile, regarding delay time/importance to the passenger. Plotting the data and the trend we got the graph in Figure 10 (x – axis is the delay time and y – axis the importance).

If we apply these formulas as is, we would get quality costs for flights that do not delay. Because of that we re-wrote the formulas. The final formulas that express the importance of the delay time for each passenger profile are presented in Table 6. It is important to point out that these formulas are valid only for this particular case and express the information we have from this specific survey data. Our goal is to update this information every year, using the annual company survey, and obtain different formulas according to flight destinations, flight schedules and/or geographical areas.

Table 4. Passenger Profiles

Profiles	Main Characteristics
Business	Travel in first or business class; VIP's; Frequent Flyer members; Fly to business destinations; More expensive tickets.
Pleasure	Travel in economy class; Less expensive tickets; Fly to vacation destinations.
Illness	Stretcher on board; Medical doctor or nurse travelling with the passenger; Personal oxygen on board or other special needs.

Table 5. Boarding Information

Profiles	Relevant Fields for Profiling
Business	#C/CL pax; #VIP's; #Freq. Flyer; #Pax according ticket price; Departure or arrival = business.
Pleasure	#Y/CL pax; #Pax according ticket price; Departure or arrival = vacation.
Illness	#Pax special needs; Stretcher on board=yes.

Table 6. Final Quality Formulas for the Airline Example

Profiles	Formula
Business	$y = 0.16*x^2+1.39*x$
Pleasure	$y = 1.20*x$
Illness	$y = 0.06*x^2+1.19*x$

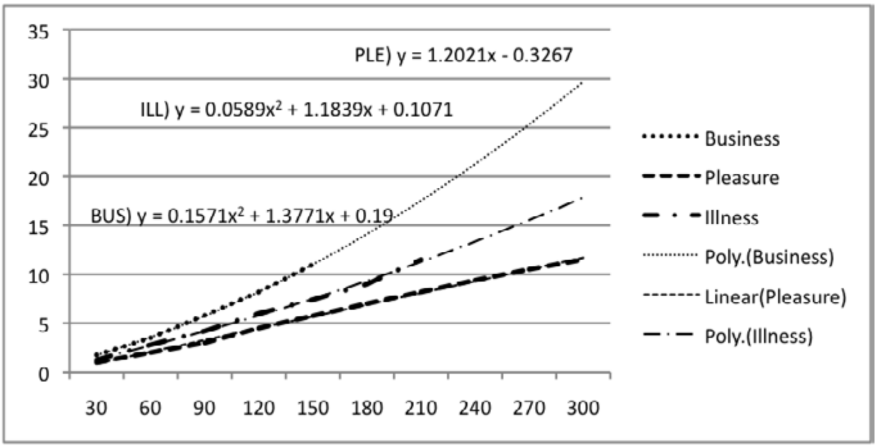


Figure 10. Case study trend formulas for the profiles.

Let's calculate the quality operational costs for the following flight (assuming 10 as the coefficient to convert to monetary costs): Flight 103 will be delayed 30 minutes at departure. It has 20 passengers in the business profile (B), 65 in pleasure profile (P) and 1 in the illness profile (I). Applying the formulas in Table 6, the cost of 30 minutes delay for each passenger in each profile is:

$$B_{cost\text{-}103} = 0.16*302+1.38*30 = 185.4$$

$$P_{cost\text{-}103} = 1.2*30 = 36$$

$$I_{cost\text{-}103} = 0.06*302+1.19*30 = 89.7$$

The quality operational cost for the flight 103 with a delay of 30 minutes is:

$$QC_{cost\text{-}103} = 10*(20*185.4+65*36+1*89.7) = 61377$$

4.6. Problem Solving Algorithms

As it is possible to see in Figure 6 (Section 4.3), the aircraft and crew dimension have, each one, a team of specialist agents. Each agent should implement a heterogeneous problem solving algorithm on the team they belong to. Preliminary results show that a single problem solving algorithm is not able to solve, dynamically and within the required time restriction, all types of problems that we have identified during our observations (see Section 3.3). Taking advantage of the modularity, scalability and distributed characteristics of the MAS paradigm, we are able to add as many specialist agents as required, so that all types of problems are covered. As we have seen in Section 4.3 and 4.4.2, the idea is to have all specialist agents of a team looking for solutions concurrently.

In this section we are going to show how we have implemented one of the specialist agents of the crew team, namely, *CrewHillClimb*. This agent implements a *hill climb* *algorithm*. For more details regarding how we have implemented this and other specialist agents, please read Mota [33].

The hill climbing agent solves the problem iteratively by following the steps:

1. Obtains the flights that are in the time window of the problem. This time window starts at the flight date, and ends at a customizable period in the future. This will be the initial solution of the problem. The crew members' exchanges are made between flights that are inside the time window of the problem.
2. While some specific and customizable time has not yet passed, or a solution below a specific and customizable cost has not been found, repeats steps 3 and 4.
3. Generates the successor of the initial solution (the way a successor is generated is described below).
4. Evaluates the cost of the solution. If it is smaller than the cost of the current solution, accepts the generated solution as the new current solution. Otherwise, discards the generated solution. The way a solution is evaluated is described below.
5. Send the current solution to the *CrewManager* agent following the protocol as we have seen in Section 4.4.2.

The generation of a new solution is made by finding a successor that distances itself to the current solution by one unit, that is, the successor is obtained by one, and only one, of the following operations:

- Swap two crewmembers between flights that belong to the flights that are in the time window of the problem.
- Swap a crewmember of a flight that belongs to the flights that are in the time window of the problem with a crewmember that isn't on duty, but is on standby.

When choosing the first element to swap, there are two possibilities: (1) choose randomly or (2) choose an element that is delayed. The choice is made based on the probability of choosing an element that is late, which was given a value of 0.9, so that the algorithms can proceed faster to good solutions (exchanges are highly penalized, so choosing an element that is not late probably won't reduce the cost, as a possible saving by choosing a less costly element probably won't compensate the penalization associated with the exchange).

If the decision is to exchange an element that is delayed, the list of flights will be examined and the first delayed element is chosen. If the decision is to choose randomly, then a random flight is picked, and a crewmember or the aircraft is chosen, depending on the probability of choosing a crewmember, which was given a value of 0.85. When choosing the second element that is going to swap with the first, there are two possibilities: (1) swap between elements of flights or (2) swap between an element of a flight and an element that is not on duty. The choice is made based on the probability of choosing a swap between elements of flights, which was given a value of 0.5.

The evaluation of the solution is done by an objective function that measures the following types of costs:

- The crew cost according to Equation 4 in Table 3;
- The penalization for exchanging elements;

Table 7. Implementation of the hill climbing algorithm in Java

```
GregorianCalendar currentDate = new GregorianCalendar();
 int secondsExecution = (int) ((currentDate.getTimeInMillis() -
startDateResolution.getTimeInMillis()) / 1000);
 while(!Shared.to(problem.getNumSeconds(), secondsExecution,
problem.getMaxCost(), currentSolutionCost))
 {
  // get successor
  successor =
Shared.generateSuccessor(Shared.copyArrayList(currentSolution));
  // checks if successor has an inferior solution cost
  successorCost = Shared.calculateCost(successor, initialPlainSolution);
  System.out.println("Successor Cost: " + successorCost + "\n");
  if(sucessorCost < currentSolutionCost)
  {
   currentSolution = successor;
   currentSolutionCost = successorCost;
  }
  currentDate = new GregorianCalendar();
  secondsExecution = (int) ((currentDate.getTimeInMillis() -
startDateResolution.getTimeInMillis()) / 1000);
 }
```

- The penalization for delayed elements. The cost associated with this aspect is the highest, because the goal is to have no delayed elements.

The Hill Climbing Objective Function (*hc*) is given by Equation 8.

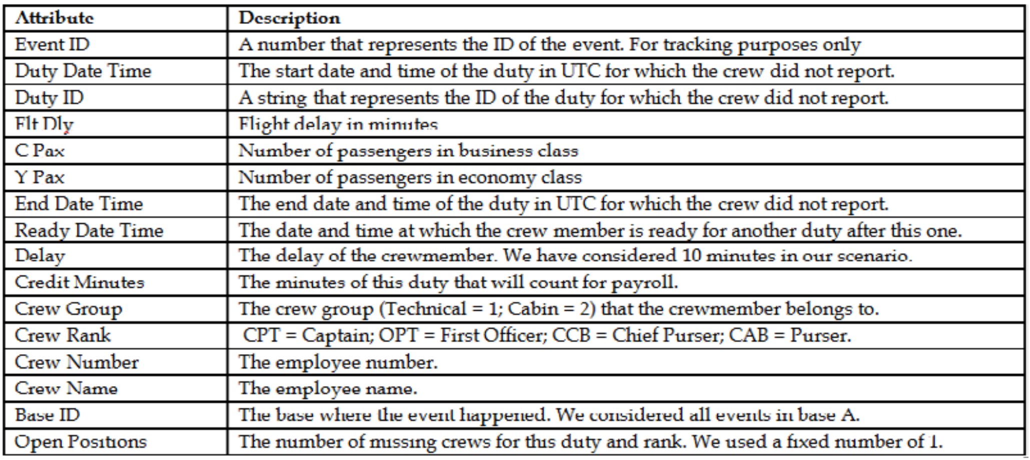
$$hc = cc + excW * nExc + delayW * nDelay \tag{8}$$

In this equation, *cc* represents the crew cost calculated according to equation 4 (table 3), *excW* represents the penalization for crew exchanges, *nExc* represents the number of crew exchanges, *delayW* represents the penalization for delaying crewmembers and *nDelay* the number of delayed crewmembers.

5. EXPERIMENTAL SETUP

To evaluate our approach we have setup a scenario that includes 3 operational bases (A, B and C). Each base includes their crewmembers each one with a specific roster. The data used corresponds to a real airline operation of June 2006 of base A. A scenario was simulated where 15 crewmembers, with different ranks, did not report for duty in base A. In table 7 we present the collected information for each event.

Table 7. Information collected



Attribute	Description
Event ID	A number that represents the ID of the event. For tracking purposes only
Duty Date Time	The start date and time of the duty in UTC for which the crew did not report.
Duty ID	A string that represents the ID of the duty for which the crew did not report.
Flt Dly	Flight delay in minutes
C Pax	Number of passengers in business class
Y Pax	Number of passengers in economy class
End Date Time	The end date and time of the duty in UTC for which the crew did not report.
Ready Date Time	The date and time at which the crew member is ready for another duty after this one.
Delay	The delay of the crewmember. We have considered 10 minutes in our scenario.
Credit Minutes	The minutes of this duty that will count for payroll.
Crew Group	The crew group (Technical = 1; Cabin = 2) that the crewmember belongs to.
Crew Rank	CPT = Captain; OPT = First Officer; CCB = Chief Purser; CAB = Purser.
Crew Number	The employee number.
Crew Name	The employee name.
Base ID	The base where the event happened. We considered all events in base A.
Open Positions	The number of missing crews for this duty and rank. We used a fixed number of 1.

Table 8. Events used (testing)

	Duty Date Time	Duty ID	Flt Dly	C Pax	Y Pax	End DateTime	Ready DateTime	Cred Min	Crew Grp	Rnk	Crw Nr	Crew Name
1	05-06 07:25	1ORY149S	0	7	123	05-06 13:35	06-06 01:35	370	2	CAB	80	John A
2	05-06 07:25	1ORY149S	10	11	114	05-06 13:35	06-06 01:35	370	2	CAB	45	Mary A
3	05-06 07:25	1ORY85P	0	10	112	05-06 13:35	06-06 01:35	370	1	CPT	35	Anthony
4	15-06 04:10	2LIS24X	30	0	90	16-06 16:15	17-06 04:15	1757	2	CAB	99	Paul M
5	15-06 04:10	3LIS25X	25	3	77	15-06 09:20	15-06 21:20	632	2	CAB	56	John B
6	15-06 12:50	2LHR63P	5	25	85	16-06 20:45	17-06 08:45	1549	1	CPT	57	Paul S
7	15-06 12:50	2LHR63P	0	20	95	16-06 20:45	17-06 08:45	1549	1	OPT	53	Mary S
8	15-06 14:15	1LHR31P	0	23	52	15-06 20:55	16-06 08:55	843	2	CCB	23	Sophie
9	15-06 15:25	2LHR19P	10	27	105	16-06 20:45	17-06 08:45	1341	2	CCB	34	Angel
10	15-06 15:25	1ZRH12X	0	5	115	17-06 09:30	17-06 21:30	1318	1	CPT	32	Peter B
11	25-06 05:20	1LIS16S	20	3	97	25-06 15:05	26-06 03:05	585	2	CAB	20	Paul G
12	25-06 05:20	1LIS16S	5	2	108	25-06 15:05	26-06 03:05	585	2	CAB	10	Alice
13	25-06 05:20	1LIS158T	0	4	92	25-06 15:05	26-06 03:05	585	2	CAB	15	Daniel
14	25-06 06:15	3LIS174S	0	1	129	27-06 16:15	28-06 04:15	1258	2	CAB	71	George
15	25-06 14:20	4LIS50A	0	2	83	28-06 19:40	29-06 07:40	219	1	OPT	65	Allan

Table 9. Partial data for method 4

	Duty ID	Base ID	Crew Grp	Rank	Hour Pay	Perdiem Pay	Quality Op. Cost	Direct Op. Cost
1	1ORY149S	B	2	CAB	0,00	72,00	0	86,40
2	1ORY149S	A	2	CAB	0,00	72,00	501,31	72,00
3	1ORY85P	C	1	CPT	0,00	106,00	0	148,40
4	2LIS24X	B	2	CAB	637,77	144,00	838,11	938,12
5	3LIS25X	B	2	CAB	0,00	72,00	1021,42	86,40
6	2LHR63P	C	1	CPT	102,90	212,00	272,10	440,86
7	2LHR63P	B	1	OPT	37,22	144,00	0	217,46
8	1LHR31P	B	2	CCB	229,17	72,00	0	361,40
9	2LHR19P	C	2	CCB	0,00	144,00	788,78	201,60
10	1ZRH12X	B	1	CPT	0,00	212,00	0	254,40
11	1LIS16S	C	2	CAB	0,00	80,00	426,98	112,00
12	1LIS16S	A	2	CAB	0,00	80,00	144,34	180,00
13	1LIS158T	C	2	CAB	0,00	31,00	0	43,40
14	3LIS174S	B	2	CAB	985,00	216,00	0	1081,20
15	4LIS50A	A	1	OPT	152,72	288,00	0	440,72
	Totals				1844,77	1945,00	3993,02	4564,36

Each event corresponds to a crewmember that did not report for duty in a specific day. The data for each event is presented in Table 8. As an example, event 15 corresponds to the following: Allan, a crewmember with number 65 and rank OPT (first officer), belongs to crew group 1 (flight crew), did not report for duty with ID 4LIS50A with briefing time at 14:20 in 25-06-2006. This flight has 83 economy passengers and 2 business passengers and it did not delay on departure. The new crewmember must have the same rank and belong to the same group. The duty ends at 19:40 on 28-06-2006 and the rest period end at 07:40 in 29-06-2006. For the payroll, the duty will contribute with 219 minutes. Solutions were found after setting-up the scenario, using four different methods.

The first three methods, named *Human (M1)*, *Agent-no-Quality (M2)* and *Agent-Quality (M3)* are explained in [32]. Basically, in the *human* method we have used a human controller from the AOCC, using current tools, to find the solutions. In the *agent-no-quality* an agent-based approach was used without considering the quality costs as presented in equation 7 in table 3. In the *agent-quality* method it was considered the quality costs. For more information, please read [32].

In the *fourth method*, we have used the approach presented in section 4, but without the user feedback (see section 4.4.1). Table 9 presents the collected data.

6. RESULTS AND DISCUSSION

For each method the experimentation results are presented in table 10. The discussion that compares method 1 (*human*), method 2 (*agent-no-quality*) and method 3 (*agent-quality*) was presented in our previous work [32]. Here, we are going to concentrate our attention in comparing the *agent-quality* approach with the one presented in this chapter (*integrated*). In the *integrated* approach we use the two levels of negotiation as explained in section 4.4 but without the user feedback. From the results we can see the following:

Table 10. Results summary

	Human (M1)		Agent-no-Quality (M2)		Agent-Quality (M3)		Integrated (M4)	
	Total	%	Total	%	Total	%	Total	%
Event base:								
- From base (A)	7	47%	3	20%	3	20%	3	20%
- From base B	6	40%	7	47%	7	47%	6	40%
- From base C	2	13%	5	33%	5	33%	6	40%
Time to Find Solution (avg sec)	101	100.00%	25	24.75%	26	25.74%	28	27.72%
Flight Delays (avg min):			11	100.00%	7	63.64%	6	54.54%
- Base A (avg)			14	40%	7	30%	5	29%
- Base B (avg)			9	26%	4	17%	6	35%
- Base C (avg)			12	34%	12	52%	6	35%
Direct Operational Costs:	7039.60	100.00%	3839.36	54.54%	4130.07	58.67%	4564.36	64.84%
Total by Base:								
- Base A	4845.55	92.42%	288.00	11.23%	578.83	14.02%	592.72	12.99%
- Base B	1796.40	34.26%	1275.80	49.77%	1429.54	34.61%	3025.38	66.28%
- Base C	397.60	7.58%	2275.56	88.77%	2121.70	51.37%	946.26	20.73%
Quality Operational Cost:			7788.47	100%	4781.53	61.39%	3993.02	51.27%
Total by Base:								
- Base A			1649.57	21.18%	593.30	12.41%	645.65	16.17%
- Base B			3617.66	46.45%	1562.19	32.67%	1859.52	46.57%
- Base C			2521.24	32.37%	2626.04	54.92%	1487.86	37.26%
Total Operational Costs:			11628.01	165%	8911.60	126.6%	8557.38	121.6%
Total by Base:								
- Base A			1937.57	16.66%	1172.13	13.15%	1238.37	14.47%
- Base B			4088.42	35.16%	2991.73	33.57%	4884.90	57.08%
- Base C			4796.80	41.25%	4747.74	53.28%	2434.12	28.44%

- The *integrated* method decreases the flights delays in approximately 14.30% (on average).
- The flight delays in each base are much more balanced than with any of the other methods. For example, with the *quality* method we got 7 minutes delay in base A, 4 in base B and 12 in base C. With our approach we got 6 minutes delay in base A, 6 in base B and the same value in base C (average values).
- The quality costs with the *integrated* method decreased on average 16.48%.
- The total operational costs decreased on average 3.95%.
- The direct operational costs increased on average 10.51%.
- The time to find a solution increased on average 7.69%.

These results are encouraging. We see that the flight delays, quality costs and total operational costs decrease. However, the direct operational costs increased around 10% and this value can correspond to a significant amount of money. If we read this figure as-is, we have to consider that we did not achieve an important goal. In our opinion, this result should be interpreted together with the flight delay result. Although the *integrated* method increases the direct operational costs in 10% it was able to select solutions that decrease the flight delays in 14.30%. So, when there are several solutions to the same problem, the *integrated* method is able to select the solution with less quality costs (corresponds to better passenger satisfaction), less operational cost and, due to the relation between flight delays and quality costs, the solution with less flight delays.

Considering the above conclusion how does it compare with minimizing the direct operational cost and the expected flight delay? It is a reasonable question because the flight delay is the variable that has the biggest impact on passenger satisfaction and we could expect that the results were the same. So, in general, we might say that this assumption is true. But what should happen when we have two solutions for the same problem, with the same *delay* and *direct operational cost*? Which one should we choose? For us, it depends on the on-board passenger profiles and the importance that they give to the delays. It is this important value that we capture with our *quality operational cost*. Our approach uses all this criteria to achieve the best integrated solution and, because of the GQ-Negotiation protocol, we were able to decrease the quality operational costs in 16.48% when compared with the *agent-quality* approach (that also uses quality operational costs).

Regarding the time to find a solution, the *integrated* approach took 7,69% more time than the *agent-quality*. The fact that we are using a negotiation protocol at the *Managers Level* explains this Figure. However, the average time (28 seconds) is still within the acceptable values, so this increase as a minor impact on the proposed approach.

It is important to point out that we need to evaluate a higher number of scenarios with data from the all year. The air transportation domain has seasonal behaviours and that might have an impact on the results we have found in our work. Nevertheless, we believe that these results are encouraging.

7. CONCLUSION

We have introduced the Airline Operations Control Problem as well as the Airline Operations Control Centre (AOCC), including typical organizations and problems, the current disruption management (DM) process, a description of the main costs involved and a classification of current tools and systems.

We proposed a new concept for disruption management in airline operations control, where the most repetitive tasks are performed by several intelligent software agents, integrated in a multi-agent system that represents the AOCC. We found that the multi-agent paradigm is very adequate to model this type of problems and, as such, we presented the reasons that make us adopt it. A description of the proposed solution with agents and some of their characteristics (social-awareness and autonomy, for example), as well as their roles and protocols used, was included. We presented the costs criteria as well as the negotiation algorithms used as part of the decision mechanisms.

Four different methods were used to test our approach using data from an airline company. The results show that with our approach and when compared with methods that minimize direct operational costs, it is possible to have solutions with shorter flight delays while contributing to better passenger satisfaction.

Several improvements are expected in a very short term. Among them, we would like to point out the following:

- Complete the implementation of the GQ-Negotiation protocol as described in section 4.4.1, especially, the inclusion of the user feedback and the associated learning mechanisms. By including knowledge provided by the user as well as from the other specialist agents, we are improving the distributed characteristics of our approach.
- Use the knowledge gathered from learning to improve robustness of future schedules.
- Improve autonomy and learning characteristics of the *Monitor* agent, so that he is able to consider new events (or change existing ones) according to the experience he gets from monitoring the operation, without relying exclusively on the definition of events created by the human operator.

ACKNOWLEDGMENTS

The first author is supported by FCT (Fundação para a Ciência e Tecnologia) under research grant SFRH/BD/44109/2008. The authors are grateful to TAP Portugal for allowing the use of real data from the airline company. We are also grateful to SISCOG for support during the ResPlan project. Finally, we wish to thank Ana Paula Rocha for the enlightening discussions about the GQ-Negotiation Protocol.

REFERENCES

[1] Clausen, J., Larsen, A. & Larsen, J. (2005). Disruption Management in the Airline Industry – Concepts, Models and Methods, Technical Report, 2005-01, *Informatics and Mathematical Modeling*, Technical University of Denmark, DTU.

[2] Kohl, N., Larsen, A., Larsen, J., Ross, A. & Tiourline, S. (2004). Airline Disruption Management – Perspectives, Experiences and Outlook, *Technical Report*, CRTR-0407, Carmen Research.

[3] Barnhart, C., Belobaba, P. & Odoni, A. (2003). Applications of Operations Research in the Air Transport Industry, *Transportation Science*, *Vol. 37*, 368-391.

[4] Liu, T., Jeng, C. & Chang, Y. (2008). Disruption Management of an Inequality-Based Multi-Fleet Airline Schedule by a Multi-Objective Genetic Algorithm, *Transportation Planning and Technology*, *Vol. 31*, No. 6, 613-639.

[5] Yang, M. (2007). *Using Advanced Tabu Search Techniques to Solve Airline Disruption Management Problems*, Ph.D. dissertation, The University of Texas at Austin, December 2007, USA.

[6] Rosenberger, J., Johnson, E. & Nemhauser, G. (2003). Rerouting aircraft for airline recovery, *Transportation Science*, *Vol. 37*, 408-421.

[7] Rosenberger, J., Schaefer, A., Goldsmans, D., Johnson, E., Kleywegt, A. & Nemhauser, G. (2002). A Stochastic Model of Airline Operations, *Transportation Science*, *Vol. 36*, No. 4, 357-377.

[8] Abdelgahny, A., Ekollu, G., Narisimhan, R. & Abdelgahny, K. (2004). A Proactive Crew Recovery Decision Support Tool for Commercial Airlines during Irregular Operations, *Annals of Operations Research*, *Vol.127*, 309-331.

[9] Bratu, S. & Barnhart, C. (2006). Flight Operations Recovery: New Approaches Considering Passenger Recovery, *Journal of Scheduling*, *Vol. 9*, No. 3, 279-298.

[10] Lettovsky, L. (1997). Airline Operations Recovery: An Optimization Approach, Ph.D. dissertation, *Georgia Institute of Technology*, Atlanta, USA.

[11] Castro, A. (2008). Centros de Controlo Operacional: Organização e Ferramentas, Monograph for Post-graduation in Air Transport Operations, *ISEC - Instituto Superior de Educação e Ciências*, Outubro 2008 (In Portuguese).

[12] Castro, A. J. M. & Oliveira, E. (2007). Using Specialized Agents in a Distributed MAS to Solve Airline Operations Problems: a Case Study, Proceedings of IAT 2007 (Intelligent Agent Technology Conference), 473-476, *Silicon Valley*, California, USA 2-5 November 2007, IEEE Computer Society, ISBN: 0-7695-3027-3.

[13] Wooldridge, M. (2009). When is an Agent-Based Solution Appropriate? *An Introduction to Multiagent Systems*, West Sussex, England: John Wiley & Sons, Ltd., 2nd Edition (15 May 2009), 183, ISBN: 978-0470519462.

[14] Castro, A. J. M. (2007). Designing a Multi-Agent System for Monitoring and Operations Recovery for an Airline Operations Control Centre, *MsC Thesis*, 1-133, Porto, Portugal: University of Porto, Faculty of Engineering.

[15] Tumer, K. & Agogino, A. (2007). *Distributed Agent-Based Air Traffic Flow Management*, 6th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2007), Honolulu, Hawaii.

[16] Wolfe, S. R., Jarvis, P. A., Enomoto, F. Y. & Sierhuis, M. (2007). Comparing Route Selection Strategies in Collaborative Traffic Flow Management., Proceedings of IAT 2007 (Intelligent Agent Technology Conference), Silicon Valley, California, USA 2-5 November 2007, *IEEE Computer Society*, ISBN: 0-7695-3027-3.

[17] Jonker, G., Meyer, J. J. & Dignum, F. (2005). *Towards a Market Mechanism for Airport Traffic Control*, 12th Portuguese Conference on Artificial Intelligence (EPIA 2005), Covilha, Portugal.

[18] Ouelhadj, D. (2003). A Multi-Agent System for the Integrated Dynamic Scheduling of Steel Production, Ph.D. dissertation, The University of Nottingham, *School of Computer Science and Information Technology*, England, August 2003.

[19] Cowling, P. I., Ouelhadj, D. & Petrovic, S. (2003). A Multi-Agent Architecture for Dynamic Scheduling of Steel Hot Rolling, *Journal of Intelligent Manufacturing*, Special Issue on Agent-Based Manufacturing Process Planning and Scheduling, *Vol. 15*, No. 5, 457-470.

[20] Grosche, T. (2009). *Computational Intelligence in Integrated Airline scheduling*, Springer-Verlag Berlin Heidelberg, 978-3-540-89886-3, Germany.

[21] Kohl, N. & Karisch, S. (2004). Airline crew rostering. problem types, modeling, and optimization, *Annals of Operations Research*, *Vol. 127*, 223-257.

[22] Bellifemine, F., Caire, G., Trucco, T. & Rimassa, G. (2004). *JADE Programmer's Guide*, JADE 3.3, TILab S.p.A.

[23] Elamy, A. (2005). *Perspectives in Agents-Based Technology*, AgentLink News 18, August 2005, ISSN: 1465-3842.

[24] Stone, P. & Veloso, M. (2000). Multi-Agent Systems: a Survey from a Machine Learning Perspective, *Autonomous Robotics*, *Vol. 8*. No. 3.

[25] Castro, A. & Oliveira, E. (2008). The rationale behind the development of an airline operations control centre using Gaia-based methodology, *International Journal of Agent-Oriented Software Engineering*, *Vol. 2*, No. 3, 350-377.

[26] Rocha, A. P. & Oliveira, E. (2001). Electronic Institutions as a framework for Agents' Negotiation and mutual Commitment, *in Progress in Artificial Intelligence (Proceedings of 10th EPIA)* Eds. P. Brazdil, & A. Jorge, LNAI 2258, 232-245,Springer, December 2001.

[27] Oliveira, E. & Rocha, A. P. (2000). *Agents advanced features for negotiation in Electronic Commerce and Virtual Organisations formation process*, in Agent Mediated Electronic Commerce: The European AgentLink Perspective, F. Dignum, & C. Sierra, (Eds), LNAI 1991, 78-97, Springer Verlag, June 2000.

[28] Ehlers, E. M. & Langerman, J. J. (2005). A Learning Agent to Assist in Airline Disruption Management, *Proceedings of the 2005 International Conference on Computational Intelligence for Modelling*, Control and Automation (CIMCA-IAWTIC'05).

[29] Fipa. (2002). *FIPA Contract Net Interaction Protocol Specification*, http://www.fipa.org/specs/ fipa00029/SC00029H.html, Accessed in 2009/06/21.

[30] Smith, R. (1980). The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver, *IEEE Transactions on Computers*, *Vol. C*, No. 29.

[31] Castro, A. J. M & Oliveira, E. (2009). Using Quality Costs in a Multi-Agent System for Airline Operations Control, 11th International Conference on Enterprise Information Systems, *Artificial Intelligence and Decision Support Systems*, 19-24, Milan, Italy, May 6-10, 2009. ISBN: 978-989-8111-85-2

[32] Castro, A. J. M. & Oliveira, E. (2009). Quantifying Quality Operational Costs in a Multi-Agent System for Airline Operations Recovery, *International Review on Computers and Software (IRECOS)*, *Vol. 4*, N. 4, July 2009. ISSN 1828-6003.

[33] Mota, A. (2007). *Multi-Agent System for an Airline Operations Control Centre*, MsC Thesis, Porto, Portugal: University of Porto, Faculty of Engineering.

[34] Clausen, J., Larsen, A., Larsen J. & Rezanova N. J. (2010). Disruption Management in the airline industry – Concepts, models and methods, *Computers and Operations Research*, *Vol. 37*, 809-821.

[35] Abdelghany, K. F., Abdelghany, A. F. & Ekollu, G. (2008). An integrated decision support tool for airlines schedule recovery during irregular operations, *European Journal of Operational Research*, *Vol. 185*, 825 848.

[36] Andersson, T. (2001). *The flight perturbation problem - operational aircraft rescheduling*, PhD thesis, Linkoping University, Sweden.

[37] Andersson, T. (2006). Solving the flight perturbation problem with metaheuristics, *Journal of Heuristics*, *Vol. 12*, 37-53.

[38] Andersson, T. & Varbrand, P. (2004). The flight perturbation problem, *Transportation Planning and Technology*, *Vol. 27*, 91-117.

[39] Arguello, M., Bard, J. & Yu, G. (1997). A GRASP for aircraft routing in response to groundings and delays, *Journal of Combinatorial Optimization*, *Vol. 5*, 211-228.

[40] Bard, J., Yu, G. & Arguello, M. (2001). Optimizing aircraft routings in response to groundings and delays, *IIE Transactions*, *Vol. 33*, 931-947.

[41] Cao, J. M. & Kanafani, A. (1997). Real-time decision support for integration of airline flight cancellations and delays, part I: mathematical formulation. *Transportation Planning and Technology*, *Vol. 20*, 183-199.

[42] Cao, J. M. & Kanafani, A. (1997). Real-time decision support for integration of airline flight cancellations and delays, part II: algorithm and computational experiments. *Transportation Planning and Technology*, *Vol. 20*, 201-217.

[43] Clarke, M. (1997). *Development of heuristic procedures for flight rescheduling in the aftermath of irregular airline operations*, Working paper, October.

[44] Clarke, M. (1997). *The airline schedule recovery problem*, Working paper, October.

[45] Eggenberg, N., Bierlaire, M. & Salani, M. (2007). A column generation algorithm for disrupted airline schedules, Technical report, *Ecole Polytechnique Federale de Lausanne.*

[46] Guo, Y. (2005). *A decision support framework for the airline crew schedule disruption management with strategy mapping*, Operations research proceedings 2004, Berlin, Heidelberg, Springer.

[47] Jarrah, A., Yu, G., Krishnamurthy, N. & Rakshit, A. (1993). A decision support framework for airline flight cancellations and delays, *Transportation Science*, *Vol. 27*, 266-280.

[48] Johnson, V., Lettovsky, L., Nemhauser, G. L., Pandit, R. & Querido, S. (1994). Final report to Northwest Airlines on the crew recovery problem, Technical report, The Logistic Institute, *Georgia Institute of Technology*, Atlanta, USA.

[49] Lettovsky, L., Johnson, E. & Nemhauser, G. (2000) Airline crew recovery. *Transportation Science*, *Vol. 34*, 337-348.

[50] Liu, T. K., Jeng, C. R., Liu, Y. T. & Tzeng, J. Y. (2006). Applications of multi-objective evolutionary algorithm to airline disruption management, *2006 IEEE international conference on systems, man and cybernetics*, New York, IEEE, 4130-4135.

[51] Love, M., Sorensen, K., Larsen, J. & Clausen, J. (2005). Using heuristics to solve the dedicated aircraft recovery problem, *Central European Journal of Operations Research*, *Vol. 13*, 189-207.

[52] Luo, S. & Yu, G. (1997). On the airline schedule perturbation problem caused by the ground delay program, *Transportation Science*, *Vol. 31*, 298-311.

[53] Luo, S. & Yu, G. (1998). Airline schedule perturbation problem: landing and take-off with nonsplitable resource for the ground delay program, *Operations research in the airline industry*, Boston, Kluwer Academic Publishers.

[54] Mathaisel, D. (1996). Decision support for airline system operations control and irregular operations, *Computers & Operations Research*, *Vol. 23*, 1083-1098.

[55] Nissen, R. & Haase, K. (2006). Duty-period-based network model for crew rescheduling in European airlines, *Journal of Scheduling*, *Vol. 9*, 255-278.

[56] Rakshit, A., Krishnamurthy, N. & Yu, G. (1996). System operations advisor: a real-time decision support system for managing airline operations at united airlines, *Interfaces*, *Vol. 26*, 50-58.

[57] Stojkovic, M. & Soumis, F. (2001). An optimization model for the simultaneous operational flight and pilot scheduling problem, *Management Science*, *Vol. 47*, 1290-1305.

[58] Stojkovic, M. & Soumis, F. (2005). The operational flight and multi-crew scheduling problem, *Yugoslavian Journal of Operations Research*, *Vol. 15*, 25-48.

[59] Stojkovic, M., Soumis, F. & Desrosiers, J. (1998). The operational airline crew scheduling problem, *Transportation Science*, *Vol. 32*, 232-245.

[60] Talluri, K. (1996). Swapping applications in a daily airline fleet assignment, *Transportation Science*, *Vol. 30*, 237-248.

[61] Teodorovic, D. & Guberinic, S. (1984). Optimal dispatching strategy on an airline network after a schedule perturbation, *European Journal of Operational Research*, *Vol. 15*, 178-182.

[62] Teodorovic, D. & Stojkovic, G. (1990). Model for operational daily airline scheduling, *Transportation Planning and Technology*, *Vol. 14*, 273-285.

[63] Teodorovic, D. & Stojkovic, G. (1995). Model to reduce airline schedule disturbances, *Journal of Transportation Engineering*, *Vol. 121*, 324-331.

[64] Thengvall, B., Bard, J. & Yu, G. (2000). Balancing user preferences for aircraft schedule recovery during irregular operations, *IIE Transactions*, *Vol. 32*, 181-193.

[65] Thengvall, B., Yu, G. & Bard, J. (2001). Multiple fleet aircraft schedule recovery following hub closures, *Transportation Research Part A*, *Vol. 35*, 289-308.

[66] Thengvall, B. G., Bard, J. F. & Yu, G. (2003). A bundle algorithm approach for the aircraft schedule recovery problem during hub closures, *Transportation Science*, *Vol. 37*, 392-407.

[67] Wei, G., Yu, G. & Song, M. (1997). Optimization model and algorithm for crew management during airline irregular operations, *Journal of Combinatorial Optimization*, *Vol. 1*, 305-321.

[68] Yan, S. & Tu, Y. P. (1997). Multifleet routing and multistop flight scheduling for schedule perturbation, *European Journal of Operational Research*, *Vol.103*, 155-169.

[69] Yan, S. & Yang, D. H. (1996). A decision support framework for handling schedule perturbations, *Transportation Research Part B*, *Vol. 30*, 405-419.

[70] Yu, G., Arguello, M., Song, G., McCowan S. M. & White, A. (2003). A new era for crew recovery at Continental Airlines, *Interfaces*, *Vol. 33*, 5-22.

[71] Zhang, Y. & Hansen, M. (2008). Real-time intermodal substitution, *Transportation Research Records*, *Vol. 2052*, 90-99.

[72] Zhao, X. & Zhu, J. (2007). Grey programming for irregular flight scheduling, *IEEE international conference on grey systems and intelligent services*, NewYork, IEEE, 1607-1611.

[73] Zhao, X., Zhu, J. & Guo, M. (2007). Application of grey programming in irregular flight scheduling, *IEEE international conference in industrial engineering and engineering management*, NewYork, IEEE, 164-168.

[74] Medard, C. & Sawhney, N. (2007). Airline Crew Scheduling: from planning to operations, *European Journal of Operations Research*, *Vol. 183*, 1013-1027.

[75] Nemhauser, G. L., Savelsbergh, M. W. & Sigismondi, G. C. (1994). MINTO, a mixed INTeger optimizer, *Operation Research Letters*, *Vol. 15*, 47-58.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 99-117
ISBN: 978-1-61122-079-7

Chapter 3

OUTSOURCING STRATEGIES OF FULL-SERVICE AIRLINES: AN APPLICATION OF TWO THEORETICAL PERSPECTIVES

Alison Rieple
University of Westminster, United Kingdom

INTRODUCTION

> *"Outsourcing is becoming the next critical business process airlines are addressing."*
> SAS Group President and CEO Jorgen Lindegaard (2004).

Over the last decade or so there has been a significant shift away from vertically integrated organisational structures and a move towards outsourcing in many industries. Outsourcing can take many different forms and go under various names such as subcontracting, contracting out or out-tasking (Fill and Visser, 2000; Cross, 1995). It is essentially a process of contracting ‘for results □ re people, collegiate obligations or assets’ (Peisch, 1995:32). It is also nothing new - some companies have always subcontracted parts of their operations to suppliers whom, it is felt, can provide these functions more efficiently or effectively. However, since the 1990s, the trend to outsource seems to have accelerated.

There are various reasons why companies may choose to contract out parts of their operations and business functions. This chapter looks at these issues and developments in a sector in which outsourcing practices have rarely been examined, the airline industry. This is an interesting and illuminating context to examine because of the criticality of certain aspects of airline operations, notably safety, and also because of its changing regulatory and competitive context over the last thirty years or so , a result of which is now to be seen in the dramatic restructuring of many major airlines around the world.

This chapter has four sections. First, we describe the international airline industry, the current trend to outsourcing within it and the main drivers behind this trend. Second, we have chosen two relevant, theoretical perspectives on outsourcing and industry structures as lenses to examine outsourcing decisions. Third, we examine the current degree of outsourcing of a number of organisational functions in a sample of major, international airlines and make a comparison with the predictions made on the basis of our chosen two theoretical frameworks. Finally, we draw out implications for the airline industry and the firms in it based on these two areas of analysis.

THE INDUSTRY CONTEXT

The passenger airline industry can be broadly divided into several distinct strategic groups based on their firms' scope, scale and type of operation:

- small, local carriers which operate mainly in one country
- short-haul carriers which operate mainly in one region or continent
- budget or 'low cost' airlines, usually short haul and regional, which operate on a low cost base structure and offer low prices and 'no frills' service
- major international airlines with global reach, often current or ex-national 'flag carriers', who operate both long haul and possibly short haul and cover many areas of the world offering a full service to their customers.

For the purposes of this chapter, we focus on the final group; major, international, full service legacy airlines which are broadly comparable in both the customer segments they focus on as well as their operational requirements and which can therefore be examined on a 'like for like' basis. For this exploratory investigation, we have chosen to concentrate on two from North America; United and American Airlines, two from the Pacific Rim; Singapore Airlines and Qantas and three from Europe; British Airways, SAS and Air France/KLM.

Over the last 20 – 25 years, this sector has been characterised by overcapacity and poor financial performance. Few airlines have been profitable or made adequate returns on capital and there have been several major cases of company failure - some estimates suggest, in fact, that over its 60 year life the international airline industry as a whole has never yielded a positive return on capital (CAA, 2006). This situation has also been influenced by government intervention in and regulation of the industry; because of political sensibilities and concern for national security, many of the largest 'flag carrier' airlines have at one time been either partially or wholly state owned and controlled. Although this support and control has weakened since the US Airline Deregulation Act of 1978, the 2007 and 2010 Open Skies Agreements, and similar deregulatory moves elsewhere, in many countries airlines are still heavily subsidized by their national governments and protected by them from failure. Even in the supposedly deregulated USA, foreign firms still cannot own more than 25% of an American carrier (Chaffin, 2010). This legacy of intervention has distorted market forces and industry structures, allowing uncompetitive airlines to remain in business and blocking many of the hostile takeovers that have acted to alter the shape of other sectors. Some consultants have gone as far as to suggest that the American airline industry will 'liquidate' if US carriers are not allowed to merge (Mifsud, Bonilla, and Cordle, 2010). Elsewhere, there has been increasing consolidation in the industry, as demonstrated by the proposed mergers between United and Continental and British Airways and Iberia, and an increasing number of alliances between international airlines, set up, in part, in order to overcome regulatory barriers on access to routes.

Thus the main strategic drivers in the airline industry since the late 1970s have been the gradual erosion of protectionism and a reduction of governmental control as well as increasing competition arising from the host of political and economic factors that usually go under the banner of ‘globaliantion’.□ The result has beent that former □ agecs in the European Union, for example, have found that their markets have been increasingly open to both existing rivals and new entrants such as low cost operators. Factors such as these appear likely to have contributed to the takeover, failure or near bankruptcy of airlines such as Sabena and Alitalia.

Intensification of competition has also pushed airlines towards organisational rationalisation and restructuring in order to reduce costs as well as cope with deregulation. SAS, for example, in 2009 hoped to reduce its operating costs by $219m through restructuring its operations (Straus, 2009), while Delta sought to save a total of about $240 million over five years through the outsourcing of maintenance services (a policy, incidentally, that it has partly rescinded since).

Similar pressures led to outsourcing in other international industries, although this move is happening rather later in the airline sector than others (Pilling 2002). While there are major forces driving the restructuring of the airline industry, these are shaped by a context that is changing but still heavily influenced by government control and safety regulation. Moves to outsource are also counterbalanced, in theory at least, by the possibility that the outsourcing of core functions is too risky to leave to partners over which a firm does not have direct hierarchical control. However, given that a number of core, safety-critical, functions such as aircraft maintenance have actually been outsourced, we consider that these apparent anomalies need further investigation.

THE THEORETICAL UNDERPINNINGS OF OUTSOURCING

A number of theoretical frameworks have been developed to examine the bases of organisational competitiveness and the degree to which functions should be retained within the organization, or sourced from outside. We focus here mainly on two; first, the resource-based view (RBV) of the firm and second, transaction cost economics (TCE). We would argue that single discipline theoretical perspectives are inadequate when examining structures in industries with complex product and market characteristics, and that these two approaches whilst overlapping in some regards and complementary in others, are more likely to provide a compelling explanation of outsourcing decisions jointly rather than separately (Williamson, 1999)

The resource-based view of the firm (Barney, 1991, 2001; Penrose, 1959; Peteraf and Barney. 2003; Rumelt, 1987) tends to focus on whether firms are able to gain competitive advantage from the possession of inimitable, rare, and valuable resources. Were resources valueless, they would not provide profits; were they imitable, they could be copied by a competitor thus diluting their value, and were they to be common, they would provide no source of differentiation from competitors’ offerings. Thus organisations that have access and congroloover suc□ superior ‘strategic’ resources or assets (as opposed to threshold resources –

those necessary for the firm simply to compete (Haberberg and Rieple, 2007) are likely to benefit from sustainable and/or distinctive sources of competitive advantage.

In contrast, transaction cost economics theory, which has underpinned much recent writing on the nature and structure of industries and the firms within them, has historically been concerned with the question, ‘why do organisations exist?’ Nowadays, it is used to consider where the boundaries of firms lie and thus the factors that make specific organisations and their industries take one form or another (Williamson, 1991; Gander and Rieple, 2004). Key issues are whether the firm buys their inputs on the open market, develops them in house, or chooses some intermediate or hybrid form such as a joint venture, or strategic alliance (Borys and Jemison, 1989; Williamson, 1985; Zenger and Hesterly, 1997). While not explicitly concerned with firm-level competitiveness, implicit within this theory is the presumption that competitive advantage comes from the ability to reduce costs through the setting up of structures in which opportunistic behaviour, and the costs of protecting against this, is minimized.

Although TCE uses assets mainly in the sense of physical things which may be customized to a specific cause, in industries where intangible resources can have significant value, this narrow terminology is not particularly helpful. Strategic resources can also include intangible assets like brands or proprietary technologies and also core competences and capabilities – things that an organization *does* exceptionally well. Thus in the airline industry, some of the most specific assets are knowledge or other intangibles that cannot be traded directly but nevertheless are potential sources of risk if lost including competences in network coordination, scheduling and customer service management for example. On the other hand, there are other key assets that are intangible but which can be traded, such as landing slots, for example.

The two theoretical frameworks overlap in a number of ways. First, the idea that a resource is asset specific in the TCE framework chimes with the notion of rarity and inimitability in the RBV. Second, TCE theory says that assets which are irrevocably committed outside the organisation to a particular undertaking and which cannot easily be reallocated elsewhere are a potential source of costs. This happens because of the need to protect against the risk of hold-up from co-stakeholders who may gain access to or control over these assets. Thus if specific assets are strategic, and thereby critical to the airlines’ competitiveness, costs will be accrued as a consequence of attempting to protect them against the risk of opportunistic behaviour.

The two theories also have commonalities in implying that costs will be minimized or value optimized if companies focus on aspects of their operations in which they can build distinctive competences while outsourcing other functions to specialists (Fill and Visser, 2000; Gadde and Snehota, 2000; Das and Teng, 2000; Tsang, 2000). However, the downside to this is that these specialists may then have increased potential for opportunism through their control of operations which may be important to their partner but at which they are less competent. In addition, firms may also lose the ability to build future capability (Cross, 1995). The costs of protecting against the risks of opportunism are likely to be higher the more critical the resource, although they may be reduced by psycho-social factors such as trust, long-standing relationships or location in an open network that is knowledgeable about behaviour and reputations. Costs may also escalate beyond expectations due to misunderstood contract details, reduced performance standards or the failure to achieve expected quality (Cross, 1995; Lacity et al., 1995; Peisch, 1995).

Thus, the picture that emerges of risks and costs as against the potential benefits of outsourcing is a complex one. Although costs may be saved through outsourcing as a result of economies of scale, low cost locations, specialization, flexibility and the resulting competences that come from experience (Fill and Visser, 2000; Jennings, 2002; Dyer, 1997; Cross, 1995; Lacity et al., 1995; Peisch, 1995), these costs may be increased by the need to protect against the risk of hold-up of valuable resources. In the airline industry, the relative weight of, or interplay between, the various mitigating factors are complicated further by high levels of government intervention and regulation, particularly in the area of safety, as well as a rapidly changing and evolving industry context that is no longer national but global in scope. Assessing the relative costs or strategic benefits of outsourcing in the airline industry is therefore likely to be challenging.

There are also clear data-gathering problems here. In the first place, it is difficult if not impossible to accurately measure whether, and if so to what extent, some resources are valuable enough to add significant profits to a firm's bottom line, and therefore can be considered to be strategic. A good example is that of an airline's capability in customer services: although a qualitative judgment can be made that repeat business follows from good customer care, pinning down precise income figures on to such an amorphous concept is almost impossible when other potential causal variables can never be eliminated. Other resources are similarly problematic. The income generated by an airline's monopolistic control over a specific landing slot is relatively easy to calculate, but is unlikely to be in the public domain. Internal financial information on the relative costs and benefits of, for example, in-house versus outsourced ticketing, even if internally available, is never going to be made public, simply because of the need to protect sensitive commercial information.

It is perhaps for these reasons that few attempts have been made to explicitly value strategic assets or transaction costs in any industry, let alone one as complex as airlines. Indeed, a major criticism of both frameworks is that although they are theoretically appealing, they are empirically under-developed (reference needed). Although the airline industry appears to be moving towards a network form, in which hierarchical control is no longer seen to be the best way of organizing, whether this has happened in line with predictive theory is worth examining.

THE INVESTIGATION

We now apply these two theoretical frameworks to an exploratory study of the international full service airline sector. As a basis, we use the key dimensions of both the RBV and TCE frameworks to examine the actual structure of the airlines against that implied by these theories. Both the RBV and TCE perspectives would predict that certain functions of the airline industry should be retained in-house whilst others could be beneficially outsourced. In our sample of seven major airlines we attempt to identify both strategic and non-strategic activities and resources and ascertain any developments in their ownership, management or control over time. Specifically we are interested in whether they are managed within a hierarchical structure, bought on the open market or outsourced in some form or another.

Table 1. Sample of Seven International Airlines

European airlines:
Air France - KLM
SAS
British Airways
US airlines:
American Airlines
United Airlines
Pacific Rim airlines:
Cathay Pacific
Qantas

Table 2. Airline Organisational Functions Examined

1. Plane acquisition and ownership
2. Engineering and aircraft maintenance
3. Customer sales and ticketing
4. In-flight catering
5. Corporate identity and brand management

The airline functions that we have chosen to examine are important operational areas that are the subject of current industry debate about the merits or otherwise of outsourcing. These functions have been chosen inductively from various bodies of literature, both academic and industrial. The sample of airlines is purposive; all seven are major, full-service carriers from different parts of the world which now compete in a global industry. The data on the degree of outsourcing by the airlines is taken from a range of secondary sources including industry surveys, academic and industry journals and the airlines' own corporate websites.

The sample of airlines investigated and the airline functions examined are shown in Tables 1 and 2:

In reality, these functions proved to be not simply either operated in-house or outsourced, but subject to more complex and diverse arrangements. Some airlines, for example, outsourced to subsidiaries that were either wholly owned or jointly owned with a partner or partners. To give an overall picture, the functions were deemed to fall into one of four categories as follows:

(a) Undertaken wholly in house or by wholly-owned division or subsidiary
(b) Partly undertaken in house or by wholly-owned subsidiary / partly outsourced
(c) Wholly outsourced to partly-owned subsidiary or joint venture
(d) Wholly outsourced to an external supplier

The results are shown in Table 3.

Table 3. Degree of Outsourcing of Functions by Sample Airlines

Airline	Air France / KLM		British Airways*		American Airlines		United Airlines**		Cathay Pacific		Qantas		SAS	
Airline Function	2007	2010	2007	2010	2007	2010	2007	2010	2007	2010	2007	2010	2007	2010
Plane acquisition and ownership	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Engineering and aircraft maintenance	a	a[1]	a	a	b	A***[2]	b	b	b	b	a	B***[3]	b	b
Customer sales and ticketing	b	b	b	b	b	b	b	b	b	b	b	b	b	b
In-flight catering	c	A***[4]	b	b	d	d	a	D***[5]	a	B***[6]	a	a	d	d
Corporate identity and brand management	b	b	b	b	b	b	b	b	b	b	b	b	b	b

Key:

a. Principally undertaken in house or by wholly-owned division or subsidiary

b. Partly undertaken in house or by wholly-owned subsidiary, partly outsourced

c. Wholly outsourced to partly-owned subsidiary or joint venture

d. Wholly outsourced to an external supplier

*At the time of writing in June 2010 BA is in the process of merging with Iberia

** At the time of writing in June 2010 United have announced that they are to merge with Continental

*** Activities where the outsourcing policy appears to have changed since our original data were obtained in 2007 (see Rieple and Helm, 2008)

FINDINGS AND DISCUSSION

We now examine these five major functions in comparison with the degree of outsourcing predicted by our two chosen theoretical frameworks using the three dimensions of the resource-based view; *inimitability, rarity* and *value* and the four dimensions of transaction cost economics; *asset-specificity, bounded rationality, opportunism and the risk of hold-up,* and *frequency of use*. In addition, we briefly discuss the reason behind any changes in outsourcing policy between 2007 (see Rieple and Helm, 2008) and 2010 when this chapter was written.

---

[1] See http://corporate.airfrance.com/en/the-airline/activities/maintenance/ accessed 15th June 2010

[2] Stewart, D.R. (2009).AA mechanics lobby capital. Tulsa World, 17th December

[3] See Schneiders, B. (2008). The Age, June 27th

[4] See http://www.airfranceklm-finance.com/other-activities.html accessed 15th June 2010

[5] IATA Airlines International (2010). http://www.iata.org/pressroom/airlines-international/feb-2010/pages/06.aspx accessed 15th June 2010

[6] http://www.qantas.com.au/qcatering/who-we-are/index-html accessed 15th June 2010

MAJOR ORGANISATIONAL FUNCTIONS OF INTERNATIONAL AIRLINES

1. Plane Acquisition and Ownership

Airlines acquire planes which, like any capital assets, are usually either bought and owned outright or operated under some kind of leasing arrangement with a finance provider such as a bank or leasing company. Two main competences are relevant here; first, the ability to negotiate the best terms when acquiring the plane from a manufacturer, and second, the ability to obtain and manage the financing and leasing deal that is most favorable to the airline over the period of ownership of the asset and in its disposal.

Airlines themselves may have skills in getting the best deal when buying or leasing aircraft and arranging finance for them. However competences in acquiring and financing capital assets like planes are not necessarily unique or specific to airlines and are therefore neither inimitable, rare nor uniquely valuable, assuming that there exists a mature finance and leasing industry which can provide these services. Competences in acquiring and financing planes are therefore not necessarily at risk of hold up, unless they involve rare, specialist, proprietary knowledge; neither are the terms of aircraft financing deals generally difficult to contract for and so not subject to constraints of bounded rationality. Acquisition and disposal of major assets like aircraft is also usually a periodic rather than a frequent occurrence for an airline.

It might be expected that a specialized leasing company which is acting on behalf of a number of airlines might enjoy benefits from relational contracts with aircraft manufacturers as well as economies of scale in the processes of financing and acquiring planes that individual airlines might not enjoy. All these factors would suggest that the acquisition, financing and ownership of planes should be outsourced to specialist providers.

Although in our sample of airlines there appeared to be an ongoing trend towards outsourcing plane acquisition and ownership - in 2006, SAS, for example, was reported to have sold and leased back part of its fleet (Bjorndal, 2004; Aviation Today, 2006) , as did UAL in 2008 (Ranson, 2008) - our results actually showed a variety of diverse arrangements. While all the airlines owned some of their planes outright, others were leased. All the airlines in the sample had leasing subsidiaries which could provide this specialist function. However, all the airlines also outsourced some of their leasing and finance activities to external providers of some description, as might be predicted by both theoretical frameworks. Leasing is a relatively easy way for airlines to acquire new aircraft, particularly useful when profitability is elusive and capital is short. Even some of the best airlines are unprofitable some of the time, and more generally, according to UAL's CEO Glenn Tilton, the industry has "systematically failed to earn its cost of capital" (Doganis, 2010). Thus airlines with weak balance sheets can acquire capacity by means of operating or finance leases from the numerous aircraft leasing companies such as GECAS or ILFC.

The fact that some of the acquisition and finance function is still retained in-house, rather in contradiction to what would be predicted by both the RBV and TCE models, raises the question as to whether there are some aspects of the aircraft acquisition process that are more asset specific than might be immediately apparent and that therefore should remain within the organization. We speculate that the reasons for this mismatch between predictive theory and observed practice could be residual legacy capabilities and long term, ingrained competences that some airlines may still possess in the acquisition and financing of aircraft or longstanding relationships and relational contracts with aircraft manufacturers.

2. Engineering and Aircraft Maintenance

The maintenance of planes so that they are safe and reliable is arguably one of the most important functions that airlines perform, not only because of the demands of regulation, but also because a perception of safety is critical to an airline's reputation. However, the predictions that our two theoretical lenses make for the outsourcing of aircraft maintenance operations is not straightforward and, indeed, there is a mixed picture of maintenance being carried out in-house and outsourced. In this industry, any purely theoretical choice of structure is complicated by high levels of regulation and inspection by government agencies.

One could imagine that a reputation for safety, being an intangible resource, would be valuable and a deciding factor in the choice of airline for customers. However, all major airlines in the developed world are now perceived to have very high levels of safety and this reputation is therefore not rare, neither are its underlying causes inimitable. Such a reputation is thus a threshold rather than a strategic resource.

Reliability is less straightforward. A decline in consumer confidence as a result of questions over cancellations of flights and plane breakdowns appears to have been at least a contributory factor in the demise of one major airline, TWA (Woolsey, 1998). A recent McKinsey study (Doig et al., 2003) also suggests that routine maintenance work causes continual delays, thus presumably affecting reliability in those airlines that are affected. Data on which airlines these are, perhaps not surprisingly, do not appear to be available in the public domain. Neither is it clear what the airlines' relative delay ratios are due to; we speculate, for example, that it may be due to an inability to negotiate privileged access to scarce time-slots within repair shops (Pilling, 2005). In the supply of maintenance functions one relevant resource is capacity - this is scarce and time-specific. The control of slot scheduling and prioritizing, and therefore the amount of time an aircraft is lying idle and out of action, allows some potential for hold up. Thus availability of and control over capacity may be an important factor underpinning any decision to outsource some aspects of aircraft maintenance.

To some extent, particularly where other aspects of maintenance are concerned, both bounded rationality and asset specificity are low. Many maintenance tasks are routine, requiring non-specialist resources. There appear to be a number of suppliers with the necessary, relatively low-grade, skills for many of these tasks. As aircraft manufacturing nowadays produces vastly more reliable planes than it did even twenty years ago, much ongoing maintenance is standardized and carried out according to detailed manuals provided by the plane's manufacturer (Argyres 1999).

A lot of maintenance can therefore be contracted out at predictable cost, which can be lower than an in-house operation because of economies of scale and scope. Efficiencies come from the possession of a suitable - perhaps dedicated - plant, but also from learning curve effects. Some maintenance providers have found that considerable cost savings can be made through dedicating repair shops to only one sort of aircraft, and some airlines, notably

Southwest and other low-cost carriers, have specialised in operating only one model of plane specifically because it minimises maintenance costs. Some estimates claim that specialist maintenance shops can have up to a 40% cost advantage (Velocci, 2004).

Heavy maintenance is a different matter and a more specialised activity, focusing on major overhaul, component replacements and structural repairs to an aircraft, all of which occur on a less frequent basis. Entry costs to heavy maintenance are high with a need for specialised hangars, staff and equipment. Because of this, the risk of hold-up is, in theory, high and outsourcing should therefore be minimal.

Maintenance in this industry is also subject to inspection by regulators. However, at least two major US air crashes in the last decade have been blamed on a combination of lax controls over maintenance and weak oversight and supervision by the industry regulator and the Federal Aviation Authority (McCartney, 2004). A recent study also suggests that maintenance mistakes have caused significantly greater safety problems than industry statistics have claimed (Pasztor, 2004). Inadequate training and supervision of mechanics and the spread of maintenance work over geographically widespread (and therefore out of sight of the regulators) locations were identified as causes, and in both these cases, in-house and outsourced maintenance contractors were blamed. On the other hand, a number of commentators have pointed out that outsourced maintenance is not necessarily bad maintenance; Continental Airlines, for example, subcontracts its engine maintenance to General Electric which built its engines in the first place and has its own reputational assets to protect. In addition, Southwest, which hasn't had a fatal crash in all its 33 years and which consistently has fewest delays and cancellations, outsources more than half of its maintenance activities (McCartney, 2004). Whether weak supervision and the passing of responsibility to the regulators is more or less likely in an in-house or an outsourced operation is a material concern here.

Although it appears that actual industry practices vary widely, the overall trend appears to be towards greater outsourcing of the maintenance function. Current levels of outsourcing of about 50% are forecast to grow to about 65% by the end of the decade (McCartney, 2004; Johnson, 2004). Lower cost carriers are the biggest outsourcers, apparently because they lack both the competence and scale to be able to compete effectively in this function (Insinga and Werle, 2000). Full-service airlines are more likely to do more work in-house, outsourcing 26%, although there are anomalies: Continental Airlines, for example, outsources about 60% of its maintenance, its goal being to do regular work in-house and outsource the peaks and valleys - a policy that allows the airline to ‘keep its experienced work group of 3,300 - and its core competency’ (Shifrin, 2004). Some airlines such as Delta and Lufthansa are increasingly specializing in the maintenance function and offering this facility to other carriers (Michaels, 2004).

FedEx, which contracts out much of its heavy maintenance, deals with the risks of hold-up and quality of supply by establishing long-term relationships with partners, looking for competence, a reputation for quality and an ability to meet promised turn-around times (Shifrin, 2004). According to Shifrin, FedEx accepts suppliers only after they meet stringent surveillance and review criteria, then on-site management teams are established at each supplier’s location. After maintenance, FedEx tracks the service performance of each aircraft by monitoring ‘post-check reliability performance’.

Within our sample of major, mixed fleet airlines, there is a similarly diverse pattern of maintenance strategies. In our sample, 50% contract out at least some of their maintenance operation. United, and Cathay Pacific have sold what they regarded as non-core divisions such as their repair shops and now subcontract maintenance, in some cases to a joint venture. United Airlines has shown the most dramatic cutback in internal maintenance activities. In 2002 it was the third largest airline maintenance provider; since then it has sharply reduced its in-house maintenance, now outsourcing heavy, low frequency, maintenance on both its Airbus and Boeing airplanes, and engine maintenance to Pratt and Whitney. Air France-KLM, and BA control all maintenance in-house. In 2004, SAS, which traditionally carried out all maintenance internally, floated its maintenance division into an autonomous subsidiary, SAS Technical Services (STS) with the mission to be a full service provider in the world-wide maintenance sector and to take advantage of a market that is growing rapidly given the increasing number of smaller airlines, particularly low cost operators. Like Lufthansa, it appears to be developing as a maintenance specialist.

However, two of our airlines have changed their policies in the last three years – in opposite directions. American Airlines having at one time sold off some of its repair shops, has now moved more of its maintenance back in-house, citing increasing (union-influenced) concerns over safety – the only major US airline to undertake maintenance almost entirely in-house (Stewart, 2009). In contrast, Qantas has chosen to move in the opposite direction from an in-house policy to increasingly outsourced maintenance – due apparently to its ability to achieve lower costs (Schneiders, 2008).

What seems clear is that this is an industry in transition and one which is also complicated by artificial influences on structure engendered by regulation (or perceived lack of competent regulation). In some regions declining fears about the quality of the standards of repair shops, and their oversight by regulators, have encouraged a greater use of outsourcing. In contrast, some US airlines appear to have retained or increased their maintenance function just because of such concerns. What appears clear is that frequency, capacity and the specialist nature of some aspects of the maintenance function are all potentially important contributors to outsourcing decisions which bear further investigation. As SAS's CEO, Jurgen Lindegaard has suggested,

‘Outsourcing in the MRO (maintenance and repair operations) industry will move from a niche management tool to a mainstream, strategic weapon for many firms … and as the move to a multi-sourced environment accelerates, outsourcing will become the next new business-critical process’ (Burchell. 2004).

3. Customer Sales and Ticketing

Customer sales and ticketing encompass a wide variety of activities involving the marketing, distribution and issue of tickets to different types of customers through a number of channels including direct sales, the internet, agents, subsidiaries and other intermediaries. An airline’s key requirements in this area are wide and effective distribution which is increasingly dependent on competences in information technology (IT) and the management of data, particularly in relation to managing and maintaining mutually beneficial relationships with customers and also key intermediaries; in other words, relational contracts with final customers, distributors and other channel members. An effective and efficient reservations and ticket distribution system is a valuable resource for an airline and one which may become more so in the future as a source of market and customer information and as means of achieving better market responsiveness.

The IT based reservation and ticketing systems that many airlines make use of or subscribe to are, to a greater or lesser degree, adaptations of standard ‘off the shelf’ systems from either specialist IT providers or from another airline. However, there are indications of a growing awareness of some of the shortcomings of using standard systems and a move towards either more custom made or hybrid systems by some carriers. A notable example of this is Southwest Airlines which in the late 1990s began to move from a standard ‘bought in’ system to one which is largely bespoke and which was developed in conjunction with Hewlett Packard. There are also signs within the industry that, even when an airline makes use of a standard, ready-made IT system, it is customised by the airline to some degree for its own purpose. Compatibility of an airline’s systems with those of its distributors, both off and online, is also a prime requirement, which would also suggest a need for a degree of customisation and control implied by a hierarchy or quasi-hierarchical arrangement.

Another motivation for the adoption of proprietary IT for reservation and sales is the apparent growing recognition that it can also be a source competitive advantage by helping to achieve significant cost savings and efficiencies in the reservations process, while at the same time providing more sophisticated and valuable management and market information and feedback. Some of the information that reservation systems hold, such as flight scheduling, current pricing policy and customer and distributor details, for example, and the way this information is processed or used, will inevitably be proprietary and specific to a particular airline and therefore may well be inimitable, rare and potentially valuable. It will also be asset specific, liable to risk of hold up by an outside supplier, suggesting that it should be kept in-house. On the other hand, those parts of the sales and ticketing function that are not specific, more frequent, routinised, easily to contract for and not susceptible to hold-up, will more likely to be outsourced.

Against a background of rapid industry adoption of e-ticketing, outsourcing of reservations seems to be part of a wider trend to contract out mainstream IT functions by major airlines. Our results show that the reservations systems of all but one of the carriers in the sample are partly in-house and partly outsourced as theory would predict, although it seems that there is a trend to consolidation around a few specialist contractors such as Amadeus. Given the increasing consolidation in the industry this trend appears likely to increase in pace: Air France/KLM for example, have recently replaced their legacy ticketing systems with an Amadeus-based ticketing system which is integrated with their Altair-based sales platform (Amadeus, 2010). This implies that there are some parts of a sales and reservations system that benefit from being kept in-house as a valuable asset requiring a high degree of control. On the other hand, as deregulation and the economic pressures in the industry force airlines towards alliances, and nowadays mergers, there are good reasons for setting up collaborative and cooperative sales and ticketing arrangements between partners.

4. In-Flight Catering

Although catering has a large unskilled manufacturing component, it also has a large service or logistics element, such as the transportation of assembled food to the aircraft on time. According to some commentators this is not only tricky, but is a 'logistical nightmare’ (see for example Pilling, 2002; Meacham, 2004). The logistics skills involved are therefore both highly specialized and rare, and the design and operation of integrated IT scheduling systems is a particularly important set of competences. On the other hand the manufacturing of the food is not complex and the task is routine and imitable. Many catering functions are relatively unskilled requiring little up-front investment and with variable costs that are proportionately higher than fixed costs. Facilities are not rare in most of the locations where our airlines are based, and asset-specificity is relatively low.

The potential for hold-up is therefore paradoxically both low and high. In practice the airline catering sector seems to be concentrated in two very large in-flight catering suppliers, Gate Gourmet, now independent but formerly a subsidiary of Swissair, and LSG Sky Chefs, owned by Lufthansa which recently took over SA ’s in-house catering operation. Other than these two major suppliers, caterers are small and regional in focus. Although there are a number of new entrants in the sector, most commentators do not anticipate that this will become a substantial trend.

The concentration of the catering supply industry is partly to do with cost reduction; Barton and Bradshaw (1994) calculated that outsourced caterers were able to achieve labour costs which were at least 30% lower than those of airlines in-house catering divisions. Large contract suppliers can also sell their products to a wide number of customers, thereby achieving substantial economies of scale as well as developing the necessary specialist competences in the crucial logistics element of the task.

As our results show, most airline catering is outsourced. However, recent experience of industry disputes with ground staff and catering suppliers suggest that the risk of hold up could in fact be higher than theory would predict. The availability of short term capacity in the catering industry may well be an issue and in-house provision may in some cases be a better strategy than the iirlines’ current stance. Gate Gourmet's disputes in recent years with both Delta and British Airways shows how vulnerable airlines can be to disruptions in catering supplies. In Delta's case, the sudden withdrawal of Gate Gourmet's services in a dispute over payment led to passengers defecting to budget airlines who did not provide food, while in August 2005 British Airway's Heathrow airport baggage handlers came out on a wildcat strike in sympathy when Gate Gourmet, BA's caterer, dismissed 600 staff, severely disrupting the airline's flights. Although BA eventually solved the absence of in-flight meals by issuing vouchers, this was only after it had grounded 900 flights, lost approximately £45m, and inconvenienced 100,000 passengers across the world. At no point did the airlines use alternative suppliers. Although both are continuing to outsource their catering, it is interesting to speculate whether their experiences will result in a view that providing in-flight meals is something that they can do without.

5. Corporate Identity and Brand Management

Corporate identity and brand management activities are concerned with creating and managing an organisation’s brand values and reputation and trying to ensure that these are reflected throughout its interactions with customers and other groups of stakeholders. It is essentially about managing the corporate face that a company presents through the design of its hardware, software, infrastructure, communications and the behaviour of its employees. A brand is inevitably tied up with an organiza□ ion s ift□] mand corporate values, how it is positioned in the marketplace and the image it seeks to present in differentiating itself from its competitors.

As Keller (1998) has pointed out, a brand identity is a unique resource which differentiates and adds value to an organisation and its products, particularly in mature industries where real, tangible differences between competing product offerings may be few. Successful branding can result in achieving premium prices, customer loyalty and repeat purchase in a competitive marketplace; thus a successful brand can be one of the most important strategic assets that a company owns and this is reflected in the growing practice of placing a significant financial value on brands on company balance sheets in some countries.

There are two distinct aspects to corporate identity and brand management. The first is the long term control and management of the brand as a whole. The second is short term, one off, project based changes or revisions to the brand in response to factors such as organisational or environmental changes, usually termedc‘□-branding exercises’. We consider each of these separately.

As a successful brand is a unique and distinctive asset that requires heavy investment to create and develop. It is intrinsically rare, inimitable and valuable and if another organization were to be allowed to exercise any influence over this process or to exploit the value of a brand in some way, this would usually be difficult to control and contract for, and thus carry major risks of hold-up. Ultimate ownership and control of a brand would therefore be expected to be kept very firmly inside an organisation.

An exception to this is when a brand is leased to another party under a licensing or franchising agreement. Licensing brands to other manufacturers or operators occurs in many industries such as retailing, fast moving consumer goods and also in airlines. Smaller, associate carriers are sometimes subcontracted to operate under a major airline’s brand and logo when this is considered to be more efficient or when outright ownership for some reason may not be possible. In these circumstances, an attempt is made to minimize the risk of hold-up by the strict contractual conditions of the licensing deal which may limit transferable aspects of the brand to, for example, the colour and design of cutlery or the placement or use of the brand mark. In practice however, there can be problems of control and enforcing a licensee to maintain the quality and service standards demanded by the brand owner over the period of the contract. There may therefore be a degree of bounded rationality in the practical implementation of licensing deals that, despite its perceived advantages, discourages outsourcing through licensing. The risks and costs in protecting against hold-up in a licensing deal may then outweigh the expected savings and efficiencies, favoring outright ownership.

Although long term brand ownership and control would expected to be kept in-house, short term rebranding exercises are different. A rebranding project involves competences in marketing, managing brand identity and design that airlines would not necessarily be expected to have or need on an ongoing basis, and which can therefore contracted out to one of the many specialist brand consultancies that exist in developed economies. Such consultancies have competence and cost advantages because they are able to achieve economies of scale and scope in design.

Our results reflect this mixed situation. Many of the most important aspects of the brand management function are retained in house, whilst rebranding exercises are outsourced. However, this latter situation is a dynamic one. During the course of a rebranding project, the advice supplied to an airline by a brand consultancy may prove to be so successful that that particular consultancy's expertise becomes more asset specific and valuable to the airline, and dependency is increased. Under these circumstances, the relationship between consultancy and airline may also become much closer and the boundaries between them more permeable and less clearly defined as the airline seeks to absorb the value created in the relationship within its own boundaries. Even though the consultancy may not be totally subsumed into the airline, a long term mutually dependent relationship may develop.

DISCUSSION AND CONCLUSIONS

This chapter has examined the outsourcing strategies for some key functions in small number of major, international, full service airlines We recognize that we have raised more questions than answers, particularly in terms of highlighting the intricacy of some aspects of the airlines' operations. Nevertheless, we believe that we have identified some interesting and apparently anomalous issues to do with what two key organisational theories predict are the most effective management and ownership structures in this industry.

The major, international carrier sector of the airline industry was, until fairly recently, relatively stable and heavily regulated and controlled by national governments. Indeed in some countries this is still the case, although the phased 'open skies' agreements such as those of 2007 between the US and EU and 2010 between the ASEAN countries are driving rapid change in the industry. As well as increasing differentiation of airlines on the basis of price or quality of service, there is evidence of a massive shift in the structure of the industry towards consolidation. Foreign companies are competing aggressively in markets previously dominated by national players and firms in other industries have entered the market to provide support services such as maintenance, ground handling and catering, activities that were traditionally managed by the airlines themselves (Barton and Bradshaw, 1994).

In this more unstable and competitive environment, those airlines that are better able to manage their organisational arrangements to achieve greater efficiency or effectiveness through lower costs, customer responsiveness or higher quality of provision, are likely to be more successful. As outsourcing arrangements or intermediate structures, such as alliances of various types, appear to be proliferating in parallel with deregulation and increasing volatility, one question is whether these two streams of developments are linked and, if so, to what eventual outcome.

Airlines may choose to outsource because specialists have greater access to superior cost drivers like low cost locations, expertise, learning and scale economies (Jennings, 2002; Peisch, 1995). Other potential benefits are the enhancement of resources (Dyer, 1997) and the maximizing of flexibility (Fill and Visser, 2000; Lacity et al., 1995). Jones and Hesterly (1997) suggest that 'under conditions of demand uncertainty, firms disaggregate into autonomous units primarily through outsourcing or subcontracting'. This decoupling increases the ability to respond to a wide range of contingencies because resources can be reallocated cheaply and quickly. This would imply that the airline industry, given its rapidly changing economic environment world-wide, particularly since 9/11, would be characterised by increasing outsourcing.

In fact, this is not always the case and we have not generally found as much outsourcing as we expected. Our results show an emerging picture of in-house provision, partial and full outsourcing among the airline functions examined that is complex, mixed and not always what theory would predict. We suggest that this may be due to three main factors. First, constraints imposed by regulatory forces acting on the industry, including safety regulation. Second, the issue that some operational functions are in fact more specialized, valuable and asset-specific than they might at first appear, and therefore are hard to outsource because of a legacy of core resources, capabilities and relational contracts retained by what were once state protected companies. Third, the fact that some supplier industries to which functions could, in theory, be outsourced are still at an early life cycle stage, and not fully developed or mature, resulting in a lack of available suppliers and readily available capacity in critical areas. Thus, in a rapidly evolving industry context like airlines, the degree of asset-specificity, uniqueness, rarity and value that can be attributed to a particular resource is not fixed and static, but changeable and dynamic. It would be useful if further studies were to examine the changes in the prevalence of outsourcing over the last twenty years or so and assess in depth the consequences on the airlines' efficiency and/or effectiveness.

There are some interesting anomalies too. Lower cost carriers do by far the most outsourcing of maintenance, implying that there are some cost related advantages to this structure. But this also implies that the full cost carriers' business model is very different from that of the low cost carriers', and therefore their in-house maintenance policies in some way confers advantage or at least does not lead to disadvantage. It is hard to see why this should be so, and thus we speculate that legacy issues, resulting from the full cost carriers' history as state owned airlines or as full-service providers in a less competitive time may provide some explanation for the present choice of hierarchical control. If this is the case, then we predict that our full cost carriers are likely to outsource more of the maintenance function in future; however, they will only be able to do so if there is a parallel development of an infrastructure of supporting industries.

On closer examination, each of the broad functional areas that we looked at comprised many sub-functions, each of which displayed different characteristics in terms of suitability for outsourcing or retention in-house. Examining them broadly at the chosen high levels of abstraction therefore offered only a preliminary opportunity to map theory against practice. Our examination of the maintenance function as a whole, for example, ignores significant differences in characteristics between the different types of maintenance. Some appear more suited to hierarchical control, while others appear more advantageously outsourced. In the airline industry, these decisions are complicated yet further by high levels of regulation and government control. Similarly, some aspects of IT could be considered to be a valuable, strategic resource and therefore to be kept within the organisation, while some non key IT functions are more amenable to being outsourced. These are issues that seem to offer scope for more finely-grained examination.

What adds to the difficulty of mapping theory against practice is the fact that the airline industry is changing rapidly and thus the effectiveness of the various outsourcing strategies is difficult to assess. This is a well known problem of both the RBV and TCE lenses; both are economics-based models which tend to ignore, or at least inadequately deal with, the issue of environmental dynamism and how resource advantage can change over time. In the increasingly competitive full service airline industry, these are issues that will become ever more urgent and challenging to address.

REFERENCES

Amadeus, (2010). Available from: http://www.amadeus.com/amadeus/x5088.html accessed 15th June 2010.

Argyres, N. S. (1999). The Impact of Information Technology on Coordination: Evidence From the B-2 Stealth Bomber. *Organization Science*, *10(2)*, 162-180.

Aviation Today, (2006). *Supply Side*, Scandinavian Airline Systems. 2nd January.

Bansal, P. & Roth, K. (2000). Why companies go green: A model of ecological responsiveness. *Academy of Management Journal*, *43(4)*, 717-736.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17(1)*, 99-120 .

Barney, J. (1995). Looking inside for competitive advantage. *Academy of Management Executive*, *9(4)*, 49-61 .

Barney, J. (2001). Is the resource based view a useful perspective for strategic management research? Yes. *Academy of Management Review*, *26(1)*, 41-56.

Barton, C. & Bradshaw, L. (1994). Is there a future for Europe's airlines? *McKinsey Quarterly*, *4*, 29-41.

Bjorndal, B. (2004). SAS moots selling entire Airbus fleet to cut costs. *AFX International Focus*, 4th February

Borys, B. & Jemison, D. (1989). Hybrid arrangements as strategic alliances: Theoretical issues in organizational combinations. *Academy of Management Review*, *14(2)*, 234-249.

Burchell, B. (2004). MRO Europe Wrap-Up; Cooperation, competition, pmas and EASA developments were hot topics. Overhaul // Maintenance, 1st November.

Byrne, J. (1993). *The virtual corporation*. Business Week, 8th February.

CAA, (2006). *Ownership and Control Liberalization*. London: Civil Aviation Authority.

Chaffin, J. (2010). Open skies deal leaves US rules intact. *Financial Times*, 25th March.

Das, T. K. & Teng, B. S. (2000), A resource-based theory of strategic alliances. *Journal of Management*, *26(1)*, 31-61.

Das, T. K. & Teng, B. S. (2001). Trust, control and risk in strategic alliances: An integrated framework. *Organisation Studies*, *22(2)*, 251-283 .

Davidow, W. H. & Malone, M. S. (1992). *The Virtual Corporation*. New York, Harper Business.

DiMaggio, R. J. & Powell, P. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*, 147-160

Doganis, R. (2010). Hanging in the balance. *Airline Business*, 26 March

Doig, S. J., Howard, A. & Ritter, R. C. (2003). The hidden value in airline operations. *McKinsey Quarterly*, *4*, 104-115.

Dyer, J. H. (1997). Effective interfirm collaboration: how firms minimize transaction costs and maximize transaction value. *Strategic Management Journal*, *18(7)*, 535-556.

Fill, C. & Visser, E. (2000). The outsourcing dilemma: a composite approach to the make or buy decision. *Management Decision*, *38(1/2)*, 43 -51.

Gadde, L. E. & Snehota, I. (2000). Making the most of supplier relationships, *Industrial Marketing Management*, *29(4)*, 305-316.

Gander, J. & Rieple, A. (2004). How relevant is transaction cost economics to inter-firm relationships in the music industry? *Journal of Cultural Economics*, *28(1)*, 57-79.

Greve, H. R. & Taylor, A. (2000). Innovations as Catalysts for Organizational Change: Shifts in Organizational Cognition and Search. *Administrative Science Quarterly*, *45(1)*, 54-80.

Haveman, H. A. (1993). Follow the leader: Mimetic isomorphism and entry into new markets. *Administrative Science Quarterly*, *38*, 593-627.

Insinga, R. C. & Werle, M. J. (2000). Linking outsourcing to business strategy. *Academy of Management Executive*, *14(4)*, 58-70 .

Jennings, D. (2002). Strategic sourcing benefits, problems and a contextual model. *Management Decision*, *40(1/2)*, 26-34.

John, C. (1995). IT Outsourcing: British Petroleum's competitive approach, *Harvard Business Review*, May-June.

Johnson, K. (2004). Lufthansa unit will handle parts for spirit airlines. *The Wall Street Journal*, 29th October.

Jones, C. & Hesterly, W. S. (1997). A general theory of network governance: Exchange conditions and social mechanisms. *Academy of Management Review*, *22(4)*, 911-946.

Keller, K. L. (1998). *Strategic Brand Management*,. Upper Saddle River N.J., Prentice Hall.

Lacity, M. C. & Willcocks, L. P. (1995). Interpreting information technology sourcing decision from a transaction cost perspective: findings and critique. *Accounting Management and Information Technology*, *5(3/4)*, 203-244.

Lacity, M. C. Willcocks, L. P. & Feeny, D. F. (1995). IT Outsourcing: Maximize Flexibility and Control. *Harvard Business Review*, *73(3)*, 84-93.

Lindegaard, J. & quoted in Velocci Jr, A L. (2004). Tailwinds. *Aviation Week // Space Technology*, *161(11)*, 20th Sept.

McCartney, S. (2004). The Middle Seat: Who's Inspecting Your Airplane? --- Carriers Now Outsource More of Their Maintenance But FAA Supervision Is Lax. *Wall Street Journal*, 3rd March.

Meacham, S. (2004). Flying high. *Sydney Morning Herald*, 17th February.

Michaels, D. (2004). Lufthansa's Diversification Plan Yields Little Payoff for Holders. *The Wall Street Journal*, 17th March.

Mifsud, P., Bonilla, C. & Cordle, V. (2010). United and Continental: a Big Win for all Stakeholders. *Airline Forecasts*, May.

Miles, R. E. & Snow, C. C. (1986). Network organizations: new concepts for new forms. *McKinsey Quarterly*, *86(4)*, 53-66.

Pasztor, A. (2004). Study cites maintenance risk. *The Wall Street Journal*, 21st April.

Peisch, R. (1995). When outsourcing goes awry. *Harvard Business Review*, May-June, 24-37.

Penrose, E. (1959). *The Theory of the Growth of the Firm*. Oxford, Blackwell.

Peteraf, M. & Barney, J. (2003). Unraveling the resource-based tangle. *Managerial and Decision Economics*, *24(4)*, 309-323.

Pilling, M. (2002). Drive to outsource. *Airline Business*, *18(1)*.

Pilling, M. (2005). Capacity crossroads. *Airline Business*, *21(10)*.

Powell, W. W. & DiMaggio, P. J. E. (1991). *The New Institutionalism in Organizational Analysis*. Chicago IL, University of Chicago Press.

Ranson, L. (2008). UAL Fleshes out details of sale-leaseback agreements. *Flightglobal*, 12th Sept. Available at: http://www.flightglobal.com/articles/2008/12/09/319955/ual-fleshes-out-details-of-sale-leaseback-agreements.html, accessed 22nd June 2010.

Richardson, S. (2004). SAS forecasts to be cut by analysts, further cost savings anticipated. *AFX International Focus*, 2nd November.

Rumelt, R. P. (1987). Theory, Strategy, and Entrepreneurship in D. Teece, Ed., *The Competitive Challenge*, 137-158. Cambridge MA, Ballinger.

Shifrin, C. (2004). Opting out. *Airline Business*, *20(10)*.

Stewart, D. R. (2009). AA mechanics lobby capital. *Tulsa World*, 17th December.

Straus, B. (2009). Huge loss spurs restructuring at SAS. *Air Transport World*, 4th Feb.

Tsang, E. W. K. (2000). Transaction Cost and Resource-based Explanations of Joint Ventures: A Comparison and Synthesis. *Organization Studies*, *21(1)*, 215-243.

Velocci Jr, A. L. (2004). Tailwinds. *Aviation Week // Space Technology*, *161(11)*.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism*. New York, Free Press.

Williamson, O. E. (1991). Comparative Economic Organization: The Analysis of discrete structural alternatives. *Administrative Science Quarterly*, *36*, 269-296.

Williamson, O. E. (1999). Strategy Research: Governance and Competence Perspectives. *Strategic Management Journal*, *20(12)*, 1087-1108.

Woolsey, J. P. (1998). The warrior airline. *Air Transport World*, *35(7)*.

Zenger, T. R. & Hesterly, W. S. (1997). The disaggregation of corporations: Selective intervention high-powered incentives and molecular units. *Organization Science*, *8(3)*, 209-222.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 119-141
ISBN: 978-1-61122-079-7

Chapter 4

THE PRICING STRATEGY OF RYANAIR

Tiziana D'Alfonso[1,3], Paolo Malighetti[1] and Renato Redondi[2]
[1]Department of Economics and Technology Management, University of Bergamo Viale Marconi 5 – 24044 Dalmine (BG), Italy
[2]Department of Mechanical Engineering, University of Brescia, Viale Branze, 38, Brescia, Italy
[3]Department of Computer and System Science, Sapienza Università di Roma Via Ariosto 25 - 00185 Rome, Italy

ABSTRACT

This chapter refers to two main fields of aviation literature, namely the analysis of the low-cost business model and the study of dynamic pricing techniques, with respect to the case of Ryanair: the European low cost leader has developed a strictly low fare leading strategies and price formation represents a cornerstone of its success, source of debate for both academic and practitioners.

Researchers have extensively examined the cost-effective policy, which so clearly permeates the low-cost business model. Nevertheless, the success of the low-cost model is based on a fragile balance between fare levels, load factors and operating costs and the importance of the different strategic choices made by carriers suggests examining other elements of the low-cost business model. In particular, the structure of revenues and the determination of prices are nearly as important as the minimisation of costs in the equation of profits and need further investigation. Relatively few facts are known about airline price setting at the micro level and results are quite different. Differences drawn from the difficulties to take into account the micro structure of low cost pricing rather than average fare and from the limited set of available data (most of the studies limited the extension of the sample, few fixed departing data, only one departing airport, a limited set of advancing booking price offered).

In this framework this chapter aims to identify the main features of Ryanair's business model, the competitive and the contextual factors that drive the choice of the average fares and their relative dynamics.

1. RYANAIR'S BUSINESS MODEL

1.1. Deregulation and LCC Spread

The Aviation industry exploded during the Second World Word due to the rapid development of military aircraft. Since then, the international airline industry has thrived on high growth rates although contemporarily incurring periods of deep losses, and in particular showing its weakness during international crises. Furthermore, its rate of technological change has been exceptionally high. However, the most important event affecting the airline industry is perhaps the deregulation process. Since the birth of the aviation industry governments have been involved: airlines were mainly state-owned (the so-called flag carriers) and the industry has always been strictly regulated. The general institutional base of the worldwide industry was introduced in the Chicago Convention 1944. Basically, international traffic was regulated by bilateral agreements, arranged between each country, fixing volume, fares, frequency and traffic share as well as designating the airlines allowed to serve the route.

The introduction of mass transport aircraft, with the introduction of the Boeing 747 aircraft at the beginning of the 1970s, sustained growth in demand for air transport to the extent that airline companies pursued a context with a greater degree of freedom. In 1978 the US domestic market was deregulated, and since then the idea that competition could provide the best service for the public even in the air transport industry started to spread. Currently international traffic is still based on bilateral agreement even if with more liberal conditions: in detail most of nations have signed the US "open skies", a bilateral agreement consisting of an increase in airlines' freedom rights, levying restrictions on capacity, fares and multi-designation procedures. Nevertheless market conditions are far from being in a complete competitive environment: there are no rights to serve domestic routes in other countries and airlines designation still includes the national ownership and control restriction. Influenced by the liberalization of US policy, in the late 1980s a deregulation process started to take place in the European Community, although it was slower and passed through different complex stages. The three European deregulation packages opened the national aviation markets of the EU member states, allowing all European airlines free entry and competition with frequency and fares on any route inside the EU space, included the domestic routes (cabotage rights from 1997).

In this scenario, low cost carriers were born and have consolidated their growth up to values of traffic comparable to the largest traditional carriers. In addition to Ryanair, among the 2009 top six European carriers for passenger traffic, other two are low cost carriers: EasyJet and Air Berlin (respectively 46.1 and 28.9 million of passengers). Figure 1 shows how different was the scenario in 1999.

Table 2 shows the growth rates with respect to 2008 and the average growth in the last five years. Because of the difficulties the world economy is going through, growth rates measured in the last year are, on average, below the average in the period 2004-09.

Despite everything, the top two European low cost carries have continued to grow during 2009: EasyJet and Ryanair have shown the highest growth rates among the top European carriers, respectively 13.2% and 3.4%.

Table 11. Deregulation process: major steps

	Major International market	Intra-European market
Chicago Convention 1944	1th e 2th 2freedom	1th e 2th 2freedom
Bilateral After 1944	Capacity and fare restriction single designation, very few 5th freedom	Capacity and fare restriction single designation very few 5th freedom
New US bilateral 1978-84	3th e 4th freedom , double disapproval rule	Few new bilateral
First package 1988	-	5th freedom less restriction on capacity and fare
Second package 1990	-	Multiple designation, further less restriction on capacity and price
US 'open sky' 1992	5th freedom, free capacity and fare setting, multi designation	-
Third package 1993	-	All 7 rights, free capacity and price setting EU ownership instead of national ownership
1997	-	Free cabotage
2002	-	EU Court of Justice declared Bilaterals illegal
2004	Start negotiation US –EU on "Open Skies"	-
2007	Start "Open Skies II"	

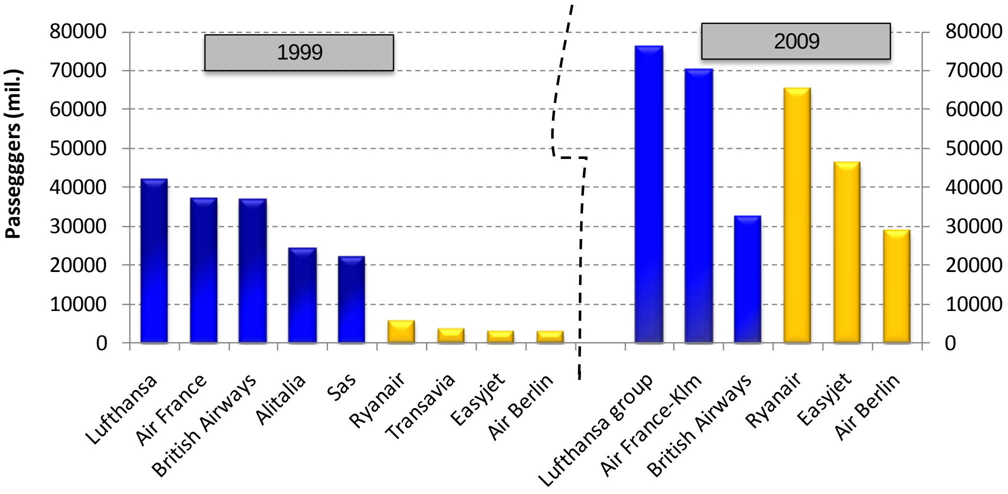


Figure 1. Competitive scenario: comparison between 1999 and 2009.

Table 2. Growth rates with respect to 2008 and the average growth in the last five years. Source: ICCSAI- Fact Book 2010

Growth of passengers carried by major European carriers						
Carriers	Δ passengers 08/09	Δ RPK 08/09	Δ ASK 08/09	CAGR $_{04\text{-}09}$ passengers	CAGR $_{04\text{-}09}$ RPK	CAGR $_{04\text{-}09}$ ASK
Lufthansa Group**	-1.7%	-2.5%	-1.4%	3.0%	3.0%	2.9%
Air France-Klm**	-4.8%	-3.6%	-4.0%	1.3%	3.2%	2.8%
Ryanair	13.2%	11.0%	9.6%	19.7%	23.8%	24.1%
Lufthansa	-2.7%	-2.5%	-1.3%	2.0%	2.4%	2.5%
Air France	-4.1%	-2.7%	-3.8%	1.1%	3.3%	2.5%
Easyjet	3.4%	10.0%	9.6%	13.7%	20.9%	19.2%
British Airways	-4.1%	-3.2%	-4.1%	-1.9%	1.0%	0.0%
Air Berlin	-0.3%	-8.0%	-6.7%	19.2%	13.8%	14.0%
Klm	-6.3%	-5.2%	-4.3%	1.8%	3.1%	3.2%
Sas	-15.7%	-16.7%	-16.3%	1.0%	-0.7%	-1.6%
Alitalia (+ Airone)	-16.6%	-2.7%	1.7%	-0.7%	-3.7%	-2.1%
Iberia	-10.3%	-6.2%	-6.0%	-4.5%	1.6%	0.4%
Swiss	2.4%	-2.2%	-1.9%	8.0%	6.0%	4.6%
Thomsonfly	-18.4%	-15.7%	-14.8%	-5.2%	16.2%	16.0%
Norwegian Air Shuttle	18.2%	10.3%	11.3%	39.1%	45.4%	41.0%
Aer Lingus	7.4%	-1.0%	-5.1%	9.1%	8.7%	9.9%
Air Europa LineasAereas	-2.0%	10.2%	n.d.	6.3%	n.d.	n.d.
Austrian	-6.7%	-10.3%	-9.5%	2.3%	-3.4%	-3.8%
TAP-Portugal	-3.4%	-3.8%	-5.9%	6.9%	9.8%	10.4%
Thomas Cook Airlines	8.3%	4.2%	2.1%	10.4%	13.6%	13.7%
Vueling (+ ClickAir)	-32.8%	56.2%	45.0%	n.d.	n.d.	n.d.

1.2. Ryanair History

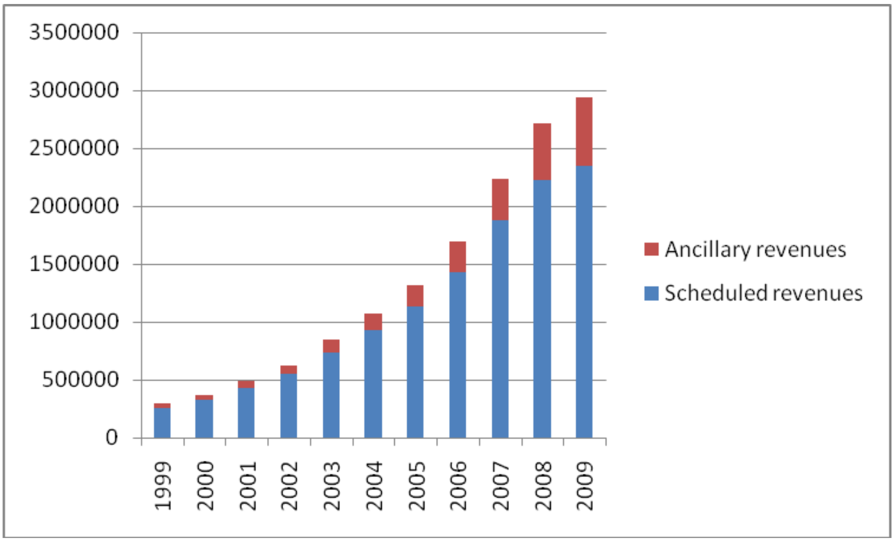
Ryanair is the largest and most successful European Low cost airlines; it has demonstrated amazing growth rate and financial performance whereas the rest of the airline industry has experienced deep losses and struggled to survive.

Historic facts

Set up by Ryan brothers, Ryanair initial services started in 1985 with a 57-member staff and one 15-seater turboprop plane. Ryanair's intent was to connect Ireland and Great Britain, covering Air Lingus's pnefficiencyand leveraging in the large number of immigrants. In 1986 it started to serve Dublin-London (Luton) route facing direct Aer Lingus and British Airways competition: Ryanair strategy focused intently on delivering first-rate customer service with single fare for a ticket with no restrictions. In the following years it started to serve several Irish and British airports: expanding its network routes very quickly, Ryanair was pointing at the heart of Air Lingus's business, facing a fierce price competition with them. Despite the enthusiastic response of passengers and the growth of traffic, the company started to accumulate losses and, in 1991, it came close to bankruptcy. In order to solve the problem it underwent an intensive reorganization also by looking at the low cost model applied in US by Southwest: since then the efforts to preserve and generate cash became paramount. Ryanair became the airlines with the most rude and extreme interpretation of the low cost idea. Non-profitable routes were eliminated and the network was cut from 19 to just 5 routes. Some aircraft were disposed of, and airfares across the remaining network were substantially reduced. In 1995 Ryanair became the major operator in term of passenger carried on the Dublin-London route, one of the busiest Intra European routes. In 1997, the firm went public, floating on both the Dublin and NASDAQ stock exchanges: in this case the IPO was the means to enter into new European markets, serving new customers with different expectations, facing new competitors and undertaking an expansion that required a massive increase in fleet size. After the complete deregulation of the intra European market, Ryanair started to attack the European market in a massive way: 45 new Boeing 737-800 (US$ 2billion) were ordered; new European bases like the contested Charleroi, Frankfurt-Hahn, Milan, were opened. With respect to 2009, only 48% of Ryanair's routes involve UK or Ireland airports, confirming the strong momentum of trade liberalization on intra-European flights phenomenon and the increasing propensity of Ryanair to operate routes within the international community.

Ryanair economic performance

The 1997 was a key year for Ryanair: the listing of a firm on public financial markets usually involves undertaking high financial risk and new operational management challenges. Ryanair showed that it was not only capable of managing itself in this new context: it even gained a new competitive advantage and its average performance level, since 1997, has been substantially higher than the average of traditional airlines, when considering overall return on capital employed.



Source: Ryanair-Investor Relations Homepage.

Figure 2. Revenues trend from 1999 to 2009.

Table 3. Summary table of 2010 results (in euro)

Full Year Results	Mar 31, 2009	Mar 31, 2010	% Change
Passengers	58.6m	66.5m	+14%
Revenues	€2,942m	€2,988m	+2%
Adjusted Profit/(Loss) after Tax	€105m	€319m	+204%
Adjusted Basic EPS(euro cent)	7.10	21.59	+204%

Source: Ryanair-Investor Relations Homepage

In Figure 2 we show the revenues trend form 1999 to 2009[1], with respect to both scheduled and ancillary revenues, i.e. revenues beyond the sale of tickets generated by direct sales to passengers, or indirectly as a part of the travel experience.

Table 3, show the summary result with respect to 2010: they show a 200% increase in profits and traffic growth during a global recession when many of the competitors have announced losses or cutbacks and more have gone bankrupt, including Bluewings (Ger), Globespan (UK), My Air (Italy), Segal Air and Sky Europe (Slovakia). Revenues rose 2% to €2,988m as air fares fell 13% while traffic grew 14% to 67m. Unit costs fell 19% due to lower fuel and rigorous cost control. Ancillary sales grew 11% to €664m slightly slower than traffic growth, and amounted to 22% of total revenues.

The principal highlights of the past year include: profits trebled to €319m; traffic growth of 14% to 67mln; 51 net new aircraft; 8 new bases: Bari, Brindisi, Faro, Leeds, Oslo Rygge, Pescara, Porto, Trapani (total 42), 284 new routes (total 940); passenger service statistics further improved (No 1 on time major airline); a dividend of €500m proposed (€846m returned to shareholders over the past 3 years).

1.3. Success Factors

Market opportunity recognized

A key driver of the emerging market opportunities is the evolution of the competition environment after the market deregulation. Both Ryanair and Southwest started their business a few years before the liberalization of their respective market: they were already "in the business", meaning that they had time to acquire knowledge, routes and customers. Since the number of contended routes with enough traffic was limited, first movers had the opportunity to gain a competitive edge. After the deregulation process, no one of the major carriers went directly inside the rivals served market: they focused on strengthened their intercontinental hub & spoke system.

New entrants likes Ryanair clearly recognized the opportunity to take advantage from high inefficiency level of incumbents on specific routes. In the United States this highly efficient business model had been already introduced by Southwest, based in the idea of offering "the speed of the plane at the price of car": similarly, Ryanair's initial idea was to offer a better alternative to the Ireland-Britain car/ship journey. In this new perspective of competition, their intent was to catch that part of the demand unmatched by traditional airlines due to high fares, based on the intuition that price elasticity was bigger than usually

---

[1] Year ended Mar-31

assumed. Therefore, the implication was to cut all unnecessary services, so-called “frills”, in order to lower fares as much as possible. The key Ryanair’s success factor was the ability to understand the real price-demand curve and to develop a business model able to catch unsatisfied demand trough the introduction of many solutions adopted by charters on scheduled service. Finally, the opportunity, offered by new technologies and the new regulation, to rebalance the supply chain value eroding part of the profit retained by the other actors (GDS, aircraft manufacturer, airports).

Strategy

It is important to highlight how Ryanair’s low cost business model resources were managed in order to catch the emerging market opportunity. The possibility of quickly adopting and implementing the low cost airline model made possible by regulatory evolution during the 1990s in Europe could only have been reached by a firm facing little constraints on growth. These constraints could arise both on internal and external resources and be related to availability of cash, assets, technology, human capital and other intangibles.

External resources. In order to rebalance the proportion of value retained in the supply chain, Ryanair took direct phone and internet reservations, excluding usage of the GDS system and avoiding high fee commission, close to 7-8 % of total operating costs and approximately 40% of total distribution cost increasing, at the same time, the customer behavior knowledge. Secondly, and alongside the choice of specific market segments, the low cost airlines’ goals were routes that enabled them to offer simple services, thus avoiding “complexity costs”, to price-sensible passengers. Consequently Ryanair used secondary uncongested airports with cheaper fees (landing, aircraft parking or handling facilities); as a first mover it chooses only selected airports that, due to the growth opportunity lead by Ryanair, engaged advantageous long term contracts. Finally, Ryanair has a homogeneous fleet (all Boeing 737s) that allows a reduction in costs of training and maintenance, mainly outsourced.

Internal resources. All the decisions are oriented to obtain the maximum utilization level of internal asset. Air flight networks were point to point routes, whereas traditional airlines used the hub & spoke system to increase connectivity with intercontinental flights. The choice of the latter over the former increased dramatically the amount of resources required at the peak times, constraining the entire scheduling system. In order to maximize aircrafts use, Ryanair minimized turnaround time and tended to start flights earlier in the morning and to end them later in the night. In so doing, each plane yielded eight to ten hours per day of activity compared to the five or six of traditional airlines on the same routes. Moreover, secondary airports were less congested and therefore it was easier to obtain slots, facilitating quicker turnaround time. Lastly, time was reduced through quicker check in and boarding procedures and no free food helped keeping the aircraft substantially clean, reducing ground handling facilities.

Human resources. A large portion of the airline cost was related to labor, accounting for up 40% of the total cost, and thus productivity was paramount. Homogeneous fleets allowed a significant higher level of flexibility and significantly reduced training costs. Furthermore, through its higher aircraft utilization rates, Ryanair showed the highest level of productivity in terms of passengers per employee.

Intangible resources. The intangible assets are composed by brand value and market knowledge. In the analysis of the market opportunities we have highlighted how the basic customer needs were to arrive safely at a desired destination. Ryanair was able to demonstrate and convince customers that lower costs were not associated with lower safety standards. The second strategic resource was related to a deep customer knowledge management: in the trade-off between a low fares strategy and the necessity to reach financial break even, decisions on prices could only have been based on a deep knowledge of the market and of customer behavior. The introduction of direct sales and limited offer range – only one fare available at a certain time, simple and clear for passengers – made it possible to find precisely the right price levels on those routes that were reaching enough overall revenues.

Entrepreneurial dimension. Ryanair was not, of course, the most docile competitor that any airlines was hoping to face, and perhaps neither an easy ally. When Ryanair entered new routes, it always did so with the most warlike approach, cutting fares by 50% and facing fierce price competition despite the airline industry being characterized by traits such as the regulatory framework, multi-market contacts and several duopolistic routes that clearly allowed collusion.

In figure 3 we summarize the competitive scenario faced by Ryanair, in terms of opportunities and threats on the part of new entrants, suppliers, competitors, customers and substitutive business.

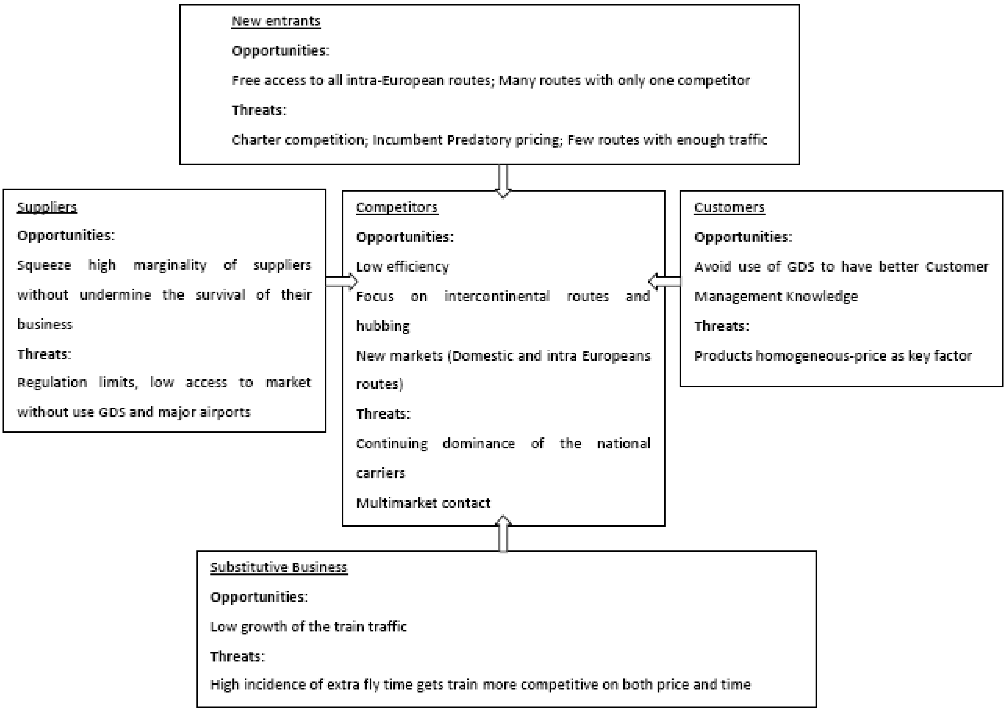


Figure 3. Competitive analysis pre-low cost.

Table 4. Ryanair's offer with respect to the period 1997-2009

Year	No. Routes (one way)	Seats	No. Flights	Average Flight Distance (km)
1997	40	5,213,060	41,170	455
1998	64	6,474,089	50,063	545
1999	70	7,569,110	56,510	607
2000	90	9,854,466	70,625	674
2001	116	12,507,807	86,641	710
2002	154	16,099,639	105,388	739
2003	276	25,231,130	158,875	784
2004	332	31,304,380	184,715	872
2005	496	40,025,856	220,537	944
2006	688	49,145,859	260,031	955
2007	1112	58,753,977	310,887	1,009
2008	1364	70,682,482	374,215	1,025
2009	1767	77,999,544	412,696	995

Source: OAG database

1.4. Network Structure

Table 4 illustrates Ryanair's offer with respect to the period 1997-2009 and show an expanding network in terms of numbers of routes, seats, number of flights and average flight distance during these years.

With respect to 2009, table 5 shows the level of direct competition on routes offered by the top 20 companies in Europe, in terms of percentage of ASK (*Available Seats Kilometers*). The index considers the routes for which there is an alternative route within a conventional catchment area of 100 km: it expresses the ratio between the volume of ASK offered on the routes in competition and the total volume of ASK offered within the departure and the destination area. Specifically, with respect to Ryanair, among the 1886 routes offered, 1638 clearly doesn't present direct competitors. The remaining 248 routes involve little more than 14.6% of the total traffic in terms of ASK. On average, Ryanair has 0.19 competitors on a single route: this value, in the previous year was, 0.18.

Table 6 and 7 illustrate Ryanair's offer during the period 1997-2009 with respect to domestic routes, i.e. linking two airports of the same nation, Great Britain and Ireland. The data show an increase in absolute values in terms of passengers and seats offered, as a consequence of the growth in the total traffic, but a decrease in terms of percentage with respect to the total volume of passengers carried and seats offered during these years.

With respect to other European domestic markets, evidence confirms an increasing propensity of Ryanair to operate routes within the international community: table 8 shows, with respect to 2009, that only 4.8% of Ryanair's routes are domestic routes, confirming the strong momentum of trade liberalization on intra-European flights phenomenon.

Table 5. Average number of competitors per route and % of ASK in direct competition. Data related to 2009

	Average number of competitors per route and % of ASK in direct competition										
Rank	Carrier	No. Routes	%ASK competitor	Average competitor	%Routes compet.	0 comp.	1 comp.	2 comp.	3 comp.	4 comp.	5 comp.
1	Ryanair	1,886	14.6%	0.19	29.5%	1638	178	55	3	6	6
2	Air Berlin	902	74.9%	1.00	41.3%	376	282	165	51	17	5
3	EasyJet	736	58.4%	0.90	35.2%	355	238	76	27	26	9
4	Hapag Lloyd Exp.*	602	86.4%	1.20	27.1%	184	227	123	48	10	4
5	Lufthansa	517	79.2%	1.05	47.6%	192	194	78	36	11	4
6	Air France	460	63.7%	0.55	58.1%	292	120	26	12	7	1
7	Iberia	448	83.5%	0.84	47.2%	267	72	64	16	18	10
8	FlyBe	364	36.1%	0.24	46.2%	285	72	5	2	0	0
9	Norwegian Air Shuttle	337	64.9%	0.82	30.6%	172	106	29	13	11	6
10	SAS	330	80.1%	0.89	46.9%	135	136	39	7	7	6
11	Condor Flugdienst	258	91.5%	1.62	28.6%	50	73	91	31	8	1
12	Wizzair	212	23.5%	0.33	33.1%	176	22	2	6	4	2
13	British Airways	207	86.1%	1.08	42.8%	65	87	37	9	9	0
14	Austrian	202	11.5%	0.11	21.7%	188	8	4	1	1	0
15	Wideroe	202	11.55	0.11	21.7%	188	8	4	1	1	0
16	Jet2	199	32.3%	0.37	23.8%	153	35	3	2	4	2
17	Air Europa Lineas Aereas	198	87.4%	2.03	24.9%	48	38	46	27	20	13
18	Transavia Airlines	198	41.5%	0.86	35.0%	134	25	14	8	6	6
19	Aer Lingus	196	54.2%	0.67	39.0%	103	63	24	4	2	0
20	Olympic Airlines	178	97.2%	1.62	29.5%	11	89	48	20	7	2

Source: ICCSAI – Fact Book 2010.

Table 6. Ryanair domestic offer (% of routes)

Year	No. Routes (one way)	% Routes (departure or arrival airport in UK or IRL)	% Routes (departure or arrival airport in UK or IRL) (Seats)	% Routes (departure or arrival airport in UK or IRL) (ASK)
1997	40	100%	100%	100%
1998	64	100%	100%	100%
1999	70	100%	100%	100%
2000	90	100%	100%	100%
2001	116	95%	97%	97%
2002	154	87%	92%	91%
2003	276	78%	81%	80%
2004	332	72%	76%	74%
2005	496	73%	75%	74%
2006	688	72%	76%	75%
2007	1,112	63%	70%	69%
2008	1,364	60%	66%	64%
2009	1,886	52%	57%	59%

Source: OAG database

Table 7. Ryanair’s domestic offer with respect to the UK and IRL market

GB				IRL		
Year	No. Routes (one way)	Seats	Total Days of Flights	No. Routes (one way)	Seats	Total Days of Flights
1997	2	394,365	3,045	0	0	0
1998	2	375,390	2,889	0	0	0
1999	4	539,588	4,113	0	0	0
2000	4	793,735	6,160	0	0	0
2001	4	974,324	7,136	0	0	0
2002	6	1,115,362	8,078	0	0	0
2003	10	1,404,349	10,984	0	0	0
2004	10	1,419,772	9,008	0	0	0
2005	10	1,461,582	7,746	2	41,580	220
2006	18	1,700,244	8,996	2	433,188	2,292
2007	38	2,089,206	11,054	4	652,428	3,452
2008	30	3,089,298	16,555	6	839,160	4,440
2009	30	2,790,396	14,764	4	1,014,174	5,366

Source: OAG database

Table 8. Routes operated by low cost Ryanair and Easyjet, by carrier and departure country

European routes																
Carrier	Country	No. Routes	Italy	UK	Spain	Germany	France	Romania	Ireland	Belgium	Holland	Albania	Switzerland	Norway	Sweden	Other
Ryanair	Ireland	1886	287	397	333	174	128	2	129	50	18	0	0	25	50	246
European domestic routes																
Ryanair	Ireland	192	80	28	56	8	12	0	4	0	0	0	0	0	0	2

Source: ICCSAI-Fact Book 2010

Table 9. Ryanair's domestic offer with respect to the Italian market

IT			
Year	No. Routes (one way)	Seats	Total Days of Flights
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	6	461,916	2,444
2006	12	836,136	4,424
2007	14	1,105,650	5850
2008	30	1,897,938	10,042
2009	90	4,606,308	24,372

Source: OAG database.

In particular, Italy appears to be the most important domestic market for Ryanair, with a percentage of 41.6%. Routes offered have been increasing from 6 in 2005 to 90 in 2009 (table 9): since 2008 Ryanair has been operating 7 Italian bases (Rome, Milan, Pisa, Bologna, Alghero, Cagliari, Trapani) and carrying more than 15 millions of passengers per year to and from Italian airports.

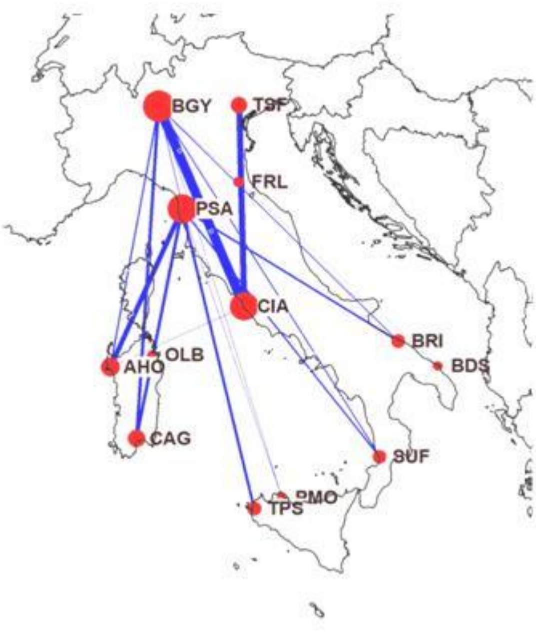


Figure 4. Continued on next page

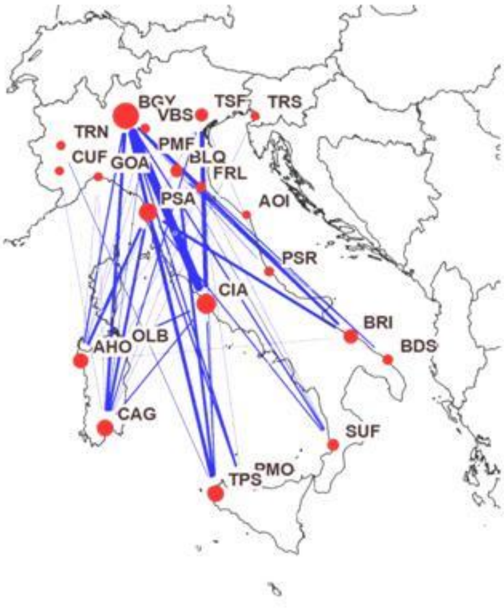


Figure 4. Evolution of Ryanair Italian network from 2008 to 2009. Source: our analysis on OAG database.

Ryanair's passenger growth has been followed by same expanding network. Figure 4 show the evolution of Ryanair Italian domestic market from 2008 to 2009 and the opening of new routes connecting new airports: TRN-Torino, CUF-Cuneo, GOA-Genova, PMF-Parma, VBS-Brescia, BLQ-Bologna, TRS-Trieste, AOI-Ancona, PSR-Pescara.

2. THE PRICING STRATEGY OF RYANAIR

In the airline business, the maximization of the profits obtained from each flight is strictly related to the maximization of revenues, because many of the costs incurred are essentially fixed, at least in the short term. As a consequence, pricing has always represented an important factor in the carriers' choices, driving the adoption of different strategies by low-cost and full-cost carriers.

Generally speaking, the fares setting problem in airlines industry involve the use of some form of yield management. This practice, also known as revenue management or, as we noted above, "dynamic pricing", consists of ''a set of pricing strategies aimed at increasing profits'' (McAfee & Velde, 2006). Yield management is particularly relevant to companies with a fixed amount of goods and low marginal costs. Typically, production capacity was determined at an early stage and the goods expire at a certain point in time (services offered only on a certain date, perishable goods). All these criteria apply very well to the tourism business and particularly to the airline industry: the schedules and aircraft are predetermined, marginal costs are low, and the value of a seat drops to zero after departure.

Specifically, low-cost airlines use a simpler dynamic pricing structure than traditional airlines. Full-cost carriers choose price discrimination techniques based on different fare classes, complex systems of discounts with limited access, customer loyalty schemes, and overbooking techniques. Low-cost carriers instead use ‘‘dynamic pricing’’. Because of dynamic pricing, it is now common for people to buy air tickets to European destinations for less than €10.00 (airport taxes excluded).

In particular, while the latter traditionally separate customers with different willingness to pay by offering a range of services (VIPs lounge, business class, flexibility) and restrictions (weekend stay, frequent flyer program, age discount), low-cost airlines base their pricing mainly on the time to departure. Since low-cost carriers sell many one-way tickets, several of the rules and restrictions traditionally employed by network carriers do not apply. Conventionally, low-cost fares increase monotonically with date: the earlier you book, the cheaper the fare will be. According to McAfee and te Velde (2006), this strategy depends mainly on the trade-off between waiting for a lower price and the risk of not finding seats.

2.1. Methodological Aspects

Airlines deal with perishable goods sold in different time steps, with the aim to maximize profits: the offer of seats on a flight can be compared to the sale of ‘‘perishable assets’’ with pre-determined capacity in conditions of negligible marginal costs.

A series of studies have analyzed the structure of optimal pricing strategies for perishable assets with respect to the airline industry. Gallego and van Ryzin (1994) explore a number of desirable properties, including closed form solutions and sharp predictions; Zhao and Zheng (2000) determine the minimum conditions necessary for a dynamic pricing strategy to be optimal: according to their study, an excellent pricing strategy for perishable assets can increase turnover by 2–5%. For an exhaustive review of these studies, see Talluri and van Ryzin (2004) and McAfee and te Velde (2006).

Because the price trend is influenced by demand, one part of the literature focuses on optimal pricing policies by using specific functional forms to represent demand and customer benefits. For example, it is quite typical to use an exponential demand curve (Gallego and Van Ryzin, 1994) and a mechanism ‘‘of customer arrival’’ into the market with a probability similar to a Poisson process.

Specifically, this study considers the functional form of demand as proposed by Anjos, Russell, Cheng, and Currie (2005), who present a family of continuous pricing functions that can be used to characterize optimal pricing strategies. According to their study, the demand for air tickets depends on price levels and on the time interval between the purchase date and the flight date:

$$q_i = Ae^{-\alpha p_i F(i)} \qquad \text{where } i \in [1, K, T] \tag{1}$$

where q_i is the number of seats booked on the same day, A and α are two constants, and F(i) is a function positively correlated to the time period between the purchase date and the flight date. In this case, the function of demand is subject to an exponential decrease as the advance purchasing time increases.

With respect to the empirical calculations, following Malighetti et al. (2009) the functions used for the estimation of prices in this study is:

$$p_i = \mu + \frac{1}{\alpha(1+\beta i)} \tag{2}$$

where i is the number of days between the advance reservation and the flight date.

The form of the optimal price is a hyperbola with the price going up as the flight date approaches. Parameters α indicates the highest price level that may be reached during the last days before the scheduled departure date. The lower α is, the higher the fare will be the day before departure. Parameter β indicates instead a decrease in the fares that is directly proportional to the of advance booking days: a low β will show a slow and steady price trend as the number of advance booking days increases. On the contrary, a high β indicates a significantly discounted fare, with respect to the highest fare ever offered, on advance purchases. Touristic passengers are particularly sensitive to β values. For example, if β is 0.1, buying the ticket 90 days in advance, yields a 90% discount on the maximum fares.

The study examined all the flight scheduled by Ryanair from 1st January, 2009, until 31th December, 2009. Our database includes the daily fare for each route[2] operated by Ryanair over the 2 months prior the flight: fares were collected daily from Ryanair website and, for each flight, we requested the price of a single seat starting 60 days prior to departure to the day before departure. According to this methodology, 1829 flights have been monitored and 109740 single prices[3] have been collected.

For each flight we calculate: i) the average price $P_{1\text{-}60}$ offered over two months prior departure; ii) the average price $P_{1\text{-}7}$ offered over one week prior departure; iii) the average price $P_{8\text{-}14}$ offered over two weeks prior departure; iv) the average price $P_{15\text{-}60}$ offered over three weeks prior departure until two months.

Moreover, the dynamic pricing coefficients, α and β, have been calculated for each flight for which fares dating back to at least two months before the actual date of flight were available.

2.2. Empirical Findings

Figure 5 describes Ryanair's network in terms of routes' length.

It comprises mainly short-length journeys, with all its routes ranging between 130 km (i.e. Prestwick – Belfast City) and 3470 km (i.e. Bremen – Tenerife Sur) and with a median value of 1270 km. The distribution proves symmetrical with respect to the median value, forming a bell-shape histogram with the exception of two peak levels at 850 and 1450 km.

Table 10 and 11 show the first ten domestic and non-domestic routes, respectively, characterized by the highest average price offered over two months prior departure.

The distributions of parameters α and β are shown in Figures 6 and 7 respectively.

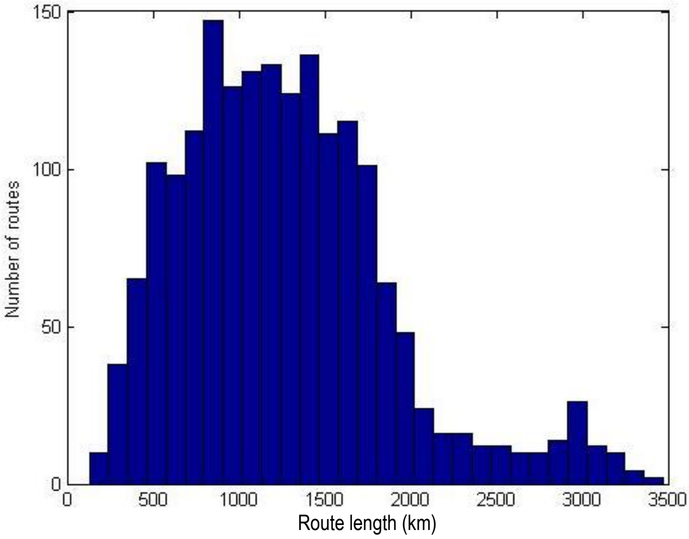
The distribution of parameter α shows a higher frequency of routes with parameter a levels around 0.008–0.01: the low levels indicate that the fares will be higher the day before departure. Parameter β shows the maximum relative frequency with levels slightly above

---

[2] The definition of the route is to be intended as directional: outbound and inbound routes between two airports are thus considered as two different routes.

[3] Prices mentioned refers to pre-tax fares indicated on Ryanair's website, which includes other cost categories such as airport taxes, security fees and credit/debit card handling fees.

zero; the frequency then decreases as parameter β gets higher. Approximately 50% of the routes register a β level greater than 0.1: in these cases, the purchase of the ticket two months before departure captures a price less than one tenth of the highest fare, which may occur just a few days before the date of flight.



Source: our analyses on web fares collected

Figure 5. Routes distribution according to route length.

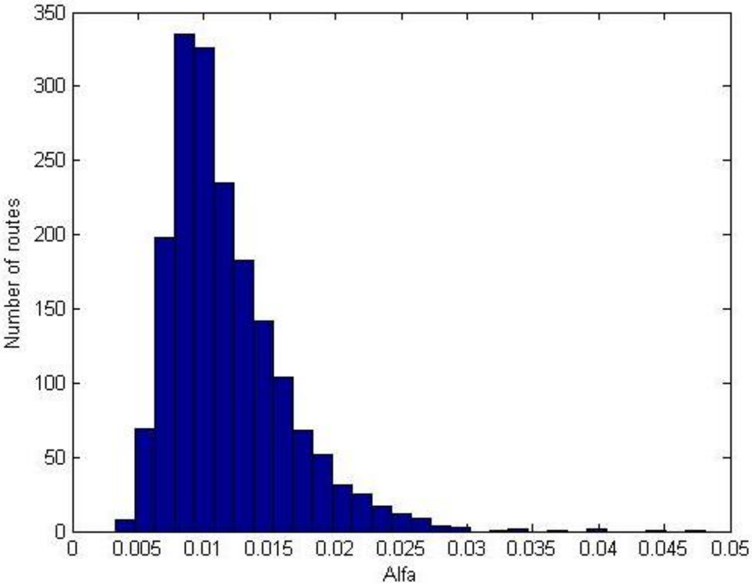


Figure 6. Distribution of the number of routes according to coefficients alfa estimated by analysing flight fares. Source: our analyses on web fares collected.

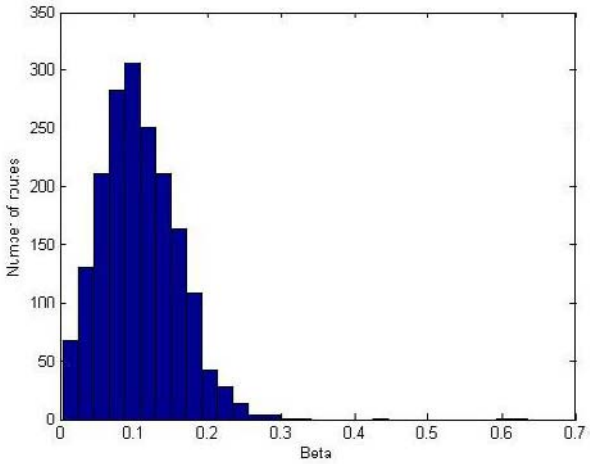


Figure 7. Distribution of the number of routes according to coefficients beta estimated by analyzing flight fares. Source: our analyses on web fares collected.

Table 10. First ten domestic characterized by the highest average price offered over two months prior departure

Departure airport	Arrival airport	$P_{1\text{-}60}$ (€)
Dublin	Edinburgh	40.09
Dublin	Manchester	37.22
Dublin	Newcastle	36.81
Edinburgh	Dublin	36.61
Dublin	London Stansted	36.07
Newcastle	Dublin	34.97
Dublin	London Gatwick	34.14
Dublin	London Luton	33.52
Dublin	Aberdeen Dyce	33.13
London Stansted	Dublin	33.08

Source: our analyses on web fares collected

Table 11. First ten non-domestic characterized by the highest average price offered over two months prior departure

Departure airport	Arrival airport	$P_{1\text{-}60}$ (€)
Kaunas	Dublin	142.67
Dublin	Kaunas	142.10
Tenerife Sur	Bremen	140.07
Tenerife Sur	Dublin	124.29
Tenerife Sur	Shannon	123.10
Dublin	Riga	121.74
Tenerife Sur	Niederrhein	118.33
Alicante	Skavsta	115.85
Charleroi Brussels	Menara	112.06
Frankfurt Hahn	Tenerife Sur	110.28

Source: our analyses on web fares collected

Table 12 and 13 show the first ten domestic and non-domestic routes, respectively, characterized by the highest intensity of dynamic pricing, i.e. the highest values for β: the results show that dynamic pricing is more intensive with respect to non domestic routes.

In Figure 8 we show the comparison between P_{1-7}, P_{8-14} and P_{15-60}, with respect to the set of 1829 flights monitored.

The average price P_{1-7} offered over one week prior departure appears higher than the average price P_{8-14} offered over two weeks prior departure, which in turn is higher than the average price P_{15-60} offered over three weeks prior departure until two months.

Therefore, as stated before, the demand for air tickets depends both on price levels and on the time interval between the purchase date and the flight date: the function of demand is subject to an exponential decrease as the advance purchasing time increases.

Table 12. First ten domestic characterized by the highest intensity of dynamic pricing

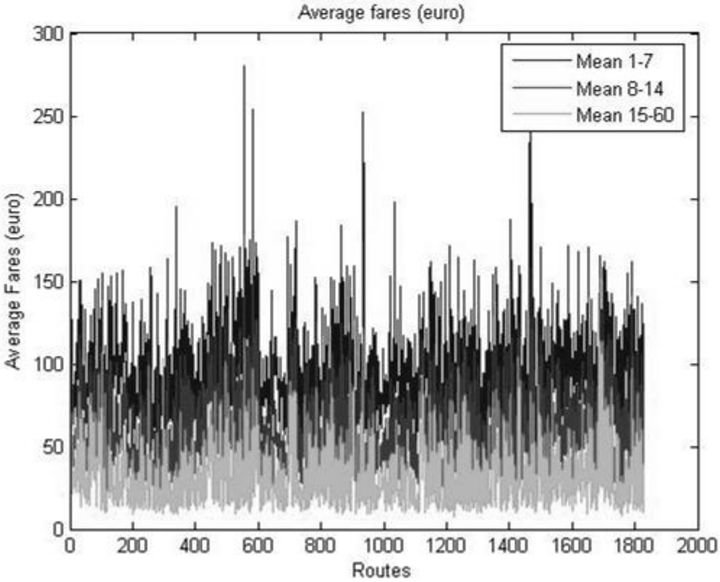
Departure airport	Arrival airport	β
Bournemouth	Prestwick	0.250495
Shannon	London Luton	0.249586
Dublin	East Midlands Nottingham	0.225326
London Luton	Shannon	0.22486
Bristol	Ireland West Knock	0.222231
Kerry County	London Luton	0.219562
Dublin	Leeds/Bradford	0.215114
East Midlands Nottingham	Dublin	0.211987
Bristol	Shannon	0.20783
London Stansted	St Mawgan	0.207788

Source: our analyses on web fares collected.

Table 13. First ten non-domestic characterized by the highest intensity of dynamic pricing

Departure airport	Arrival airport	β
Bremen	Kaunas	0.635438
Bergamo Orio Al Serio	Riga	0.603511
Riga	Bremen	0.428541
Szczecin - Goleniów	London Luton	0.320859
Bremen	Riga	0.312646
Kaunas	Bremen	0.298162
Eindhoven	Bristol	0.293299
Shannon	Katowice	0.283854
Frankfurt Hahn	Riga	0.278691
Shannon	Gdansk	0.272728

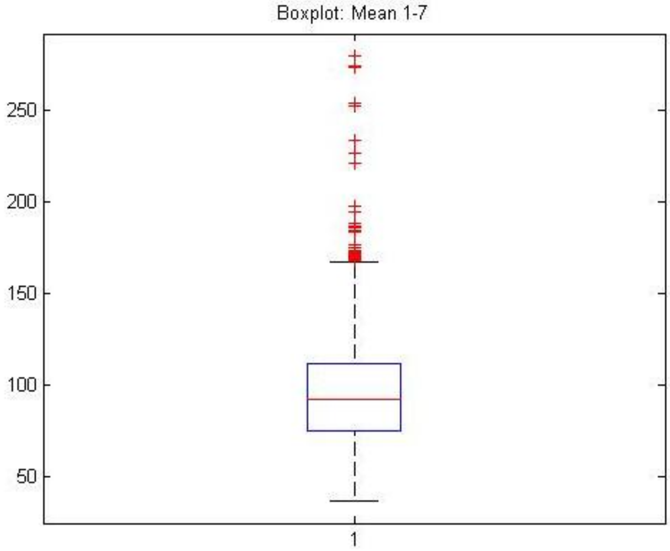
Source: our analyses on web fares collected.



Source: our analyses on web fares collected.

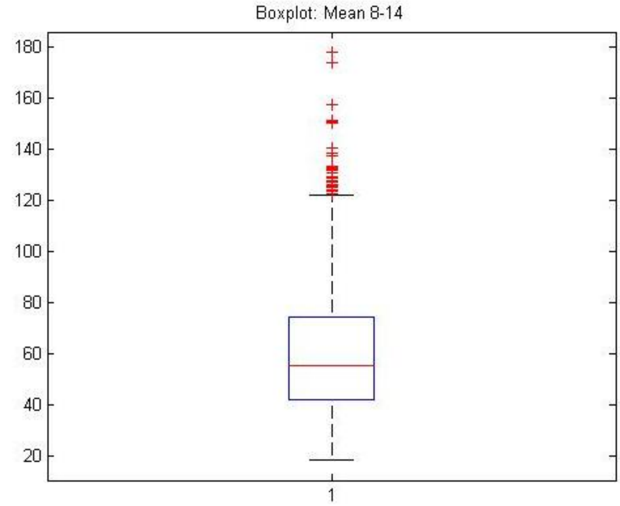
Figure 8. Comparison between P_{1-7}, P_{8-14} and P_{15-60}.

Same conclusions can be reached observing the box plots of P_{1-7}, P_{8-14} and P_{15-60} as illustrated in Figures 9-11, which show the sample minimum, lower quartile, median, upper quartile and the sample maximum with respect to the average prices according to the different advance in purchasing the flight ticket.



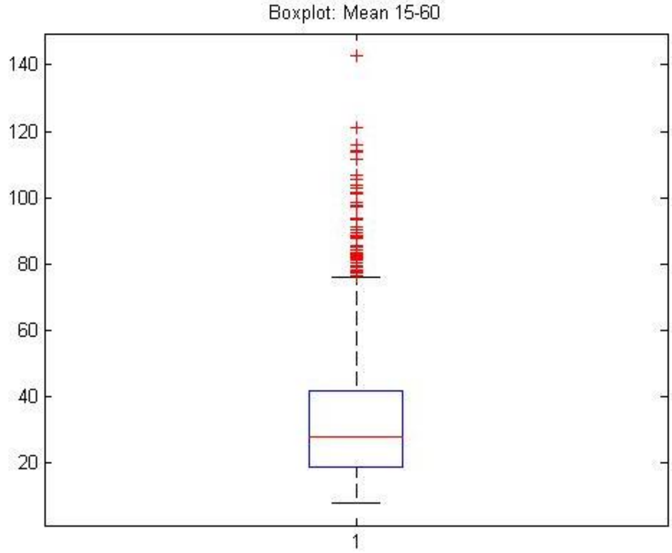
Source: our analyses on web fares collected.

Figure 9. Boxplot for average price P_{1-7} offered over one week prior departure.



Source: our analyses on web fares collected.

Figure 10. Boxplot for average price $P_{8\text{-}14}$ offered over two weeks prior departure.



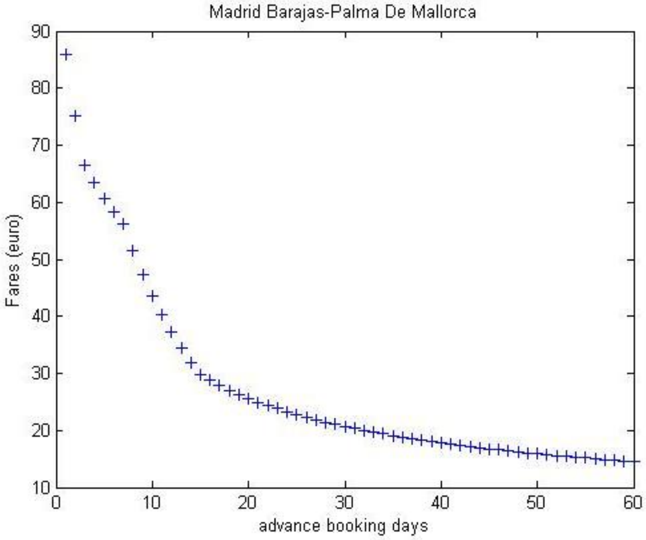
Source: our analyses on web fares collected.

Figure 8. Boxplot for average price $P_{15\text{-}60}$ offered over three weeks prior departure until two months.

Figures 12 and 13 shows the average price trend on the Madrid Barajas – Palma De Mallorca (the highest frequency route, i.e. 140) and the Dublin – London Gatwick route. No steady price trend can be observed in either case: over the 60 days leading to the flight date, lower fares are offered as the departure day approaches, even if this occurs in the two cases during different periods of time, with different lengths and intensities. If it is assumed that this phenomenon may occur often in Ryanair's pricing policy, it may be inferred that the expectations of the passengers should admit a probability (p) for the price to fall in the following days.

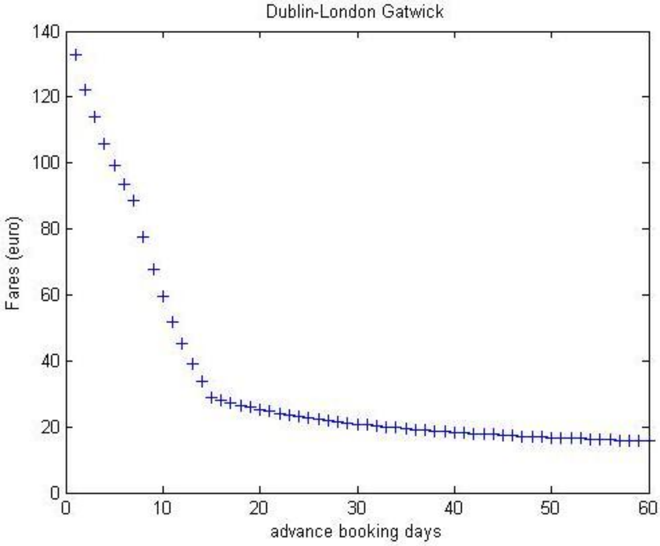
Finally we summarize our previous results (Malighetti et al., 2010) about the question of whether Ryanair's pricing strategies have changed over time.

Looking at 2006-2007 fares we calculated the average fare over a 90-day period prior to departure and the intensity of dynamic pricing for each flight in the panel, in particular analyzing the changes in these variables observed between pairs of ''equivalent'' flights (same route, same departure time, same week, weekday and month. Their results show that overall, both average fares and the intensity of dynamic pricing decreased in 2007.



Source: our analyses on web fares collected.

Figure 12. Average price trend on Madrid Barajas – Palma de Mallorca route.



Source: our analyses on web fares collected.

Figure 13. Average price trend on Dublin-London Gatwick.

We find that more than one-third of flights saw a price reduction of more than 10%. Now that it has become the dominant low-cost carrier in Europe, Ryanair appears to be softening its dynamic pricing activities on existing routes, typically employed to stimulate additional touristic demand: thus, booking in advance becomes relatively more expensive.

CONCLUSIONS

This chapter represents an attempt to identify the main features of Ryanair's business model with respect to the competitive and the contextual factors that have driven the choice of the average fares and their relative dynamics. Empirical evidences confirm an increasing propensity of Ryanair to operate routes within the international community and show that dynamic pricing is effectively performed by Ryanair on both domestic and non-domestic routes.

REFERENCES

Anjos, M., Cheng, R. & Currie, C. (2005). Optimal pricing policies for perishable products. *European Journal of Operational Research*, *166*, 246-254.

Gallego, G. & Van Ryzin, G. (1994). Optimal dynamic pricing of inventories with stochastic demand over finite horizons. *Management Science*, *40*, 999-1020.

Malighetti, P., Paleari, S. & Redondi, R. (2009). Pricing strategies of low-cost airlines: the Ryanair case. *Journal of Air Transport Management*, *15(4)*, 195-203.

Malighetti, P., Paleari, S. & Redondi, R. (2010). Has Ryanair's pricing strategy changed over time? An empirical analysis of its 2006–2007 flights. *Tourism Management*, *31*, 36-44.

McAfee, P. R. & te Velde, V. (2006). Dynamic pricing in the airline industry. In T. J. Hendershott, (Ed.), *Handbook in economics and information systems*, *Vol. 1*. Elsevier.

Talluri, K. T. & van Ryzin, G. J. (2004). *The theory and practice of revenue management*. Norwell, MA: Kluwer Academic Publishers.

Zhao, W. & Zheng, Y. (2000). Optimal dynamic pricing for perishable assets with non homogeneous demand. *Management Science*, *46*, 375-388.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 143-160
ISBN: 978-1-61122-079-7

Chapter 5

MEASURING AND BENCHMARKING AIRPORT EFFICIENCY: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS (DEA) AND STOCHASTIC FRONTIER ANALYSIS (SFA)

Tony Diana[*]
Federal Aviation Administration, USA

ABSTRACT

Airports are multidimensional organizations whose efficiency is difficult to measure on the basis of a single criterion. Differences in terminal layout, runway configurations, passengers' origin and destination, and hub versus non-hub status all make comparisons among airports even more challenging. In a context of airline consolidation, tightening noise and environmental regulations, as well as competition for scarce resources in capacity expansion, managers find it more compelling to measure the efficiency of their airport as a whole and to benchmark it with others.

The present article will provide an introduction to two methods for measuring and comparing airport efficiency. The criterion for efficiency is the System Airport Efficiency Rate (SAER) published daily in the Aviation System Performance Metrics (ASPM). Even though one method is parametric (Stochastic Frontier Analysis) while the other is not (Data Envelopment Analysis), they both attempt to derive an efficiency frontier that serves to define technical efficiency in the former case or an empirical technology frontier in the latter case.

This article will start with the differences between DEA and SFA, their theoretical underlining, and their limitations. Then, it will illustrate the use of both analytical methods to determine how efficiently each sampled airport utilizes its available capacity. The discussion will end with some remarks derived from the application of either model.

---

[*] Corresponding author: Email: Tony.Diana@faa.gov

1. INTRODUCTION

Feedback and benchmarking are two essential components of performance evaluation and improvement. Track and field athletes, for instance, could not improve their performance if they do not know how fast they are running and what the best time record is. Benchmarking is about identifying the best performers and understanding the reasons for the gap between the top performers and the rest so as to narrow any differences. For organizations, however, things get more complex because they represent clusters of sub-organizations, each with their own goals and motivations. In such a case, management's role consists in determining an overall vision and goals for the entire organization, while coordinating the efforts of each level of business in their achievement.

Performance evaluation is even more of a challenge for natural monopolies such as airports and other public entities. One may argue that it is easier to do so for businesses than mostly publicly-controlled organizations such as airports that do not have profit-making goals. Airports are unique organizations that differ in terms of landside and airside attributes, passenger origin and destination, the presence of dominant carriers, among other factors.

How is it possible, then, to measure such an organization's efficiency and compare it with others that are so different? What are the criteria to measure such diverse organizations? Performance evaluation implies the comparison of actual performance with an 'optimum value' characterized by an efficiency frontier to be determined. Analysts have two main tools at their disposal that are fundamentally designed to achieve the same goal: evaluating the distance between actual performance and an efficiency frontier. Fried and al. (2008: 33) asked the question of "whether the two techniques tell consistent stories when applied to the same data." They believed that "The higher the quality of the data, the greater the concordance between the two sets of efficiency estimates."

Although performance evaluation can be traced back to the work of Pareto (1971) and Koopmans (1951), Farrell (1957) showed how relative efficiency can be reached. His work was influential in the field of Stochastic Frontier Analysis (SFA) further developed by Aigner and Chu (1968), Meeusen and Van den Broek (1977) and Aigner et al. (1977). Charnes et al. (1978, 1979 and 1981) have played a significant role in the development of a non-parametric method to assess efficiency called Data Envelopment Analysis (DEA). The latter methodology has proved useful in measuring the performance of public sector organizations and others that transform multiple inputs into multiple outputs (Chalo and Cherian 1995). SFA and DEA can deal with cross sectional or panel data. Both methodologies have found many applications in the airline industry and the next section will briefly make references to some applications in the DEA and SFA literature.

2. BACKGROUND

Over the last twenty years, DEA and SFA have gained some popularity in the study of airline and airport performance. This section will provide a brief reference to DEA first and then SFA.

Gillen and Lall (1997) used DEA to evaluate airport productivity and performance for a panel of twenty-one U.S. airports over a period of five years. DEA enabled the determination of performance indices that were integrated into a Tobit regression model to determine a net performance index and to evaluate what variables are most likely to affect them.

Sarkis (2000) focused on airport operational efficiency. His empirical study evaluated the operational efficiencies of forty-four major U.S. airports using DEA. Efficiency measures were based on four resource input measures including airport operational costs, number of airport employees, gates and runways, and five output measures including operational revenue, passenger flow, commercial and general aviation movement, and total cargo transportation.

Fernandes and Pacheco (2002) analyzed the capacity of thirty-five Brazilian airports to determine whether they were efficient in terms of the number of passengers processed. DEA made it possible to construct the efficient frontier for the sampled airports and to evaluate how resources were used by each facility. Using passenger demand forecasts, Fernandes and Pacheco evaluated, for each airport, the periods when capacity expansions would become necessary to maintain services at standards currently perceived by passengers.

Diana (2006) replicated Gillen and Lall's methodology using on-time gate arrivals as a measure of performance based on a sample of the thirty-five largest U.S. airports. Regression analysis was performed to assess the impact of selected input variables on the likelihood that an airport is efficient. The study indicated that 'airport efficiency' for the largest thirty-five airports in terms of operations had declined from 2004 onward as airport delays and congestion returned to the year 2000 levels.

Lin and Hong (2006) applied DEA to study the operational performance of 20 major airports around the world. The performance of an airport is not correlated with the form of ownership and its size. In contrast, the status of an airport as a hub, the location, and the economic growth rate of the country where the airport is located have been found to be related to the operational performance of airports.

In the SFA area, Good et al. (1995) examined the performance of the eight largest European and U.S. airlines during the period 1976–1986. They used a parametric methodology based on statistical estimation and a nonparametric one relying on linear programming. If European airlines were as productively efficient as their U.S. counterparts in a deregulated environment, the European industry would have saved approximately $4 billion per year (in 1986 dollars).

Martin-Cejas (2002) analyzed the productive efficiency of the airport industry. The analysis was carried out using a dual cost function. A translog joint cost function was applied to the study of productive efficiency in the Spanish airport network. He found some evidence of possible inefficiencies related to the airport's size, which impacted investment programs and airport cost structure.

Pels et al. (2003) argued that European airports, on average, were inefficient. Low load factors—an indicator of airline inefficiency—represented a major contributor to airport inefficiency in terms of air passenger movements. The authors maintained that European airports usually operated under constant returns to scale in "producing" air transport movements and under increasing returns to scale in producing passenger movements. Pels et al. resorted to SFA in order to test these operating characteristics. According to their study there appeared to be no region-specific effect on airport efficiency.

Pestana Barros (2008a and 2008b) utilized a stochastic frontier model to estimate the relative technical efficiency respectively of UK airports (from 2000 to 2005) and Portuguese airports (between 1990 and 2000). In the latter, the rate of technical progress was divided into pure technical progress, nonneutral technical progress, and scale-augmenting technical progress. A relatively large amount of waste was found even though technical change contributed to a reduction in costs.

Pestana Barros and Dieke (2008) applied the two-stage procedure of Simar and Wilson (2007) to estimate the efficiency of Italian airports. First, the airports relative technical efficiency was determined using DEA and then the Simar-Wilson procedure was applied to find the most efficient airports in terms of total productivity from 2001 to 2003. Oum et al. (2008) used SFA to measure the impact of ownership forms on airport efficiency.

Diana (2010) examined whether the technical efficiency of the three largest New York airports improved in summer (June to August) 2008 compared with the summers of 2000 and 2007. An airport is efficient if it can handle operations on-time by minimizing overall demand and maximizing available airport capacity. Granger-causality tests determined the factors that may cause changes in key components and indicators of airport performance. The Granger-causality tests stressed the significance of airport operations and enroute factors in supporting efficiency.

3. MODEL VARIABLES

The DEA and SFA models include daily observations by hour for June 2000, 2007 and 2009. The choice of June is justified as one of the peak traffic months. The increase in the number of delays in 2007 compelled the U.S. Department of Transportation (USDOT) and the Federal Aviation Administration (FAA) to implement delay reduction initiatives at the most congested airports such as New York John F. Kennedy International (JFK) and Newark Liberty International (EWR) airports. A new runway was inaugurated in late 2008 at Chicago O'Hare International (ORD), one of the key hubs in the U.S. Since these airports have a significant impact on the National Airspace System (NAS) in the form of propagated delays, it can be assumed that changes in capacity at congested airports are likely to have an impact on the overall efficiency of the NAS. This analysis focuses on the operational factors most likely to affect airport efficiency.

The dependent variable in this analysis is the ***System Airport Efficiency Rate*** (SAER) used by the FAA to measure the individual contribution of airports to the efficiency of the NAS. It is the demand-weighted average of the arrival and departure efficiency rates published daily in the Aviation Systems Performance Metrics (ASPM). The arrival efficiency rate is found by dividing actual arrivals by the lesser of the arrival demand or the airport arrival rate (AAR) provided by each airport. The SAER is a measure designed to determine how well the demand for arrivals is met and is determined by three factors:

- Actual arrivals during a given quarter hour (how many aircraft landed during that quarter hour),
- Arrival demand for a given quarter hour (how many aircraft “wanted” to land during that quarter hour),
- Airport arrival rate (the facility-set airport arrival rate for that quarter hour).

The SAER is computed as follows:

(Departure Demand/Overall Demand)* Departure Efficiency Rates
+(Arrival Demand/Overall Demand)* (Arrival Efficiency Rates)

The explanatory variables are as follows:

- The ***Average Minutes of Gate Arrival Delay*** (arrdel) represent all the flights arriving one minute or more past their scheduled arrival time. The data sources for the computation of this delay metric are ASPM, Innovata, OAG (Official Airline Guide) and ARINC[1].
- The ***Average Minutes of Gate Departure Delay*** (depdel) measure the difference between the actual and the scheduled gate departure time. The sources are ASPM, Innovata, OAG and ARINC.
- The ***Average Minutes of Taxi-Out Delay*** (txoutdel) determine the difference between the actual and the unimpeded taxi-out times. Unimpeded times are computed for ASQP-reporting carriers and by season. Unimpeded taxi times measure the time from gate-out to wheels-off when there is only one plane ahead in the departure queue. The sources are the Airline Service Quality Performance (ASQP) monthly survey of the largest U.S. carriers reported by the Bureau of Transportation Statistics (BTS), ASPM, Innovata, OAG and ARINC.
- The ***Average Minutes of Taxi-In Delay*** (txindel) are computed as actual minus unimpeded taxi-in times. Taxi-in delays may occur, for example, when a gate is not available for an arriving aircraft. The data sources are the same as for the taxi-out delays.
- The ***Percent of the Airport's Total Available Capacity Utilized*** (caputil) is the ratio of the actual arrivals and departures to an airport's stated arrival (AAR) and departure (ADR) rates. The data sources are the Air Traffic Control System Command Center and ASPM. The arrival and departure rates called by a facility represent a significant element in the management of airport congestion and reflect:

  Weather Conditions. Acceptance rates decline as weather conditions worsen.

  Runway Configurations. Some configurations are optimal for departures or arrivals, given prevailing winds or traffic mix. Moreover, the efficiency of some configurations at a specific airport is interdependent on the runway configuration in use at the other two airports. That is the case of the New York area airports.

  Scheduled Operations. Arrival and departure rates vary with scheduled traffic.
- ***Airborne Delay*** (airbndel) captures the difference between the actual airborne time minus a carrier’s submitted estimated time en route. The sources are ETMS (Enhanced Traffic Management System) and ASPM.
- ***Block Delay*** (blockdel) measures the difference between the actual and the scheduled gate-out to gate-in times. The data sources are ASPM, ARINC, Innovata, OAG, and ETMS.

---

[1] ARINC provides the Out-the-gate, wheels-Off, wheels-On and gate-In (OOOI) data.

4. THE DATA ENVELOPMENT ANALYSIS MODEL

4.1. The Characteristics of the DEA Model

Data Envelopment Analysis is a non-parametric method based on linear programming to derive the most efficient Decision Making Unit (DMU) that can be compared with each other within a group. In the present case, the DMUs are airports. The terminology "Data Envelopment Analysis" originates from Charnes et al. (1978) and it refers to the efficiency frontier that envelopes data. DEA can be used to measure both technical and allocative efficiency. As Sengupta (2000:1) explained, "Technical efficiency measures the DMU's success in producing the maximum possible output from a given set of inputs, while allocative efficiency measures the firm's success in choosing an optimal set of inputs with a given set of input and/or output prices." Allocative efficiency is more suited to the concept of cost than efficiency frontier. Fried et al. (2008:46) maintained that "Like the economic approach [SFA], the programming approach [DEA] can be categorized […] according to the types of variables available (quantities only, or quantities and prices). With quantities only, technical efficiency can be estimated and decomposed into technical and allocative components."

In DEA, efficiency can be defined as the weighted ratio of outputs to inputs. According to Ramanathan (2003:39), "The weights assigned should be flexible and reflect the requirement (performance) of the individual DMUs." Mathematical programming determines the weights that maximize efficiency, while subject to the constraint that efficiency has a value between 0 and 1. The DMU closer to 1 becomes the reference DMU. The optimal weights are specific to each DMU. Ramanathan (2003:40) specified the linear programming that determines the efficiency of the mth DMU as follows:

$$\text{Max } E_m = \Sigma^J_{j=1} v_{jm} y_{jm} / \Sigma^i_{i=1} u_{im} x_{im} \quad (1)$$

Subject to

$$0 \leq \Sigma^J_{j=1} v_{jm} y_{jn} / \Sigma^i_{i=1} u_{im} x_{in} \leq 1 \text{ with } n = 1,2,\ldots,K, N$$
$$v_{jm}, u_{im} \geq 0 \text{ with } i = 1,2,\ldots, K, J \quad (2)$$

E_m represents the efficiency of the mth DMU
y_{jm} is the jth output of the mth DMU
v_{jm} is the weight of that input
x_{im} is the ith input of the mth DMU
u_{im} is the weight of that input
y_{jn} and x_{in} are the jth output and ith input, respectively of the nth DMU, n = 1,2,…, N.

The multiplier can be considered as the linear programming designed to minimize the shadow cost and can be formulated as

$$\text{Min } z' = \Sigma^I_{i=1} u'_{im} x_{in} \quad (3)$$

Subject to

$$\Sigma^{J}_{j=1} v'_{jm} y_{jm} = 1 \tag{4}$$

$$\Sigma^{J}_{j=1} v'_{jm} y_{jn} - \Sigma^{I}_{i=1} u'_{im} x_{in} \leq 0 \text{ with } n = 1,2, k, n \tag{5}$$

$$v'_{jm}, u'_{im} \geq \varepsilon \text{ with } I = 1,2,k, I; j - 1,2,k,j \tag{6}$$

Linear programming will provide the values of the weights u and v that determine the efficiency of a DMU. Charnes et al. (1978 and 1979) who developed the DEA made a change later and replaced the non-negative constraints by the strictly positive constraint. Another important point is that DEA can be not only output-oriented as SFA, but also input-oriented. This requires converting the maximization into a minimization program and changing the multiplier problem into a maximization program.

So far, we have assumed a constant return to scale (CRS). However, this may not be adequate when modeling airport efficiency. Banker et al. (1984) introduced some changes in the algorithm that allowed variable returns to scale (VRS). There are four other types of returns to scale: Non-Increasing Returns to Scale (NIRS), Non-Decreasing Return to Scale (NDRS), Increasing Returns to Scale (IRS), and Decreasing Return to Scale (DRS). A VRS DEA program can be expressed as

$$\text{Min}_{\theta,\lambda}\theta_m \tag{7}$$

Subject to

$$Y_\lambda \geq Y_m \tag{8}$$

$$X_\lambda \leq \theta X_m \tag{9}$$

$$\Sigma^{N}_{n=1}\lambda_n = 1 \text{ (or } e^T\lambda = 1 \text{ where e is a unit vector)} \tag{10}$$

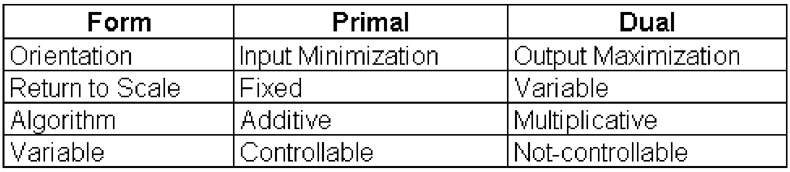
$$\lambda \geq 0 \text{ and } \theta_m \text{ free} \tag{11}$$

Equation 10 is called the convexity constraint. Only convex combinations of efficient producers form the efficient frontier.

There are several orientations within DEA. This article will focus on an additive, constant-returns-to-scale model. Readers interested in other models are referred to Charnes et al. (1995), Sengupta (1995), Cooper et al. (2000), Thanassoulis (2001), Zhu (2003), Cooper et al. (2004), Coelli et al. (2005) and Fried et al. (2008). The key differentiating elements among DEAs are summarized in the table below.

DEA is a non-parametric method that analysts can use to measure the efficiency of DMUs compared with a reference DMU. There are four major advantages related to DEA. First, it can handle multiple inputs and multiple outputs. Second, there is no need to formulate a model relating outputs to inputs. Third, DEA involves direct comparison among peers. Finally, the inputs and outputs do not have to be expressed in the same units.

Table 1. Summary of Key Elements in DEA



Form	Primal	Dual
Orientation	Input Minimization	Output Maximization
Return to Scale	Fixed	Variable
Algorithm	Additive	Multiplicative
Variable	Controllable	Not-controllable

On the other hand, DEA presents some weaknesses. First, DEA is a non-parametric method that makes it difficult to estimate production, cost and profit functions from the data. Second, DEA ignores that the inputs and outputs may be affected by measurement errors and disturbances. Third, DEA ranks DMUs based on technical efficiency. However, efficiency estimates may not be robust and subject to outliers since there is no possibility to test hypotheses. In fact, DEA does not measure absolute efficiency. Fourth, there is no assumption and formal model to evaluate as in the case of SFA. As a result, it is not possible to use statistical tests. As Ray (2004:2) remarked, “Being non-statistical in nature, the LP solution of a DEA problem produces no standard errors and leaves no room for hypothesis testing.” Fifth, DEA may be viewed as more static and less dynamic than stochastic frontier. Fried et al (2008:45) argued that “[DEA] makes no accommodation for noise and so does not “nearly” envelop a data set the way the deterministic kernel of a stochastic frontier does.” Sixth, DEA is affected by the curse of dimensionality: As more variables are input, the program becomes increasingly complex to solve. Finally, there is no provision for random shocks as in the case of SFA and any deviation from the frontier is considered as inefficiency.

4.2. An Illustration of a DEA Model

This example involves a sample of 30 airports[2] for June 2000, 2007 and 2009. The DEA model is output-oriented, additive and features constant returns to scale. In the DEA model, there are seven inputs (defined in section 3), with a minimum weight to all factors of 0.0005 and the largest weight of 999.999. The scores were derived using the Lingo programming software. The DEA scores are summarized in the table below (with ‘+’ for positive change, ‘-‘ for negative change and ‘N.C.’ for no change):

Based on the input variables specified in Section 3, only PDX and TPA were on the efficiency frontier in June 2000, 2007 and 2009. Overall, the scores and statistics in Table 2 indicate that airport efficiency improved in June 2009 compared with June 2007 and 2000. Table 3 shows that differences in the scores for the three months under investigation are significant at a 95% confidence level (p = 0.05).

The standard deviation in Table 2 implies that there was more variability in the performance of the sampled airports in June 2007 than during the other two periods under consideration based on the model’s operational variables. Despite improvements in the scores of the three largest New York area airports (between 2009 and 2007), EWR, JFK and LGA remained at the bottom of the sampled airports in terms of efficiency.

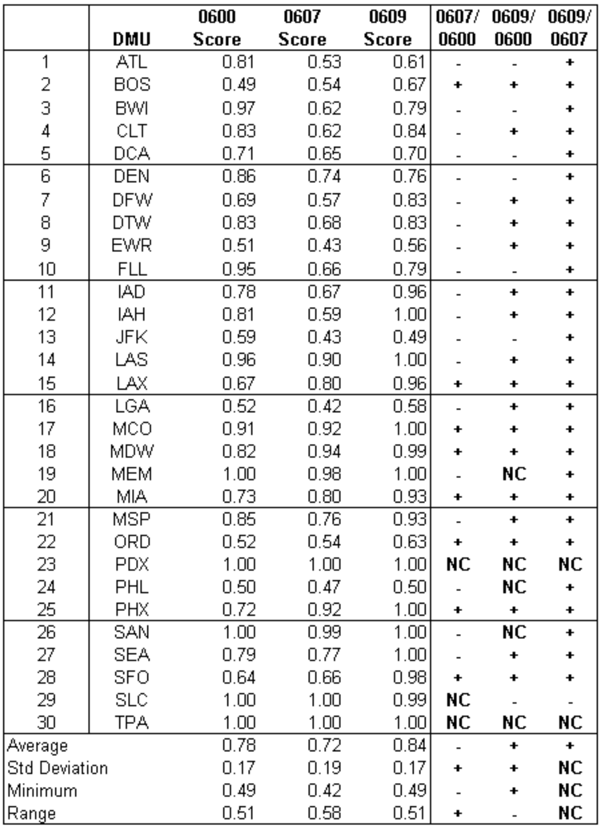
---

[2] This sample of 30 airports includes most of the OEP 35 airports except CLE, CVG, HNL,PIT, and STL (see appendix).

Since the dependent variable has a left limit of 0 and an upper limit of 1, a Tobit (censored) regression is appropriate to evaluate the impact of the selected variables on the likelihood that an airport will be on the efficiency frontier. The Tobit regression model is characterized as $y_i = x'_i*\beta + u_i$ if $y_i > 0$. Otherwise, $y_i = 0$. Since $x'_i*\beta + u_i > 0$, $u_i > - x'_i*\beta$. Therefore, the probability that $y_i > 0$ is in fact the probability that $u_i > - x'_i*\beta$. The coefficient of determination R^2 measures the impact of the seven input variables on the likelihood that an airport is on the efficiency frontier. In June 2000, R^2 was 89.80%, 81.02% in June 2007 and 82.00% in June 2009.

According to Breen (1996:28), “Taken by themselves, each [Tobit coefficient] shows the effect of a change in a given x variable on the expected value of the latent variable, holding all x variables constant.” As an example, a coefficient of -0.0042 for capacity utilization in June 2009 represents the degree to which the propensity of an airport to be on the efficiency frontier changes for a decline in the percent capacity utilized, holding other factors constant. In other words, the percent capacity utilization coefficient of -0.0042 indicates how a change of one percent capacity utilized affects the propensity for an airport to be on the efficiency frontier. The coefficient shows how a small change in the percent capacity utilization affects the probability that an airport is on the efficiency frontier. At a 95% confidence level, the variables percent capacity utilized and airborne delay are significant in the three samples.

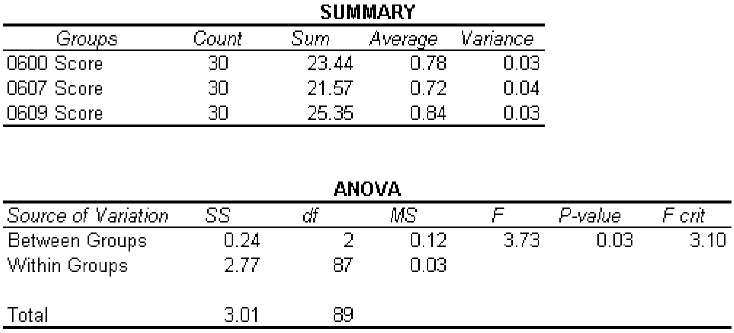
Table 2. DEA Scores and Changes (June 2000, 2007 and 2009)



	DMU	0600 Score	0607 Score	0609 Score	0607/ 0600	0609/ 0600	0609/ 0607
1	ATL	0.81	0.53	0.61	-	-	+
2	BOS	0.49	0.54	0.67	+	+	+
3	BWI	0.97	0.62	0.79	-	-	+
4	CLT	0.83	0.62	0.84	-	+	+
5	DCA	0.71	0.65	0.70	-	-	+
6	DEN	0.86	0.74	0.76	-	-	+
7	DFW	0.69	0.57	0.83	-	+	+
8	DTW	0.83	0.68	0.83	-	+	+
9	EWR	0.51	0.43	0.56	-	+	+
10	FLL	0.95	0.66	0.79	-	-	+
11	IAD	0.78	0.67	0.96	-	+	+
12	IAH	0.81	0.59	1.00	-	+	+
13	JFK	0.59	0.43	0.49	-	-	+
14	LAS	0.96	0.90	1.00	-	+	+
15	LAX	0.67	0.80	0.96	+	+	+
16	LGA	0.52	0.42	0.58	-	+	+
17	MCO	0.91	0.92	1.00	+	+	+
18	MDW	0.82	0.94	0.99	+	+	+
19	MEM	1.00	0.98	1.00	-	NC	+
20	MIA	0.73	0.80	0.93	+	+	+
21	MSP	0.85	0.76	0.93	-	+	+
22	ORD	0.52	0.54	0.63	+	+	+
23	PDX	1.00	1.00	1.00	NC	NC	NC
24	PHL	0.50	0.47	0.50	-	NC	+
25	PHX	0.72	0.92	1.00	+	+	+
26	SAN	1.00	0.99	1.00	-	NC	+
27	SEA	0.79	0.77	1.00	-	+	+
28	SFO	0.64	0.66	0.98	+	+	+
29	SLC	1.00	1.00	0.99	NC	-	-
30	TPA	1.00	1.00	1.00	NC	NC	NC
Average		0.78	0.72	0.84	-	+	+
Std Deviation		0.17	0.19	0.17	+	+	NC
Minimum		0.49	0.42	0.49	-	+	NC
Range		0.51	0.58	0.51	+	-	NC

Source: ASPM

Table 3. Analysis of variance of efficiency scores



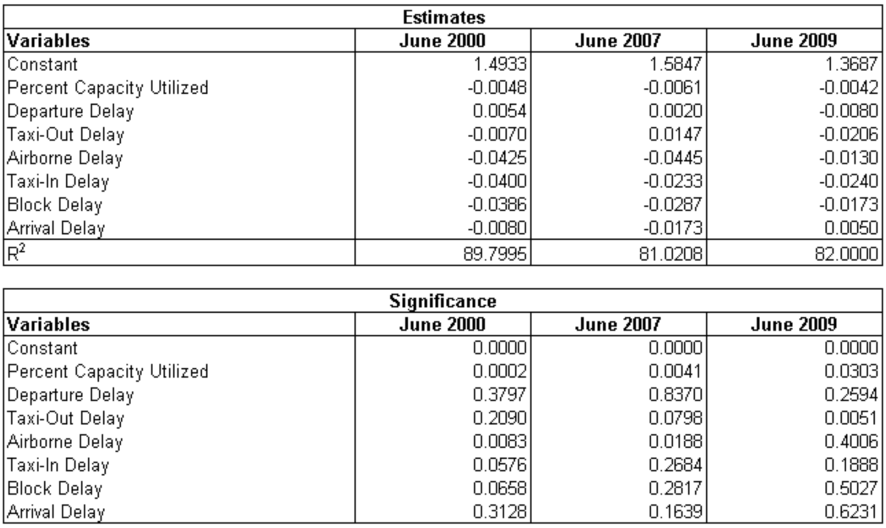
SUMMARY

Groups	Count	Sum	Average	Variance
0600 Score	30	23.44	0.78	0.03
0607 Score	30	21.57	0.72	0.04
0609 Score	30	25.35	0.84	0.03

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.24	2	0.12	3.73	0.03	3.10
Within Groups	2.77	87	0.03			
Total	3.01	89				

Table 4. The Tobit model estimates and significance



Estimates			
Variables	**June 2000**	**June 2007**	**June 2009**
Constant	1.4933	1.5847	1.3687
Percent Capacity Utilized	-0.0048	-0.0061	-0.0042
Departure Delay	0.0054	0.0020	-0.0080
Taxi-Out Delay	-0.0070	0.0147	-0.0206
Airborne Delay	-0.0425	-0.0445	-0.0130
Taxi-In Delay	-0.0400	-0.0233	-0.0240
Block Delay	-0.0386	-0.0287	-0.0173
Arrival Delay	-0.0080	-0.0173	0.0050
R^2	89.7995	81.0208	82.0000

Significance			
Variables	**June 2000**	**June 2007**	**June 2009**
Constant	0.0000	0.0000	0.0000
Percent Capacity Utilized	0.0002	0.0041	0.0303
Departure Delay	0.3797	0.8370	0.2594
Taxi-Out Delay	0.2090	0.0798	0.0051
Airborne Delay	0.0083	0.0188	0.4006
Taxi-In Delay	0.0576	0.2684	0.1888
Block Delay	0.0658	0.2817	0.5027
Arrival Delay	0.3128	0.1639	0.6231

Source: ASPM

In summary, the conditional probability that an airport is on the efficiency frontier, as measured by the SAER, depends on how a facility manages its available capacity and how close airborne time is from estimated time enroute.

In the next section, we will focus on the stochastic frontier model and provide an illustration of the algorithm.

5. THE STOCHASTIC FRONTIER ANALYSIS MODEL

5.1. The Characteristics of the SFA Model

SFA is an econometric method designed to benchmark best performance. According to Greene (2008:93), “The frontier model is (essentially) a regression model that is fit with the recognition of the theoretical constraint that all observations lie within the theoretical extreme." SFA focuses on efficiency defined as "the ratio of actual output to the optimal value as specified by a production function" (Greene 2008:100). Technical efficiency can be expressed as $TE_i = y_i/f(x_i;\beta)*\exp\{v_i\}$. According to Kumbhakar and Lovell (2003:65), "y_i achieves its maximum feasible value of $[f(x_i;\beta) *\exp\{v_i\}]$ if and only if $TE_i = 1$." SFA recognizes that efficiency may be affected by factors that an organization does not totally control. Moreover, any inefficiency may result from errors in data or model misspecifications. The effect of random shocks are added to the deterministic frontier $f(x_i;\beta)$ with the addition of the term $\exp\{v_i\}$.

The SFA model can focus on panel and cross-sectional data. Multiple equations are also possible. Usually, SFA is characterized by cross section, single equation models. Readers interested in variants in SFA models are sent to Schmidt and Sickles (1984) for single equation, panel data models and to Christensen and Greene (1976) for multiple equation models.

The SFA model assumes a specific form of the production frontier and a composite error structure. The frontier can be expressed as follows:

$$y_j = f(x_j,\beta) + \varepsilon_j \text{ with } \varepsilon_j = v_j + u_j \qquad (12)$$

where y_j represents the single output of the organization j, f(.) is the production function, x_j is the vector of m inputs and β is the vector of unknown parameter to be estimated.

As for the error terms, v_j is the noise statistics assumed to be independent and identically-distributed random variables $[v_j \sim N(0, \sigma^2_v)]$. V_j is greater than zero and it is characterized by either a gamma or a truncated normal distribution. V_j accounts for the random effects that cannot be accounted for by an organization. On the other hand, u_j is the technical inefficiency and $u_j \geq 0$. As Greene (2008:538) put it, "Because the data are in log terms, u is a measure of the percentage by which the particular observation fails to achieve the frontier, ideal production rate." U_j implies that an organization either lie on the efficiency frontier defined as $[f(x_j) + v_j]$ and that any deviation from it is due to stochastic factors and errors. The distance from the efficiency frontier constitutes technical inefficiency. There are several important parameters in SFA: $\sigma^2 = \sigma^2_u + \sigma^2_v$ and the inefficiency component of the model $\lambda = \sigma_u/\sigma_v$. If $\lambda = 0$, then an organization operates on its efficiency frontier. Also, for the half normal model[3] used in this study, $\text{var}[\varepsilon] = \text{var}[u] + \text{var}[v] = (1 - 2/\pi)* \sigma^2_u + \sigma^2_v$.

According to Kumbhakar and Lovell (2003:42), "Technical efficiency refers to the ability to minimize input use in the production of a given output vector, or the ability to obtain multiple outputs from a ven input vector." Greene (2008: 96) further maintained that "Inefficiency can arise from two sources: technical inefficiency, which arises when, given he chose inputs, output falls short of the ideal; and allocative inefficiency, which arises from suboptimal input choices given prices and output."

By contrast to DEA, the provision for random shocks in SFA makes the efficiency frontier more dynamic. The parametric nature of SFA facilitates the measurement of marginal changes in the position of the efficiency frontier and how much of the change can be attributed to technical inefficiency or errors. Second, SFA makes it possible to account for

---

[3] The distribution of ε can be either half-normal, truncated normal, gamma, or exponential . See Coelli et al. (2005) for further explanations.

random errors and external conditions not under the control of an organization. Third, SFA handles truncated technical inefficiency errors that are not properly handled by Ordinary Least Square (OLS) regression. Fourth, whereas regression analysis focuses on *average* performance, SFA concentrates on *best* performance. Fifth, SFA allows the identification of best performance and makes it possible to measure the gap between best performers and the others.

Yet, SFA is limited by several factors. Although SFA incorporates noise and inefficiency, this is achieved at the expense of distributional and independence assumptions. Second, SFA, as a parametric method, is more 'rigid' than DEA because it requires a functional form. Third, SFA can be affected by model misspecifications.

5.2. An Illustration of an SFA Model

Poor weather conditions (thunderstorms and low cloud cover) on the East Coast and the Chicago area in summer 2000 generated many delays throughout the NAS. However, congestion and delays at busy airports in summer 2007 forced the Federal government to implement delay reduction initiatives at JFK and EWR the following summer in the form of capped operations at peak afternoon times. According to ASPM[4] (used as background reference), the average minutes of delay for all gate arrivals at the largest thirty-five airports were 18.67 in June 2000, 20.55 in June 2007 and 15.34 in June 2009. In fact, 69.67% of the flights arrived on time in June 2000 compared with 58.41% in June 2007 and 76.28% in June 2009. There were 1,195,799 total scheduled operations (arrivals and departures) in June 2000, 1,136,282 in June 2007 and 1,056,516 in June 2009 (sources: OAG and Innovata). Finally, 14.92% of the total operations were in Instrument Approach Conditions (IAC) compared with 11.91% in June 2007 and 15.59% in June 2009. Although weather conditions were no worse in June 2007 than during the other sampled months and despite fewer operations in June 2007 compared with June 2000, the poor on-time arrival performance of the OEP 35 airports in June 2007 may be explained by technical inefficiencies.

2.1. The Model

The SFA model for the OEP 35 airports can be expressed as follows:

$$\begin{aligned} \ln SAER = \beta_0 + \ln\beta_1{*}ARRDELAY + \ln\beta_2{*}DEPDELAY + \\ \ln\beta_3{*}TXOUTDEL + \ln\beta_4{*}TXINDEL + \ln\beta_5{*}CAPUTIL \\ + \ln\beta_6{*}AIRBNDEL + \ln\beta_7{*}BLOCKDEL + v_i - u_i \end{aligned} \qquad (3)$$

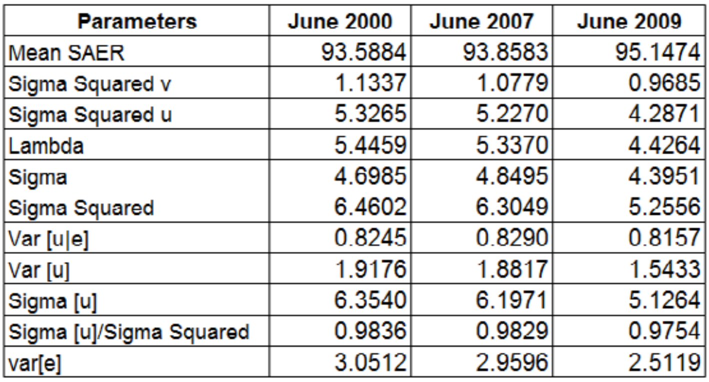
---

[4] In ASPM, the percent of on-time gate arrivals includes domestic and international flights for which a schedule can be matched with. Contrary to ASQP that reports the on-time performance of the major domestic carriers, ASPM does not include cancellations and diversions in the computation of the percentage of on-time gate arrivals.

The key components in SFA are λ (lambda) = σ_u/σ_v (the contribution of u and v to the compounded error) and σ (sigma) = $(\sigma_u^2/\sigma_v^2)^{1/2}$ (the variance parameter in the compounded distribution). If λ = 0, then every DMU would operate on the efficiency frontier. Table 5 provides the SFA stochastic components:

Overall, the efficiency of the OEP 35 airports increased in June 2009 compared with June 2000 and 2007. The increase in efficiency is supported by the decline in the contribution of technical inefficiency and error to the compounded error (λ), which decreased from 5.4459 in June 2000 to 4.4264 in June 2009. Although the conditional variance of technical inefficiency given the compounded error (var[u|e]) has not significantly changed, improvement in the SAER can be attributed to less variance in technical inefficiency (var[u]) as well as less variation in the composite error term due to the inefficiency component (sigma[u]/sigma squared).

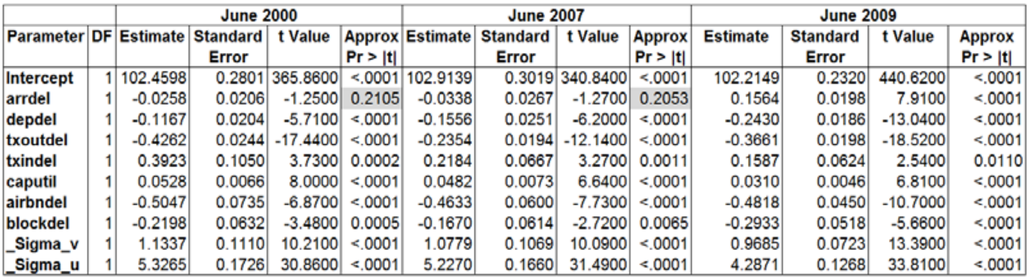
Table 5. The Stochastic Components (OEP 35 Airports)



Parameters	June 2000	June 2007	June 2009
Mean SAER	93.5884	93.8583	95.1474
Sigma Squared v	1.1337	1.0779	0.9685
Sigma Squared u	5.3265	5.2270	4.2871
Lambda	5.4459	5.3370	4.4264
Sigma	4.6985	4.8495	4.3951
Sigma Squared	6.4602	6.3049	5.2556
Var [u|e]	0.8245	0.8290	0.8157
Var [u]	1.9176	1.8817	1.5433
Sigma [u]	6.3540	6.1971	5.1264
Sigma [u]/Sigma Squared	0.9836	0.9829	0.9754
var[e]	3.0512	2.9596	2.5119

Source: ASPM (SAS)
Optimization: Newton-Raphson
Model Type: Production Frontier (Half Normal)

Table 6. Stochastic Frontier Analysis Estimates (OEP 35 Airports)



		June 2000				June 2007				June 2009			
Parameter	DF	Estimate	Standard Error	t Value	Approx Pr > |t|	Estimate	Standard Error	t Value	Approx Pr > |t|	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	102.4598	0.2801	365.8600	<.0001	102.9139	0.3019	340.8400	<.0001	102.2149	0.2320	440.6200	<.0001
arrdel	1	-0.0258	0.0206	-1.2500	0.2105	-0.0338	0.0267	-1.2700	0.2053	0.1564	0.0198	7.9100	<.0001
depdel	1	-0.1167	0.0204	-5.7100	<.0001	-0.1556	0.0251	-6.2000	<.0001	-0.2430	0.0186	-13.0400	<.0001
txoutdel	1	-0.4262	0.0244	-17.4400	<.0001	-0.2354	0.0194	-12.1400	<.0001	-0.3661	0.0198	-18.5200	<.0001
txindel	1	0.3923	0.1050	3.7300	0.0002	0.2184	0.0667	3.2700	0.0011	0.1587	0.0624	2.5400	0.0110
caputil	1	0.0528	0.0066	8.0000	<.0001	0.0482	0.0073	6.6400	<.0001	0.0310	0.0046	6.8100	<.0001
airbndel	1	-0.5047	0.0735	-6.8700	<.0001	-0.4633	0.0600	-7.7300	<.0001	-0.4818	0.0450	-10.7000	<.0001
blockdel	1	-0.2198	0.0632	-3.4800	0.0005	-0.1670	0.0614	-2.7200	0.0065	-0.2933	0.0518	-5.6600	<.0001
_Sigma_v	1	1.1337	0.1110	10.2100	<.0001	1.0779	0.1069	10.0900	<.0001	0.9685	0.0723	13.3900	<.0001
_Sigma_u	1	5.3265	0.1726	30.8600	<.0001	5.2270	0.1660	31.4900	<.0001	4.2871	0.1268	33.8100	<.0001

▨ Not Significant at 95% confidence level
Optimization Method: Newton-Raphson
Generated by the QLIM procedure in SAS

2.2. Interpretation of the Model Outputs

Table 6 features the estimates from the three models. Most of the variables in the SFA model are significant at a 95% confidence level except for the average minutes of delay for all arrivals in June 2000 and 2007. The negative estimated elasticity of SAER with respect to airborne delay and taxi out delays implies that the stochastic frontier is likely to be affected by airport congestion. This is supported by the fact that gate departure delays are significant at a 95% confidence level for the three samples. A one percent change in gate departure delays induced a decline in SAER of respectively 0.12% in June 2000, 0.16% in June 2007 and a 0.24% in June 2009. This can be explained by the use of ground stops[5] in order to help facilities manage their available capacity at origin and destination airports.

It is also important to remark that the elasticity of the percent capacity utilized decreased from 0.05 in June 2000 to 0.03 in June 2009. In other words, a one percent change in the percent of capacity utilized led to a 0.05% increase in the SAER in June 2000 compared with 0.03% in June 2009. The reduction in the elasticity can be explained by an overall lower volume of traffic at the OEP 35 airports. Scheduled operations declined at airports such as STL, PIT, CVG and CLE when the dominant carriers serving these airports either merged (TWA and American Airlines in the case of STL) or 'de-hubbed' the airport such as PIT in the case of US Airways. Moreover, fewer flights contribute to a reduction in the variability of technical inefficiency.

6. CONCLUSION

Data Envelopment Analysis and Stochastic Frontier Analysis are two complementary methods for assessing efficiency, the former being non-parametric. The challenge of evaluating complex organizations whose multiple inputs are transformed into multiple outputs makes DEA more appropriate as a benchmarking technique. It is especially appropriate for airports whose unique attributes (i.e., runway configurations, passenger terminals, passengers' origin and destination) make it more complex to compare with others. On the other hand, SFA provides analysts with more control over model specification and validity testing through hypothesis testing.

REFERENCES

Aigner, D. J. & Chu, S. C. F. (1968). "On Estimating the Industry Production Function," *American Economic Review*, *58*, 4, 826-839.

Aigner, D. J., Lovell, C. A. K. & Schmidt, P. (1977). "Formulation and Estimation of Stochastic Frontier Production Function Models," *Journal of Econometrics*, *6*, 1, 21-37.

---

[5] According to OPSNET, the average minutes of ground stops were 84.86 in June 2000, 93.52 in June 2007 and 51.57 in June 2009.

Banker, R. D., Charnes, A. & Cooper, W. W. (1984). "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," *Management Science*, *30*, 9, 1078-1092.

Breen, R. (1996). Regression Models: Censored, Sample Selected, *or Truncated Data (Quantitative Applications in the Social Sciences)*, Thousand Oaks, CA: Sage Publications.

Chalo, P. & Cherian, J. (1995). "An Application of Data Envelopment Analysis to Public Sector Performance Measurement and Accountability," *Journal of Accounting and Public Policy*, *14*, 2, 143-160.

Charnes, A., Cooper, W. W., Lewin, A. Y. & Seiford, L. M. (1995). *Data Envelopment Analysis*. Norwell, MA: Kluwer Academic Publishers.

Charnes, A., Cooper, W. W. & Rhodes, E. (1981). "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis To Program Follow Through," *Management Science*, *27*, 6, 668-697.

Charnes, A., Cooper, W. W. & Rhodes, E. (1979). "Short Communication: Measuring the Efficiency of the Decision Making Units," *European Journal of Operations Research*, *3*, 4, 339.

Charnes, A., Cooper, W. W. & Rhodes, E. (1978). "Measuring the Efficiency of Decision-Making Units," *European Journal of Operations Research*, *2*, 6, 429-444.

Christensen, L. R. & Greene, W. H. (1976), "Economies of Scale in U.S. Electric Power Generation," *Journal of Political Economy*, *84*, 4 Part 1, 655-676.

Coelli, T., Rao, D. S. P., O'Donnell, C. J. & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis*, New York, NY: Springer.

Cooper, W. W., Seiford, L. M. & Tone, K. (2000). *Data Envelopment Analysis*. Boston, MA: Kluwer Academic Publishers.

Diana, T. (2010). "Can We Explain Airport Performance? A Case Study of Selected New York Airports Using a Stochastic Frontier Model," *Journal of Air Transport Management*, 16, 6, 310-314.

Diana, T. (2006). "Benchmarking Airport Efficiency: An Application of Data Envelopment Analysis," *Air Traffic Control Quarterly*, *14*, 3, 183-202.

Farrell, M. J. (1957). "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society*, Series A, General *120*, 3, 253-282.

Fernandes, E. & Pacheco, R. R. (2002). "Efficient Use of Airport Capacity," *Transportation Research Part A: Policy and Practice*, *36*, *3*, 225-238.

H., Fried, C. A. K. Lovell, & S. S. Schmidt, editors (2008). *The Measurement of Productive Efficiency and Productivity Growth*, Oxford, U.K.: Oxford University Press.

Gillen, D. & Lall, A. (1997). "Developing Measures of Airport Productivity and Performance: An Application of Data Envelopment Analysis," Transportation Research Part E: *Logistics and Transportation Review*, *33*,*4*, 261-273.

Good, D. H., Roller, L. H. & Sickles, R. C. (1995). "Airline Efficiency Differences between Europe and the US: Implication for the Pace of EC Integration and Domestic Regulation," *European Journal of Operational Research*, *80*, *3*, 508-518.

Greene, W. H. (2008). "*The Econometric Approach to Efficiency Analysis*," in H., Fried, C. A. K. Lovell, & S. S. Schmidt, editors (2008). *The Measurement of Productive Efficiency and Productivity Growth*, Oxford, U.K.: Oxford University Press, 92-250.

Koopmans, T. C. (1951). “An Analysis of Production as an Efficient Combination of Activities,” in T. C. Koopmans, editor, Activity Analysis of Production and Allocation. *Cowles Commission for Research in Economics Monograph*, No. 13. New York, NY: John Wiley and Sons.

Kumbhakar, S. C. & Lovell, C. A. K. (2000). *Stochastic Frontier Analysis*, New York, NY: Cambridge University Press.

Lin, L. C. & Hong, C. H. (2006). “Operational Performance Evaluation of International Major Airports: An Application of Data Envelopment Analysis”, *Journal of Air Transport Management*, *12*, 6, 342-35.

Martin-Cejas, R. (2002). “An Approximation to the Efficiency of Spanish Airports Network Through a Deterministic Cost Frontier”, *Journal of Air Transport Management*, *8,* 14, 233-238

Meeusen, W. & van den Broeck, J. (1977). “Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error,” *International Economic Review*, *18*, 4, 293-323.

Oum, T.H., Yan, J. & Yu, C. (2008). “Ownership Forms Matter for Airport Efficiency: A Stochastic Frontier Investigation of Worldwide Airports”, *Journal of Urban Economics, 64,* 2, 422-435.

Pareto, V. (1971). *Manual of Political Economy*, translated by Ann S. Schwier. New York: Augustus M. Kelley Publishers.

Pestana Barros, C. (2008a). “Technical Efficiency of U.K. Airports”, *Journal of Air Transport Management*, *14,* 4, 175-178.

Pestana Barros, C. (2008b). “Technical Change and Productivity Growth in Airports: A Case Study”, *Transportation Research Part A: Policy and Practice, 42*, 5, 818-832.

Pestana Barros, C. and Dieke, P.U.C. (2008). “Measuring the Economic Efficiency of Airports: A Simar-Wilson Methodology Analysis, *Transportation Research Part E: Logistics and Transportation Review, 44*, 6, 1039-1051.

Pels, E., Nijkamp, P. & Rietveld, P. (2003). “Inefficiencies and Scale Economies of European Airport Operations,” *Transportation Research Part E: Logistics and Transportation Review*, *39*, 5, 341-361.

Ramanathan, R. (2003). An Introduction to Data Envelopment Analysis: *A Tool for Performance Measurement*. London, U.K.: Sage Publications.

Ray, S. C. (2004). Data Envelopment Analysis: *Theory and Techniques for Economics and Operations Research*, New York, NY: Cambridge University Press.

Sarkis, J. (2000). “An Analysis of the Operational Efficiency of Major Airports in the United States,” *Journal of Operations Management*, *18*, 3, 335-351.

Schmidt, P. & Sickles, R. (1984). “Production Frontier and Panel Data,” *Journal of Business and Economic Statistics*, *2*, 4, 367-374.

Simar, L. & Wilson, P.W. (2007). “Estimation and Inference in Two-Stage, Semi-Parametric Models of Production Processes”, *Journal of Econometrics, 136*, 1, 31-64.

Sengupta, J. (2000). Dynamic and Stochastic Efficiency Analysis: *Economics of Data Envelopment Analysis*, Singapore: World Scientific Publishing.

Sengupta, J. (1995). Dynamics of Data Envelopment Analysis: *Theory of Systems Efficiency*, Norwell, MA: Kluwer Academic Publishers.

Thanassoulis, E. (2001). Introduction to the Theory and Application of Data Envelopment Analysis: *A Foundation Text with Integrated Software*, Boston, MA: Kluwer Academic Publishers.

Zhu, J. (2003). Quantitative Models for Performance Evaluation and Benchmarking: *Data Envelopment Analysis with Spreadsheets and DEA Excel Solver*, New York, NY: Springer.

8. APPENDIX

Sampled Airports

DMU		Name	OEP 35	Sampled 30
1	ATL	Atlanta Hartsfield/Jackson International	√	√
2	BOS	Boston Logan International	√	√
3	BWI	BWI Thurgood Marshall	√	√
4	CLE	Cleveland Hopkins International	√	X
5	CLT	Charlotte International	√	√
6	CVG	Cincinnati/Northern Kentucky International	√	X
7	DCA	Ronald ReaganWashington National	√	√
8	DEN	Denver International	√	√
9	DFW	Dallas/Fort-Worth International	√	√
10	DTW	Detroit Detroit Metropolitan Wayne County	√	√
11	EWR	Newark Liberty International	√	√
12	FLL	Fort Lauderdale/Hollywood International	√	√
13	HNL	Honolulu International	√	X
14	IAD	Washington Dulles International	√	√
15	IAH	George H W. Bush Intercontinental Houston	√	√
16	JFK	New York John F. Kennedy International	√	√
17	LAS	Las Vegas McCarran International	√	√
18	LAX	Los Angeles International	√	√
19	LGA	New York LaGuardia	√	√
20	MCO	Orlando International	√	√
21	MDW	Chicago Midway	√	√
22	MEM	Memphis International	√	√
23	MIA	Miami International	√	√
24	MSP	Minneapolis/St. Paul International	√	√
25	ORD	Chicago O'Hare International	√	√
26	PDX	Portland International	√	√
27	PHL	Philadelphia International	√	√
28	PHX	Phoenix Sky Harbor International	√	√
29	PIT	Pittsburgh International	√	X
30	SAN	San Diego International	√	√
31	SEA	Seattle/Tacoma International	√	√
32	SFO	San Francisco International	√	√
33	SLC	Salt Lake City International	√	√
34	STL	Lambert/St. Louis International	√	X
35	TPA	Tampa International	√	√

The list of ‘OEP 35’ was compiled in 2000 and it refers to a group of thirty-five airports that account for at least 70% of the total passenger traffic. These airports are also very likely to be delayed and congested. The ‘Sampled 30’ group does not include scaled back hubs like St. Louis (STL) or Pittsburgh (PIT).

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 161-173
ISBN: 978-1-61122-079-7

Chapter 6

EVIDENCE-BASED PROCESS (EBP) CONSIDERATIONS OF HYPOXIA DURING FLIGHT FOR FLIGHT NURSES: THE AEROHEMODYNAMICS THEORY REVISITED

Darlene Sredl[*]
College of Nursing, University of Missouri at St. Louis,
St. Louis, Missouri, USA

ABSTRACT

The Aerohemodynamics Theory is more cogent to flight nursing practice and safety in the new millennium than it was when first identified in 1983. Major advances in the commercial airline industry and military transport capabilities have challenged nursing's comprehension of physiological adaptations necessitated by the flight environment, and those challenges are significant. The airline industry transported almost two billion passengers in 2002, many with serious cardiovascular and respiratory problems. Although the incidence of death among air travelers is low (frequency of occurrence approximately 0.3-1 per 3,000,000 passengers), medical emergencies of various other etiologies are more common, occurring 1 per every 14,000-40,000 passengers. Awareness of the risks and principles of nursing that augment nursing practice at altitude is necessary both for the specialty of flight nursing, as well as for the occasional nursing traveler who might be called upon to assist in an airborne emergency. This article explores the construct and use of the Aerohemodynamics Theory, identifies research on some of the physiologic adaptations to the flight environment that nurses must recognize, and offers recommendations for education and practice by medical, nursing, and airline personnel, .for future safety considerations.

---

[*] Corresponding author Email: dsredl@aol.com

Barb Hughes shifted uneasily in the cramped back seat of the single engine Cherokee. The weather looked much more ominous than it did just an hour before, but while the light plane buffeted in the strong winds aloft, her patient continued to sleep.

Barb is a volunteer flight nurse with Wings of Hope, a world-wide non-profit flight service that provides air transport to tertiary hospitals for medically indigent patients. As the pilot radioed Flight Control for permission to climb in order to minimize the effects of wind shear on the wings, Barb quickly took stock of her options.

Her patient had suffered a recent MI, a condition further complicated by Chronic Obstructive Pulmonary Disease (COPD). Recalling the Aerohemodynamics course she took preparing to be a flight nurse, Barb thought over the effects of hypoxia of her patient's condition, now that they were ascending to 7,000 feet in an unpressurized aircraft. She recalled her training in Aerohemodynamics Theory.

AEROHEMODYNAMICS THEORY

Definition

The Aerohemodynamics Theory provides a framework inter-relating the dynamics of physiology with stressors endemic within the flight environment. Once cognizant of the physiological, psychological, environmental, ergonomical, and task-related stressors, a nurse can appropriately care for patients in the airborne environment.

The Aerohemodynamics Theory,(Sredl, 1983) evolved from nursing aviator observations that different airborne conditions led to different physiological effects upon a body subjected to those conditions; hence the derivation of the term, Aero/hemo/dynamics, or the dynamic interrelationship of the blood (hemo) with the stressor forces of the air (aero).This short definition evolved quite naturally from the composition of the aerodynamic forces that were found to be acting upon the body at altitude (Sredl, 1983). Defining and structuring the variable relationships that ultimately yielded the empiric model that guides the practice discipline of nursing took a little longer (Chinn, 2004).

The need for a conceptual model to guide practice in the foreign ambient environment of altitude was spawned in part by the enormous numbers of people who utilize air travel. In 2002 commercial airlines transported over 2 billion passengers. While the incidence of death on board an aircraft is low, occurring only 0.1-3,000,000 passengers per year, the incidence of injury or cardio-pulmonary insult is much higher at 1- 14,00-40,000 passengers per year.

Since air travel is used as a transportation choice for recreational destinations, an adjunct to medical treatment as an air ambulance, a delivery method for warfare, and as a mechanism whereby space exploration is becoming a commonplace reality the necessity of having a theory to guide practice is evident (Kuhn, 1970; Sredl, 1983).

Empiric research that guides contemporary nursing practice is research that has been done on earth, under relatively stable barometric pressure, temperature and oxygen availability. None of the variables affecting the human body is likely to be "normal" in the airborne flight environment, hence the need for this model to be articulated.

Transforming one's perspective from earth-based nursing research to research performed in a foreign ambient environment is just one way the Aerohemodynamics Theory reflects broad scope and universality in practice. The inter-workings of the theory are designed to be applied in a flight environment. The distance from earth is one of the aspects of the theory that determine how many and which of the variables will act upon the body at any given altitude. Broad and comprehensive in scope, the Aerohemodynamics Theory is also wholistic and universal in applicability. Aerohemodynamics applies material from every aspect of the flight environment that is necessary to sustain life: oxygen, temperature, pressure, and positional comfort. These necessities govern life sustenance for everybody. The Aerohemodynamics conceptual model is also culturally congruent. Sub theories may eventually develop with further research that identify substantive changes within the health status of people with certain types of diseases (diseases that are associated with ethnic origin). For example, a child with sickle cell anemia may be more at risk of a sickle-cell crisis occurring in the commercial flight environment (30,000-38,000 ft) not because he is of African-American derivation, but because his ethnic background places him at higher likelihood of having sickle cell disease.

Applicability to Broad Scope of Practice

Many of the scientific laws that the Aerohemodynamics Theory is based upon originate within the physical sciences. These laws have formed the basis for such therapeutic diagnostics as blood-gas theory, and ultra-sound technology. We turn again to these laws as comprising some of the basic building blocks of the Aerohemodynamics Theory (Sredl, 1983).

CONCEPTS

Acceleration Forces

Acceleration forces are one variable of interest within the Aerohemodynamics Theory (Sredl, 1983). All aircraft maneuver through the air by means of velocity changes and directional alterations. Velocity is the rate of change of position.

- *Acceleration* is the rate of change of velocity; and/or change in rate/direction of that velocity.
- *Deceleration* is any reduction in rate and/or direction of velocity. Sometimes referred to as “negative acceleration”.

Acceleration forces occur through one of three defined axes of rotation of an aircraft: Roll, pitch and yaw. *An* ***axis*** *is a line passing through a body and about which the body revolves.* **Roll-** is a *longitudinal axis* of rotation. An aircraft roll axis is an imaginary line drawn from the aircraft’s nose through its center of gravity and out to it’s tail. The aircraft could literally “roll” wing over wing. **Pitch** is a *lateral axis* produced by an imaginary line drawn from wing-tip, through the center of gravity to wing-tip. Climbing and diving (pitching forward or up) are the accelerative motions produced by the *lateral axis* of pitch. **Yaw** is the *vertical* axis of rotation that occurs when an imaginary line is drawn from the top, through the center of gravity, to the bottom of the aircraft. The aircraft rotates in a horizontal plane around the imaginary axis. Acceleration varies directly with the square of the airspeed and inversely with the radius of the turn (a = V2/r). **Acceleration** is measured in terms of units of G force (gravity)

There are 3 types of acceleration forces: Linear, radial, and angular that give rise to 3 types of G forces: Positive, negative, and transverse. Variables that influence the effect of G forces are: *Intensity* of the force; *Duration* of the force; *Rate* of applied force; *Site & area* over which force is applied to body (Sredl, 1983 p. 30-31).

Nursing Challenges- Acceleration Stress

The nurse must maintain communication with the pilot in order to be pre-informed of any directional changes that the pilot anticipates in order to allow enough time for patient repositioning, if that is indicated by the planned maneuver. If the pilot plans a descent for example, the nurse would position the patient with feet toward the cockpit in order to minimize the deceleration pressure forces upon the body. This is especially important in caring for patients with closed head trauma.

Barotrauma

Barotrauma is another variable of interest within the Aerohemodynamics conceptual model (Sredl, 1983). *Dysbarism*- (a collective term used to describe all of the physiological effects occurring within the body as a direct result of changes in barometric pressure). ***Barotrauma*** is tissue trauma resulting from changes in barometric pressure that may be of the following types: sudden decompression syndrome, barotitis media/barosinusitis, or barodontalgia (Sredl, 1983).

Nursing Challenges

The nurse must have a complete health history of the patient available. Any recent dental work or recreational sport such as scuba diving recently participated in, or any recent upper respiratory infection (URI) must be noted so that observations for barodontalgia (dental pain), barosinusitis (sinus blockage pain), barotitis media (ear pain) caused by changes in barometric pressure can be identified.

Thermostability

A thermostabile environment is one in which the temperature remains constant. The airborne environment produces cold stress because of decreased air temperature, lack of humidity and reflection of radiant surfaces (Sredl, 1983).

Nursing Challenges

The nurse must be aware of the temperature changes precipitated by the flight environment and counteract these stressors by application of blankets, etc because cold stress accelerates shock.

Gaseous Toxicities, Diffusion and Vacuolization

Many gaseous abnormalities can affect the individual at altitude. Hypoxia, or oxygen deficiency in tissues can affect the individual via many routes at altitude (Sredl, 1983).

Hypoxia types:

- Simple hypoxia- inability of the body to take in enough oxygen to meet the cellular demands of tissues
- Stagnant or circulatory hypoxia- caused by gross malfunction of circulatory system. Ex. Cardiac arrest or G-force venous pooling.
- Histotoxic hypoxia- tissues unable to accept &/or metabolize oxygen due to synaptic bridge barriers such as in disease-causing microbials that render RBCs ineffective
- Hemolyzed hypoxia- mechanical rupture of RBC rendering hemoglobin useless for transport.
- Hypemic or anemic hypoxia- decreased hemoglobin-oxygen affinity. Ex: Carbon monoxide; sickle cell diosease.
- Hypoxia caused by decreased lung capacity—minimization of available lung tissue. Ex: atelectasis and penetrating chest wounds.

Vacuolization is the process of gaseous bubble formation &/or expansion in response to a decrease in atmospheric (barometric) pressure. Rapid pressure decrease causes bubble formation. The following Laws of Gaseous Diffusion apply to situations in the airborne environment:

- Dalton’s law- total pressure exerted by a mixture of gases is sum of pressures that would be exerted by each of the gases (partial pressure of each gas) if it alone were present occupying the total volume.
- Boyle’s law- volume of a gas will vary inversely as the absolute pressure, while the density varies directly as the pressure.
- Charles’ Law- all gases, by equal degrees of heat & under the same conditions, expand proportionately just alike.
- Avogadro’s Law- for a given mass, pressure & temperature,the volume of a gas is inversely proportional to it’s molecular weight.
- Graham’s law of Diffusion- rate at which a gas diffuses is proportional to the square root of it’s molecular weight (Sredl, 1983, p 44-47).

Carbon monoxide (CO) is one of the end-product of tobacco consumption. At altitude, the decrease in oxygen tension, coupled with the hemoglobin saturation properties of smoked

CO, potentiates the effects of hypoxia. A concentration of 0.01%CO (safe at ground level) reduces the oxygenation of the blood by 10.5% at 10,000 feet.

Ozone poisoning (O3) is particular to the flight environment. Even small amounts can predispose toward the following symptoms: chest tightening, choking, anxiety, all of which can mimic a myocardial infarction.

Nursing Challenges

The nurse must recognize the limited availability of oxygen in the flight environment and be alert to subtle signs of oxygen deprivation. This is especially important when flying in unpressurized aircraft at altitudes at or below 10,000 ft. Supplemental sources of oxygen and masks must be onboard before take-off.

In the event of ozone poisoning, a community health perspective may be in order regarding nursing assessment because the throat irritation caused by ozone would affect ALL passengers and crew, not just one patient (as in the case of an MI) thereby making identificAtion of an exterior toxin easier.

Radiation Exposure

Radiation is the process whereby electromagnetic waves are emitted from a specific broadcast source (Sredl, 1983). Radiation exposure occurs from a variety of sources at altitude. Radiant energy forms include: visible light, radio waves, ultraviolet light, infra-red light, X-rays, gamma rays, cosmic rays (Sredl, 1983). Because most commercial aircraft fly at altitudes above the clouds there is no filter for the sun’s ultraviolet rays. Also the aircraft is in continuous communication with a radio-signal relay station via the continuously operating transponder. This transponder signal emits radiation signals, as does communication from the aircraft to control tower. Ultrasound devices emit low levels of radiation. Radio frequency (10KHz-300GHz) radiation insult is strongly communication frequency dependent (Sredl, 1983).

While the most significant circumstances of radiation exposure occur on space flights, especially if of long duration, radiation exposure from the afore-mentioned sources can be cumulative and especially deleterious to pregnant crew members or passengers (Control, 2003).

Nursing Challenges

The wearing of radiation badges during flight is encouraged. If significant exposure occurs the pilot could request turning to a different flight vector to avoid direct sunlight on one part of the plane housing the patient.

Psychosocial Considerations

Psychosocial manifestations may occur at each variable comprising the Aerohemodynamics Theory. These manifestations may take the form of ‘fear of flying’, to anxieties brought on by acceleration or barotraumatic forces causing change in aircraft direction or pressure.

Nursing Challenges

The nurse must recognize the potential for behavioral acting-out as a result of anxieties triggered by the flight environment, and take steps to communicate calming messages to the patient. Message-based persuasion strategies such as affirmations, and guided imagery may be very effective in these situations.

Aerohemodynamics Theory Effect Equation

Aerohemodynamic Effect = forces of Acceleration + Barometric Pressure + Thermostability + Gaseous Toxicities & availability of Oxygen + Radiation & Safety Hazards.

Acceleration Force Changes

Some of the physiological effects of acceleration forces upon the body include venous engorgement in upper or lower extremities that can lead to thrombus formation or loss of consciousness (Sredl, 1983; Wilson, 2005). EEG changes and eye activity changes also occur under acceleration stress with blink inhibition and the possibility of cognitive changes occurring in later stages of pressure (Wilson, 2005). Studies demonstrate that cardiac responses to linear acceleration result in transient increases in heart rate and blood pressure (Jauregui-Renaud, 2006; Radtke, 2000; Yates, 1999).

Acceleration forces significantly hasten motion sickness symptoms because they intermittently alter rotation directions thus altering vestibular input (Bonato, 2005). Additionally pilots in high-performance aircraft including pilots in fighter and experimental aircraft have experienced significant physiological threats to acceleration-induced cerebral perfusion insults as a result of acceleration in the head-to-foot, or z-axis (McKinley, 2005).

Motion Sickness Susceptibility

Survey studies of gender susceptibility to motion sickness have shown a wide variation of results. Surveys of motion sickness at sea demonstrates a 5 to 3 female to male risk ratio for vomiting (Lawther, 1988). One theory relating this consequence to female hormone/menstrual cycle remains contradictory (Cheung, 2001). A study by Golding, Kadzere and Gresty (2005), however concluded that there was a greater trend for female susceptibility to motion sickness at menstrual day #5 (Golding, 2005).

Barotrauma

The ambient pressure changes that can initiate the tissue trauma known as barotraumas exhibit markedly in the ear (Klokker, 2005). Ear barotrauma is characterized by pain and sensation of pressure, diminished hearing and sometimes, dizziness (Klokker, 2005). Not usually a problem on ascent, the need to equalize pressure in the inner ear compartment on descent may cause rupture of the eardrum if techniques like the Valsalva maneuver, or swallowing do not result in the desired pressure equalization (Klokker, 2005). It can readily be seen how this attempt at pressure equalization can be more problematic for infants, young children, mentally/cognitively impaired individuals of all ages, and comatose patients on descent from altitude (Klokker, 2005).

Thermostability

Heat stress and cold stress situations can, and do, occur at altitude. The body's thermoregulatory controller issues different metabolic rates for different areas of the body. These weighted thermal thresholds respond to indicators in different segments of the body according to tissue composites of core, muscle, fat and skin (Xiaojiang, 2004). Different areas of the body have different heating and cooling requirements and need support systems in the foreign airborne environment to provide life-sustaining comfort levels (Xiaojiang, 2004). A pilot study of exposure to cold (N=10) by Makinen et al found that cold exposure affects postural control due to suppression of tendon-reflex responses (Makinen, 2005). This result indicates a greater need for vigilance in flight as elderly people, or people of any age exposed to cold stress are more likely to be a risk for falls.

Gaseous Toxicities

The lack of oxygen that may be experienced at altitude can pose ominous risks for passengers. It has been demonstrated that cerebral metabolism decreases with increased cerebral hypoxia (McKinley, 2005). Reductions in mental functioning has been shown to occur when oxygen pressure are reduced by only a small amount (Bolgg, 2006). Normally the body's circulating leukocyte count rises as a response to a variety of stressful situations, but in vitro studies conducted in extreme localized hypoxic situations have shown that neutrophil phagocytic function is suppressed (Lingaas, 1987; Thake, 2004).

The emergence of gaseous bubbles (vacuolization) in the bloodstream such as occur during transition through different pressure gradients can now be detected using Doppler ultrasound technology (Payne, 2005; Sredl, 1983).

Table 1. Chart of hypoxic complications to physical compromise at altitude

Medical Condition	Hypoxic Complication?	Physiological alteration	Consequence	Treatment
Myocardial Infarction (MI)	Yes	Obstructed coronary artery	Tissue hypoxia	Angioplasty (with or without stint)
COPD	Yes	Alveolar distention	Lack of diffusion	
Sickle cell disease	Yes	Lack of oxygen causes cells to form sickle shape	Potential preciptiation of sickle cell crisis	Oxygen therapy; pain medication; IV fluids
Sealed air pockets in dental enamel	Yes	Air expansion with no escape route	Pain	Dental venting
Upper respiratory Infection (URI)	Yes	Lessened ambient air pressure combined with mucous production obstructs nasal passages	Mild to moderate air hunger	Antihistamine if not contraindicated to reduce tissue swelling and mucous discharge
SARS	Yes	Infectious process causing fever and SOB	May progress quickly-ultimately to death	None known. Use of isolation and barrier protection techniques mandated (Sredl, 2003)
Sinus Infection	Yes	Lessened ambient air pressure combined with mucous production obstructs nasal passages	Mild to moderate air hunger	Antibiotic if infection is bacterial, and Antihistamine if not contraindicated to reduce tissue swelling and mucous discharge
Sudden Decompression	Yes	Lysis of red blood cells	Severely compromised oxygen transport system	Immediate descent with possibility ofpacked cell transfusion and oxygen administration
Caisson's Disease	Yes	Sudden release of pressure surrounding body causes vacuolization (expansion) of air bubbles to gravitate to body cavities	Severe pain	Immediate decompression chamber treatment

Table 1. (Continued)

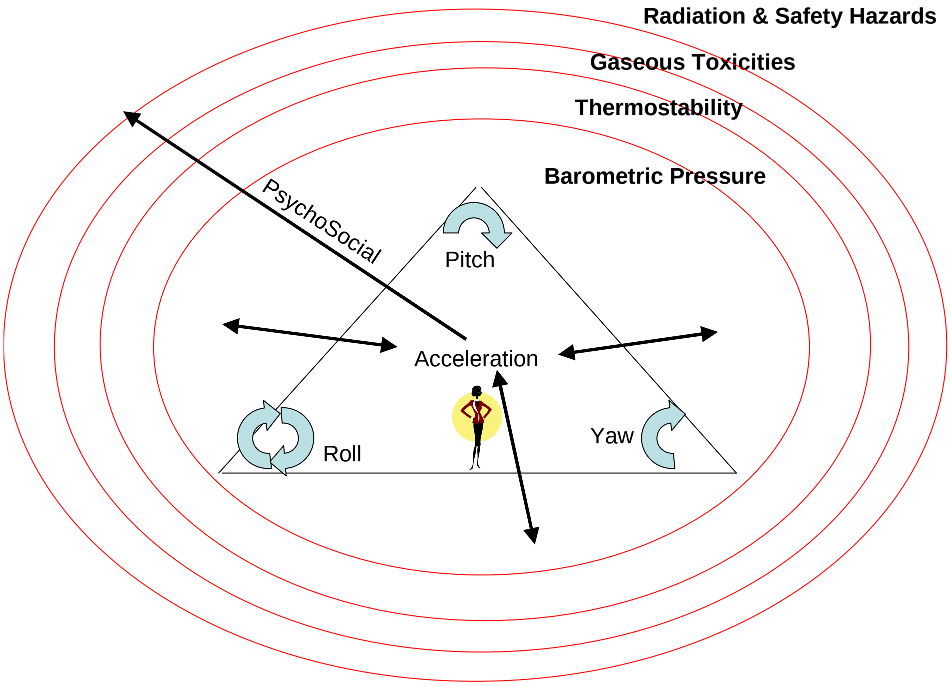
Medical Condition	Hypoxic Complication?	Physiological alteration	Consequence	Treatment
Infection	Yes	Infectious process raises need for oxygen	Potential for tissue and circulating hypoxia	Oxygen administration; antibiotic if not contraindicated
Chest Trauma	Yes	Decreased capacity for oxygen uptake	Potential for hypoxia	Close sucking chest wounds with sterile procedure. Apply oxygen
Recent CVA	Yes	If brain is compromised near hypothalamus the potential exists for VS changes especially respiratory insufficiency	Observe patterns of breathing; monitor oxygen saturation level	Oxygen administration may be indicated
Anemia	Yes	Decreased number of circulating red blood cells	Air hunger	Oxygen administration
Thalesemia	Yes	Decreased number of circulating red blood cells	Air hunger	Oxygen administration
Recent Carbon Monoxide poisoning	Yes	Irreversible chemical bonding of CO to RBC rendering it ineffective for oxygen transport	Remove person from source of CO contamination quickly. Exposure to CO may lead to death	Administration of oxygen; may require packed cell transfusion
ARDS	Yes	Pulmonary edema	Systemic hypoxia due to pulmonary ventilation/perfusion mismatching	Oxygen administration (Sredl, 2003)
Fever	Yes	Infectious process anywhere in body raises need for oxygen	Potential for tissue and circulating hypoxia	Oxygen administration; antibiotic if not contraindicated
Recent Drowning	Yes	Fluid-filled pleural cavity and alveoli	Decreased capacity to transfer oxygen	Positioning to allow chest cavity to drain; CPR, oxygen administration

Radiation and Other Safety Hazards

Hazards of working in a radiation enhanced environment have not been as adequately studied in a commercial aircraft as in examining the cumulative effects of space radiation on crew members of extended duration flights. These studies, however, have resulted in a new medication (Amifostine) designed to prevent some of the symptoms of ionizing radiation-induced damage (Epelman, 2006).

NURSING IMPLICATIONS

As a passenger, nurses can gain from the adoption of the Aerohemodynamics Theory. A nurse flying as a passenger can utilize the conceptual background in order to make healthy choices for herself/himself as well as for their families. As an in-flight nurse, air ambulances are now supported both by private aviation companies as well as by hospitals. The new specialty of flight nursing holds appeal for nurses wishing to exercise more autonomy in practice. CAMS is the regulating body for medical flight-related services. The new occupation/professional position of aviation medical/nursing director is now available. The obligation to have a person trained in the aviation physiological sciences is one of CAMS requirements for accreditation.



AEROHEMODYNAMICS CONCEPTUAL MODEL

Figure 1. The Aerohemodynamics Theory Model.

NURSING RESEARCH

Nursing research opportunities at all levels exist in the flight environment. The airborne environment is comprised of non-linear complex relationships (Beard, 1995). These relationships provide the framework for the empiric collections of facts, assumptions, hypotheses, and nursing critical thinking that comprise the Aerohemodynamics Theory.

CONCLUSION

As the Wings of Hope pilot started the descent toward reaching their final destination, Barb reviewed a mental checklist of things needed to be ready for landing, and, as her patient dozed contentedly, Barb removed the oxygen mask.

Reproduced with permission from:
Sredl, D. (2008). Conceptual Model: The Aerohemodynamics Meta-Theory. *Journal of Teaching and Learning in Nursing, 3,* 115-120.

REFERENCES

Alligood, M. & Tomey, A. (2006). *Nursing Theory: Utilization and Application*. St. Louis: Mosby.

Beard, M. E. (1995). *Theory Construction and Testing*. Lisle, IL: Tucker Publications.

Bolgg, S. & Gennser, M. (2006). Cerebral blood flow velocity and psychomotor performance during acute hypoxia. *Aviation*, *Space and Environmental Medicine*, *77(2)*, 107-113.

Bonato, F., Bubka, A. & Story, M. (2005). Rotation direction change hastens motion sickness onset in an optokinetic drum. *Aviation*, *Space*, *and Environmental Medicine*, *76(9)*, 823-827.

Cheung, B., Heskin, R., Hofer, K. & Gagnon, M. (2001). The menstrual cycle and susceptibility to Coriolis-induced sickness. *Journal of Vestibular Responses*, *11*, 129-136.

Chinn, P. & Kramer, M. (2004). *Integrated Knowledge Development in Nursing*. St. Louis: Mosby.

Control, C. f. D. (2003). *Acute radiation syndrome*, *fact sheet for physicians*. Atlanta: CDC.

Epelman, S. & Hamilton, D. (2006). Medical mitigation strategies for acute radiation exposure during spaceflight. *Aviation, Space and Environmental Medicine, 77(2)*, 130-137.

Fawcett, J. (1995). *Analysis and evaluation of Conceptual Models of Nursing*. Philadelphia: F.A. Davis Company.

Fawcett, J. (2005). *Contemporary Nursing Knowledge: Analysis and Evaluation of Nursing Models and Theories* (2nd ed.). Philadelphia: F.A.Davis.

Golding, J., Kadzere, P. & Gresty, M. (2005). Motion sickness susceptibility fluctuates through the menstrual cycle. *Aviation*, *space*, *and Environmental medicine*, *76(10)*, 970-973.

Jauregui-Renaud, K., Reynolds, R., Bronstein, A. & Gresty, M. (2006). Cardio-respiratory responses evoked by transient linear acceleration. *Aviation, Space, and Environmental Medicine, 77(2)*, 114-120.

Klokker, M., Vesterhauge, S. & Jansen, E. (2005). Pressure-equalizing earplugs do not prevent barotrauma on descent from 8000 ft cabin altitude. *Aviation, Space, and Environmental Medicine, 76(11)*, 1079-1082.

Kuhn, T. (1970). *The Structure of Scientific Revolutions* (2 nd ed.). Chicago: University of Chicago Press.

Lawther, A. & Griffin, M. (1988). A survey of the occurrence of motion sickness amongst passengers at sea. *Avistion, Space, and Environmental Medicine, 59*, 399-406.

Lingaas, E. & Midtvedt, T. (1987). The influence of high and low pressure on phagocytosis of escherichia coli by human neutrophils in vitro. *Aviation, Space and Environmental Medicine, 58*, 1211-1214.

Makinen, T., Rintamaki, H., Korpelainen, J., Kampman, V., Paakonen, T., Oksa, J., Palinkas, L., Leppaluoto, J. & Hassi, J. (2005). Postural sway during single and repeated cold exposures. *Aviation, Space and Environmental Medicine, 76(10)*, 947-953.

McKinley, R., Tripp Jr., L., Bolia, S. & Roark, M. (2005). Computer modeling of acceleration effects on cerebral oxygen saturation. *Aviation, Space, and Environmental Medicine, 76(8)*, 733-737.

Payne, S. & Chapell, M. (2005). Automated determination of bubble grades from Doppler ultrasound recordings. *Aviation, Space and Environmental Medicine, 76(8)*, 771-777.

Powers, B. & Knapp, T. (1995). *A Dictionary of Nursing Theory and Research* (2 nd ed.). Thousand Oaks, CA: Sage.

Radtke, A., Popov, K., Bronstein, A. & Gresty, M. (2000). Evidence for a vestibulo-cardiac reflex in man. *Lancet, 356*, 736-737.

Sredl, D. (1983). *Airborne Patient Care Management: A Multidisciplinary Approach*. St. Louis: Medical Research Associates Publications.

Sredl, D. (2003). Sars: Here today, gone tomorrow? *Nursing Made Incredibly Easy*. Nov/Dec. 28-35.

Thake, C., Mian, T., Garnham, A. & Mian, R. (2004). Leukocyte counts and neutrophil activity during 4 h of hypocapnic hypoxia equivalent to 4000m. *Aviation, Space and Environmental Medicine, 75(9)*, 811-817.

Wilson, G., Reis, G. & Tripp, L. (2005). EEG correlates of G-induced loss of consciousness. *Aviation, Space and Environmental Medicine, 76(1)*, 19-27.

Xiaojiang, X., Berglund, L., Cheuvroni, S., Endrusick, T. & Kolka, M. (2004). Model of human thermoregulation for intermittent regional cooling. *Aviation, Space and Environmental Medicine, 75(12)*, 1065-1069.

Yates, B., Aoki, M., Bronstein, A. & Gresty, M. (1999). Cardiovascular response to linear acceleration in humans. *Experimental Brain Research, 125*, 476-484.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 175-185
ISBN: 978-1-61122-079-7

Chapter 7

CORPORATE SOCIAL RESPONSIBILITY REPORTING OF ASIAN AIRLINES

Fang-Yuan Chen
Department of Transportation Technology and Management,
Feng Chia University, Taichung, Taiwan

ABSTRACT

Corporate social responsibility (CSR) plays an important role in the formation of airlines' strategies due to the unique characteristics of the airline industry. Nevertheless, CSR in the airline industry has received relatively little attention from academics. The purpose of this study is to present a preliminary exploration of the CSR issues being addressed and reported by twelve major Asian airlines. This research is exploratory by nature and is based on he CSR reports published by the selected airlines and related CSR information on the company websites. The main focuses of major Asian airlines' CSR commitments and practices are identified, which will set the foundation for future enquiry and research.

Keywords: Airline, Corporate Social Responsibility, Asia.

1. INTRODUCTION

Corporations are an integral part of society. Nowadays, the responsibility of corporations is not solely based on providing products and services; it must also include taking care of the welfare of the various stakeholders in society [1]. Consumers' expectations for firms to assume more social responsibilities are increasing as well. As a result, there is a growing attention to the topic of corporate social responsibility (CSR) from the corporate world.

In view of the unique characteristics of the airline industry, CSR may play an important role in the formation of airlines' strategies. First, the flying of airplanes will adversely affect the global environment [2]. Airlines embracing environmental protection can create a favorable public image. Second, the fact that the airline industry is characterized by growing competition and airlines are offering increasingly similar products and services in the marketplace makes the promotion of CSR an attractive differentiation strategy. Lastly, international airlines operate in multiple countries and are increasingly expected to fulfill their responsibilities as corporate citizens to meet the expectations of various stakeholders and customers [3]. As such, airlines can take advantage of the positive effect of implementing CSR.

In response to the global trend towards CSR, this study aims to present a detailed and comprehensive overview of the current status and progress of CSR activities in the airline industry in Asia where the air transport will experience the highest growth rate compared to all other areas.

2. CORPORATE SOCIAL RESPONSIBILITY

CSR has been gaining momentum across the business community as a growing number of companies recognize that businesses are part of society and become aware of the impact they have on society.

There seems to be no universally agreed upon definition of CSR. Frankental even argues that “CSR is a vague and intangible term which can mean anything to anybody, and therefore is effectively without meaning” [4]. Holmes and Watts, on behalf of the World Business Council for Sustainable Development (WBCSD), provide a reasonably representative definition: “the continuing commitment by businesses to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large” [5]. It is generally agreed that CSR refers to the social obligations of the firm to society [6]. Carroll suggests that CSR includes four kinds of responsibilities: economic, legal, ethical, and philanthropic. The economic responsibility refers to a firm’s obligations to be productive and profitable, as well as to maintain wealth. Firms’ legal responsibilities refer to carrying out their activities within the confines of legal requirements. Their ethical responsibility refers to having ethical codes/norms which exceed mere legal frameworks, and being honest in their relationships with their customers and their own employees. Finally, the discretionary component includes voluntary or philanthropic activities aiming to raise the well-being and development of society as a whole [7]. The Commission of the European Communities identifies an internal and external dimension to a company’s approach to CSR. The former concerns socially responsible practices within the company while the latter extends outside the company into the local community and beyond and involves a wide range of external stakeholders [8].

The development of CSR reporting has witnessed three stages. The first stage dating from the early 1970s was mostly in the form of advertisements and annual reports that focused on environmental issues but was not directly linked to corporate performance. The second stage, in the late 1980s, emphasized the introduction of a social audit which examined the performance of social responsibility on the part of companies with respect to all affected stakeholders. The third stage, beginning from the 1990s, was evidenced by the strengthening of social auditing by the introduction of externally set and certified standards [9].

3. METHOD

Twelve airlines based in Asia were analyzed in this study to identify the nature of issues related to CSR commitment: China Airlines (CAL), Eva Air (EVA), Japan Airlines (JAL), All Nippon Airways (ANA), Korean Air, Asiana, Cathay Pacific, Singapore Airlines (SIA), Garuda Indonesia, Philippine Airlines, Malaysia Airlines, and Thai Airways. Most of the selected airlines are considered to be flag carriers or business leaders in this region and are generally more vulnerable to public scrutiny for socially responsible behaviors. Chinese airlines were excluded in this study because data were not available.

The research method involved an Internet search for CSR information on the company websites to discover variations in both content and extent of CSR-related information posted on the websites by the selected airlines. The units of sampling were mostly the annual, CSR or Sustainability Reports of the twelve airlines.

4. RESULTS

4.1. CSR Reporting Formats

Up to 2008, only three airlines (JAL, ANA, and Cathay Pacific) produced standalone CSR Reports. In an attempt to cover broader domains, Korean Air and Asiana each publish a Sustainability Report, respectively; these are also their annual reports. These reports outline the company’s endeavors in regard to social responsibility, environmental soundness, and economic achievements. Far ahead of the publication of CSR or Sustainability Reports, ANA, Korean Air, Asiana, Cathay Pacific, and SIA have produced standalone Environmental Reports. ANA produced an Environmental Report as early as 1998. These reports were available via downloadable PDF format.

In addition, all of the selected airlines devote part of their annual reports to CSR-related information. The majority of the airlines have links on their websites to specific CSR-related activities such as the environment, social activities, and community involvement; some airlines provide relatively limited CSR information on company websites. The reporting formats and periods of reporting are shown in Table 1 and Table 2.

The selected airlines report their CSR issues under a variety of headings. Similar socially responsible behavior may be labeled differently by different companies. This study follows Jones, Comfort and Hiller’s classification of marketplace, workplace, community, and environment in an attempt to capture CSR agendas as reported by the selected airlines [9, 10]. These dimensions are believed to best fit the activities that the selected airlines were reporting. Key components that explain the content of these dimensions were identified. The dimensions and key components are presented in Table 3. The CSR information reported in the following sections is primarily drawn from the CSR/ Sustainability Reports or company websites [11-22].

Table 1. CSR Reporting Formats

	Standalone CSR Reports	Standalone Sustainability Reports	Standalone Environmental Reports	CSR information in annual reports	CSR information on company website
CAL				✓	✓
EVA				✓	
JAL	✓			✓	
ANA	✓		✓	✓	✓
Korean Air		✓	✓	✓	✓
Asiana		✓	✓	✓	✓
Cathay	✓		✓	✓	✓
SIA			✓	✓	✓
Garuda				✓	
Philippine Airlines				✓	
Malaysian				✓	✓
Thai Airways				✓	✓

Table 2. Periods of CSR Reporting

	Standalone CSR Report	Standalone Sustainability Report	Standalone Environmental Report
CAL			
EVA			
JAL	2005-2009		
ANA	2005-2009		1998-2005
Korean Air		2006-2009	2004-2005
Asiana		2009	2002-2008
Cathay	2006-2008		2003-2005
SIA			-2008/2009
Garuda			
Philippine Airlines			
Malaysian			
Thai Airways			

4.2. CSR Organization

Most of the airlines have not established full-time departments related to CSR. However, some airlines have set up high-ranking Committees to work in unison to promote CSR activities. Cathay Pacific, for example, has a CSR Steering Committee composed of senior management representatives from 18 departments, including Dragonair, who meet regularly to discuss the company’s CSR performance. ANA also has a CSR Promotion Committee which directly reports to its president and CEO. A number of committees such as a Risk Management Committee and Compliance Committee are structured under the CSR Promotion Committee at ANA.

The JAL Group established the CSR Committee in 2004, which also reports directly to the president. Directors responsible for each business areas serve as CSR Committee members and work in unison to promote CSR activities. In addition, the JAL group has set up a social activities section within the Public Relations Department dedicated full time to addressing CSR matters. China Airlines also has staff within the Public Relations Department to manage the company's CSR activities.

Some airline groups have set up self-funding Foundations responsible for the planning and implementation of humanitarian and social development assistance. These Foundations include: the JAL Foundation (the JAL Group), the PAL Foundation (Philippine Airlines), and Chung Yung-Fa Foundation (EVA Air). The airlines collaborate with these Foundations to promote CSR activities.

Table 3. CSR dimensions and key components

	Dimension			
Key components	Marketplace	Workplace	Community	Environment
	Safety	Safety and health	Charity activities	Sustainability
	Customer service	People	Grants	Environmental responsibility
	Customer satisfaction	Employee engagement	Sponsorships	Environmental and protection conservation
	Competition compliance	Employee communication	Educational programs	Global warming
	Code of conduct	Employee satisfaction	Donations	Climate change
	Partnership	Advancement	Community investment	CO_2 emissions
	Stakeholders	Benefits and incentives	Employee volunteerism	Fleet modernization
		Ethical management	Art, sports, cultural events	Air traffic management
		Education and training	Long-term relationships	Aircraft maintenance
				Noise reduction
				Waste disposal
				Carbon offset programs

4.3. The Marketplace

Safety is the most important social responsibility of the aviation industry. All of the selected airlines stress their commitment to the pursuit of improved flight safety. Cathay Pacific, for example, has established a series of safety performance targets, including: zero accidents, zero high risk or severe incidents, and regulatory report rates below 4 per 1,000 flights. In 2008, Cathay Pacific only experienced a single serious injury and zero passenger fatalities. To ensure passenger safety, Cathay Pacific has implemented an airline Safety Management System (SMS) that manages safety as an integral part of its overall business.

In addition to safety, the airlines report a number of issues related to the marketplace. Among them, customer service receives the most widespread attention. Being a service-intensive industry, responding to customers' needs is at the heart of airline businesses. Cathay Pacific, for example, measures customer satisfaction through an ongoing Reflex Passenger Survey which collects around 30,000 responses per month across all cabin classes for both Cathay Pacific and Dragonair. Asiana's corporate mission is to achieve "customer satisfaction through maximum safety and pleasant service. Their efforts have earned international recognition: Asiana received the Skytrax 5-Star status in 2007 and 2008 and was named "Airline of the Year 2009" by Air Transport World, the prestigious aviation magazine. To restore the stakeholders' trust, ANA reported, in the beginning of the Company's CSR Report 2009, on the preventive measures for two incidents which had occurred in the previous year.

As an international business, any violation of applicable antitrust and competition rules may cost airlines millions of dollars. Cathay Pacific announced that it had reached an agreement with the United States Department of Justice under which it pleaded guilty to a violation of the US Sherman Act and paid a fine of US$60 million. Cathay Pacific has a Competition Compliance Office which ensures that the airline and all its employees comply with the airline's antitrust policy and other competition laws. The airline established the competition compliance guidelines and has also organized workshops and training courses on this issue since 2007.

Increasingly, airlines are requesting their business partners to do their best in regard to CSR. Airlines work closely with their suppliers to ensure that ethical standards and practices are implemented throughout the procurement and supply chain management processes. Cathay Pacific's suppliers were sent a Supplier Code of Conduct questionnaire in 2007 and 2008. No bribery case was reported in 2008. Furthermore, Cathay Pacific encourages its partners to make significant contributions related to their social and environmental performances in their respective fields.

4.4. Workplace

All of the selected airlines emphasize that safety and people are at the core of their organizational culture and they continually strive to provide a safe and harmonious work environment.

Cathay Pacific sets a variety of safety performance targets in the areas of operational safety, passenger safety, food safety, staff safety, and public health. The Company stresses the importance of employee engagement in the form of consultation with different members of its staff and ensures that adequate feedback mechanisms are available. At Cathay Pacific, the Cabin Crew Consultative Group, composed of a diverse range of cabin crew, helps identify and articulate issues such as: retirement age, absence management, hourly paid crew issues, and different aspects of their working environment. For example, a great deal of attention has been focused on galley services and equipment as well as handling baggage, which accounted for the majority of the cabin crew injuries in 2008.

Korean Air reported on Ethical Management at the very beginning of its Sustainability Report of 2009. The Company instituted the Korean Air Ethical Charter in 2000, which provides guidelines for their employees regarding ethical behavior when engaged in business activities. In addition, Korean Air entered into the UN Global Compact in 2007 to further upgrade the standards of its ethical management practices and to actively fulfill their corporate social responsibilities. In order to improve workplace relationships and employee morale, Korean Air has created an Employee Counseling Center to resolve complaints and receive suggestions from employees. The Company is also proud of its industry-leading level of wages and incentives which is effective in promoting financial stability and fostering a positive workplace environment. As an example, new employees with a Bachelor’s degree are paid at a rate of 310% of Korea’s legal minimum wage.

4.5. Community

The selected airlines recognize the impacts they may have on the communities within which they operate and they all report on these issues in their CSR reports and disseminated information. The majority of airlines report on their charity contributions to local and international organizations. Asian, for example, has been working with the Korean Committee for UNICEF (United Nations Children’s Fund) to conduct Change for Good collections on its international routes. In the spring of each year, the Company has held a bazaar, in which they sell food and goods donated by their employees and contribute the profit to help the underprivileged. Korean Air contributes to the well-being of local communities through global art and cultural sponsorships; for example, it sponsors multimedia guiding services in the Korean language with three of the world’s most famous museums.

Cathay Pacific engages in a variety of activities both in Hong Kong and the countries to which it flies. The “English on Air” educational program is designed to provide students with a chance to practice English with the multinational English-speaking pilots, cabin crew, and staff while visiting Cathay Pacific City. The Cathay Pacific Volunteers Team, set up in 2007, contributes significantly to various community activities in Hong Kong. Being an international airline, Cathay Pacific’s community investments also extend to communities outside of Hong Kong. For example, staff in Sri Lanka pool efforts for a community project at the Children’s Convalescent Home, which provides refuge for abandoned children. In Singapore, the Company is involved in various initiatives supporting Habitat for Humanity, a non-profit organization addressing poverty and housing needs.

The JAL Group started a “Wings of Love” program in 1988. With this program, students from children’s homes across Japan are invited for a three-day trip to Tokyo. Every January, two employees from the JAL Group are selected to run the “Wings of Love” program office and plan safe and practical activities for the children. In addition, JAL collaborates with the JAL Foundation by providing air tickets to participants in various programs. Interestingly, JAL gets closer to the community through sports, such as women’s basketball, men’s rugby, and cheer leaders. The women’s basketball team participates in the national tournament each year and holds training sessions for young students in different cities.

4.6. Environment

All of the selected airlines recognize the aviation industry's relatively small but growing contribution to the environment. The extent and quality of environmental reporting is however highly varied across the sector. SIA has been consistently publishing Environmental Reports over the past decade. Korean Air and Asiana each published a Sustainability Report in 2009, which devoted a large portion to environmental responsibility. JAL presents a link to "JAL and the Environment" on its website, outlining its efforts in regard to their environmental action program, conservation initiatives, and social action program. Other environmental issues of concern include: climate change, fleet modernization, air traffic management, aircraft maintenance, noise management, in-flight waste management, and initiatives on the ground. In addition, there is an increasing move towards the implementation of Environmental Management Systems (EMS) and in many cases certification to the international environmental management standard ISO 14001.

Cathay Pacific, for example, was among the 140 major companies signing the Poznan Communiqué on Climate Change and became a founding member of the Aviation Global Deal Group, which aims to contribute to the debate on including emissions from international aviation in a global climate change treaty. CO_2 accounts for the majority of the greenhouse gases which are believed to be the primary cause of global warming. Burning fuel is the major source of CO_2 emissions. In 2008, Cathay Pacific produced a total of 14.4 million tons of CO_2 emissions, for a total efficiency of 22.5% since 1998 and achieved an efficiency gain of 6% over 2005. The Company also continues its fleet modernization plan by introducing newer and more fuel-efficient aircraft, such as 777-300ERs, 747-400ERFs, and Airbus 330-300s, while phasing out older aircraft types. This will exert a positive impact on fuel efficiency through reduced fuel consumption and fleet maintenance costs. To increase air traffic efficiencies, Cathay Pacific uses two new shortened routes on their Hong Kong to Europe routes, resulting in a savings of between 0.6-0.9 tons of CO_2 per flight on these routes. Similar route-shortening approach has been adopted by JAL, Korean Air, and Asiana to select the optimal one-way routes. The expected reduction in CO_2 emissions is approximately 4,000-5,000 tons per year. Cathay Pacific also makes use of real time wind data to generate flexible flight tracks for dynamic flight planning. By flying these optimized routes, Cathay Pacific is able to reduce the amount of fuel burned and CO_2 emissions. In addition, Cathay Pacific is famous for its carbon offset program, *FLY greener*, which offers passengers the options of using cash or frequent flyer miles to pay for their offsets. In 2008, the program encouraged its passengers to offset 3,457 tons of CO_2. Cathay Pacific has set up an Environmental Affairs Department to ensure the implementation of its environmental commitments and the Company has been accredited with the ISO 14001 Environmental Management System. As for noise management, Cathay Pacific continues to invest in quieter aircraft such as the Boeing 747-8 freighter equipped with new GEnx engines, and follows noise-reducing operating procedures during take-off and landing. A Boeing 747-8, at take-off, will make these aircraft quieter than a Boeing 747-400.

JAL addresses a number of environmental issues in its CSR Report. In 2006, JAL established the Operations Division Team-6%, which communicates directly with all flight crew members to combat global warming. Some simple measures have been adopted by JAL's flight crew to reduce fuel use such as taxiing to the arrival gate on three rather than four engines and making the aircraft lighter by offloading unnecessary personal effects. Other measures include: introducing porcelain tableware, which is 20% lighter, for the meal service in First and Business classes, using new lightweight cargo containers, uploading less water on each flight, etc. In 2006, JAL's total CO_2 emissions were 15.8 million tons, down 6.5% from the previous year. Asian was the first airline to adopt the Continuous Decent Approach (CDA). CDA is a fuel-efficient landing procedure recommended by the International Civil Aviation Organization (ICAO). In this new landing format, the airplane descends like a glider compared to regular landing by which the airplane descends in stages. This reduces fuel consumption and noise pollution by approximately 40%.

5. CONCLUSION

The majority of the major Asian airlines demonstrate their commitment to CSR through different ways of reporting. The airlines provide a vast amount of information on their websites regarding their CSR activities. These reports identify priority areas of greatest concern to both the Company and society. Nevertheless, the content and extent of these reports exhibit marked variations.

Cathay Pacific, JAL, and ANA produce dedicated and detailed CSR reports on an annual basis. Korean Air and Asiana report on their social responsibility initiatives in a broader, comprehensive Sustainability Report. Some airlines have previously published standalone Environmental Reports, which are subsequently incorporated into either CSR or Sustainability Reports. Those who do not produce either a CSR or Sustainability Report devote a portion of their annual reports to CSR. In regard to CSR organizations, most of the airlines have not established full-time departments to manage their CSR activities. Instead, high-ranking committees serving different purposes have been set up to plan and promote CSR initiatives. The general themes of social responsibility reported in this study appear to cover issues in the marketplace, the workplace, the environment, and the community. While flight safety stands out as the most important social responsibility, Asian airlines are becoming more environmentally conscious and have invested heavily in this area.

Another issue facing the airlines is how to choose the right combination of CSR activities both at home and abroad. As Sethi pointed out " an evaluation of corporate social performance that ignores its cultural and socio-political environment is fraught with conceptual and methodological dangers."[24] It is advised that, as an international business, airlines should fine-tune their behavior to contextual characteristics such as the geographical, social, cultural, political and economic characteristics of the places where airlines operate [25].

It must be pointed out that simply having produced a CSR report does not imply that it is implemented. Conversely, companies may actually support and contribute significantly to social responsibility without producing a CSR report [8]. Furthermore, it is suggested that an industry-side framework for CSR reporting be developed to allow inter-airline comparisons to be made [11].

REFERENCES

[1] Robin, D. P. & Reidenbach, R. E. (1987). Social responsibility, ethics, and marketing strategy: closing the gap between concept and application. *Journal of Marketing*, *51*, 44-58.

[2] Miyoshi, C. & Mason, K. J. (2009). The carbon emissions of selected airlines and aircraft types in three geographic markets. *Journal of Air Transport Management*, *15*, 138-147.

[3] Antal, A. B. & Sobczak, A. (2007). Corporate social responsibility in France – a mix of national traditions and international influences. *Business & Society*, *46*, 9-32.

[4] Frankental, P. (2001). Corporate social responsibility – a PR invention? Corporate Communication: *An International Journal*, *6*, 18-23.

[5] Holmes, L. & Watts, R. (2000) Corporate Social Responsibility: *Making Good Business Sense*, Geneva: World Business Council for Sustainable Development.

[6] Smith, N. C. (2003). Corporate social responsibility: *whether or how? California Management Review*, *45*, 52-76.

[7] Carroll, A. B. (1991). The pyramid of corporate social responsibility: toward the moral management of stakeholder organization. *Business Horizon*, *34*, 39-48.

[8] Welford, H. (2005). Corporate social responsibility in Europe, North America and Asia. The *Journal of Corporate Citizenship*, *17*, 33-52.

[9] Jones, P., Comfort, D. & Hillier, D. (2006). Reporting and reflecting on corporate social responsibility in the hospitality industry – a case study of pub operators in the UK. *International Journal of Contemporary Hospitality Management*, *18*, 329-340.

[10] Jones, P., Comfort, D. & Hillier, D. (2005). Corporate social responsibility and the UK's top ten retailers. *International Journal of Retail & Distribution Management*, *33*, 882-892.

[11] All Nippon Airways company website, available at: http://www.ana.co.jp/asw/LocaleSelectServlet.

[12] Asiana Airlines company website, available at: http://us.flyasiana.com/Global/US/en/index.

[13] Cathay Pacific Airways company website, available at: http://www.cathaypacific.com/cpa/zh_TW/homepage?WAcampid=CX_TW_BCX_TC_GOO_JAN80&WAemail=SEARCH.

[14] China Airlines company website, available at: http://www.china-airlines.com/ch/index.htm.

[15] Eva Air company website, available at: http://www.evaair.com/html/b2c/chinese/.

[16] Garuda Indonesian Airways company website, available at: http://www.garuda-indonesia.com/.

[17] Japan Airlines company website, available at: http://www.jal.com/.

[18] Korean Air company website, available at: http://www.koreanair.com/.

[19] Malaysia Airlines company website, available at: http://www.malaysiaairlines.com/my/en/home.aspx.

[20] Philippine Airlines company website, available at: http://www.philippineairlines.com/home/home.jsp.

[21] Singapore Airlines company website, available at: http://www.singaporeair.com/saa/en_UK/index.jsp.

[22] Thai Airways company website, available at: http://www.thaiair.com/homepage/en/home.htm.

[23] Mark, B. & Chan, W. W. (2006). Environmental reporting of airlines in Asia Pacific region. *Journal of Sustainable Tourism*, *14*, 618-628.

[24] Sethi, S. P. (1975). Dimensions of corporate social performance: an analytical framework. *California Management Review*, *17*, 58-64.

[25] Vidal, N. G. & Kozak, R. A. (2008). Corporate responsibility practices in the forestry sector. *The Journal of Corporate Citizenship*, *31*, 59-75.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 187-192
ISBN: 978-1-61122-079-7

Chapter 8

SERVICE QUALITY AND INTERNAL DIFFERENCES AMONG MEMBERS OF THE AIRLINE ALLIANCES

***Jesús Manuel López-Bonilla*[*]**
and Luis Miguel López-Bonilla
University of Seville, Spain

ABSTRACT

The topic of global airline alliances has received much attention in the literature in recent years. The vast majority of these studies on strategic alliances are the focus upon issues relating to the organization. However, little attention to date has been paid to strategic airline alliances from the consumer perspective. This paper attempts to empirically investigate the internal differences among members of the global airline alliance from the quality of service perspective. The present study is based on a sample of the international airlines from the three major airline alliances. This research has analysed the internal differences among members of the global airline alliances from the quality of service perceived by the passengers. The alliance founding members have higher scores in the majority of service attributes than other full members. However, there are few significant differences.

Keywords – air transport, airline alliance, service quality, passengers.

INTRODUCTION

Within the airline industry the term 'strategic airline alliance' has been used to described everything from a simple route codesharing to the elaborate agreement (Rhoades and Lush, 1997). According to Doganis (2006), the most significant alliances in terms of network

---

[*] Corresponding author: E-mail: lopezbon@us.es

expansion are clearly those with a global scope. Here the prime purpose is to achieve all the marketing benefits of scope and the scale economies from any synergies, through linking the networks of two or more large airlines operating in geographically distinct market, ideally in different continents. Global alliances normally involve code-sharing on a very large number of routes, but ideally they aim to go much further. They may include schedule co-ordination, joint sales offices and ground handling, combined frequent-flyer programmes (FFP), joint maintenance activities and so on.

Airline alliances are not merely a function of synergies and economies. Hence, one of the reasons for the existence of global airline alliances is global geopolitics, in particular the persistence of regulated international markets and protectionism embodied in bilateral agreements, means that no one carrier could launch a global network while consolidation is precluded by limitations on foreign ownership of airlines.

A global alliance is also denominated by Gudmundsson et al. (2002) as branded alliance or multilateral alliance, as opposed to bilateral alliance. As Gudmundsson and Lechner (2006) indicate, multilateral alliances are multilateral dyads that have some form of authority. Being part of a multilateral alliance allows airlines to access resources otherwise not attainable. Such alliances are horizontal and therefore coopetition relationships where airlines are competing on some aspects and cooperating on other. At the theoretical level, there are both benefits and costs associated with alliances (Oum et al., 2001). But potential alliance benefits are likely to be greater than potential costs (Oum et al., 2004). Moreover, multilateral global alliances are usually associated with the most prominent factor for a lasting alliance that embraces, in order of their relative importance: joint marketing, flight scheduling, joint FFP, sharing airport facilities, and ground support (Li, 2000). As Fan et al. (2001) note, two definitive characteristics of strategic alliances, to date, are exclusive memberships and a joint marketing entity. In other words, a formal member of one strategic alliance cannot simultaneous be a formal member of another strategic alliance, while all carriers can at any time engage in tactical cooperative agreements with multiple airline in the same or different alliance.

The topic of global airline alliances has received much attention in the literature in recent years. As Kalligiannis, Iatrou and Mason (2006) have described, much research has been carried out to evaluate the impact of strategic alliance membership on the performance of airlines. The vast majority of these studies on strategic alliances are the focus upon issues relating to the organization. However, little attention to date has been paid to strategic airline alliances from the consumer perspective. As Weber (2002) affirms, the consumer perceptions and attitudes have generally been ignored in research on airline alliances in view of pivotal role of the consumer in airline service settings, a surprising neglect. This paper attempts to empirically investigate the internal differences among members of the global airline alliance from the quality of service perspective.

HYPOTHESES

Following Doganis (2006), there are three phases in building alliances. As one moves through them, alliance partners' operations become more integrated and the alliance more durable. The first phase is orientated primarily towards generating extra revenue through network expansion and joint marketing. The second phase is also commercial but the focus is more on cost saving, while continuing and reinforcing cooperation of the Phase 1 revenue aspects. Implementation of the first two phases does not necessarily cement an alliance. Break-up and separation is still possible, though increasingly difficult the longer the alliance has been in existence, especially if co-operation in most of the cost-cutting areas has been implemented. The third phase in cementing an alliance is when partners begin to co-mingle their assets and use them jointly. This will involve joint product development and the creation of joint companies to manage different aspects of their operations. It is during this phase that alliance partners will move from having separate brand identities to emphasising and even adopting a single alliance brand.

To move successfully from Phase 1 to Phase 3 and cement an alliance, all airlines need to manage their partnership carefully (Doganis, 2006). This author indicates that, among the goals to be achieved by an alliance, are high customer-orientated service standards being maintained by all partners. But it is difficult to achieve this objective because each airline joining an alliance initially differs significantly from other members in terms of corporate objectives and operations, as well as its management and socio-cultural behaviour. However, founding members may offer higher service standards than other alliance members due to their alliance probably being more grounded on terms of objectives and strategies. Therefore, we expect that founding members differ significantly from subsequent alliance members. The theoretical arguments are hypothesized as follows.

Hypothesis H1: Founding members will exhibit higher service quality levels than subsequent Star Alliance members

Hypothesis H2: Founding members will exhibit higher service quality levels than subsequent Oneworld members

Hypothesis H3: Founding members will exhibit higher service quality levels than subsequent SkyTeam members

RESULTS

The present study is based on a secondary source. Data was obtained from the Euroconsumers group, bringing together consumer associations in Belgium, Italy, Portugal and Spain. Our data were obtained from a survey on air passengers in 2005. This survey was carried out from September to November was made with 8,638 European passengers who travelled by air at least one journey by plane within the previous 14 months. Respondents were asked to indicate how they rated the quality of the service attributes.

We used a sample of 17 international airlines. These airlines are currently –and in 2005- members of one global alliance:

- Founding members of Star Alliance: Lufthansa, Scandinavian Airlines System, Thai Airways International
- Subsequent members of Star Alliance: Singapore Airlines, Spanair, TAP Portugal
- Founding members of Oneworld: American Airlines, British Airways, Qantas Airways

- Subsequent members of Oneworld: Iberia, LAN Chile
- Founding members of SkyTeam: Aeroméxico, Air France
- Subsequent members of SkyTeam: Alitalia, Continental Airlines CSA Czech Airlines, KLM Royal Dutch Airlines

We have analyzed the service attributes provided to customers by carriers and groups of airlines. The following ten attributes were used to evaluate the services provided to customers. Four attributes were ground services (check-in service, courtesy of employees, interest in solving problems, and information service by the airline at the airport). Six attributes were on-board services (courtesy of employees, seat space and legroom, comfort, food service aboard, in-flight entertainment services, and cleanliness). The statements are measured on a five-point semantic differential-type scale ranging from very bad (1) to very good (5).

The attributes of the alliance founding members (named Oneworld1, SkyTeam1 and Star Alliance1) are compared to the attributes from other full members of the same alliance (named Oneworld2, SkyTeam2 and Star Alliance2). All the items of Oneworld1 are better than Oneworld2's. The SkyTeam1 scores are similar to the SkyTeam2 scores, although the founding member scores are higher in most attributes, except courtesy in ground services. Star Alliance1 scores higher than Star Alliance2 on most attributes, with a few exceptions (courtesy on-board services). Founding members obtain higher scores than other full members, except courtesy on-board services.

To investigate the differences of passengers' perceptions, independent samples *t*-tests are applied to the data collected from global airline alliances. As shown in Table 1, Oneworld founding members exhibit higher satisfaction levels than other full members of Oneworld. Three factors are found to be significantly different when the relationship between Oneworld1 and Oneworld2 is examined: information and seat space. Hence, it was found that the hypothesis H1 was partially supported. Oneworld1 airline passengers perceive these two factors as significantly higher compared to Oneworld2 passengers. Hypotheses H2 and H3 are not confirmed. Hence, there are not significant differences between founding members and other full members in SkyTeam and Star Alliance.

CONCLUSION

In this paper, we have investigated the strategic differences of three major airline alliances in the world. The analysis is based on the comparison between the airlines of the same alliance, distinguishing founding members versus subsequent alliance members. The alliance founding members have higher scores in the majority of service attributes than other full members. However, there are only significant differences in the case of Oneworld. Hence, the passengers of the Oneworld founding airlines perceive information and seat space as significantly better than other Oneworld passengers. As Weber and Sparks (2004) indicate, negative perceptions of one member airline may have negative implications for the entire alliance. This is why the airline executives must bring the positions between the Oneworld members nearer and attain a more standardized orientated-consumer service.

Table 1. The differences of passenger perceptions within each airline alliance

Attributes	Oneworld1-Oneworld2	SkyTeam1-SkyTeam2	Star Alliance1-Star Alliance2
Ground Services			
Check-in	0.25	0.00	0.00
Courtesy	0.50	-0.13	0.50
Solving problems	1.17	0.13	0.17
Information	0.92*	0.13	0.33
On-board services			
Courtesy	0.33	0.00	-0.17
Seat space	0.67*	0.13	0.33
Comfort	0.75	0.00	0.17
Food	0.50	0.00	0.67
Entertainment	0.25	0.13	0.42
Cleanliness	0.50	0.13	0.25

*Significance level <0.05

REFERENCES

Doganis, R. (2006). *The Airline Business*. New York: Routledge.

Fan, T., Vigeant-Langlois, L., Geissler, C., Bosler, B. & Wilmking, J. (2001). Evolution of global airline strategic alliance and consolidation in the twenty-first century. *Journal of Air Transport Management*, *Vol. 7*, 349-360.

Gudmundsson, S. V. & Lechner, C. (2006). Multilateral airline alliances: balancing strategic constraints and opportunities. *Journal of Air Transport Management*, *Vol. 12*, 153-158.

Gudmundsson, S. V., de Boer, E. R. & Lechner, C. (2002). Integrating frequent flyer programs in multilateral airline alliances. *Journal of Air Transport Management*, *Vol. 8*, 409-417.

Kalligiannis, K., Iatrou, K. & Mason, K. (2006). How do airlines perceive that strategic alliances affect their individual branding? *Journal of Air Transportation*, *Vol. 11*, 3-21.

Li, M. Z. F. (2000). Distinct features of lasting and non-lasting airline alliances. *Journal of Air Transport Management*, *Vol. 6*, 65-73.

Oum, T. H., Park, J. H., Kim, K. & Yu, C. (2004). The effect of horizontal alliances on firm productivity and profitability: evidence from the global airline industry. *Journal of Air Transport Management*, *Vol. 57*, 844-853.

Oum, T. H., Yu, C. & Zhang, A. (2001). Global airline alliances: international regulatory issues. *Journal of Air Transport Management*, *Vol. 7*, 57-62.

Rhoades, D. L. & Lush, H. (1997). A typology strategic alliances in the airline industry: propositions for stability and duration. *Journal of Air Transport Management*, *Vol. 3*, 109-114.

Weber, K. & Sparks, B. (2004). Consumer attributions and behavioural responses to service failures in strategic airline alliance settings. *Journal of Air Transport Management*, *Vol. 10*, 361-367.

Weber, K. (2002). Consumer perceptions and behavior: neglected dimensions in research on strategic airline alliances. *Journal of Travel & Tourism Marketing*, *Vol. 13*, 27-45.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 193-212
ISBN: 978-1-61122-079-7

Chapter 9

DAYS ON AND DAYS OFF SCHEDULING OF PILOTS UNDER A VARIABLE WORKLOAD

***Broos Maenhout*[1]*and Mario Vanhoucke*[1,2]**

[1]Faculty of Economics and Business Administration,
Ghent University, Tweekerkenstraat 2,
9000 Gent, Belgium
[2]Operations and Technology Management Centre,
Vlerick Leuven Gent Management School,
Reep 1, 9000 Gent, Belgium

Abstract

Personnel costs typically are the second largest costs for airline operations after fuel costs. Since efficient crew employment can drastically reduce operational costs of airline companies, the crew scheduling problem in the airline industry has been extensively investigated in the operations research literature. This problem typically consists of assigning duties to crew members securing the safety of all flights minimizing the corresponding overall cost for personnel. Due to the typical size and complexity of the crew rostering problem, airline companies want to adopt scheduling policies that roster crew members according to fixed days on and days off patterns. However, as the distribution of work duties over the planning horizon is typically highly variable in airline operations, the scheduling according to these fixed work patterns is seriously hindered. In this chapter, we give an overview of different measures that help to schedule airline crew under a variable workload using fixed days on and days off patterns.

1. Introduction

Although the air traffic increased with an annual rate of 5.4% between 1985 and 2008, the profitability of airline companies still remains an arduous task. This is caused by the high

---

[*] Email address: Broos.Maenhout@Ugent.be
[†] Email address: Mario.Vanhoucke@Ugent.be

fixed costs of airlines companies, the low profit margins in the sector and the increasing fuel costs. These issues force the airline companies to optimize their operational policies in order to minimize cost. In order to deliver service, the primal resources for airline companies are airplanes, personnel, ground infrastructure and fuel. Personnel costs are typically the second largest costs after fuel costs confiscating about 30% of the operational costs. Consequently, it is important to optimally design the workforce management process by selecting the right personnel scheduling policies and to operationalize these policies to an optimal (best) outcome.

Personnel scheduling is the process of constructing duty timetables for staff in order to meet the product or service demand. Ernst et al. (2004) decompose personnel scheduling into 6 different planning modules i.e.

Module 1. The *demand modelling* step involves the identification of the required duties to deliver service.

Module 2. *Days off scheduling* deals with the determination of how rest days are to be combined with working days.

Module 3. *Shift scheduling* or *duty generation* deals with the problem of selecting what duties are to be worked, together with an assignment of the number of employees to each duty, in order to meet demand.

Module 4. *Line of work construction* refers to the creation of duty timetables for each staff member over the rostering horizon. In this step, feasibility rules for the lines of work are under consideration. Additionally, the lines of work should be constructed in such a way that the work requirements are satisfied at all times in the rostering horizon.

Module 5. The *task assignment* step involves the allocation of one or more tasks to particular lines of work associated with specific staff skills or levels of seniority.

Module 6. *Staff assignment* involves the assignment of individual staff to the constructed lines of work.

Depending on the nature of the application, personnel schedulers have to solve one or more of these modules whether or not in an integrated way. Not all modules are required to be carried out to construct a roster for all kinds of applications. This is also valid for the airline crew scheduling problem that is typically decomposed into different scheduling problems that have to be solved sequentially (Gopalakrishnan and Johnson, 2005). Figure 1 displays the relationship between the general personnel scheduling framework and the airline crew scheduling problem. In the following, we discuss the specificities of airline crew scheduling in the perspective of this personnel scheduling framework.

In airline scheduling, demand modelling is a complex step, which encompasses two optimisation problems. First, the *flight scheduling problem* is solved. This is the most important step in modelling the demand as this problem determines the flight legs to be operated by the airline company and the start and end times of these duties. Secondly, aircrafts are assigned to the flight legs as a result of solving the fleet assignment and routing

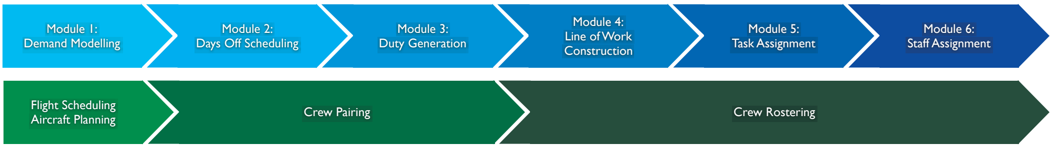


Figure 1. Modular analysis of the airline crew scheduling problem.

problem. Important determinants in this process are the capacity, the flight range, the direct costs and maintenance requirements of each aircraft. This *aircraft planning problem* further models the demand as the pilot qualifications to fly a particular flight leg is highly dependent of the selected aircraft type.

As tasks are associated with location dependencies, individual flight legs are combined into task sequences that allow staff to return to their home base and, hence, could be carried out by one aircraft and corresponding crew composition. In airline crew scheduling, this step is referred to as *crew pairing optimisation* and the duties are roundtrips or pairings. This optimisation problem encompasses the days off scheduling and duty generation module. The main task is to select a good set of feasible duties to cover all tasks and to aggregate the large set of tasks into larger duties in order to make the problem tractable. In later stages of the airline crew scheduling problem these pieces of work are treated as indivisible units that are to be performed by the same person.

When the crew pairing problem is worked out, a duty timetable should be constructed for each crew member of a given workforce by solving the *crew rostering problem*. In this problem, the constructed set of pairings as well as other activities, i.e. pre-assigned activities (e.g. vacation, training) and reserve duties, are assigned to individual crew members and sequenced to individual crew rosters considering all governmental rules, union- and company agreements. These rules secure the safety of all flights and guarantee the social quality of the individual crew rosters. The planning horizon is usually 2 to 6 weeks. Depending on the application and company policy, the crew rostering problem encompasses modules 4, 5 and/or 6. The two most common approaches are the ’bidlines approach’ and the ’personalised approach’. When using bidding systems, anonymous lines of work are generated (module 4). These individual duty timetables are then assigned to specific crew members after a bidding process (module 5 and 6). The ’personalized rostering approach’ directly constructs individual rosters for each crew member (module 4, 5 and 6). This approach is based on a fair-and-equal share principle with respect to workload. Moreover, crew members can express their preference for certain attributes of their rosters without knowing exactly how their rosters will look like. The crew pairing and crew rostering process together are referred to as the crew scheduling problem. For an overview of the crew rostering problem we refer to Kohl and Karisch (2004).

In this chapter, the research focus is on the crew rostering problem and more specifically on the line of work construction. Due to the typical size, the large set of constraints and multiple objectives, airline companies want to adopt scheduling policies that reduce the scheduling complexity and improve the transparency of the crew rosters. One of these policies is to employ cyclic schedules that use stints as basic building blocks during the line of work construction. Stints are fixed work patterns with a predefined sequence of working days (days on) and rest days (days off) reflecting the company's workplace rules and regulations. In a cyclic roster all employees of the same class perform exactly the same line of work, but with different starting times for the first working day. This roster type is most applicable for situations with repeating demand patterns. However, the distribution of the number of work duties per day over the planning horizon is typically highly variable over time in airline operations. This seriously hinders the application of pure cyclic personnel scheduling in airline operations. In this chapter, we analyze the impact of different fixed work patterns on different objectives, i.e. roster feasibility, cost, personnel productivity and fairness between personnel members. Moreover, starting from a pure cyclic personnel schedule, we give an overview of different measures that improve the different objectives. The computational analysis is based on a real-life situation of a midsize European airline company.

The outline of this chapter is given along the following lines. In section 2., we describe all components of the airline crew scheduling in detail. In section 3., we introduce different rostering procedures and explain how to insert flexibility into consistent schedules. Section 4. gives some conclusions and directions for future research.

2. Basic Characteristics of the Airline Crew Rostering Problem

In the crew rostering problem, different sets of activities are assigned to a given workforce and duty timetables for crew members are constructed in line with a large set of rules and regulations. All the pairings need to be assigned to as many crews as required and each crew member receives a roster. The crew rostering process generally tries to minimise the operational cost for the airline company and to maximise the social quality as perceived by the crew members. Figure 2 is a schematic representation of the rostering organization and displays the different input information sources required to compose a crew roster. In the following we examine these different elements more closely.

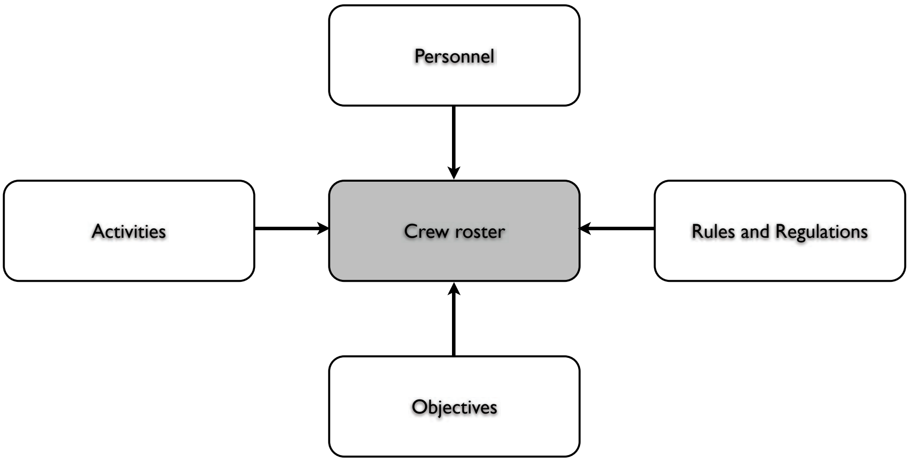


Figure 2. Input components required to compose a crew roster.

Crew information When producing personalized rosters, each crew member's personal records (e.g. hours flown, trainings), qualifications (e.g. seniority, list of destinations, language proficiency, skill competency), pre-assigned activities (e.g. training, medical checks) and vacation days are known. The airline crew rostering problem is typically decomposed per function type since there is no substitutability possible between cabin and service personnel. In our study, we focus to schedule a set of 120 to 135 anonymous pilots for the AVRO RJ-85, AVRO RJ-100 and the BAE-146 types of aircrafts. We assume that all pilots are able to operate as captains and that they have the same qualifications to fly the different types of aircraft to the different destinations. As the crew members are anonymous, no schedule preferences are taken into account in this stage.

Activity information The set of activities consists of pairings, reserve duties and pre-assigned activities. This set covers the service requirements and is assumed to be given, i.e. the crew pairing problem has been solved.

Each activity has a specific start time and duration. Pairings are additionally described by the time spent away from the base (TAFB), flight time (FT) and duty time (DT). Figure 3 illustrates these pairing characteristics for a specific pairing travelling from Brussels (Belgium) to Sevilla (Spain) and back.

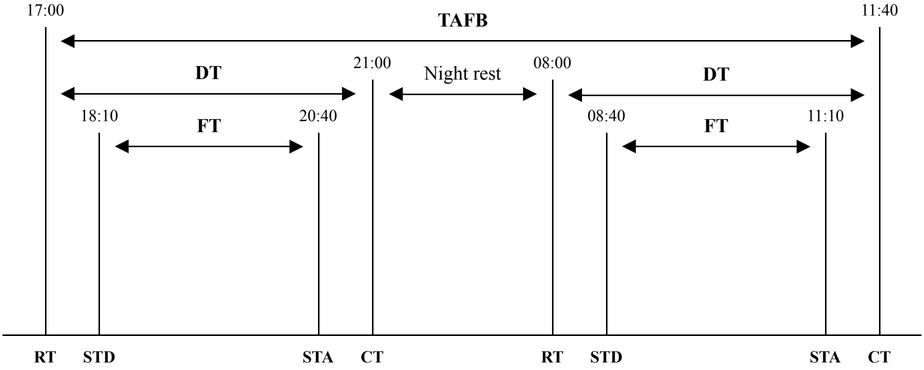


Figure 3. Pairing characteristics illustrated on the flight pairing Brussels (Belgium) to Sevilla (Spain).

The time windows between the reporting time (RT) and the standard departure (STD) and the arrival time (STA) and the closing time (CT) are strictly regulated and defined in the crew pairing step. Pairings are also described by the aircraft type, the required visa type and required language competency. Based on the required qualifications, the compatibility of a crew member with a specific activity can be determined in advance.

Further, an activity is defined as a morning activity, a day activity, a night activity or a night stop activity which includes a night rest in a hotel (e.g. pairing Brussels (Belgium) to Sevilla (Spain) cfr. figure 3). Pairings and reserve duties are characterized by a required number of crew members performing the task. Pre-assigned activities are characterized by the specific crew member required to perform the duty.

In our computational experiments, we utilised problem instances with, on the average, 150 flights legs per day. For the month May 2008, for example, these flight legs are automatically converted into 1312 assignable pairings. Additionally there are 62 reserve duties and 45 pre-assigned activities to schedule. A close examination of these duties revealed a highly variable workload over the planning horizon for all problem instances. Figure 4 displays the duty workload pattern of the problem instance for May 2008. There are many peaks and valleys in the pattern.

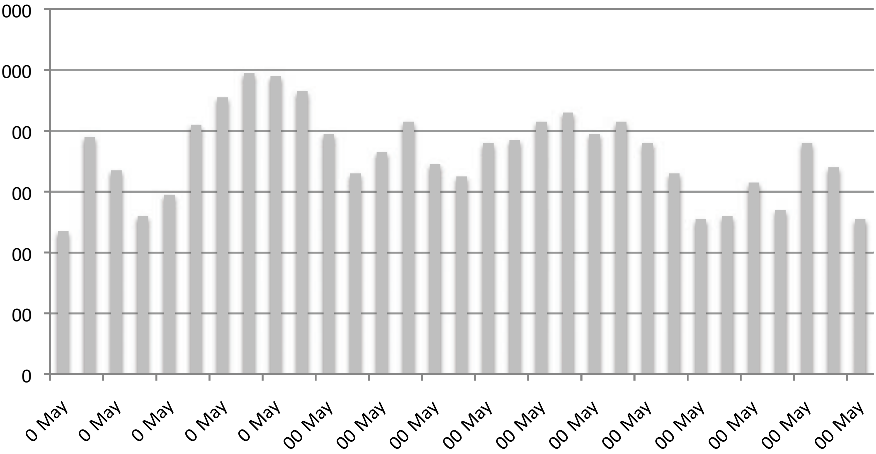


Figure 4. Duty workload pattern for the month May 2008.

Rules and regulations The rules and regulations monitoring the quality of a schedule in airline crew scheduling can basically be divided in vertical and horizontal rules (Gamache et al., 1999; Maenhout and Vanhoucke, 2010; Kohl and Karisch, 2004).

The horizontal rules govern the quality of a single crew members roster line. These rules are concerned with the attributes of the involved crew member and with the properties of the assigned activities. In the following some important types of rules are discussed, i.e.

- The collective agreements affect which pairings and rest periods (breaks) can be assigned to each employee. Crew members can only be assigned to pairings and reserve duties compatible with the crew's qualifications and pre-assigned activities.

- There are many rules governing the sequencing of activities and rest periods, e.g. the minimum rest time between successive activities, at most one activity per day and the number of consecutive working days.

- All airline companies are confronted with many regulations restricting the amount of activities and rest days to be assigned to a single crew member. Often, weekly and/or monthly constraints are imposed concerning e.g. the number of night stops, the number of rest days, the total duty time per month/year, the (required) allowed (minimum) maximum flight time per month/year.

The vertical rules concern the constitution of several roster lines and crew members. These rules stipulate the crew composition assigned to an activity. Each activity must be staffed correctly by the correct number of cabin and service personnel. The composition of the crew must further comply with certain requirements concerning e.g. the experience of the crew members and crew members who must or cannot fly together (Gamache et al., 1999).

In the computational experiment we take all the rules into account that are written down in the operations manual guide of the involved airline company. These rules have been recently adapted following the regulations of the European Union ’EU-OPS 1’ concerning the flight and duty time limitations and rest schedule for crew members. The staffing requirements stipulate that pairings require exactly one pilot, six pilots should be assigned to reserve duties and pre-assigned activities should be carried out by a specific crew member.

For transparency reasons and easiness of use, the airline company tries to organise the crew rostering process cyclically. Cyclical rosters imply that each crew member works a cyclic schedule of *n* days, which is repeated over time. In a (pure) cyclic roster all employees of the same class perform exactly the same line of work, but with a different start time for the first working day. Sometimes a complete cyclic roster, for all staff, is not feasible, but it may be possible to have cyclic rosters within subgroups of the workforce or over subperiods of the rostering horizon. According to Warner (1976), cyclical schedules offer several advantages, i.e. personnel know their schedules a long time in advance, the same blocks are used repeatedly, schedules are consistent over different planning periods and over different personnel members, the work is divided evenly and unhealthy work rotations are avoided. However, this approach has some serious drawbacks for practical applications. Cyclical schedules do not provide high levels of flexibility, i.e. they cannot easily address flexible work regulations, fluctuating personnel demands and personal preferences.

The current standard applied cyclical pattern is working 5 consecutive days on followed by 2 consecutive rest or idle days (which is further denoted as a (5,2) pattern). A complete day is called idle if no duty or part of a duty is executed during that day, otherwise the day is called working (Caprara et al., 1998). Figure 5 displays a pattern of 5 days on and 2 days off. The working days are filled in by pairings, reserve duties and pre-assigned activities. Pairings are designated by ”P” and their pairing number, reserve duties by ”R”, pre-assigned activities by ”PA” and a day off by ”DO”. The pilot is assigned to pairing 477, pairing 139, pairing 62 and reserve duty 19. After 5 days of work, the pilot has two days off.

P477	P477	P139	P62	R19	DO	DO

Figure 5. Example work pattern with assigned activities.

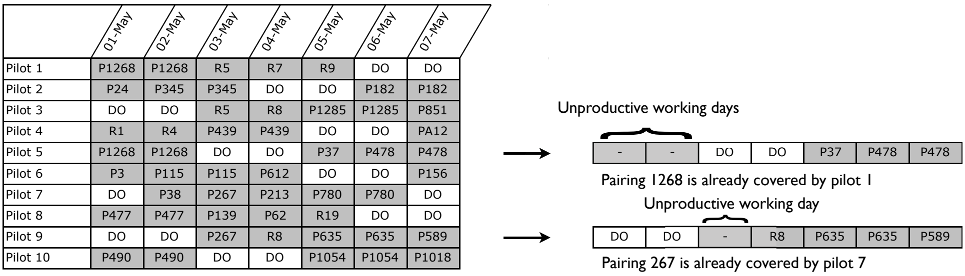
Pilots are assigned to the required activities corresponding to this standard work pattern. In practice, however, there are a lot of violations against these patterns due to the required flexibility when scheduling pilots for a specific month in real-life applications.

Objectives Airline companies usually set different kind of objectives, i.e.

- **Schedule feasibility.** As a first objective, airline companies want to obtain a feasible roster. To that purpose we consider the horizontal rules as hard constraints. Satisfying these rules guarantees the quality of the line of work for each crew member. Further, we aim at the minimization of the so-called open time or sum of the time length of the unassigned activities. The objective maximizes the total duration of activities that is covered by the crew members. When not all activities can be staffed properly, the understaffed activities are assigned to freelancers or are cancelled. This implies that the vertical rules are treated as soft constraints. These constraints can be violated but then a penalty cost is accounted.
- **Cost minimisation.** In the highly competitive airline industry, it is imperative to manage the operations at minimum cost. Consequently, airline companies want to limit the budgeted number of pilots. In our computational study, we varied the number of crew to see the effect of cost minimisation on the other objectives. When crew members are scheduled to work overtime, additional costs are accounted following a stepwise increasing function. For the number of overtime hours pilots above the postulated 60 hours of flight time per month, an extra per hour is remunerated of 1.7 times the hourly wage rate. For the overtime hours a pilot works above 75 hours of flight time, the pilot is rewarded with twice his normal hourly base wage.
- **Pilot satisfaction.** The pilot job satisfaction is composed out of two components. On the one hand, the crew members express their preferences for certain roster attributes, i.e. certain activities and/or the moment (day/time) they want to be scheduled. As the computational experiments are carried out by anonymous crew members having no crew preferences, we do not measure the personnel preference satisfaction. On the other hand, the solution needs to ensure impartiality and fairness to all regular crew members. When working with a cyclical roster, the rosters should be fair per definition. However, as there is only a fair distribution with respect to the number of days on and days off, the airline company defined a number of measures to maintain fairness between crew members, i.e.
    - the flight time (FT)
    - the duty time (DT)
    - the number of night stops (NS)
    - the time spent away from the base (TAFB)

  To implement the equal assignment criteria, the deviations from the average or standard values of the involved resource consumption constraints are penalized.

As it is important in this study to find a match between the daily workload and the fixed work patterns of a cyclical roster approach, we add another objective next to these usual objectives, i.e. we want to minimise the so-called unproductive working days. Unproductive working days are identified as working days on which crew members are assigned to activities that are already covered by other crew members. When using these fixed work patterns, it is not unimaginable that in some cases crew members are obliged to work activities that are already satisfactorily covered by (an-)other crew member(s). In practice, pilots will never be actually assigned to these activities and, hence, the assigned working day is denoted as unproductive, which is a deviation from the postulated fixed work patterns. Figure 6 displays a crew roster for several crew members. The crew members work according to a pattern of 5 days on and 2 days off. The unproductive working days are indicated by ”-”. In the example crew roster pilot 5 and 9 are confronted with an unproductive working day.



	01-May	02-May	03-May	04-May	05-May	06-May	07-May
Pilot 1	P1268	P1268	R5	R7	R9	DO	DO
Pilot 2	P24	P345	P345	DO	DO	P182	P182
Pilot 3	DO	DO	R5	R8	P1285	P1285	P851
Pilot 4	R1	R4	P439	P439	DO	DO	PA12
Pilot 5	P1268	P1268	DO	DO	P37	P478	P478
Pilot 6	P3	P115	P115	P612	DO	DO	P156
Pilot 7	DO	P38	P267	P213	P780	P780	DO
Pilot 8	P477	P477	P139	P62	R19	DO	DO
Pilot 9	DO	DO	P267	R8	P635	P635	P589
Pilot 10	P490	P490	DO	DO	P1054	P1054	P1018

Unproductive working days

-	-	DO	DO	P37	P478	P478

Pairing 1268 is already covered by pilot 1

Unproductive working day

DO	DO	-	R8	P635	P635	P589

Pairing 267 is already covered by pilot 7

Figure 6. Example crew roster with unproductive working days.

Consequently, in se, there are two objectives that measure the match between the work patterns and the workload, i.e.

- the number of unassigned activities
- the number of unproductive working days

In the following section, we analyse especially the impact of different measures on these objectives in order to find a good match between the workload and the fixed work patterns in a cyclical rostering approach.

3. Bridging the gap between schedule consistency and flexibility

In this section, we propose different measures that make it possible to construct a cyclical schedule when the workload is highly variable from day to day. The mismatch between supply and demand can be eliminated when developing cyclical schedules that partly incorporate the flexibility of ad hoc rostering. The new constructed roster is in first instance a cyclical schedule that is consistent over different planning periods. Introducing higher flexibility in the scheduling organisation helps to lower the required number of pilots to obtain a feasible schedule when the workload is highly variable. The procedure that is utilised to gain these insights is described in Maenhout and Vanhoucke (2008). Figure 7 gives an overview of this section.

The starting point of the computational study described in this chapter are the results and insights of Maenhout and Vanhoucke (2008). In their study, the authors tested the impact of different fixed work patterns on costs and personnel productivity in order to improve the

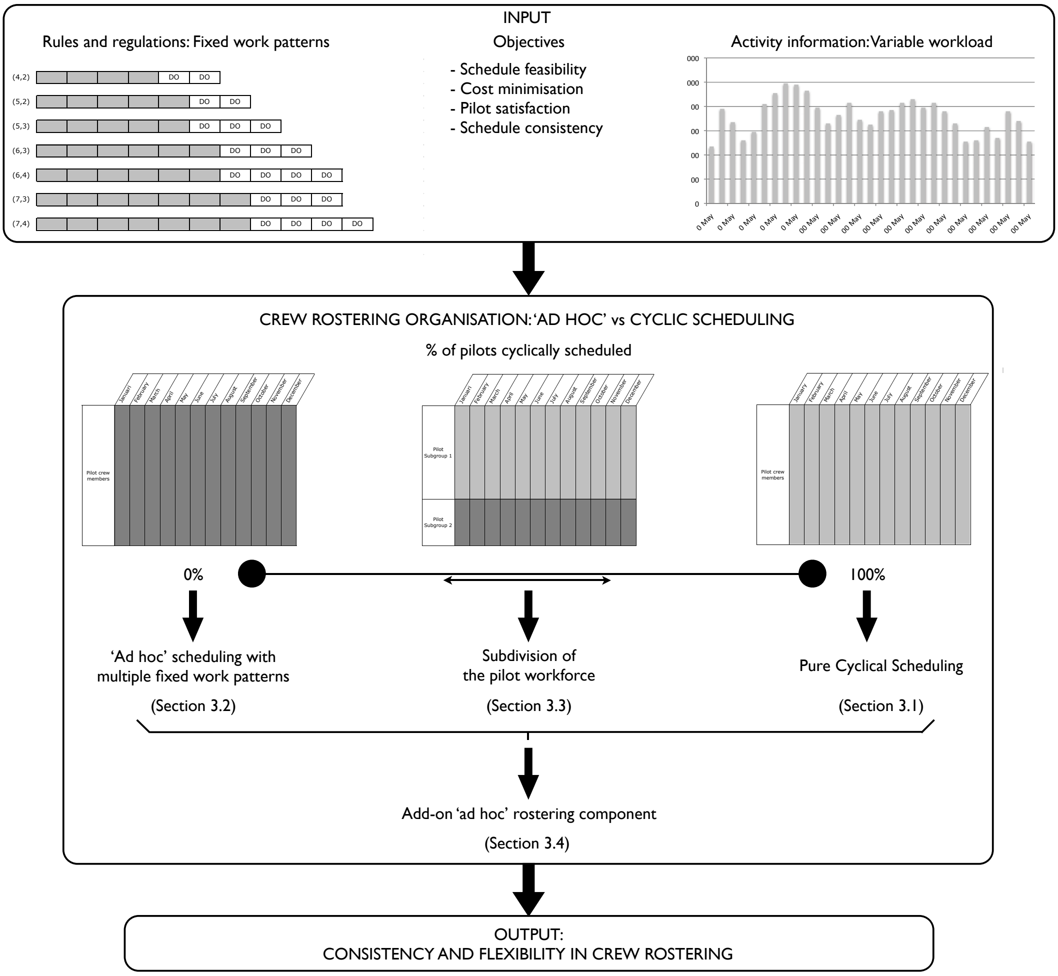
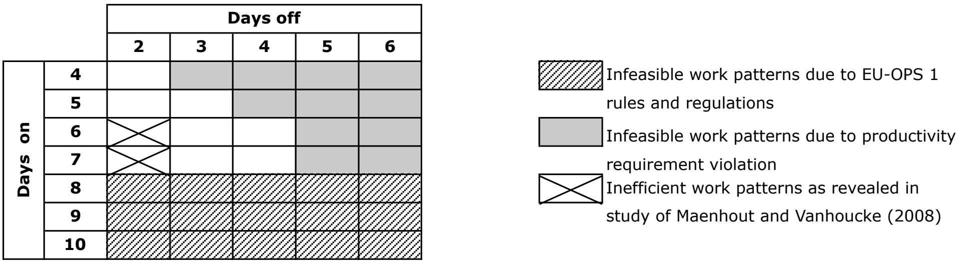


Figure 7. Overview of the steps to incorporate demand variability in a cyclical schedule.

pilot working conditions and the company's competivity. Figure 8 defines a grid that reflects the current work patterns considered by the airline company with all possible combinations of days on and days off. The horizontal dimension indicates the different possible values for consecutive days off. The vertical dimension provides the different values for consecutive pilot working days. We varied the consecutive working days from four to seven followed by a rest period from two to six days. Hence, the pilots are obliged to work in a cyclical pattern of for example six consecutive working days followed by five consecutive free days.

However, not all combinations of days on and days off are feasible. A number of the combinations of days on and days off are ruled out because they do not comply with the regulations of the European Union 'EU-OPS 1' concerning the flight and duty time limitations and rest schedule for crew members (e.g. combinations with more than 7 consecutive working days are not explored).

Further, based on the simulation study, another number of combinations dropped out since they do not fulfill the productivity requirement that is postulated by the involved



		Days off				
		2	3	4	5	6
Days on	4		▒	▒	▒	▒
	5			▒	▒	▒
	6	☒			▒	▒
	7	☒			▒	▒
	8	▨	▨	▨	▨	▨
	9	▨	▨	▨	▨	▨
	10	▨	▨	▨	▨	▨

▨ Infeasible work patterns due to EU-OPS 1 rules and regulations

▒ Infeasible work patterns due to productivity requirement violation

☒ Inefficient work patterns as revealed in study of Maenhout and Vanhoucke (2008)

Figure 8. Days on and days off combinations under consideration.

airline company. The company stipulates that the work pattern should allow more than 650 flight hours per year for pilots. Only the work patterns leading to 18 or more working days per 30 days fulfil the productivity requirement.

Last, Maenhout and Vanhoucke (2008) analysed the different work patterns in terms of costs. Their results lead to the following insight and trade-off: the lower the number of working days in the work pattern, the higher the cost to hire freelance personnel and the higher the number of working days, the higher the overtime cost. The study identified a number of interesting cost-efficient work patterns i.e., (6,4), (7,4), (5,3), (4,2), (6,3), (7,3), and (5,2). All these work patterns have a number of days on within the range of 18 to 22 days per 30-day period.

3.1. Pure Cyclical Scheduling

In this section we consider different approaches to organise the scheduling process pure cyclically.

Pure cyclical scheduling in the assumption of an equal demand

In a first approach we construct a pure cyclical roster where all pilots perform exactly the same line of work, based on one of the 7 selected work pattern of figure 8. The individual lines of work can have different starting times for the first shift of duty and, hence, are shifted in time in order to meet the staffing requirements. The shifting period in time is one day. Figure 9 indicates that there are 7 possible lines of work when pilots are scheduled following a (5,2) pattern. In the assumption of an equal workload over the time horizon, there is an equal proportion of pilots that start the work pattern on day 1, on day 2, on day 3, etc. In this case all cyclic schedules are present in the cyclic roster with a degree of 14.28% ($= \frac{1}{7}$).

Figure 9 indicates an equal distribution of manpower supply over the planning horizon when all cyclic schedules of a particular work pattern appear in the same degree in a cyclic roster. This implies that under a variable demand and a proper workforce size (leading to an average supply in the middle), there are several understaffed activities during demand peaks and several unproductive working days during demand valleys. Depending on the ratio of days on versus days off in the applied work pattern, the manpower supply will be higher or lower. In figure 9 we have each day 5 working days scheduled over the 7 cyclic

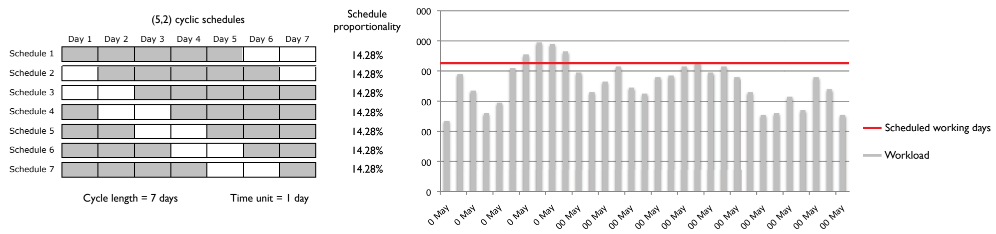


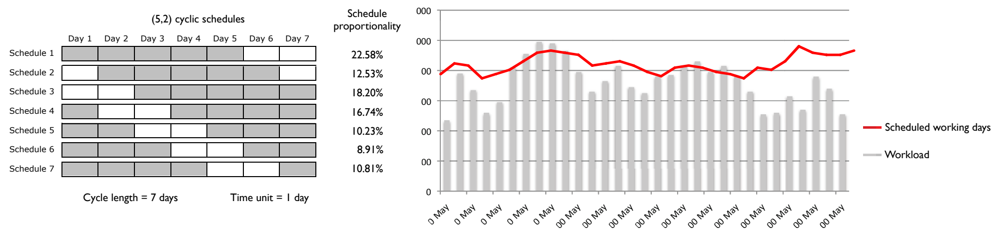
Figure 9. Proportional cyclic scheduling using the (5,2) work pattern.

schedules. Hence, with a workforce size of 120 pilots we have 85.71 ($= \frac{5}{7} \times 120$) working days scheduled per day. Similar calculations for a (6,3) work pattern lead to 80 working days scheduled per day for a workforce size of 120 pilots.

Results As pure cyclical scheduling with an equal distribution of manpower is unresponsive to the variability in the demand pattern, this approach performs poorly with respect to the schedule feasibility and the matching ability between the workload and the pilots' lines of work. The peaks in demand are not adequately covered and there are many unproductive working days when the demand is low. When we compare different work patterns, we observe the following: the higher the ratio of days on versus days off in the applied work pattern, the better the schedule feasibility and the higher the number of unproductive working days. These two effects neutralize each other, which implies that the matching ability of different work patterns in the assumption of an equal workload is similar.
Consequently, in case of a variable demand pattern cyclical scheduling in its 'purest' form is not beneficial. The schedule feasibility and the matching ability are low. The cost depends on the employed work pattern and the pilot satisfaction is high.

Pure cyclical scheduling under a variable workload
In order to come towards the variable demand, a pure cyclical roster is constructed where the work pattern of each pilot is shifted over the time horizon such that the demand is satisfied as best as possible. In this case, the proportions of pilots that start the work pattern on day 1, on day 2, on day 3, etc. are different from each other and are dependent on the peaks in the demand pattern. Figure 10 indicates a better match between the scheduled duties and the duty workload as the different cyclic schedules are present with a different degree ranging between 8.91% and 22.58%.

Results Although pure cyclical scheduling under a variable workload performs somewhat better than when assuming an equal workload, this approach is not able to obtain satisfiable results with respect to the schedule feasibility and the matching ability between the workload and the pilots' lines of work. As the flexibility in the line of work construction is too low, this approach can not deal with large variation in the demand pattern. The results revealed that short patterns perform typically better than long work patterns as these patterns are more flexible to schedule. The length of a work pattern is calculated as the sum of days on and days off. The (4,2) and (5,2) patterns lead to the best results in terms



(5,2) cyclic schedules

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Schedule proportionality
Schedule 1	▨	▨	▨	▨	▨			22.58%
Schedule 2		▨	▨	▨	▨	▨		12.53%
Schedule 3			▨	▨	▨	▨	▨	18.20%
Schedule 4	▨			▨	▨	▨	▨	16.74%
Schedule 5	▨	▨			▨	▨	▨	10.23%
Schedule 6	▨	▨	▨			▨	▨	8.91%
Schedule 7	▨	▨	▨	▨			▨	10.81%

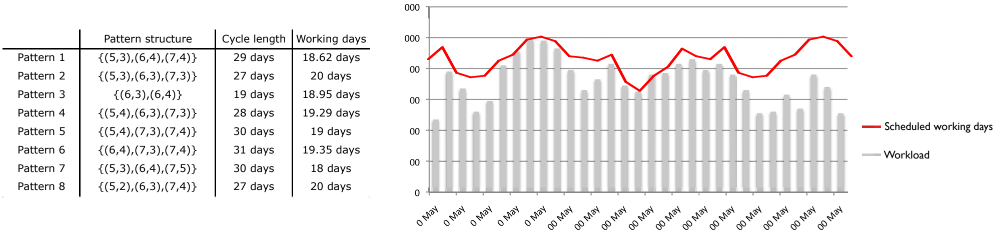
Cycle length = 7 days   Time unit = 1 day

Figure 10. Cyclic scheduling following the demand using the (5,2) pattern.

of schedule feasibility and matching ability. (5,2) and (5,3) have the lowest cost.
In conclusion, cyclical scheduling with lines of work that rely on a single work pattern do not lead to satisfiable results. The schedule feasibility and the matching ability are low as many activities are unassigned. Further, the schedule cost depends on the employed work pattern. The pilot satisfaction (measured by the fairness) is high as all pilots work the same number of working days.

Pure cyclical scheduling combining multiple work patterns
There is still a significant mismatch between the variable workload pattern and all cyclical rosters constructed using a single work pattern as building block (cfr. supra). The number of unproductive working days and the unassigned activities are still substantial. Additionally, the schedule cost is high due the required assignment of activities to freelancers and overtime. In order to overcome these problems, we combine different work patterns in order to increase the flexibility in scheduling the pilots.

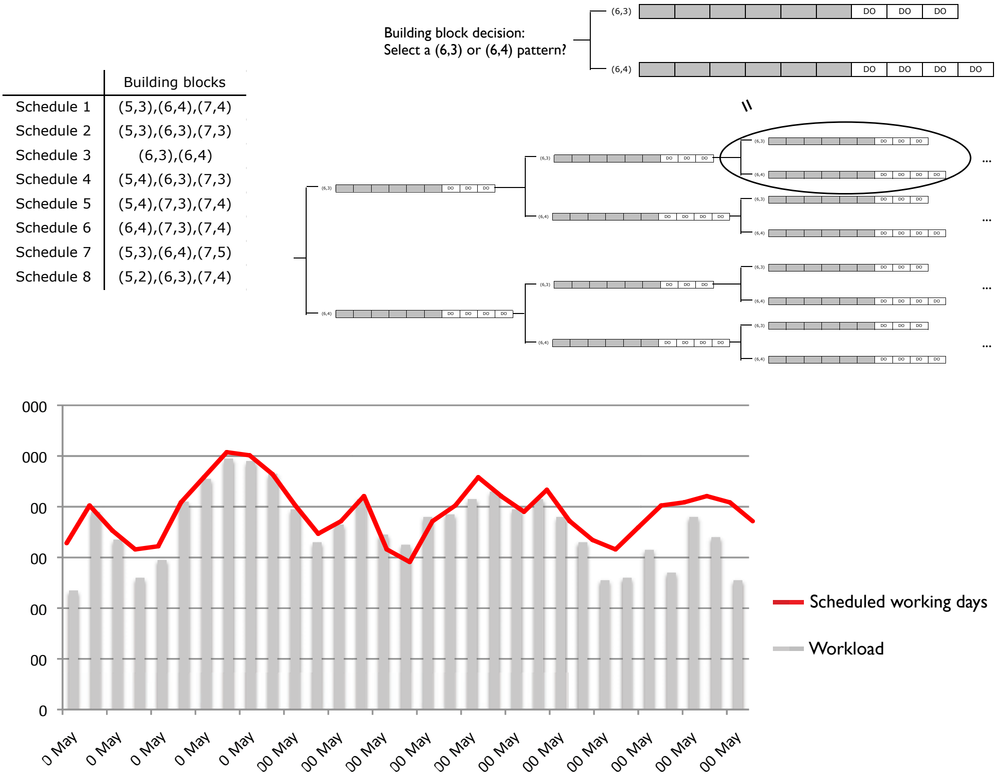
The combined patterns of the newly constructed cyclical rosters are displayed left in figure 11. The work patterns are combined as such that the cyclical schedules patterns embody a minimal number of 18 working days in a 30-day period. As a pure cyclical schedule is constructed, the different work patterns are applied in a strict order (e.g. pattern (6,3)-(6,4) always schedules a pattern (6,4) after a pattern (6,3)). For each pattern the cycle length and the average number of working days in a 30-day period are displayed. The figure right displays the best match between supply and demand for the {(5,2), (6,3), (7,4)}-pattern.



	Pattern structure	Cycle length	Working days
Pattern 1	{(5,3),(6,4),(7,4)}	29 days	18.62 days
Pattern 2	{(5,3),(6,3),(7,3)}	27 days	20 days
Pattern 3	{(6,3),(6,4)}	19 days	18.95 days
Pattern 4	{(5,4),(6,3),(7,3)}	28 days	19.29 days
Pattern 5	{(5,4),(7,3),(7,4)}	30 days	19 days
Pattern 6	{(6,4),(7,3),(7,4)}	31 days	19.35 days
Pattern 7	{(5,3),(6,4),(7,5)}	30 days	18 days
Pattern 8	{(5,2),(6,3),(7,4)}	27 days	20 days

Figure 11. Cyclic scheduling using different work patterns.

Results The results reveal that the cyclical schedules that combine multiple work patterns outperform the cyclical schedules that employ only a single work pattern. As more flexibility is introduced, the schedule feasibility, the costs and the matching ability are improved. The constructed crew rosters obtain about the same quality with respect to the pilot satisfaction (i.e. fairness). However, the match between the demand pattern and the scheduled duties is still far from perfect. The best combination of work patterns is very dependent on the problem instance. The cyclical schedule constructed according to the pattern (5,2)-(6,3)-(7,4) provides the best solution on the average. This solution provides not only the best match between supply and demand, but is also the minimum cost solution. The structure of the pattern can be labelled as flexible as the lengths of the days on (5, 6 and 7) and the lengths of the days off (2, 3 and 4) are different.



	Building blocks
Schedule 1	(5,3),(6,4),(7,4)
Schedule 2	(5,3),(6,3),(7,3)
Schedule 3	(6,3),(6,4)
Schedule 4	(5,4),(6,3),(7,3)
Schedule 5	(5,4),(7,3),(7,4)
Schedule 6	(6,4),(7,3),(7,4)
Schedule 7	(5,3),(6,4),(7,5)
Schedule 8	(5,2),(6,3),(7,4)

Figure 12. Ad hoc scheduling with multiple fixed work scheduling.

In conclusion, cyclical scheduling with lines of work that combine multiple work patterns lead to consistent crew rosters with an acceptable quality for a starting point. However, when constructing a month-specific roster many adaptations are required, which advance the use of an add-on ’ad hoc’ rostering component (cfr. section 3.4.). These pure cyclical schedules result in a high fairness among crew members.

3.2. Ad hoc Scheduling Combining Multiple Fixed Work Patterns

Similar to the approach in section 3.1., multiple fixed work patterns can be used as building blocks to construct a monthly roster. Contrarily to the constructed cyclical roster of section 3.1., the personnel scheduler can choose each time a pattern has ended between the different work patterns which pattern to schedule next (e.g. the scheduler has each time the choice to schedule pattern (6,3) or pattern (6,4)). These patterns are denoted as variable ’ad hoc’ patterns but deliver a proper balance between schedule consistency and schedule flexibility.

Figure 12 indicates how ’ad hoc’ crew rosters are constructed using fixed work patterns as building blocks. The table left displays the work patterns used for the construction for eight crew schedules that are constructed with different work pattern combinations. The figure right displays the construction of individual crew rosters using the (6,3) and (6,4) work patterns. At the end of a work pattern, a decision is needed on which pattern to select next: (6,3) or (6,4). The bottom graph displays the best match between supply and demand for composing crew rosters with the (5,2), (6,3) and (7,4) work patterns as building blocks.

Results Constructing ’ad hoc’ schedules with multiple work patterns as building components lead to significantly better results compared to pure cyclical rostering (cfr. section 3.1.). This more flexible approach leads to a better match between supply and demand, a better feasibility and lower costs. These better results are only attained when the different building blocks have sufficient diversity. Again, the ad hoc schedule constructed with the patterns (5,2), (6,3) and (7,4) provides the best solution. The major issues with ad hoc scheduling are the lack of schedule consistency and the fairness, which is difficult to achieve and has a negative impact on the pilot satisfaction. Schedules differ significantly more from crew member to crew member and from time period to time period.

In conclusion, ad hoc scheduling with fixed building blocks is a useful approach when the demand pattern is highly variable. This method results in a good quality in terms of feasibility, cost and matching ability. However, the drawbacks are that crew members do not know their duty timetable far in advance, there is lack of schedule consistency and more attention should be paid to maintain the fairness among crew members.

3.3. Subdividing the workforce into different groups for crew rostering

As a complete cyclic roster for all staff is not feasible, it would be interesting to explore the possibility to have different rostering organisations within subgroups of the workforce or over subperiods of the rostering horizon. One of these possibilities is to employ as much as possible full-time pilots that follow a cyclical roster without having any unproductive working days. The peaks in demand are covered by freelance pilots or crew members that are scheduled ’ad hoc’ when the monthly roster are constructed. This mixed scheduling approach could be organised in different ways, e.g.

(a) Pilots are always scheduled cyclically or ’ad hoc’ following their contract type.

(b) Pilots are scheduled according to a cyclical schedule for a subperiod of the yearly planning horizon. The remaining months the pilots are scheduled ’ad hoc’. The ratio cyclical versus ad hoc scheduling period is dependent on the proportion required number of ad hoc pilots versus the total number of required pilots.

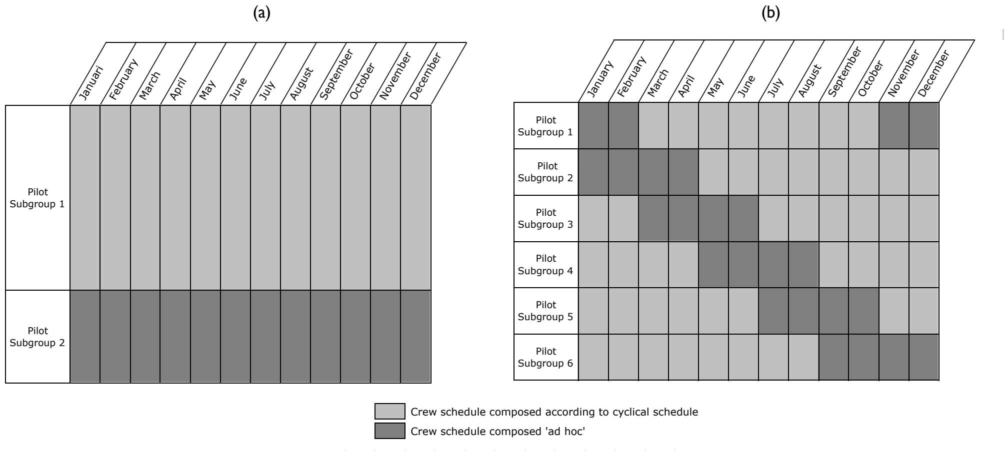


Figure 13. Roster organisation with different pilot groups.

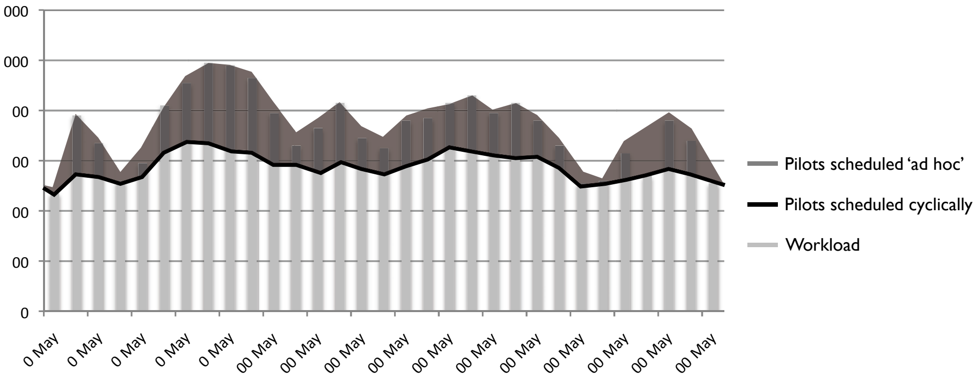


Figure 14. Match between supply and demand for combining cyclical and 'ad hoc' scheduling.

In this way, monthly rosters that are constructed over time, are consistent to some extent. Both organisations (a) and (b) are displayed in figure 13. The left figure (a) illustrates that the workforce is divided into two groups and a minority of the pilot workforce is scheduled 'ad hoc'. The right figure (b) illustrates that the workforce is subdivided into six groups and each group is scheduled 'ad hoc' for two months. The other ten months the crew is scheduled according to their cyclical pattern.

Results This approach bridges schedule flexibility and schedule consistency as a cyclical roster organisation is developed that can cope with demand variability. Combining a cyclical schedule with 'ad hoc' rostering outperforms the other approaches in terms of schedule feasibility, matching ability and costs. The best results are again achieved when the building blocks are diverse. Another prerequisite is that the number of pilots that are cyclically scheduled is fairly high in comparison with the total number of pilots in order to retain a consistent roster. In other words, the variability in the demand pattern should not be too high, i.e. the peaks and valleys should not be too steep. The more equal the workload distribution, the more pilots that are scheduled cyclically.

In conclusion, the subdivision approach is an extremely useful approach to construct a consistent roster when the demand is variable. The involved airline company constructed a cyclical roster for as much full-time pilots as possible (without scheduling unproductive working days) according to the fixed patterns (5,2), (6,3) and (7,4). Additionally, about one third of the pilots are scheduled ’ad hoc’ for a period of about four months. During this period pilots are scheduled in series of 5, 6 or 7 days on and in between they are able to take vacation. Figure 14 displays the match between the supply and the demand for subdividing the crew into two groups with different roster organisations when using the patterns (5,2), (6,3) and (7,4).

3.4. Extension with an ’ad hoc’ Rostering Component

In this section, we analyse the add-on of an ad hoc rostering component, i.e. a so-called post-optimisation procedure. The post-optimisation procedure improves the constructed roster in two ways. First, the procedure tries to reduce the number of deviations (i.e. unassigned activities and unproductive working days) from a feasible cyclic roster using fixed work patterns. Secondly, the resulting crew roster is possibly improved following other objectives (cost minimisation and pilot satisfaction).

The post-optimisation procedure is carried out at the start of each month in order to fix the unbalances in supply (i.e. the cyclical pilot roster) and demand as follows

(a) Unassigned activities are assigned to unproductive working days. In this way, we reduce the number of deviations from the cyclical roster.

(b) In order to attain a feasible roster with respect to the staffing requirements, unassigned pairings can be assigned to one of the corresponding free days of a specific pilot. Such moves are allowed as long as the number of consecutive free days within the roster does not fall below a strict minimum or the consecutive working days goes beyond a strict maximum. This action improves the feasibility of the roster, but reduces the consistency of the monthly schedule with the cyclical schedule.

(c) If desired, the post-optimisation procedure is able to additionally bundle all unproductive days to one or a couple of pilots or level the unproductive working over all crew members. The latter results in a minimum deviation from the cyclical schedule for each pilot. The first gives the opportunity to diminish the workforce and/or to allow for vacation to a couple of pilots.

Hence, inherently a cyclical schedule is utilised, but monthly adaptations are required to match the cyclical roster with the variability in the demand pattern.

In figure 15 we illustrate the different improvements carried out by the add-on rostering procedure. For (a) and (b) the postoptimisation procedure improves the schedule feasibility as the unassigned pairing 997 is assigned to a crew member. For case (b), assigning pairing 997 has a negative effect on the schedule consistency as this leads to a deviation from the

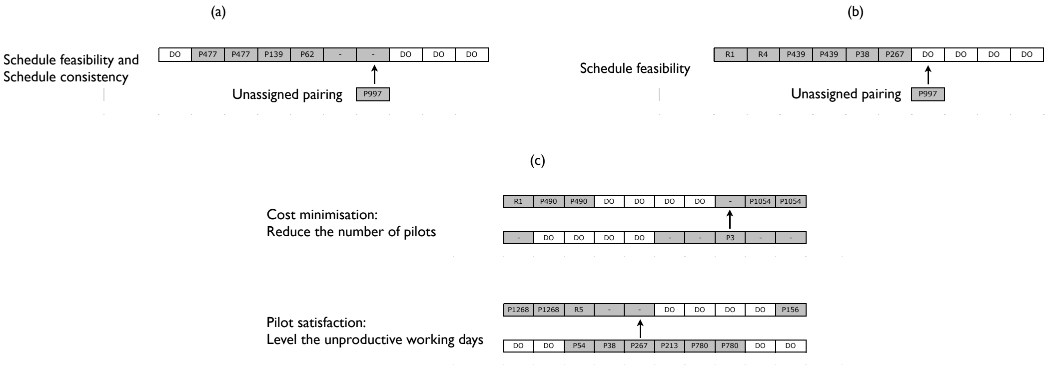


Figure 15. Improvements obtained by the post-optimisation procedure.

fixed work patterns. Case (c) describes two cases that improve the other two objective function components, cost and pilot satisfaction. For the first case, pairing 3 is assigned to the other crew member, which makes it possible to lay off one of the crew members. In the second case the unproductive working days are leveled over the two crew members by assigning pairing 267 to the other crew member. Hence, both crew members work one unproductive working day.

Results The use of an add-on 'ad hoc' rostering component leads to significant schedule improvements in terms of schedule feasibility, cost and pilot satisfaction. Involving the match between supply and demand, the add-on component increases the number of deviations on the average. When comparing the number of schedule adaptations and the schedule quality before and after this method is applied, we see that the quality improvement and required adaptations are by far the largest for the pure cyclical scheduling method (cfr. section 3.1.), followed by ad hoc scheduling with fixed work patterns (cfr. section 3.2.) and the mixture of both approaches (cfr. section 3.3.).

Furthermore, the add-on component is especially effective for work patterns with a large number of days off (more than two). Only then, we can assign pairings to the free days of a pilot as the involved airline company stipulated a minimum (maximum) of two days off (eight days on).

4. Conclusions and Future Research

The research study described in this chapter provides different ways to construct a crew roster that incorporates roster consistency and flexibility. Fixed work patterns are matched to a highly variable demand pattern. Depending on the workload variability and the company's policy to support long-term schedule transparency, an airline company can select to construct a pure cyclical approach, an 'ad hoc' approach with fixed building components and a mixture of both approaches. In the latter, the pilot workforce is subdivided into different groups, which are scheduled according to different rostering organisations.

Our future research intentions are threefold. Firstly, the suitability of the decision support system is only examined for the pilot crew of the medium-haul flights. Other crew types (e.g. service personnel) and activity types (e.g. the long-haul flights) are confronted with a different set of company rules and regulations and another workload pattern. Hence, the applicability of the different models should also be investigated in these settings. Secondly, we aim to further improve the procedures used to assign activities to working days. The further development of high-quality meta-heuristic approaches is an important factor in this step due to the problem size, rules and regulations and often conflicting objectives. Thirdly, the construction of robust schedules will become a main issue in future research. Generally, schedules need to be maintained and repaired until the moments of operations resulting in delays and cancellations which lead to unproductive working days, unavailable pilots for activities, higher operational costs, a lower social quality for the crew members, etc. Procedures need to be developed which can uptake this uncertainty and variability upfront leaving out the costly ad hoc adjustments.

Acknowledgments

We acknowledge the support for the postdoctoral research project fundings by the Fonds voor Wetenschappelijk Onderzoek (FWO), Vlaanderen, Belgium under contract number FWO08/PDO/098.

References

Caprara, A., Toth, P., and Vigo, D. (1998). Modeling and solving the crew rostering problem. *Operations Research*, 46:820–830.

Ernst, A., Jiang, H., Krishnamoorthy, M., and Sier, D. (2004). Staff scheduling and rostering: A review of applications, methods and models. *European Journal of Operational Research*, 153:3–27.

Gamache, M., Soumis, F., Marquis, G., and Desrosiers, J. (1999). A column generation approach for large-scale aircrew rostering problems. *Operations Research*, 47:247–263.

Gopalakrishnan, B. and Johnson, E. (2005). Airline crew scheduling: State-of-the-art. *Annals of Operations Research*, 140:305–337.

Kohl, N. and Karisch, S. (2004). Airline crew rostering: Problem types, modeling and optimization. *Annals of Operations Research*, 127:223–257.

Maenhout, B. and Vanhoucke, M. (2008). Automatic personalized crew rostering at Brussels Airlines. Technical report, Ghent University, Ghent, Belgium.

Maenhout, B. and Vanhoucke, M. (2010). A hybrid scatter search for personalized crew rostering in the airline industry. *European Journal of Operational Research*, 206:155–167.

Warner, D. (1976). Scheduling nursing personnel according to nursing preference: A mathematical programming approach. *Operations Research*, 24:842–856.

In: Airline Industry: Strategies, Operations and Safety
Editor: Connor R. Walsh, pp. 213-231
ISBN: 978-1-61122-079-7

Chapter 10

PRICING AND TRAVELERS' DECISION TO USE FREQUENT FLYER MILES: EVIDENCE FROM THE U.S. AIRLINE INDUSTRY

***Diego Escobari*[1]*,[∗] *Michael Bar*[2] *and Kirill Chernomaz*[2]**
[1]Department of Economics & Finance,
The University of Texas - Pan American, Edinburg, TX, USA
[2]Department of Economics, San Francisco State University,
San Francisco, CA, USA

Abstract

Previous research on Frequent Flyer Programs (FFP) covered various topics, from analyzing the effect of international airline alliances on domestic travel demand to the effect of airport dominance and FFP on pricing. However, one important constraint in previous empirical research on FFP is the lack of a measure of these programs at a specific time-variant route and carrier level. In this chapter we use a novel way to measure the extent of FFP that allows us to analyze how these programs change from route to route, across carriers and over time. The dataset, which covers the quarters from 1993.1 to 2009.3, was constructed with data obtained from the Bureau of Transportation and Statistics, and it has information on prices, proportion of frequent flyer tickets as well as various route and carrier variables. Using panel data techniques to control for unobservables along with the use of instrumental variables to control for potentially endogenous regressors, the results found are consistent with our economic model: travelers are more likely to redeem their frequent flyer miles in more expensive routes. Moreover, business travelers, who usually pay higher prices, were found to be less price sensitive than tourists when switching to buy with accumulated miles.

Keywords: Frequent Flyer Programs; Airlines; Panel Data

JEL Classifications: L11; L93; C23

[∗] Email address: escobarida@utpa.edu

1. Introduction

Since 1981 with the introduction of AAdvantage, the Frequent Flyer Program from American Airlines, Frequent Flyer Programs (FFP) have been growing enormously. It was the combination of deregulation of the industry and the introduction of computer reservation systems that gave rise to this highly popular marketing strategy. The goal is simple: to create travelers' loyalty towards a single carrier. It has been calculated that FFP have more than 80 million participants, with the three largest U.S. FFP, American Airlines' AAdvantage, United Airlines' Mileage Plus and Delta's Sky Miles, having more than 20 million members each.[1]

Despite of the large success of these programs, empirical research in economics on the analysis of FFP is scarce. The main restriction is that data on miles balances of individual travelers are unavailable to researchers. One exception is Lederman (2008), who looks at the effect of these programs on the 'hub premium' —higher fares charged by hub airlines for flights originating at the hub— by using the formation of international partnerships. Other related research has focused on airline alliances (e.g., Lederman (2007)) and partnerships (e.g., Bilotkach (2009)), but not on travelers' choice on the usage of these programs. In this chapter we use a novel way to measure the extent of FFP which allows us to analyze how the extent of these programs changes from route to route, across carriers and over time.

In particular, we employ data from the Bureau of Transportation Statistics to identify how the proportion of Frequent Flyer Tickets (FFT) changes across various time-variant carrier and route characteristics. This proportion can be interpreted as an aggregation of individual travelers' decisions between paying to fly and using their accumulated frequent flyer miles to obtain a free ticket. The analysis takes advantage of a panel of carriers and routes that spans over seventeen years of data, from the first quarter of 1993 to the third quarter of 2009. Initially we analyze the market equilibrium proportion of FFT, but after instrumenting for price, we are able to measure the pricing effect on travelers' choices. We find that if average prices in a route increase by one dollar, one of every 802 paying passengers will decide to shift and use his frequent flyer miles to obtain the ticket instead of paying for it. The results also show that the lower tail of the distribution of prices has a much larger positive effect on the proportion of FFT than the positive effect of the upper tail. This is consistent with business travelers being less price sensitive than tourists.

Our theoretical model presents an explanation of this positive effect of prices on the proportion of FFT. In a dynamic setting we show how a traveler, who faces a positive probability of making a trip, decides between paying for a ticket and using miles. When needing to fly he can either buy a ticket and accumulate miles or, if he already achieved the required number of miles, he can choose to obtain the ticket by redeeming a fixed amount of accumulated miles. The model's implication is consistent with our empirical findings: if average prices in a route are higher, the proportion of travelers who decide to use their miles is greater.

The chapter is structured as follows. Section 2. presents an overview of frequent flyer programs. Section 3. describes the empirical approach starting with the explanation of the sources of the data and sample in Section 3.1.. Then we present the motivation for the empirical model in Section 3.2. and show the estimated equation, along with the selection

---

[1] This figure comes from www.frequentflier.com.

of the instruments in Sections 3.3. and 3.4., respectively. Section 4. presents the empirical results by describing the summary statistics (4.1.), explaining the results for the time trend and route specific characteristics (4.2.), the price effect (4.3.), airport dominance (4.4.), and product quality and capacity constraints (4.5.). To provide a theoretical explanation of the price effect on frequent flyer programs, Section 5. introduces a simple dynamic model of a traveler's choice between purchasing a ticket or using accumulated miles. Finally, Section 6. concludes.

2. Frequent Flyer Programs

One key step that led to the appearance of frequent flyer programs (FFP) in 1981 was the deregulation of airline markets that happened three years earlier. Deregulation not only allowed carriers to optimize their network structure —that led to the hub-and-spoke system which appeared shortly after deregulation— but also to offer additional incentives to attract passengers. One of those very successful ways to attract consumers is frequent flyer programs. These programs offer free travel, as the most common gift, once a customer has conducted a certain number of trips with the airline. The first airline that introduced FFP was American Airlines, but similar products were quickly introduced by United Airlines, Continental, Delta and TWA.[2]

The success of these programs has been partly attributed to the creation of consumer's loyalty towards a specific airline. The consumer has incentives to concentrate all of his business in one particular carrier because in this way it will be easier to achieve the required accumulated miles to redeem a free ticket. In addition, they are set to take advantage of a principal/agent problem when business travelers are not usually the ones who pay for their tickets, but do decide on which carrier to fly. In this way travelers will benefit from the accumulated miles, but it will be their businesses that pay for the tickets. As noted by Borenstein (1989), although this may increase the firm's costs associated with employees' travel, it also increases one non-taxed compensation received by its employees.

The effectiveness of FFP depends in large degree on the carrier's network size. Whether a carrier is able to attract travelers into their FFP is a function of its overall network size and its business size at the traveler's departing airport. Airlines that have a large network will be able to offer a larger number of alternatives for their travelers in both accumulating and redeeming the miles. This is a simple explanation of why during the nineties various airline alliances were born and also helps explain code sharing flights.[3] For the same reasons the size of the carrier at a departing airport serves to attract travelers to a particular FFP. The benefits of being the dominant carrier in an airport then becomes apparent, in addition to the well known 'hub premium' —a premium that the dominant carrier in an airport is able to charge.[4]

---

[2] See Mason and Baker (1996) for a history of FFP.

[3] See Lederman (2007) for international FFP partnerships and their effect on domestic airline demand and Bilotkach (2009) for local FFP partnerships.

[4] See Borenstein (1989) for the effect of route and airport dominance on fares, Lee and Luego Prado (2005) for the effect of passenger mix on the 'hub premium' and Lederman (2008) for the effect of FFP on the 'hub premium.'

3. Empirical Approach

3.1. Sources of Data and Sample

The dataset used in this chapter focuses on domestic, round-trip, coach class tickets and covers the period starting with the first quarter of 1993 and ends with the third quarter of 2009. It was obtained from the Bureau of Transportation and Statistics (BTS) website, Transtats. We use the market data and the ticket data sub-sections of the DB1B database and the segment data from the T-100. The DB1B database is a 10% random sample quarterly data of airline passenger ticket transactions. Each observation contains information about the ticket price, origin, destination and any connecting airports, number of passengers at each ticket, carrier, type of ticket (e.g. one-way, round-trip), and the service class. The T-100 segment data offers information on the total number of performed departures by carrier in an airport, as well as information on the total number of seats and transported passengers between an origin and destination airport pair.

The analysis is restricted to round-trip tickets because these tickets allow us to identify the originating airport of the ticket. Essentially we need to distinguish between SFO-DFW-SFO (San Francisco-Dallas/Forth Worth-San Francisco) and DFW-SFO-DFW because we also want to see how a carrier's specific attributes in the departing airport affect the demand for frequent flyer tickets. To restrict the analysis to economically significant routes, the sample includes all routes that had at least one carrier transporting an average of 40 passengers per week, by either direct or connecting service. The dataset is constructed in such a way that each observation in the sample corresponds to a route —a pair of origin and destination airports— served by a given carrier during a specific quarter and year. The carriers considered are AirTran, Alaska, American, Continental, Delta, Frontier, JetBlue, Northwest, Spirit, Trans World Airlines, United, and US Airways, each with its corresponding FFP partners.

Because travelers can also obtain frequent flyer miles by traveling with the carrier's FFP partner, we identified the partners of each of the carriers and considered those tickets as belonging to the main carrier. For example, passengers flying on American Eagle can count those miles towards American Airlines' frequent flyer program, hence we consider all tickets from American Eagle as if they were tickets from American Airlines. The other frequent flyer partnerships in the sample include Air Wisconsin Airlines and American West with US Airways; ATA Airlines, Atlantic Southeast Airlines, Skywest and Comair with Delta; and Mesaba with Northwest.

3.2. Model Setup

To be able to investigate the relationship between the usage of frequent flyer tickets and various airport, route and carrier specific characteristics, we model the total number of passengers who purchase tickets using frequent flyer miles, Y_{ijt}, as a binomial random variable, $Y_{ijt} \sim Bin\left(n_{ijt}, \pi_{ijt}\right)$. The subscript i refers to the carrier, j refers to the departure and destination airport pair, and t refers to the time period. Therefore, the total number of travelers served by carrier i in route j during time t is given by n_{ijt}, with π_{ijt} being the probability that a given traveler on ijt obtains the tickets through a frequent flyer program.[5] Thus, theproportion of travelers with free ticket in ijt is $P_{ijt} = Y_{ijt}/n_{ijt}$ with $E\left(P_{ijt}\right) = \pi_{ijt}$ and $Var\left(P_{ijt}\right) = \pi_{ijt}\left(1 - \pi_{ijt}\right)/n_{ijt}$. Notice that the variance of the proportion is decreasing with the number of travelers on the route, i.e. n_{ijt}.

The object of our study is the proportion of free tickets in each route in the population, i.e. π_{ijt}. We model it as a function of carrier, airport and route characteristics that are allowed to change over time, $\pi_{ijt} = F\left(\mathbf{X}\beta\right)$. β is the vector of the coefficients of interest that we will estimate, $\mathbf{X}$ is the matrix of carrier, airport and route characteristics and F is a monotonically increasing function that maps the value of characteristics into the $[0,1]$ interval. The empirical model can then be written as:

$$P_{ijt} = F\left(\mathbf{X}\beta\right) + \varepsilon_{ijt} \tag{1}$$

where $E\left(\varepsilon_{ijt}\right) = 0$ and $Var\left(\varepsilon_{ijt}\right) = F\left(\mathbf{X}\beta\right)\left[1 - F\left(\mathbf{X}\beta\right)\right]/n_{ijt}$. To obtain a linear model, we apply the inverse transform F^{-1} to both sides of Equation 1 and obtain a Tailor series approximation around $\varepsilon_{ijt} = 0$. Thus, the linear model can be written as:

$$F^{-1}\left(P_{ijt}\right) = \mathbf{X}\beta + u_{ijt} \tag{2}$$

where $u_{ijt} = \varepsilon_{ijt}/F'\left(\mathbf{X}\beta\right)$. To estimate Equation 2 we need to specify the function F^{-1}. As a first approach we will use a linear probability model where $F^{-1}\left(P_{ijt}\right) = P_{ijt}$. OLS estimates with appropriate weights to take care of the heteroskedasticity present in the model will be unbiased and consistent, but the predicted values of P_{ijt} are not restricted to lie on the $[0,1]$ interval.[6] To take care of this problem we will provide estimates using two functional forms for F^{-1}. The first one is the log-odds ratio:

$$F^{-1}\left(P_{ijt}\right) = \log\left(\frac{P_{ijt}}{1 - P_{ijt}}\right) \tag{3}$$

which gives us the logistic function $F\left(\mathbf{X}\beta\right) = \exp\left(\mathbf{X}\beta\right)/\left(1 + \exp\left(\mathbf{X}\beta\right)\right)$ that can be estimated via maximum likelihood. When this transformation is estimated via OLS and not via maximum likelihood, it requires all observation P_{ijt} to be strictly between 0 and 1. To be able to use panel data techniques that consider different structures in the error term and allow us to have values of P_{ijt} of 0 and 1, we will use the second functional form for F^{-1}. This one was proposed by Cox (1970) and it is given by:

$$F^{-1}\left(P_{ijt}\right) = \log\left(\frac{P_{ijt} + a_{ijt}}{1 - P_{ijt} + a_{ijt}}\right) \tag{4}$$

where $a_{ijt} = \left(2n_{ijt}\right)^{-1}$.

3.3. Estimated Equation and Panel Structure

We now rewrite Equation 2 to emphasize the fact that we are considering the proportion of frequent flyer tickets, $P_{ijt} = PROPFFT_{ijt}$, as a function of various airport, route, and

---

[5] It is straightforward to see that this binomial distribution has mean $E\left(Y_{ijt}\right) = n_{ijt}\pi_{ijt}$ and variance $Var\left(Y_{ijt}\right) = n_{ijt}\pi_{ijt}\left(1 - \pi_{ijt}\right)$.

[6] The weights will also make sure that each observation is given the appropriate importance according to the corresponding total number of travelers.

carrier specific characteristics taking into account the panel structure of the data. Hence, we break down the error term into different components, $u_{ijt} = \upsilon_t + \eta_{ij} + \mu_{ijt}$. The resulting reduced-form equation is:

$$\begin{aligned} F^{-1}(PROPFFT_{ijt}) = {} & \beta_1 MEANFARE_{ijt} + \beta_2 MILES_j + \beta_3 DEPAHUB_{ij} \\ & + \beta_4 PROPDEST_{ijt} + \beta_5 PROPDEPA_{ijt} \\ & + \beta_6 PROPDIRECT_{ijt} + \beta_7 LOADFACT_{ijt} + \upsilon_t + \eta_{ij} + \mu_{ijt} \end{aligned} \tag{5}$$

Let υ_t denote any unobservable time specific effect, η_{ij} denote the unobservable carrier/route time-invariant specific effect and μ_{ijt} denote the remaining disturbance. The dependent variable is our measure of frequent flyer tickets, with $PROPFFT$ calculated as the ratio of frequent flyer tickets to the total number of tickets. The number of frequent flyer tickets is obtained from the number of tickets with a price equal to zero, as recorded in the DB1B database. $MEANFARE$ is the average price paid by passengers flying with carrier i during quarter t in route j. Notice that route j is defined as a combination of origin and destination airports, so the average is taken over all direct and connecting flights. Two route specific characteristics that we have are $MILES$, that is the number of miles between the origin and destination airports and $DEPAHUB$, that is a dummy variable that equals to one when the departing airport j is a hub for carrier i and zero otherwise. Notice that we will only be able to identify the route specific characteristics if Equation 5 is estimated without route specific fixed effects.

In addition to the main variable of interest, $MEANFARE$, and the two time-invariant route/carrier characteristics, we constructed four additional variables that change across carriers, routes and over time. The first two are similar to $DEPAHUB$ and should capture the effect of time-variant airport presence or airport dominance on frequent flyer miles usage. These variables are included to evaluate the idea that passengers will typically join the program of the dominant carrier at their departing airport. The reason is simple: passengers will be able to accumulate miles more easily if they join the program of the dominant carrier at their departing airport because most of their destinations will be covered by this carrier. Moreover, the dominant carrier will also give them more options in terms of destinations at the time of redeeming their miles. The variable $PROPDEST$ is the proportion of nonstop destinations. It is obtained by dividing the nonstop destinations of carrier i out of the departing airport in route j during time t by all the nonstop destinations out of route j's departing airport during time t. Likewise, $PROPDEPA$ measures the proportion of departures out of the departing airport in route j that belong to carrier i. According to an airport dominance story, both, more destinations and more departures from a specific carrier in an airport should attract more people to its frequent flyer program, hence $PROPDEST$ and $PROPDEPA$ would have a positive effect on $PROPFFT$.

The variable $PROPDIRECT$ —proportion of carrier i's direct flights on route j during time t— was obtained by dividing carrier i's total number of direct flights by the total number of flights offered by the same carrier. $LOADFACT$, the average load factor or capacity utilization, is a measure of the usage of aircraft's capacity. Its value is in the $[0, 1]$ interval, being equal to one when aircrafts operate at full capacity.[7]

---

[7] A more detailed construction of the variables is presented in Appendix A.

Equation 5 will be estimated with different specifications of the error term. When focusing on the regressors that change across carriers, routes and over time, we will include two sets of fixed effects. First, we use time fixed effects to control for changes over time in the industry-level demand, which may be correlated with the industry-level trends, such as the adoption of new technologies like Internet bookings, but that affect all carriers and all routes equally. Second, we use route/carrier fixed effects to control for time-invariant unobservable factors that affect frequent flyer tickets' demand. Because each departing airport belongs to a specific route, these fixed effects will control for the hub effect or level of dominance of an airport. Time-invariant regressors (e.g. $DEPAHUB$) cannot be separately identified when these fixed effects are included, so we will be able to see how the other two measures of airport dominance, $PROPDEST$ and $PROPDEPA$, affect the proportion of frequent flyer tickets once the time-invariant component of airport dominance is controlled for. Notice that because $DEPAHUB$ is a dummy equal to one when the departing airport is a hub, it assumes that the effect should be equal across different hubs from different carriers. However, including carrier-route fixed effects controls for the time-invariant hub effect without having to impose a one-size-fits-all effect for airport dominance.

3.4. Instruments

One concern in the estimation of Equation 5 is that fares and the allocation of frequent flyer tickets may be determined simultaneously, making fares correlated with the error term. For example, Escobari (2009) empirically shows that carriers will be setting higher prices during *ex-ante* known peak periods. In this case it is likely that during high demand periods carriers will also restrict the availability of tickets assigned to passengers that obtain them through frequent flyer miles. We expect that this effect is captured by capacity utilization, $LOADFACT$, as well as by our various time and route/carrier fixed effects. However, as mentioned by Lederman (2007), there may be factors such as advertisement of a particular frequent flyer program, that can affect prices as well as the proportion of people choosing to enroll and fly using accumulated miles. Here $LOADFACT$ and the fixed effects variables may not be enough, hence we need to instrument for the potential endogeneity of fares.

The selection and construction of the instruments is similar to the ones used in Lederman (2007) and come from the discrete-choice demand literature. The idea is that firms that offer multiple products, such as connecting and direct flights in airlines, will jointly set the prices for these products. There is a degree of substitutability between direct and connecting service because as a given carrier increases its prices for direct service, some of its consumers may not only shift to its competitors but also to its own connecting flights. The dataset DB1B allows us to distinguish between these two products within the same airport pair, so we use this to construct two instruments. The first one is the dummy variable $CONNECT$, which takes the value of one when carrier i offers connecting service in route j and zero otherwise. The second variable, $NUMCONN$, counts the total number of connecting combinations that carrier i offers in route j.

4. Empirical Results

4.1. Summary Statistics

The summary statistics of the variables is presented in Table 1. The mean of the proportion of frequent flyer tickets indicates than on average airlines have 4.85% of the travelers using their accumulated miles to obtain a ticket. To measure prices at the carrier, route and quarter level we use three variables. The average fare ($MEANFARE$) —which excludes free tickets— has an average of US$ 180.9 and the 20^{th} and 80^{th} percentiles of fares ($20PCTFARE$ and $80PCTFARE$) have an average of US$ 113.7 and US$ 238.4, respectively. The time-invariant variables $MILES$ and $DEPAHUB$ show that the nonstop distance between airports in a route ranges from 67 to 6,089 miles and that on average about 20.4% of the observations have the carrier's hub as the departing airport. The other four controls as well as the two instruments for the fare variables complete the table. The sample used is an unbalanced panel with 45,000 different origin and destination pairs for a total of 474,856 airline-route-carrier observations.

Table 1. Summary Statistics

VARIABLES	(1) mean	(2) sd	(3) min	(4) max
Dependent Variable				
PROPFFT	0.0485	0.0655	0.00	0.934
Fare Variables				
MEANFARE	180.9	65.76	11.05	774.9
20PCTFARE	113.7	41.55	0.450	676
80PCTFARE	238.4	113.1	1.450	1,178
Characteristics / Controls				
MILES	1,288	780.1	67	6,089
DEPAHUB	0.204	0.403	0.00	1.00
PROPDEST	0.422	0.261	0.00532	1.00
PROPDEPA	0.183	0.195	1.67e-05	1.00
PROPDIRECT	0.453	0.457	0.00	1.00
LOADFACT	0.707	0.109	0.00	1.00
Instruments				
CONNECT	0.637	0.481	0.00	1.00
NUMCONN	2.180	2.171	0.00	56

Notes: An observation is an airline i in route j during quarter t. The sample is from 1993:1 to 2009:3 and consists on 474,856 observations.

4.2. Trend and Route Specific Characteristics

The results from the estimation of Equation 5 using the linear transformation, $F^{-1}(P_{ijt}) = P_{ijt}$, are presented in Table 2. All estimates in this table were obtained using the total number of observations per route-carrier-time combination as weights to account for potential heterosckedaticity and to give each observation the appropriate importance. The sample starts with the first quarter of 1993 until the third quarter of 2009 and the numbers in parentheses are heteroskedasticity robust standard errors, correction included in addition to the weights. In different columns we provide different specifications for the error term, starting with the first column that gives the OLS estimates from pooling across carriers, routes, and time periods and the second column that provides the estimates for the variance component —random effects— model. Both of these first two specifications allow us to identify the effect of time-invariant route/carrier specific characteristics as well as the existence of a time trend. Consistent with the existence of an airport dominance effect, the proportion of frequent flyer tickets is larger for the carrier that has a hub at the departing airport. The statistically significant point estimate of 0.637 in the random effects specification indicates that when the departing airport is a hub, the proportion of frequent flyer tickets increases by 0.637 percentage points. This is an economically significant effect given the average of the proportion of frequent flyer tickets of 4.85%. In addition, the positive coefficient in $MILES$ is consistent with travelers picking to redeem their miles in longer haul routes.

Table 2. Regression Results, Linear Model

VARIABLES	(1) Pooled	(2) RE	(3) Within	(4) Within
MEANFARE	0.0245*	0.0423*	0.0418*	0.0393*
	(0.000218)	(0.000222)	(0.000859)	(0.000854)
MILES/10^3	1.483*	0.394*		
	(0.0239)	(0.0459)		
DEPAHUB	0.303*	0.637*		
	(0.0269)	(0.0753)		
YEAR	-0.394*	-0.453*	-0.350*	
	(0.00285)	(0.00216)	(0.00858)	
PROPDEST	1.114*	0.566*	1.530*	1.706*
	(0.0619)	(0.0647)	(0.278)	(0.276)
PROPDEPA	0.989*	0.973*	1.756*	0.557
	(0.0923)	(0.0919)	(0.418)	(0.430)
PROPDIRECT	-1.756*	-1.780*	-2.566*	-2.614*
	(0.0271)	(0.0408)	(0.209)	(0.209)
LOADFACT	0.150	-1.518*	-0.895*	-1.444*
	(0.109)	(0.0949)	(0.241)	(0.254)
Observations	474856	474856	474856	474856
R-squared	0.415	0.311	0.320	0.374
Route/Carrier FE	No	No	Yes	Yes
Time FE	No	No	No	Yes

Notes: The dependent variable is $F^{-1}(P_{ijt}) = P_{ijt} \times 100$, where $P_{ijt} = PROPFFT_{ijt}$. Figures in parentheses are robust standard error. ‡ significant at 10%; † significant at 5%; * significant at 1%. Using the total number of tickets in the route/carrier as weights.

The evolution of the proportion of frequent flyer tickets can be observed by looking at the variable $YEAR$, with the negative coefficient showing that the proportion of frequent flyer tickets has been decreasing over time. The third column, that further controls for unobserved route and carrier specific characteristics, provides additional support for this negative effect.

To complete the set of estimates for the trend and the route specific characteristics, the maximum likelihood estimates using the transformation presented in Equation 3 are presented in Table 3. Moreover, the pooled, random effects and the route/carrier fixed effects specifications using the Cox transformation shown in Equation 4 are presented in the first, second and third columns of Table 4, respectively. The coefficients are all statistically significant and the signs are the same as the ones obtained in Table 2 and discussed above.

Table 3. Regression Results, Log-odds Ratio

	(1)	(2)	(3)
VARIABLES	MLE	MLE	MLE
MEANFARE	0.00203*		
	(3.21e-06)		
20PCTFARE		0.00290*	
		(6.38e-06)	
80PCTFARE			0.000675*
			(1.50e-06)
MILES/10^3	0.164*	0.205*	0.243*
	(0.000356)	(0.000365)	(0.000312)
DEPAHUB	0.0794*	0.103*	0.0838*
	(0.000469)	(0.000463)	(0.000467)
PROPDEST	0.245*	0.268*	0.261*
	(0.00137)	(0.00135)	(0.00136)
PROPDEPA	-0.0443*	-0.000770	-0.00438*
	(0.00157)	(0.00154)	(0.00155)
PROPDIRECT	-0.186*	-0.137*	-0.175*
	(0.000588)	(0.000590)	(0.000592)
LOADFACT	0.121*	-0.219*	-0.0296*
	(0.00240)	(0.00222)	(0.00235)
Observations	474,856	474,856	474,856

Notes: The dependent variable is $F^{-1}(P_{ijt}) = \log\left(\frac{P_{ijt}}{1-P_{ijt}}\right)$, where $P_{ijt} = PROPFFT_{ijt}$. Figures in parentheses are robust standard error. ‡ significant at 10%; † significant at 5%; * significant at 1%. All specifications include time FE.

4.3. The Price Effect

The main variable of interest is the price. We are interested in knowing how average prices affect the equilibrium proportion of frequent flyer tickets as well as how travelers respond to prices. Table 2 presents the results for the linear transformation, ignoring the potential endogeneity of $MEANFARE$. All four columns have very similar positive and highly statistically significant coefficients. We focus on the last column, as it is the one that controls for unobserved route/carrier characteristics as well as any unobserved time effects. The coefficient of 0.0393 indicates that an increase of one standard deviation in $MEANFARE$ —an increase of US$ 65.76— increases the proportion of FFT by 2.58 percentage points. [8] This figure corresponds to a 0.39 standard deviations increase in FFT, which is economi-

---

[8] This is calculated as ($\partial PROPFFT$ / $\partial MEANFARE$) × 100 = (0.0393 × 65.76). A one dollar increase in mean fares will increase the proportion of FFT by 0.0393 percentage points.

Table 4. Regression Results, Cox

VARIABLES	(1) Pooled	(2) RE	(3) Within	(4) Within
MEANFARE	0.00673*	0.00753*	0.00957*	0.00834*
	(5.82e-05)	(3.81e-05)	(0.000236)	(0.000233)
MILES/10^3	0.190*	0.0883*		
	(0.00614)	(0.00628)		
DEPAHUB	0.0490*	0.0541*		
	(0.00929)	(0.0131)		
YEAR	-0.154*	-0.128*	-0.136*	
	(0.000932)	(0.000450)	(0.00281)	
PROPDEST	-0.0373	-0.0737*	0.534*	0.573*
	(0.0228)	(0.0134)	(0.102)	(0.0990)
PROPDEPA	0.571*	0.564*	1.296*	0.872*
	(0.0261)	(0.0183)	(0.119)	(0.116)
PROPDIRECT	-0.796*	-0.675*	-0.818*	-0.847*
	(0.00692)	(0.00782)	(0.0432)	(0.0399)
LOADFACT	0.103*	-0.824*	-0.775*	-0.787*
	(0.0367)	(0.0208)	(0.0793)	(0.0801)
Observations	474856	474856	474856	474856
R-squared	0.528	0.453	0.400	0.504
Route/Carrier FE	No	No	Yes	Yes
Time FE	No	No	No	Yes

Notes: The dependent variable is $F^{-1}(P_{ijt}) = \log\left(\frac{P_{ijt}+a_{ijt}}{1-P_{ijt}+a_{ijt}}\right)$, where $P_{ijt} = PROPFFT_{ijt}$. Figures in parentheses are robust standard error. ‡ significant at 10%; † significant at 5%; * significant at 1%. Using the total number of tickets in the route/carrier as weights.

cally significant.

One limitation of the linear model discussed above is that it does not restrict the fitted values of the proportion to be between zero and one. To overcome this restriction, we present additional estimates in Tables 3 and 4 that employ the nonlinear transformations presented in Equations 3 and 4, respectively. The MLE estimates in Table 3 were obtained with time-specific effects, robust standard errors and without instrumenting for any of the fare variables. For this specific transformation the marginal effect of the regressors is given by $\partial \pi_{ijt}/\partial x_{ijt,k} = \beta_k \pi_{ijt}(1 - \pi_{ijt})$, where $\pi_{ijt} = E(PROPFFT_{ijt})$. To calculate this marginal effect we will use the sample average of $PROPFFT_{ijt}$ as π_{ijt}, which is 0.0485, and it is presented in Table 1. Then from the $MEANFARE$ coefficient in the first column of Table 3 we can read that a one standard deviation increase in mean fares increases the proportion of FFT by 0.616 percentage points, which corresponds to a 0.09 standard deviations increase in FFT. Table 4 shows the estimates using the Cox transformation presented in Equation 4 for various specifications of the error term; pooling across panels, random effects and two specifications with fixed effects. For a large number of observations within each carrier, route, and time, n_{ijt}, the marginal effect of a regressor can be approximated by $\partial \pi_{ijt}/\partial x_{ijt,k} \approx \beta_k \pi_{ijt}(1 - \pi_{ijt})$, where $\pi_{ijt} = E(PROPFFT_{ijt})$.[9] Column 4, our

---

[9] To derive the marginal effect when using the transformation in Equation 4, we first set it equal to $\mathbf{X}\beta$ and

preferred specification because it controls for most of the unobservables, indicates that a one standard deviation increase in mean fares increases the proportion of FFT by 2.53 percentage points, figure that is very close to the 2.58 point estimate of the linear model.

The point estimates of the price effect presented in Tables 2 through 4 can be interpreted as the price effect on the equilibrium proportion of FFT. Then, the positive coefficient can have both, supply and demand side explanations. For example, on the demand side it could be travelers using frequent flyer tickets in more expensive routes. Moreover, on the supply side it could be carriers restricting the number of available frequent flyer tickets while setting lower fares. The concern is that prices could be correlated with some supply side unobservables, making prices endogenous in the estimation of Equation 5. To be able to restrict the interpretation to a demand side story, we proceed by instrumenting for the price variable and provide two stage least squares estimates (2SLS) of Equation 5. The first stage estimates using the instruments and the matrix of regressors $\mathbf{X}$ are presented in Table 6 of Appendix B.[10] This first stage is the pricing equation as specified in Equation 7 with the dependent variable being the mean fare for column one and the 20^{th} and 80^{th} percentiles for the second and third columns. These estimations use the full sets of route/carrier fixed effects as well as the time fixed effects. The second stage coefficients are obtained using the Cox transformation of Equation 4 and are presented in Table 5. Interestingly, the highly significant $MEANFARE$ estimated coefficient of 0.027 in column one is larger than the 0.008 of the fourth column in Table 4, obtained when not instrumenting for fares. This 2SLS estimate indicates that a one standard deviation increase in mean fares increases the proportion of FFT by 8.19 percentage points, which corresponds to a 1.25 standard deviations increase in the proportion of FFT. In dollar terms, a one dollar increase in average fares increases the proportion of FFT by 0.12 percentage points. In other words, if on a given route a carrier transports 802 paying passengers per week, a one dollar increase in fares will make one of those passengers decide to use his frequent miles to obtain the ticket. Given the instrumentation of the fare variable, this effect has only a demand side interpretation.

The intuition behind this positive coefficient is the following, passenger enrolled in frequent flyer programs can accumulate miles as they travel or through various other channels, such as AAdvantage.[11] Once the traveler has accumulated a certain amount of miles, let's say more than 25,000 miles, he will be able to redeem a fixed amount of miles to obtain a free ticket. When the traveler needs to fly again and he already has enough miles to obtain a free ticket, he needs to decide whether to buy the ticket and keep accumulating miles or use

---

isolate π_{ijt} to obtain:

$$\pi_{ijt} = F\left(\mathbf{X}\beta\right) + \frac{\left(1 + a_{ijt}\right)\exp\left(\mathbf{X}\beta\right) - a_{ijt}}{1 + \exp\left(\mathbf{X}\beta\right)}$$

Then, the marginal effect of $x_{ijt,k}$ on π_{ijt} is:

$$\frac{\partial \pi_{ijt}}{\partial x_{ijt,k}} = \beta_k \frac{\exp\left(\mathbf{X}\beta\right)}{1 + \exp\left(\mathbf{X}\beta\right)} \left[\frac{1 + 2a_{ijt}}{1 + \exp\left(\mathbf{X}\beta\right)}\right]$$

For large n_{ijt}, the marginal effect is approximately: $\partial \pi_{ijt} / \partial x_{ijt,k} \approx \beta_k \pi_{ijt} \left(1 - \pi_{ijt}\right)$.

[10] The first stage estimates in Appendix B also provide weak instruments test using the conventional F statistic on the set of excluded instruments of the second stage. The F statistics of more than 10 in all three specifications signals that we do not have a weak instruments problem.

[11] AAdvantage is the credit card associated with American Airlines, and this one offers frequent flyer miles for purchases made with the card.

his accumulated miles and fly for free. As we argue in Equation 5, such decision depends on various carrier, route and time characteristics, and in particular, it depends on the average price of the ticket. If the ticket is more expensive, he will be more likely to choose to obtain it using his accumulated miles, but if it is cheaper, he will be more likely to choose to pay for it. That is exactly what the positive coefficient of prices means. As average fare increases, the proportion of travelers who choose to fly using their accumulated miles also increases. The theoretical model presented in Section 5. formalizes this idea to show how in a dynamic model the proportion of FFT is larger when average prices are higher.

Table 5. Regression Results, 2SLS with Cox

	(1)	(2)	(3)
VARIABLES	2SLS	2SLS	2SLS
MEANFARE	0.0270*		
	(0.00629)		
20PCTFARE		0.0621*	
		(0.0141)	
80PCTFARE			0.0122*
			(0.00287)
PROPDEST	-0.00174	0.166	0.221
	(0.216)	(0.180)	(0.172)
PROPDEPA	0.529*	0.0806	0.656*
	(0.176)	(0.256)	(0.157)
PROPDIRECT	-0.758*	-0.732*	-0.761*
	(0.0544)	(0.0576)	(0.0543)
LOADFACT	1.554†	0.330	1.344‡
	(0.783)	(0.489)	(0.739)
Observations	474856	474856	474856
R-squared	0.465	0.465	0.465

Notes: The dependent variable is $F^{-1}(P_{ijt}) = \log\left(\frac{P_{ijt}+a_{ijt}}{1-P_{ijt}+a_{ijt}}\right)$, where $P_{ijt} = PROPFFT_{ijt}$. Figures in parentheses are robust standard error. ‡ significant at 10%; † significant at 5%; * significant at 1%. Using the total number of tickets in the route/carrier as weights. All specifications include route/carrier FE and time FE.

Because it has been widely documented that there is significant price dispersion in tickets bought within the same route (see for example Borenstein and Rose (1994) or more recently Gerardi and Shapiro (2009)), investigating just the effect of the average route/carrier prices is restrictive. Therefore, we extend the analysis to see how the upper and the lower tails of the price distributions affect the proportion of FFT. To do this we constructed two additional variables, the 20^{th} and the 80^{th} percentiles of fares paid. Columns two and three of Table 3 present the maximum likelihood estimates when using the log-odds ratio transformation presented in Equation 3 and columns two and three of Table 5 present the estimates from the 2SLS using the Cox transformation of Equation 4. While the MLE estimates do not control for the potential endogeneity of the fares variable, the 2SLS estimates do. Interestingly, we observe that all fare coefficients of the different specifications of Table 5 are highly statistically significant. The magnitude of the coefficients indicates that more expensive fares have a smaller effect on the proportion of FFT than less expensive fares. The coefficient of the 20^{th} percentile is a little more than double of the mean fare coefficient and coefficient of the 80^{th} percentile is a little less than half of the mean fare coefficient. The differences in the coefficients can be explained by the fact that more expensive tickets are usually obtained by business travelers, who are less sensitive to price changes. On the other hand, cheaper tickets are usually bought by more price sensitive travelers, tourists. Then it makes sense for business travelers who buy in the upper tail of the price distribution to respond less and for more price sensitive buyers in the lower tail to respond more.

4.4. Airport Dominance

Airport dominance, as discussed in Borenstein (1989), refers to a particularly large share of passengers that a specific airline may have in an airport. The well documented effect of airport dominance is that the dominant carrier in an airport will be able to charge significantly higher prices than the rest of the carrier serving that airport. Because dominance at an airport is related to the hub-and-spoke network of a carrier, this is also referred to as the 'hub premium.' The existence of a hub premium is important in our estimation of the effect of prices on the proportion of FFT because airport dominance is related to the enrollment of a particular frequent flyer program. Travelers are more likely to enroll in the program of the dominant carrier in their departing airport, hence not appropriately controlling for airport dominance will bias our estimates of the price effect. In particular, a positive correlation between prices and airport dominance and a positive correlation of FFT usage and airport dominance will bias our estimate of prices upwards, overestimating the price effect.

In section 4.2. we discussed how when route/carrier fixed effect are not included, we are able to identify a positive effect of $DEPAHUB$. However, the specifications in the fourth column of Table 4 and all specifications in Table 5, with this set of fixed effects, are aimed at controlling for time-invariant characteristics, which wipes out any time-invariant hub effect. Then, the concern is whether there exists any remaining airport dominance effect that changes over time. To capture this we included the variables $PROPDEST$ and $PROPDEPA$ that measure the relative importance of a given carrier in an airport in terms of the number of destinations and number of departures, respectively. The last column in Table 4 shows a positive sign for both coefficients, consistent with what we expect from airport dominance. When instrumenting for mean fares, the first column of Table 5 shows that only $PROPDEPA$ has a positive and significant effect. An increase of 10 percentage points in the proportion of departures of a carrier out of the departing airport increases its proportion of FFT by 0.24 percentage points.

4.5. Product Quality and Capacity Constraints

The two last controls included in Equation 5 are the proportion of direct flights on the route, $PROPDIRECT$, and the average aircraft capacity utilization or load factor, $LOADFACT$. Because carriers offer both direct and indirect service between the city pairs on a route, $PROPDIRECT$ is used to evaluate whether a carrier with a larger proportion of passengers serviced in direct flights is associated with larger or smaller FFT usage. This variable can be viewed as a measure of quality because nonstop or direct service is usually regarded of a higher quality than indirect service. The negative and highly significant coefficient of $PROPDIRECT$ in all the specifications across all tables suggests that carriers that serve routes with a larger proportion of nonstop service —higher quality— have a lower proportion of FFT. From the results in the first column of Table 5, we can say that a 10 percentage points increase in the proportion of direct flights in a route decreases the proportion of FFT by 0.35 percentage points.

The variable $LOADFACT$ is included in the estimation of Equation 5 to capture the role of capacity constraints. We were not able to obtain a sign and a coefficient robust to different specifications. When not instrumenting for fares, the regression results show a highly significant negative coefficient, but when instrumenting for fares the negative effect disappears. The negative sign would be consistent with carriers allocating fewer frequent flyer tickets in more congested routes, where capacity constraints make paying passengers more valuable to the carrier than passengers that travel with frequent flyer miles. An important idea behind free tickets is that carriers accommodate those travelers when capacity constraints are not binding, hence the costs for the carrier associated with those tickets are expected to be lower.

5. A Simple Model of the Price Effect

In this section we present a simple dynamic model that motivates the findings that the proportion of tickets obtained through frequent flyer miles is larger when the average price is higher. We model the decision of an individual who every time he needs to fly, has to decide whether to pay for the ticket or, if he has enough accumulated miles, to obtain the ticket with his miles. Let n be the time (in months) since he last flew and the number of accumulated miles in his frequent flyer account be given by k. Each period the individual will fly with probability π and stay home with no activity in his frequent flyer account with probability $1 - \pi$. In the case where the individual needs to make a trip, this trip is characterized by a pair of variables: distance between the airports and price, (d, p). The price p is only paid if the individual decides not to use his miles. In this scenario, he will be able to save p dollars and next period his number of accumulated miles will increase to $k' = k + d$. In the event he decides to use his miles, he will need to exchange a number of miles to obtain a free ticket, then he saves p, and the following month he will be left with $k - a$ miles. Notice that in any given period he will only be able to use his miles if $k > a$.[12]

An important characteristic in the way frequent flyer programs work is that miles expire after certain amount of time of account inactivity.[13] To be able to model the expiration of miles, we count the number of months since last account activity. If there is activity this period, the expiration clock is reset to zero, so next period $n' = 1$. In case there is no activity this period, miles do not change, but their age increases, $n' = n + 1$. With δ being the time discount factor, the dynamic decision problem of a traveler can then be described

---

[12] This threshold a varies from carrier to carrier. The most typical value is 25,000 miles for round trip tickets during peak demand periods.

[13] For example, the AAdvantage account from American Airlines expire after 18 months of inactivity, the Dividend Miles program from US Airways has its miles expire after 18 months as well as Mileage Plus from United.

with the following Bellman's equation:

$$V(k,n) = \pi \max\{p + \delta EV(k-a,1), \delta EV(k+d,1)\} + (1-\pi)\delta EV(k,n+1)$$

If the account does not have any activity for certain amount of time $\bar{n}$, then miles expire. In that case the value function is defined by:

$$V(k,n) = V(0,0) \qquad \forall n \geq \bar{n}$$

When the individual has enough miles, $k > a$, he will use them for thecurrent flight if and only if:

$$\begin{aligned} p + \delta EV(k-a,1) &\geq \delta EV(k+d,1) \\ p &\geq \delta E[V(k+d,1) - V(k-a,1)] > 0 \end{aligned}$$

In other words, for any price above $p_{min} = \delta E[V(k+d,1) - V(k-a,1)]$, the individual will use his accumulated miles to obtain a ticket. The difference $V(k+d,1) - V(k-a,1)$ represents the extra future utility from purchasing the ticket with money, and thereby increasing the stock of miles in the next period. Only if the flight is expensive enough, the traveler would prefer to use up existing miles. Moreover, when the discount factor δ is greater, the minimum price that induces travelers to use their miles increases because the future gain of accumulating miles is more valuable.

The term on the right-hand side is strictly positive since V is strictly increasing in the first argument. This proves that the average price among passengers who used miles is higher than the unconditional average ticket price:

$$E[p|p \geq p_{min}] > E(p) \tag{6}$$

Hence, when the average price in a route is higher, the proportion of travelers who decide to use their miles is greater.

6. Conclusion

This chapter's aim is to show the importance of pricing in the usage of Frequent Flyer Tickets (FFT). The theory section presents a simple dynamic model that illustrates how prices affect a traveler's decision between paying and using his accumulated miles to obtain a ticket. The model's empirical implication is that when average prices are higher, a larger proportion of travelers use their accumulated miles to obtain a free ticket.

The empirical section models the same traveler's decision and uses aggregate data from the Bureau of Transportation and Statistics to estimate how prices and other route and carrier characteristics affect the proportion of travelers who fly using FFT. Initial estimations focus on the equilibrium number of FFT and employ various specifications of the error term to control for carrier and route time-invariant unobserved specific characteristics as well as unobserved time-variant characteristics common to all carriers and routes. OLS, MLE, FE and RE estimates combined with linear and nonlinear transformations of the proportion of frequent flyer tickets all consistently found a positive correlation between prices and FFT usage. Moreover, weighted 2SLS estimates that account for potential heteroskedastic errors and the endogeneity of fares identified the travelers' response to changes in average prices. The results were found to be consistent with the theoretical model's implications, namely, higher average prices increase the proportion of passengers who use their free FFP tickets to fly. In addition to the response to average prices, we also showed the effect of the upper and lower tails of the pricing distribution. The response to the upper tail was smaller than the response of the lower tail, indicating that business travelers, who usually pay higher fares than tourists, are less likely to switch to FFT in response to a price increase.

The results also show that the proportion of FFT decreased over time, is larger in longer haul routes, and increases when the carrier has a hub at the departing airport. Our time-variant airport dominance regressors were found to have a significant effect on the proportion of FFT, even after controlling for any unobservable time-invariant hub effect. Other time-variant covariates indicate that carriers that serve routes with a larger proportion of nonstop service also have a lower proportion of FFT. Finally, the results showed some evidence that carriers restrict the number of passengers flying with free tickets in more congested routes.

A Variable Construction

Variables were constructed excluding all tickets priced below $20 and all tickets that had questionable fare values based on credit limits, as classified by the BTS. The descriptions of the variables used in this chapter are the following:

$PROPFFT_{ijt}$: Number of tickets priced at zero divided by the total number of tickets that belong to carrier i on route j during quarter t. *Source*: DB1B.

$MEANFARE_{ijt}$: Average price paid by all passengers traveling on the observed airline i during quarter t on the observed combination of origin and destination airports in route j. The average is taken from all passengers flying with direct or connecting service and fares are represented as one-way fares by dividing round trip ticket prices by two. *Source*: DB1B.

$20PCTFARE_{ijt}$: The 20^{th} percentile fare paid by passengers from carrier i on route j during quarter t. *Source*: DB1B.

$80PCTFARE_{ijt}$: The 80^{th} percentile fare paid by passengers from carrier i on route j during quarter t. *Source*: DB1B.

$MILES_j$: Number of nonstop miles between the origin and destination airports in route j. *Source*: DB1B.

$DEPAHUB_{ij}$: A dummy variable equal to one if carrier i has a hub at the departing airport corresponding to route j.

$PROPDEST_{ijt}$: Proportion of nonstop destinations from the originating airport in route j that belong to carrier i. *Source*: DB1B.

$PROPDEPA_{ijt}$: Proportion of departures from the originating airport in route j that belong to carrier i. *Source*: T-100 Domestic Segment.

$PROPDIRECT_{ijt}$: Proportion of direct flights, constructed as the number of direct flights offered by carrier i on route j divided by the total number of flights (direct and connecting) serving route j. *Source*: DB1B.

$LOADFACT_{ijt}$: Load factor in a segment is defined as the total number of passengers divided by the total number of seats. Because we have routes j that involve more than one segment and different combinations of segments for the same carrier i (e.g. SFO-MIA, SFO-DFW-MIA or SFO-LAX-MIA), we calculate the load factor in a route as the weighted average of load factors in each of the segments. The weight is the traffic of passengers flying on the specific route. *Source*: T-100 Domestic Segment and DB1B.

$CONNECT_{ijt}$: A dummy variable equal to one if the carrier i offers connecting service in route j, zero otherwise. (instrument) *Source*: DB1B.

$NUMCONN_{ijt}$: Count on the total number of connecting combinations that carrier i offers in route j. (instrument) *Source*: DB1B.

B First Stage Regressions

The first stage regression for the 2SLS estimation of Equation 5 is given by:

$$MEANFARE_{ijt} = \alpha_1 CONNECT_{ijt} + \alpha_2 NUMCONN_{ijt} + \mathbf{X}\delta + \varepsilon_{ij} + \mu_{ijt} \quad (7)$$

where the dependent variable is either $MEANFARE$, $20PCTFARE$, or $80PCTFARE$. $CONNECT$ and $NUMCONN$ are the excluded instruments for the fare variable, and the matrix **X** is the same as the one defined for Equation 5. From the F tests reported in Table 6, with the corresponding p-values, we can see that the instruments comply with the identification assumption of being correlated with fare.

Table 6. First Stage Regressions, 2SLS

VARIABLES	(1) *MEANFARE*	(2) *20PCTFARE*	(3) *80PCTFARE*
CONNECT	-0.830‡	1.039†	-4.704*
	(0.503)	(0.445)	(1.074)
NUMCONN	-1.320*	-0.573*	-2.811*
	(0.287)	(0.114)	(0.606)
Observations	474856	474856	474856
F stat: $\alpha_1 = \alpha_2 = 0$	11.80	16.14	19.48
p value: $\alpha_1 = \alpha_2 = 0$	7.52e-06	9.87e-08	3.51e-09

Notes: The dependent variable is shown below the column number. Figures in parentheses are robust standard error. ‡ significant at 10%; † significant at 5%; * significant at 1%. All specifications include route/carrier FE and time FE.

References

Bilotkach, V. (2009). Parallel Frequent Flier Program Partnerships: Impact on Frequency. Working Paper. University of California, Irvine.

Borenstein, S. (1989). Hubs and High Fares: Airport Dominance and Market Power in the U.S. Airline Industry *Rand Journal of Economics* 20, 344-365.

Borenstein, S. & Rose, N.L. (1994). Competition and Price Dispersion in the U.S. Airline Industry *Journal of Political Economy* 102, 653-683.

Cox, D. (1970). Analysis of Binary Data. London: Methuen.

Escobari, D. (2009). Systematic Peak-load Pricing, Congestion Premia and Demand Diverting: Empirical Evidence. *Economics Letters* 103, 59-61.

Gerardi, K.S. & Shapiro, A.H. (2009). Does Competition Reduce Price Dispersion? New Evidence from the Airline Industry. *Journal of Political Economy* 117, 1-37.

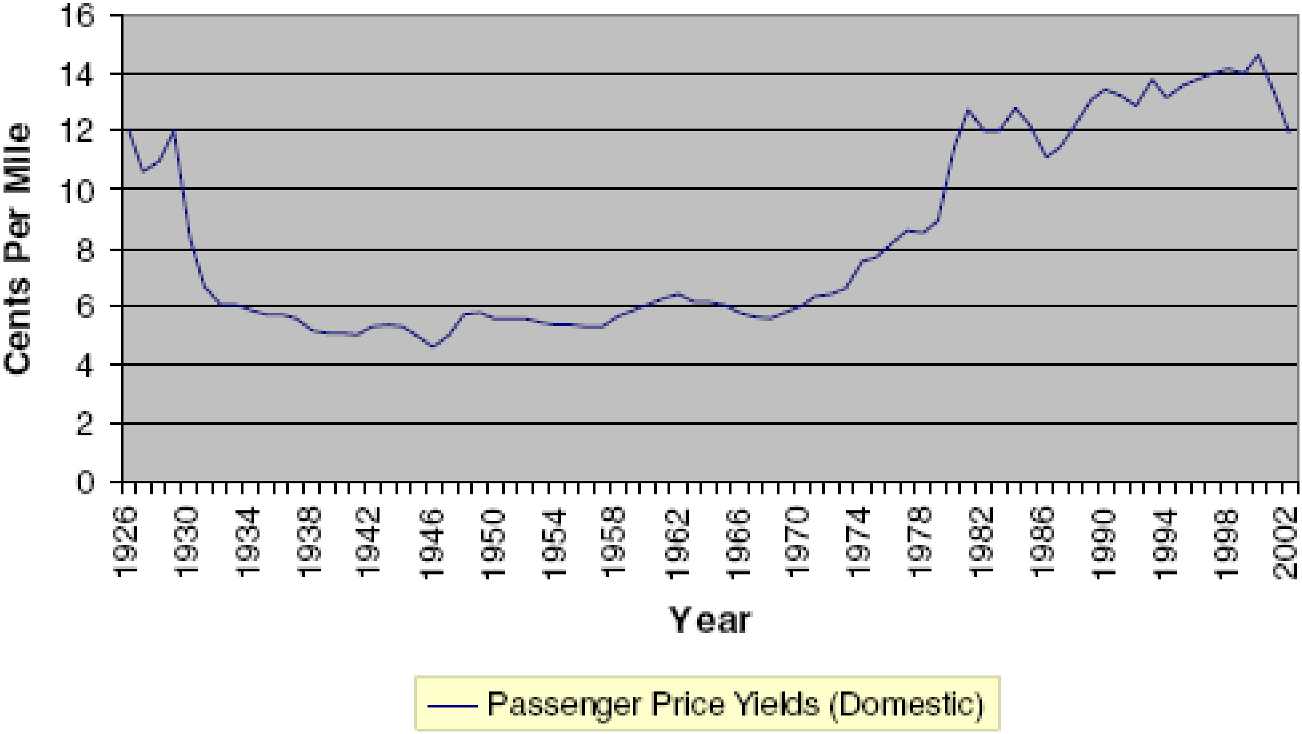
Lederman, M. (2007). Do Enhacements to Loyalty Programs Affect Demand? The Impact of International Frequent Flyer Partnerships on Domestic Airline Demand. *Rand Journal of Economics* 38, 1134-1158.

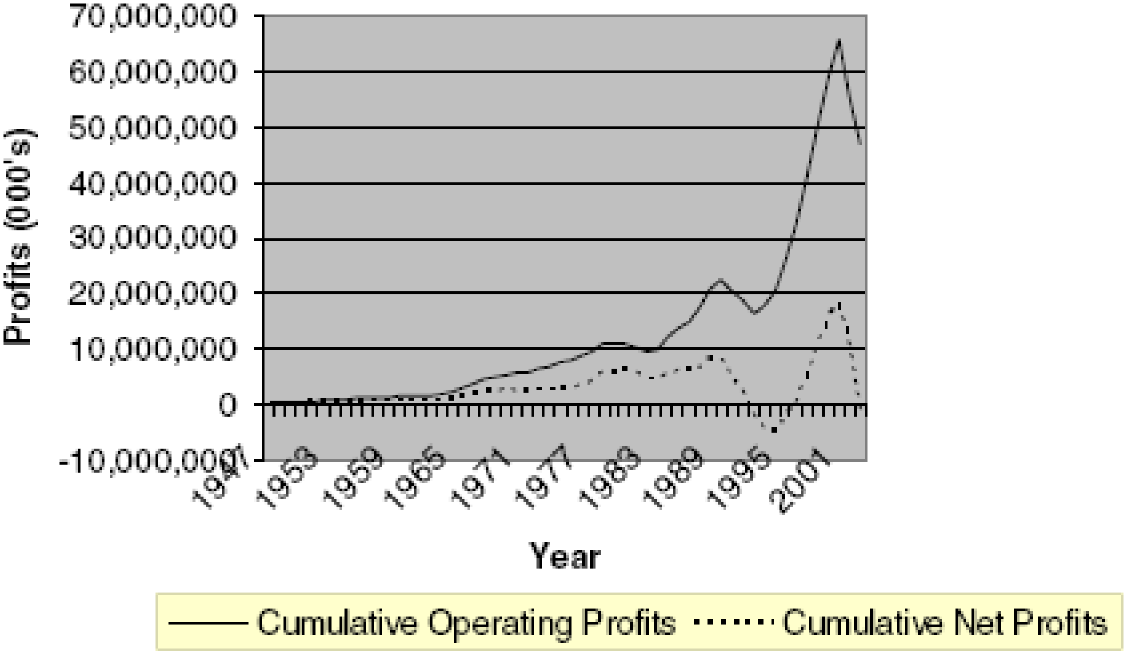
Lederman, M. (2008). Are Frequent Flyer Programs a Cause of the ‘Hub Premium’. *Journal of Economics and Management Strategy* 17, 35-66.

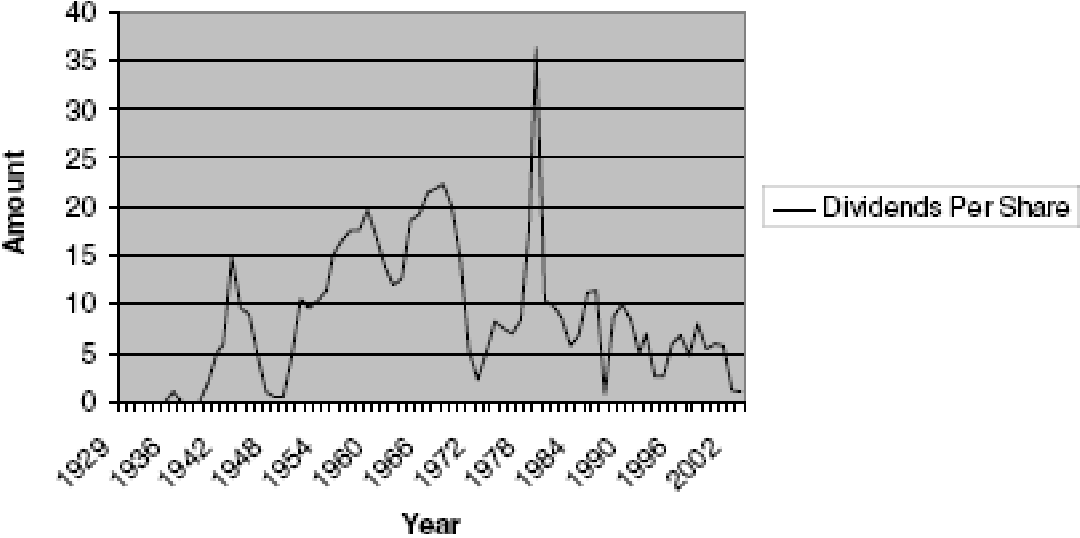
Lee, D. & Luego Prado, M.J. (2005). The Impact of Passenger Mix on Reported Hub Premiums in the U.S. Airline Industry. *Southern Economic Journal* 72, 372-394.

Mason, G. & Baker, N. (1996). Buy Now Fly Later: An Investigation of Airline Frequent Flyer Programs. *Tourism Management* 17, 219-232.

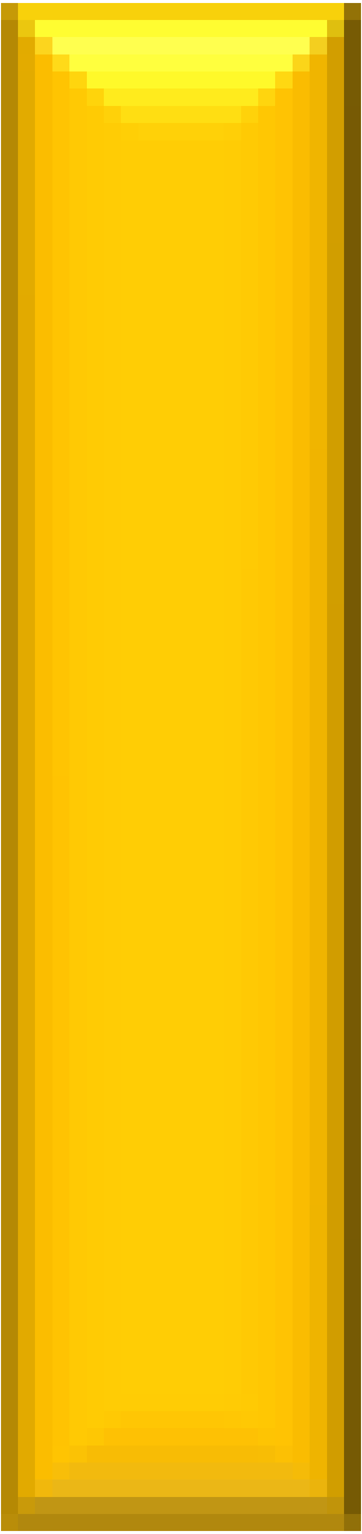
INDEX


Cents Per Mile
16
14
12
10
8
6
4
2
0
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
Year
Passenger Price Yields (Domestic)


70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
-10,000,000
Profits (000's)
1947
1953
1959
1965
1971
1977
1983
1989
1995
2001
Year
Cumulative Operating Profits
Cumulative Net Profits


40
35
30
25
20
15
10
5
0
Amount
1929
1936
1942
1948
1954
1960
1966
1972
1978
1984
1990
1996
2002
Year
Dividends Per Share

$$\sum_{t=0}^{n} \frac{(D_t + I_t)\, T_{ordt} - (CG_t)(T_c)}{(1 + r_{dt})^n} = \sum_{t=0}^{n} \frac{L_t T_{ordt}}{(1 + r_{Lt})^n}$$



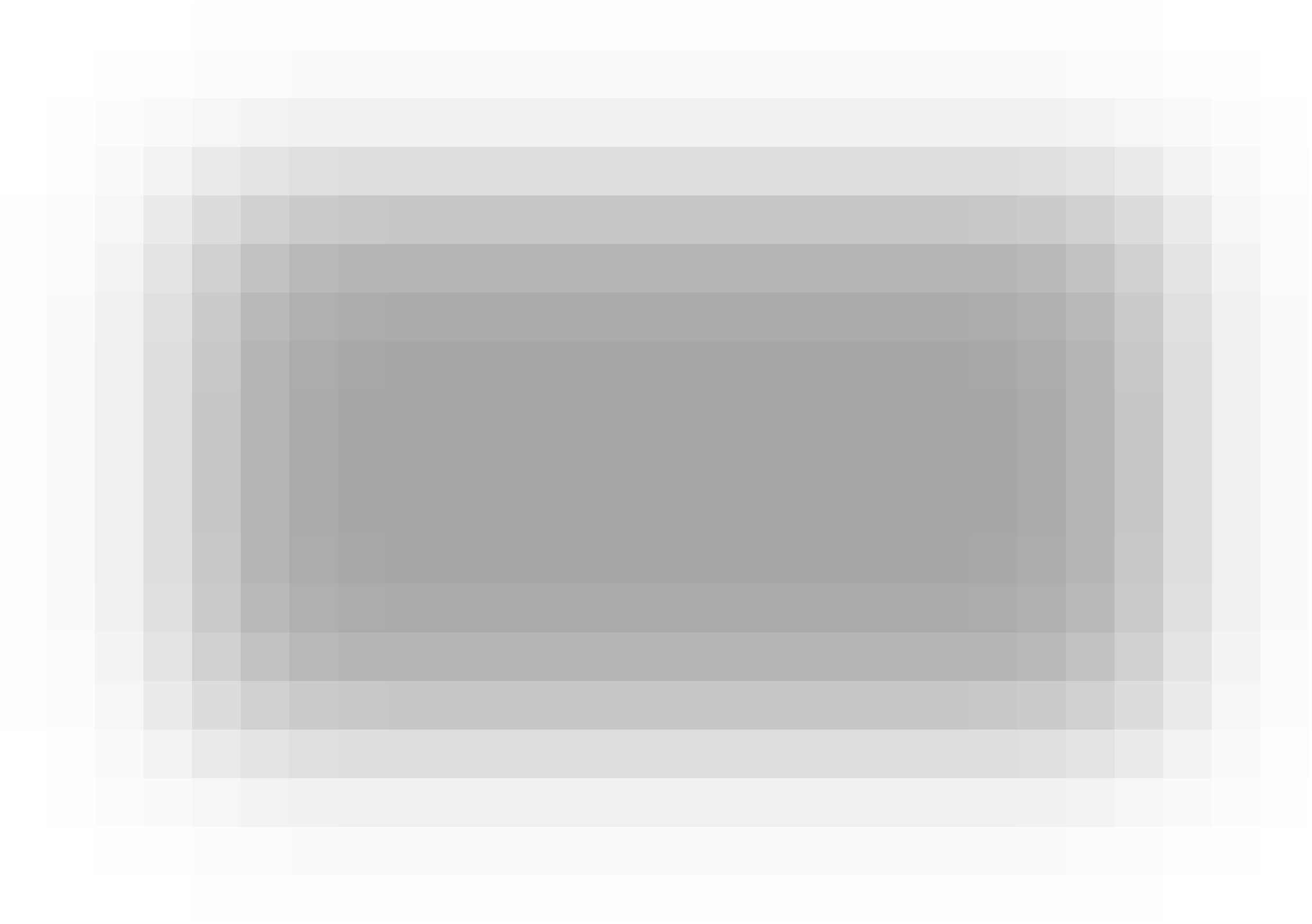
[redacted]

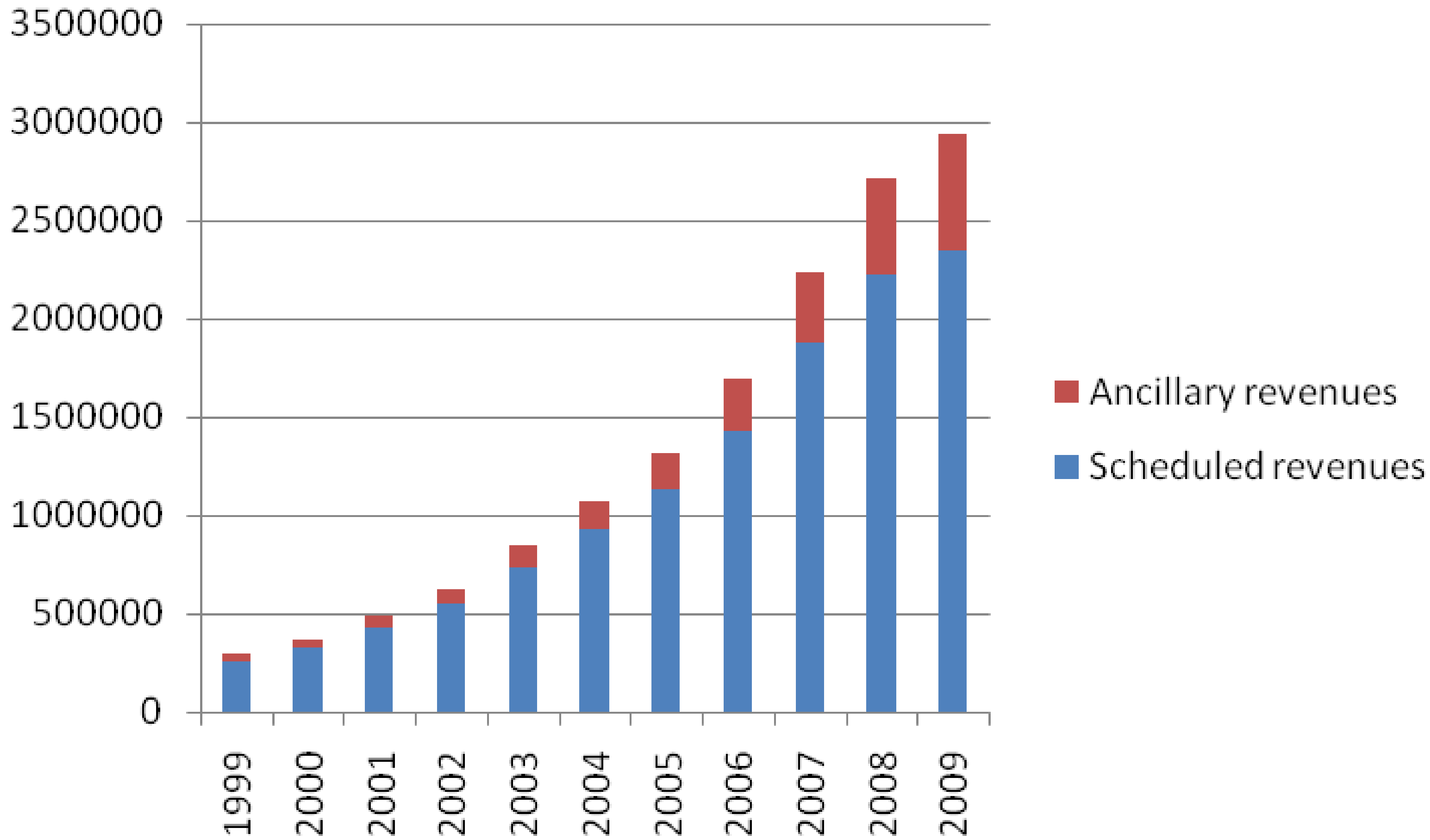
1999

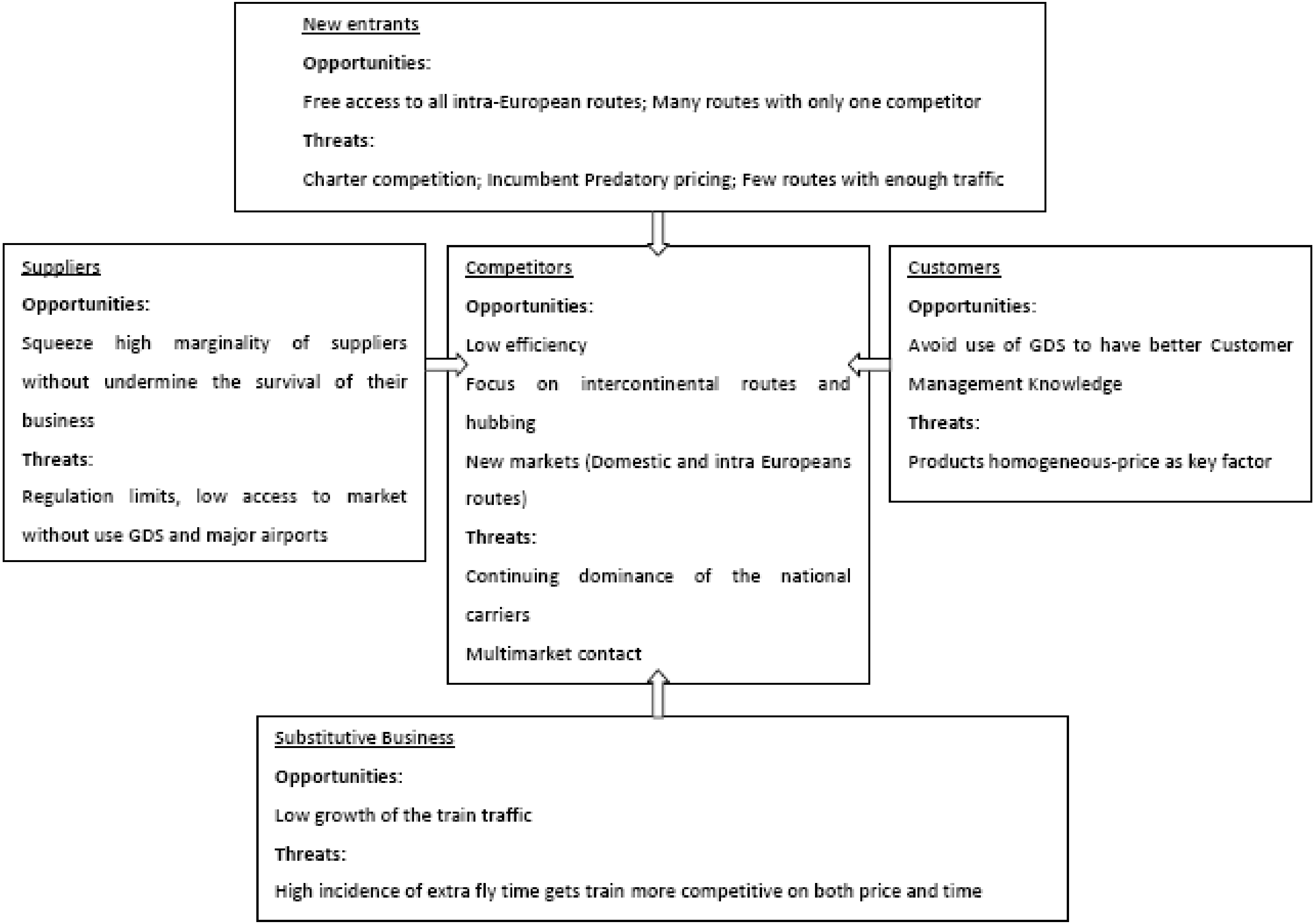
1999

2000

2009




3500000
3000000
2500000
2000000
1500000
1000000
500000
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Ancillary revenues
Scheduled revenues



New entrants

Opportunities:

Free access to all intra-European routes; Many routes with only one competitor

Threats:

Charter competition; Incumbent Predatory pricing; Few routes with enough traffic

Suppliers

Opportunities:

Squeeze high marginality of suppliers without undermine the survival of their business

Threats:

Regulation limits, low access to market without use GDS and major airports

Competitors

Opportunities:

Low efficiency

Focus on intercontinental routes and hubbing

New markets (Domestic and intra Europeans routes)

Threats:

Continuing dominance of the national carriers

Multimarket contact

Customers

Opportunities:

Avoid use of GDS to have better Customer Management Knowledge

Threats:

Products homogeneous-price as key factor

Substitutive Business

Opportunities:

Low growth of the train traffic

Threats:

High incidence of extra fly time gets train more competitive on both price and time

Airline Industry

Strategies, Operations and Safety

Transportation Infrastructure
Roads, Highways, Bridges, Airports and Mass Transit

Connor R. Walsh
Editor

NOVA