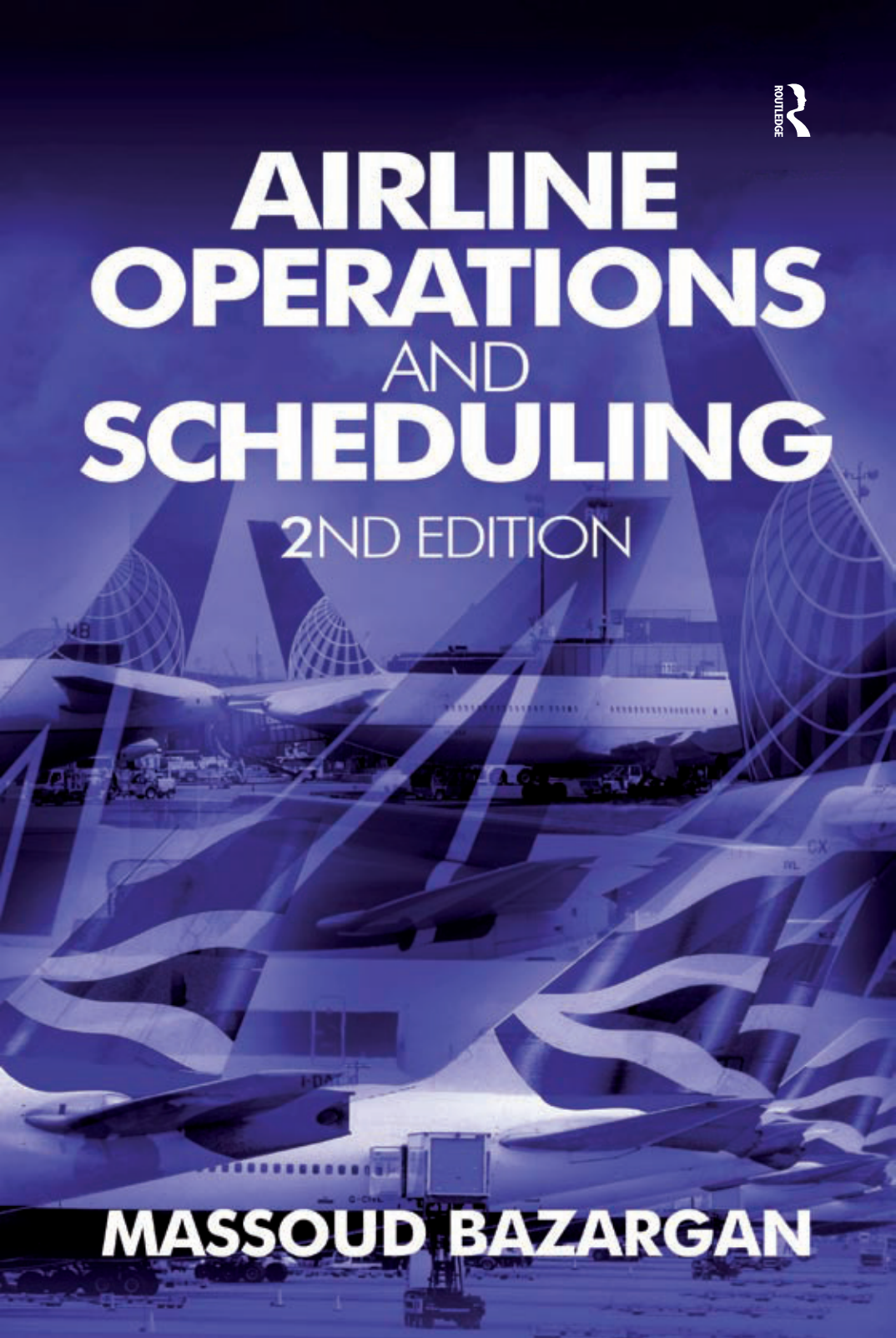
ROUTLEDGE
AIRLINE
OPERATIONS
AND
SCHEDULING
2ND EDITION
MASSOUD BAZARGAN

AIRLINE OPERATIONS AND SCHEDULING

Dedicated to my wonderful family,
Soheila, Sina, Shiva, and Sarah
and to the memory of my Mother

Airline Operations and Scheduling

Second Edition

MASSOUD BAZARGAN
Embry-Riddle Aeronautical University, USA

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Preface to Second Edition

The airline industry has evolved and gone through many challenges since the first edition of this book in 2004. It was felt that the time was right for a new edition of the book addressing these challenges. Four new chapters have been added, and the chapters in the first edition have been revised. The new chapters present real-world applications and projects that the author and his MBA students conducted for airlines and airports.

The book is divided into three major parts: planning, operation and dispatch optimization, and case studies. Two of the new chapters are in the area of operations and dispatch relating to fuel management systems and aircraft boarding strategy. A major challenge for the airlines is the significant rise in jet fuel price since the first edition was published. The chapter on fuel management systems explains how airlines purchase fuel and how they try to reduce cost by adopting fuel ferrying (tankering). The chapter on aircraft boarding strategy presents an interesting application of operations research to minimize delays in boarding passengers on to the aircraft.

The other two chapters are introduced in the case studies category. These cases relate to recent projects for airlines and airports. These two chapters are on aircraft tow tugs and airport runway-capacity planning. In both case studies, simulation modeling is utilized to identify economic and operational justification for purchasing aircraft tow tugs and to examine how capacity can be increased by changing airport runway layout configurations respectively.

The chapters in the first edition have been revised for typo errors and include more updated and recent references. In particular, Chapter 11 on gate assignment is revised to accommodate baggage handling in the mathematical model. Chapter 13 on computational complexity and heuristics has a new section about software vendors who develop solution suites for the airline industry.

The first edition of this book was published in 2004 as a result of developing an MBA course on Airline Planning and Operations in the College of Business at Embry-Riddle Aeronautical University. The course was initiated based on feedback received from alumni, mostly working at airlines, as well as students undertaking the author's operations research and operations management classes. The feedback indicated that a follow-up course, specifically focused on airline scheduling based on optimization methodologies, would be very appealing to them and to the aviation audience. The idea of developing such a course was additionally encouraged by the college's airline industry advisers. The development of the course was long and time-consuming. Owing to its unique nature, there were limited suitable texts,

and related materials are very technical, thus beyond the scope of an MBA class. Some of the motivations for the first edition include:

- Introducing the importance and complexity of planning and operations at the airlines.
- Operations research techniques are extremely important tools for planning the operations in airlines. There are a large number of technical papers on airline optimization models. However, this literature is very advanced and therefore of interest only to a limited audience. This book attempts to fill this gap by simplifying the models and applying them to relatively simple examples, thus exposing them to a larger audience.
- There has been a growing concern among the operations research community that the materials offered in operations research courses at MBA or senior undergraduate business classes are too abstract, outdated, and at times irrelevant to today's fast and dynamic world. The book seeks to provide alternative and hopefully relevant materials for such courses.

Intended Audience

This book is intended to serve both as a textbook and as supporting material for graduate and undergraduate business, management, transportation, and engineering students. Currently, the airlines spend a long time training and acquainting new recruits with the planning and scheduling processes of various operations. This book can serve as an additional resource for such training. Other aviation audiences such as general aviation, flight schools, International Air Transport Association (IATA) and International Civil Aviation Organization (ICAO) training-course instructors, executive-jet and chartered-flight operators, air-cargo and package-delivery companies, and airline consultants may find the material in this book relevant and useful.

Required Background

The main background requirement on the part of the reader for a major portion of this book is basic familiarity with linear and integer programming. Linear and integer programming topics are widely covered in many disciplines at colleges and universities at different levels. Chapters 4 and 8 require some basic understanding of statistics in general and normal distribution in particular.

Adopting this Book as a Text

The author has offered the contents of this book in an MBA course as follows:

The students are grouped into teams, three students per team, each team representing operation managers of an airline company. As the course progresses, the teams are responsible for creating their own airlines, selecting routes, flight networks, fleet diversity, aircraft routings, maintenance locations, hub and spoke systems, air and ground crew scheduling, and gate assignments. The students need to conduct thorough research on passenger demand on city pairs, fleet cost, crew cost, determine ASM, CASM, RASM, yield, and so on, for their airlines. The teams should address how to determine their fares (revenue management) and how they accommodate unexpected interruptions in their flight schedule (irregular operations). If the teams are familiar with simulation software such as Arena (www.arenasimulation.com) then they enjoy simulating the operation of each airport within their network to assess the smooth operations such as adequate numbers of check-in counters, availability of gates, baggage handlers, and so on. The teams make a final presentation of their airlines and submit a comprehensive report detailing these operations.

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Finally, I would like to thank my wife Soheila, my son Sina, and daughters Shiva and Sarah for their patience, understanding, and support throughout the writing of both editions of this book.

Massoud Bazargan

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Chapter 1
Introduction

Introduction

The United States Airline Deregulation Act of 1978 paved the way for major structural changes in the US airline industry. Airlines were allowed to select their network as well as their fares. This prompted a rush of new startup airlines to the market. After deregulation, the competition was not only between the pre-deregulation airlines, but also from the new entrants. Airlines were no longer protected, and if they wanted to be profitable, they had to manage their operations more efficiently.

Airlines use numerous resources to provide transportation services for their passengers. It is the planning and efficient management of these resources that determines the survival or demise of an airline. The airline industry is an excellent example of the 'survival of the fittest concept.' Table 1.1 shows the number of certificated airlines from 1976–2007 in the United States. The table also presents the number of airlines that were closed or merged with other airlines, and the number of newly established airlines. As the table implies, the airline industry operates in a very dynamic and uncertain environment. Furthermore, low flexibility to respond to changes, tightly coupled resources and limiting FAA regulations make the airline industry a complex environment (Yu 1998). To handle the complexity, robust and efficient planning tools and techniques are required. Operations research tools and techniques have played an important role in handling such complexities.

Operations Research and Airlines

Airlines have been using operations research techniques since the 1950s (Barnhart and Talluri 1997). Operations research models have had a tremendous impact on planning and managing operations within the airlines. The advances in computer technology and optimization models have enabled airlines to tackle more complex problems and solve them in a much shorter span of time. The vast contribution of these models has led to the establishment of operations research departments in many airlines, which help save millions of dollars. These departments have helped create an important professional society within the field of operations research, the Airline Group of the International Federation of Operational Research Societies (AGIFORS). AGIFORS is a professional society that seeks to advance, promote, and apply operations research within the airline industry (see www.agifors.org). A brief look at their website shows that Operations Research techniques have been

Table 1.1 Number of US certificated (DOT) airlines in the years 1976–2007

Year	Total Number of U.S. Airlines	Closed or Merged	Newly Established
2007	80	2	16
2006	66	11	10
2005	67	18	16
2004	69	14	18
2003	65	18	11
2002	72	3	12
2001	63	10	2
2000	71	13	9
1999	75	6	6
1998	75	12	8
1997	79	13	4
1996	88	6	9
1995	85	7	16
1994	76	8	14
1993	70	3	11
1992	62	4	12
1991	54	9	7
1990	56	7	4
1989	59	7	3
1988	63	4	5
1987	62	16	6
1986	72	15	17
1985	70	16	13
1984	73	16	21
1983	68	10	14
1982	64	28	14
1981	78	1	13
1980	66	1	13
1979	54	0	17
1978	37	10	5
1977	42	2	5
1976	39	4	1

Source: Bureau of Transportation Statistics.

successfully applied to many diverse problems such as revenue management, crew scheduling, aircraft routing, fleet planning, maintenance, and so on, within the airline industry. Barnhart (2008) discusses the accomplishment, opportunities and challenges of Operations Research in airline scheduling.

Outline of this Book

This book explores a variety of optimization models adopted by the airlines for scheduling and planning. The chapters discussing these models start with an example and then explain the process of developing a mathematical model. At the end of the chapter the general mathematical model is presented. The contents of this book are divided into three parts as follows:

Part 1 – Planning Optimization

- Chapter 2 – Network Flows and Integer Programming Models: This chapter is intended as a review of the basic concepts in network flows and integer programming models. These models are adopted later on in the following chapters.
- Chapter 3 – Flight Scheduling: Construction of flight schedules is the starting point for all other airline optimization problems. This chapter discusses the construction of flight schedules for a fictitious airline. This schedule is then used in the following chapters to address fleet assignment, aircraft routing, crew scheduling, and manpower planning.
- Chapter 4 – Fleet Assignment: Airlines typically operate a number of different aircraft, each having different characteristics, seating capacity, landing weights, and crew and fuel costs. This chapter introduces the basic fleet assignment model and its application to the fictitious airline.
- Chapter 5 – Aircraft Routing: This chapter presents the process of assigning individual aircraft to fly each flight segment assigned to the fleet. The chapter discusses mathematical models and their applications to the fictitious airline.
- Chapter 6 – Crew Scheduling: This chapter discusses the process of assigning crew to flight segments in two phases. First, crew pairing is introduced to determine which flight segments should be paired. The second phase, crew rostering, discusses how these pairings are assigned to the crew incorporating various rules and regulations.
- Chapter 7 – Manpower Planning: This chapter discusses manpower planning for ground crew through the fictitious airline case.

Part 2 – Operations and Dispatch Optimization

- Chapter 8 – Revenue Management: This chapter introduces revenue management, probabilistic models, and case studies.
- Chapter 9 – Fuel Management Systems: This chapter introduces jet fuel cost, hedging strategies, case study, and a mathematical model for fuel tankering.
- Chapter 10 – Airline Irregular Operations: When faced with a lack of resources and/or disruptions caused by various internal and external factors, airlines often are not able to fly their published flight schedule. This chapter provides an introduction to irregular operations, delays, cancellations, a mathematical model for irregular operations, and a case study.

- Chapter 11 – Gate Assignment: This chapter introduces the gate assignment mathematical model through a case study.
- Chapter 12 – Aircraft Boarding Strategy: This chapter explores various aircraft boarding strategies adopted by the airlines. It introduces a mathematical approach for an efficient aircraft boarding strategy applied to an Airbus A-320.

Part 3 – Computation Complexity and Simulation

- Chapter 13 – Computational Complexity, Heuristics, and Software: This chapter discusses inherent computational complexity with the airline problems and how heuristics are implanted to solve large scale problems. It also highlights some of the software vendors who provide solution suites for different airline problems.
- Chapters 14–18: These chapters introduce case studies on a start-up airline, and simulation modeling for airlines and airports. Simulation studies have become an alternative and/or integrated part of mathematical models when faced with complex problems.
- Appendix: provides the full name of the airports presented as their three/four letter codes in this book.

Software

Throughout this book references are made to software for solving linear/integer program models. Many of these models can be solved using student/trial versions of optimization software, which are typically available at colleges, universities, and airlines. There are many software vendors who provide these student/trial versions free to download on their websites (see, for example, www.lindo.com or www.maximal-usa.com). For larger problems, which exceed the student/trial version limits, we used full version of MPL software (www.maximal-usa.com) with CPLEX solver (www.ilog.com).

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Table 13.5 List of major ticket-distribution solution-providers Company Product Website Abacus FareX www.abacus.com.sg Amadeus Amadeus Airline R etailing Platform www.amadeus.com Galileo Galileo Agency Private Fares www.travelport.com KIU KIU System Solutions www.kiusys.com Lufthansa Systems P assenger Core Systems www.lhsystems.com Navitaire New Skies www.navitaire.com Patheo PAL , FareMate www.patheo.com Sabre Sabre Sonic www.sabreairlinesolutions.com SITA Horizon www.sita.aero W orldspan Worldspan FareS ource www.worldspan.com

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