Introduction to the Special Issue on Aviation Operations Research: Commemorating 100 Years of Aviation

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One hundred years ago amid the dunes on the Outer Banks of North Carolina, Orville Wright piloted a gasoline-powered aircraft down a single iron track. That aircraft lifted into the air, flew 120 feet, and came to a controlled landing. This flight represented the result of five years of research and experiments by two bicycle makers, Wilbur and Orville Wright. The Wright brothers developed fundamental aviation technologies that are still in use in more advanced form today, including an aileron, rudder, and elevator. Probably more important to their ultimate success was that they viewed the aircraft as a system that had to dynamically adjust to variations in conditions that could arise during flight. Competing, better-funded efforts to develop heavier-than-air flying machines did not meet the Wright brothers’ success, largely because of their lack of a comprehensive dynamic control system. The Wright brothers used the control of a bicycle as their model, noting that one must constantly adapt weight distribution, steering, and speed to keep the bike upright during travel.

Thus, in many respects the Wright brothers’ achievement can be viewed as a success for systems engineering. Of course, over the years the aircraft has developed substantially, evolving into today’s large, powerful jet. Yet, more impressive than the aircraft itself may be the systems surrounding the provision of services based on it. These include the passenger and freight air transport networks; airline-reservation systems; passenger-, crew-, and fleet-scheduling systems; maintenance operations; package-sorting systems; baggage-handling systems; etc. Operations research has played a fundamental role in the development of these systems, and their analysis has led to many important developments in the field of operations research. In fact, it can be argued that air transport systems have played a leading role in fostering the development of operations research. Air crew scheduling was one of the first real applications of integer programming. By the early 1980s, most air carriers had implemented crew-scheduling systems based on the exact or approximate solutions of integer-programming representations of this problem. Air crew scheduling motivated much of the early developments on the set-partitioning problem and continues to challenge research in the area today.

The airline industry pioneered the development of the field of yield management. Yield management is credited with increasing the revenues of the airline industry by as much as 8%. Today yield management represents one of the most vibrant research areas within operations research, and applications within a broad range of industries are now underway. The importance of operations research to aviation spurred the early development of OR groups within most major airlines. In fact, the airlines have their own operations research society: AGIFORS.

The strong link between operations research and aviation makes it very natural and perhaps mandatory to commemorate the Wright brothers’ first flight with a special issue of Transportation Science. Transportation Science is the leading operations research journal dedicated to the analysis of transportation systems. No special call for papers was released for this special issue. Rather, one overview paper was commissioned, and a set of papers was selected from the publication queue. It is a testament to the vibrancy of the field of aviation operations research that such a high-quality set of papers could be assembled from the publication queue.
The first paper, by Barnhart, Belobaba, and Odoni, provides an overview of research in aviation operations research. It focuses on three areas: aircraft- and crew-schedule planning, revenue management, and the planning and operation of aviation infrastructure. These areas probably represent the application areas that have received the most research focus. One is struck by their long history as well as their current vibrancy.

Over the past 10 years there has been an increasing awareness of the importance of effective management of airline operations, particularly in cases of major schedule disruptions, which are usually caused by weather. Operations research modelers have addressed this area by developing models to support the dynamic adjustment of schedules on the day of operations and by developing fleet-assignment and crew-scheduling models that create “robust” schedules that can better withstand various types of disruptions. The papers by Thengvall, Bard, and Yu, and by Rosenberger, Johnson, and Nemhauser fall into this first category. The Thengvall et al. paper addresses schedule recovery in the event of a very severe disruption, the closure of a hub airport. They employ a bundle algorithm to solve a Lagrangian relaxation of an appropriately defined integer program. The Rosenberger et al. model specifically takes into account reductions in airport arrival capacity, which usually results from the imposition of ground delay programs. Their model, which employs a combination of integer programming and heuristics, determines appropriate flight cancellations and rerouting to adapt to disruptions caused by weather, mechanical failures, and other events.

The previous two papers solve problems faced by airlines. The papers by Andersson, Hall, Atkins, and Ferron, and by Sherali, Staats, and Trani address problems encountered by air traffic service providers such as the U.S. Federal Aviation Administration. However, both of these papers take approaches consistent with the new collaborative decision-making (CDM) paradigm. A principal goal of CDM is to provide the airlines with more control over traffic-flow management decisions that involve economic trade-offs. Thus, while these papers deal with air traffic service provider models, they also allow for significant airline decision-making components. Andersson et al. develop an optimization-based approach to assess the benefits of a technique for sequencing aircraft arrivals into an airport, whereby the airlines have significant control over, or visibility into, the final sequencing decisions. Sherali et al. formulate and solve a model for selecting a set of conflict-free routes for a large set of flights based on airline-provided route alternatives. Their model is novel both in its use of probabilistic flight trajectories and its definition and use of measures of equity.

The paper by Willemain continues in the important tradition of operations research contributions to the modeling of flight-safety issues. Free flight is a long-range, broad objective espoused both in the United States and Europe. One of its principal goals is to eliminate, to the extent possible, artificial restrictions on the flight paths that aircraft can follow. Willemain analyzes and quantifies factors that influence collision risk in a free-flight environment.

It has been my pleasure and honor to organize this special issue. I personally wish to congratulate the authors for the quality of the contributions. I also thank John-Paul Clarke, Chair of the Aviation Applications Section of INFORMS; Bernard Gendron, Chair of the INFORMS Transportation Science and Logistics Section; and HaniMahmassani, Editor-in-Chief of Transportation Science, for supporting the development of this special issue.