A Classification and Literature Survey on Aviation Management

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***Abstract*—Aviation or air transportation refers to the activities surrounding mechanical flights in the airlines and the aircraft industries. In this paper, we present a recent literature survey on aviation management. The literature review is classified into the following main categories: Airline Capacity Analysis; Air Traffic Flow Management; Airline Fleet Assignment; Tail Assignment with Aircraft Maintenance Routing; Airline Crew Pairing; Airline Recovery and Rescheduling; Airline Revenue Management; Collaborative Decision Making; Aircraft Scheduling. This classification aims to motivate the researchers and practitioners in aviation management to develop more applicable, realistic and wide-ranging optimization methodologies for meeting the current needs of aviation industry.**

Keywords—aviation management; airline industry; aircraft scheduling; transportation research; planning and scheduling

I. Introduction

The air transportation industry has developed rapidly over the past 100 years and has become an important global economic sector. Since the 1950s, the Operations Research (OR) discipline played a key role in helping the airline industry and its infrastructure to operate in efficiency and sustain in a high growth rate. Although there are a great deal of research output on aviation management, there is a lack of precise and convenient classification on the papers recently published in leading OR journals. In this paper, we attempt to fill this gap by presenting a recent comprehensive literature survey on aviation planning and scheduling. To better organize and analyze these research ideas, we further classify them into the following nine main categories, namely, Aviation Capacity Analysis; Air Traffic Flow Management; Tail Assignment with Aircraft Maintenance Routing; Crew Pairing; Airline Recovery and Rescheduling; Airline Revenue Management; Collaborative Decision Making; Aircraft Scheduling. The main contribution of such a literature survey and classification is to motivate the researchers and practitioners in aviation management to develop more applicable, realistic and comprehensive OR methodologies that are directly linked with aviation industry.

II. Classification

A. *Aviation Capacity Analysis*

The main objective of airline capacity analysis aims to analyse the capacity of the airline facilities for aircrafts' arrivals and departures. The following leading papers addressed the airline capacity analysis problems (Barnhart et al., 2012; Dalmau and Prats, 2017; Derigs and Illing, 2013; Flores-Fillol, 2010; Kim, 2016; Lapp and Cohn, 2012; Lonzius and Lange, 2017). Dalmau and Prats (2017) investigated an optimal control problem for evaluating the effects of continuous descent operations with arrival time windows. Lonzius and Lange (2017) studied an econometric model to analyst the real-world impact of two robust scheduling methods, i.e., hub connectivity and swap opportunities. Kim (2016) applied a probabilistic simulation method to analyze the impacts of changing flight demands and throughput performance on airport delays in the recession. Derigs and Illing (2013) introduced a model-based evaluation of network configuration and optimization at cargo airlines in different European emissions trading schemes. Lapp and Cohn (2012) presented a new metric maintenance reachability model which measures the capacities and robustness of a planned set of lines-of-flights. Barnhart et al. (2012) concluded research trends and opportunities in the area of managing air transportation demand and capacity; then described a strategic approach for the better management of demand and available capacity in terms of specifying, allocating, and utilizing capacity in air transportation. Flores-Fillol (2010) proposed a congestion-pricing model to justify the interplay between flight frequency and aircraft size and thoroughly evaluated the effects of airport hub congestion..

B. *Air Traffic Flow Management*

The main target of Air Traffic Flow Management (ATFM) is to maintain the traffic flow of en route airspace and reduce the ground holding cost (Bertsimas et al., 2014; Bertsimas and Gupta, 2016; Ivanov et al., 2017; Kim and Hansen, 2015; Koepke et al., 2008; Lulli and Odoni, 2007; Zhang et al., 2017). Ivanov et al. (2017) proposed a two-level mixed-integer optimization model to solve en-route demand-capacity imbalance problem, reduce the ATFM delay and improve airport slot adherence. Zhang et al. (2017) developed the MIP models and a two-stage hybrid algorithm to solve the hub location and plane assignment problems for the air-cargo delivery service. Bertsimas and Gupta (2016) proposed a two-stage approach for that incorporates fairness and collaboration in air traffic flow management. Kim and Hansen (2015) presented a game theoretic model of a sequential capacity allocation process in a congestible transportation system and investigated the principles at work in how airlines will time their requests for en-route resources under capacity shortfalls and uncertain conditions. Bertsimas et al. (2014) introduced a binary optimization framework for modelling dynamic resource allocation problems. The framework was applied to three widely studied problems, namely, the Air Traffic Flow Management, the Aircraft Maintenance Problems and Job Shop Scheduling.

C. Airline Fleet Assignment

The main objective of Airline Fleet Assignment is to specify what size aircraft to assign to each flight, which are exemplified by the following important papers in the literature (Andreatta et al., 2011; Barnhart et al., 2012, 2009; Bélanger et al., 2006; Benlic, 2018; Bertsimas et al., 2011; Haddad et al., 2008; Haouari et al., 2009; Liang et al., 2014; Pilla et al., 2012; Rey et al., 2016; Safak et al., 2017; Sherali et al., 2006a; Sherali and Zhu, 2008; Smith et al., 2012). Safak, Gurel and Akturk (2017) developed an integrated aircraft-path assignment and scheduling problem with the consideration of flight timing, passenger demand and fuel consumption cost related to cruise speed control. Rey et al. (2016) presented a deterministic conflict resolution model adapted to subliminal speed control. The proposed models are formulated as nonlinear optimization problems that seek to minimize indicators related to air traffic controllers' workload. Liang et al. (2014) developed a flight sequence assignment model (FSAM) that selects an optimal set of flight sequences to minimize the total penalty cost. Smith et al. (2012) investigated the weight constrained shortest path problem with replenishment and developed a new algorithm that exploits the inter-replenishment path structure. Andreatta et al. (2011) developed an aggregate stochastic programming model for airline fleet management with three important aspects, namely, uncertainties in airport capacities; trade-off between aircraft arrivals and departures; and interactions between different airport hubs.

D. Tail Assignment with Aircraft Maintenance Routing

Most papers on Tail Assignment and Aircraft Maintenance Routing aim to determine how to assign the airplanes to flight legs and route the aircrafts to minimise the total flight operating and maintenance cost (Ben Ahmed et al., 2017; Faust et al., 2017; Grönkvist, 2006; Khaled et al., 2018; Liang et al., 2015; Maher et al., 2014; Marla et al., 2018; Quan et al., 2007; Reményi and Staudacher, 2014). Marla et al. (2018) discussed different classes of robust aircraft routing models from a data-driven perspective. Khaled et al. (2018) developed a compact mathematical formulation model to solve the airplanes' tail assignment problem (i.e., assigning the airplanes to flight legs) with the objective of minimizing the total flight operating and maintenance cost. Ben Ahmed et al. (2017) introduce a hybrid optimization-simulation aircraft scheduling methodology, methodology, in which a mixed-integer nonlinear programming model is developed for optimize aircraft maintenance routing and a Monte-Carlo-based procedure is used for sequentially adjusting the flight departure times. Faust, Gönsch and Klein (2017) developed a new integrated scheduling problem to optimize the choice of flights and aircraft maintenance routing based on the real-world data provided from an airline information technology provider called Lufthansa Systems. Liang et al. (2015) solved two closely related airline planning problems, i.e., the robust weekly aircraft maintenance routing problem and the tail assignment problem, in order to minimize the total expected propagated delay of the aircraft routes. Weiszer et al. (2015) developed a real-time active routing approach via a database for airport surface movement. Maher et al. (2014) investigated the single day aircraft maintenance routing problem by applying the recoverable robustness framework and the Pareto-optimal approach. Reményi and Staudacher (2014) proposed a systematic-simulation-based approach for the identification and implementation of a scheduling rule in the aircraft engine maintenance.

E. Airline Crew Pairing

The Airline Crew Pairing problem in aviation management aims to assign the appropriate personnel to each flight for minimising the total crew cost (Beliën et al., 2013; De Bruecker et al., 2018, 2015; Ho and Leung, 2010; Maher et al., 2018; Quan et al., 2007). De Bruecker et al. (2018) developed a three-stage mixed integer programming method to optimize the skill mix and training schedule of aircraft maintenance workers. De Bruecker et al. (2015) developed a new mixed integer linear programming model to obtain the robust aircraft maintenance personnel rosters with the objective of minimizing the total labour costs. Maher (2015) applied the column-and-row generation solution approach to solve a passenger recovery problem through a unique description of the cancellation variables in the event of flight cancellations. Beliën et al. (2013) proposed a mixed integer linear programming model for constructing the workforce schedules of an aircraft maintenance company. Ho and Leung (2010) investigated a manpower scheduling problem for airline catering whereby airline meals and other supplies are delivered to aircrafts on the tarmac just before taking-off. Tabu search and simulated annealing metaheuristics are developed to solve this manpower scheduling problem.

F. Airline Recovery and Rescheduling

Most studies on Airline Recovery and Rescheduling aim to handle unexpected disruptions (e.g., storms, frog or haze) and prevent them from operating in routine to reduce the delay propagation (Aktürk et al., 2014; Arıkan et al., 2017; Atkinson et al., 2016; Burke et al., 2010; Cadarso and de Celis, 2017; Clausen et al., 2010; Eggenberg et al., 2010; Kohl et al., 2007; Maher, 2015; Manley and Sherry, 2010; Mukherjee and Hansen, 2007; Rosenberger et al., 2003; Takeichi, 2017; Thengvall et al., 2003; Zhang et al., 2016). Takeichi (2017) developed a nominal flight time optimization method to minimize the delay accumulation of the whole traffic stream. Zhang et al. (2016) investigated an integrated airline service recovery problem in which the aircraft and passenger schedule recovery problems are simultaneously considered, with the objective of minimizing aircraft recovery and operating costs, passenger itinerary delay cost, and passenger itinerary cancellation cost. To solve this complicated problem, a three-stage sequential math-heuristic approach is developed to solve the flight schedules and aircraft rotations in the first stage. Then, a flight rescheduling problem and passenger schedule recovery problems are iteratively solved in the next two stages. Atkinson et al. (2016) investigated how three common practices (i.e., flexibility to swap aircraft, flexibility to reassign gates, and scheduled aircraft downtime) to mitigate the effect of unanticipated disruptions on airlines' profits. It is found that "the per-dollar return from expenditure on gates, or more effective management of existing gate capacity, is three times larger than the per-dollar returns from other inputs". Akturk et al. (2014) proposed an airline recovery optimization model to achieve good balance between fuel consumption and cruise speed due to flight rescheduling situations.

G. Airline Revenue Management

The Airline Revenue Management problem aims to fill each flight with the maximum possible revenue to maximize the total profit (Abdelghany et al., 2017; Bollapragada et al., 2007; Czerny et al., 2017;Yan et al. 2019; Ge et al., 2010). Abdelghany et al. (2017) developed a flight timetabling modelling framework to maximize the airline's revenue by satisfying the constraints of the airline's resources (e.g. aircraft and crew) as well as passenger demand shift due to the network-level competition. Czerny et al. (2017) compared the optimal mix of per-passenger and per-flight based airport charges from the carriers' and the social viewpoints when carrier markets are oligopolistic. The proposed method is able to reduce the airport aeronautical charges which are traditionally aircraft-weight related and to increase the share of aeronautical airport revenues derived from passenger related charges. Ge et al. (2010) proposed an overbooking model to handle the optimal transferring quantity among flights with different departure times and the overbooking limit of each flight. Bollapragada et al. (2007) developed an integer programming model to minimize the total portfolio cost of long-term service agreements for the maintenance of capital-intensive equipment.

H. Collaborative Decision Making

The main idea of Collaborative Decision Making is to build up a decentralization framework through the application of a dedicated communication network and a standard set of database systems (Adler et al., 2013; Grushka-Cockayne et al., 2008; Lo and Hall, 2008; Masoud et al. 2016a, 2017, 2011; Sherali et al., 2011, 2006b, 2003; Yao et al., 2008). Benchmarking airports is currently popular both in the academic literature and in practice but has proved rather problematic due to the heterogeneity inherent in any reasonably sized dataset. Most studies either treat the airport production technology as a black box, or separate the terminal and airside activities, assessing them individually. To deal with this issue, Adler et al. (2013) applied a Data Envelopment Analysis (DEA) method to describe the each airport's individual reference set, and unique outliers influence for benchmarking airports. Sherali et al. (2011) investigated an airspace flow program in the context of weather-related disruptions by augmenting the airspace planning and collaborative decision-making model. Yao et al. (2008) addressed some strategic planning issues such as aircraft maintenance, crew swapping, demand increase and differentiation in fractional aircraft ownership programs. Grushka-Cockayne et al. (2008) developed an integrated decision-making approach to identify a preferred set of improvements on the arrival and departure procedures of aircrafts. Sherali et al. (2006) further addressed the airspace-planning and collaborative decision-making model's parameter estimations and implementation test results. Sherali et al. (2003) introduced a large-scale airspace planning and collaborative decision-making model to enhance the management of the U.S. National Airspace System with the consideration of probabilistic conflicts, workload, and equity.

I. Aircraft Scheduling Problems

Aircraft Scheduling Problems (ASPs) aims to aims to determine the accurate timing information (timetable/schedule) of each aircraft on the airport terminal resources (e.g., taxiways, air segments, runways) in such that any potential conflicts between aircraft are resolved at a microscopic level. In practice, however, air traffic control operations and related issues are still scheduled by human controllers, who construct feasible aircraft schedules in the airport terminal control area based on their previous experience, intuition and straightforward scheduling rules without using performance indicators. A detailed description and the literature review on the ASPs can be found in the recent publications (D'Ariano et al., 2015; Samà et al., 2017, 2014, 2013). The theoretic footstone of the ASPs methodology is actually based on the extensions of job shop scheduling models (D'Ariano et al., 2015; Liu et al., 2018; Liu and Kozan, 2017, 2016, 2011, 2009; Masoud et al. 2016b, 2013, 2015; Samà et al., 2017). In terms of this main idea, we will report a detailed literature review in another journal paper which is being under preparation.

III. Conclusion

In conclusion, this paper presents a recent literature survey on aviation management. The literature review is classified into nine main categories, namely, Airline Capacity Analysis; Air Traffic Flow Management; Airline Fleet Assignment; Tail Assignment with Aircraft Maintenance Routing; Airline Crew Pairing; Airline Recovery and Rescheduling; Airline Revenue Management; Collaborative Decision Making; Aircraft Scheduling. Based on this literature review and classification, we discern that the research on the aircraft scheduling problems at the operational level is receiving more and more attention, because aviation authorities are seeking advanced scheduling optimization tools for the better management of the available infrastructure and resources.

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