Journal of Air Transport Management 59 (2017) 143–154

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Optimal assignment of aircrew trainees to simulator and classroom training sessions subject to seniority and preference restrictions

George Kozanidis

Systems Optimization Laboratory, Department of Mechanical Engineering, University of Thessaly, Volos 38334, Greece

ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form
27 November 2016
Accepted 27 November 2016
Available online 15 December 2016

Keywords:
Aircrew training
Strict seniority
Preference restrictions
Assignment problem
Integer programming
Airline management

ABSTRACT

We develop an integer programming model and an exact solution methodology for assigning aircrew members to training sessions which they need to attend in order to fulfill the requirements for renewal of their flight capability. The aim is to find the optimal assignment that minimizes the number of unassigned trainees, while also satisfying a variety of seniority, preference, capacity and language compatibility restrictions. The proposed methodology partitions the aircrew members into distinct groups based on their seniority, making the optimal assignment decisions pertaining to each of these groups sequentially. We present extensive computational results demonstrating that the proposed methodology enables the solution of realistic size problems in moderate computational times.

1. Introduction

We consider the problem of assigning a set of aircrew members to training sessions which they need to attend in order to fulfill the requirements for renewal of their flight capability. Typically, a set of training sessions sufficient for covering the training needs of the crew is determined at an earlier stage, while the assignment of trainers and trainees to these sessions is made independently at a later stage, taking into consideration various hard and soft preference restrictions. Each crew member is characterized by his/her seniority, the language(s) he/she speaks, the month after which his/her flight capability expires, a list of valid sessions to which he/she can be legally assigned, and a list of priorities expressing his/her preference order for each of his/her valid training sessions. The aim is to find the optimal assignment that minimizes the number of unassigned trainees subject to a variety of seniority, preference, capacity and language compatibility restrictions. The seniority restrictions dictate that the satisfaction of a crew member's preference must never be attained at the expense of the dissatisfaction of a more senior crew member's preference. The preference restrictions dictate that the maximum preference satisfaction must be attained for each individual crew member, according to the priority order that he/she has expressed. The capacity restrictions dictate that the trainee capacity of each session should not be violated. Finally, the language restrictions dictate that all crew members assigned to the same session must be compatible with the spoken language of that session.

We consider two different versions of this problem, both encountered in the typical operation of an actual commercial airline. In the first one, training is performed in simulators, while the crew members to be assigned are pilots (captains - CPs) and co-pilots (first officers - FOs). In this case, the capacity of each session is equal to 1 for CPs and 1 for FOs. In the second version of the problem, training is performed in classrooms, and the crew members to be assigned are of various positions. In this case, the capacity restrictions apply to individual positions, to position groups, as well as to the total number of crew members.

For each of these two problem versions, we develop an integer programming formulation and an associated exact solution methodology. The existence of the seniority and the preference restrictions makes impractical the one-step application of this methodology; therefore, it is employed in subsequent rounds, with the assignment of the most senior unassigned crew members being determined in each of these rounds, and then being fixed and passed as input for the determination of the assignment of the less senior ones. This approach has been used successfully in the past for solving airline management problems which include similar

E-mail address: gkoz@mie.uth.gr.

http://dx.doi.org/10.1016/j.jairtraman.2016.11.012
0969-6997/

crew seniority and preference restrictions.

The present research has been conducted in the occasion of a fruitful collaboration with AIMS Inc. (2016), a company that, since 1983, has been engaged in the development of a quite advanced and highly popular software package for the efficient management of airline operations. The problem under investigation arises in the typical operation of an actual airline client of AIMS, whose name is available but is not disclosed for confidentiality reasons. This airline has been using the proposed methodology for the last 3 years, with very positive feedback so far and no critical problems/bugs having being reported whatsoever. Some of the computational results that we present in Section 6 pertain to problem instances drawn from the live database of this airline, to which AIMS has full access. These results demonstrate the performance of the proposed methodology on realistic problem scenarios and predispose the reader of the computational difficulties that might arise in practice.

One of the main contributions of the present work is the development of an original unified methodology for addressing an important airline optimization problem arising in practice, without any simplifications that would cause deviation from reality. To the best of our knowledge, this problem has not been addressed in the related airline management literature in the past. Although the proposed optimization model includes some constraints which are typically employed in similar application contexts, it also utilizes customized modeling techniques to accommodate special problem requirements, such as the reverse expiration/seniority constraints. The extensive computational results that we present demonstrate the efficiency of the proposed methodology, and highlight the problem parameters which have a strong impact on its performance. These results show that the exact optimal solution of realistic problem instances can be identified in very reasonable computational times.

The remainder of this work is structured as follows. In Section 2, we summarize the related literature, while in Section 3 we develop two integer programming models for the formulation of the two versions of the problem under consideration. In Section 4, we develop the proposed solution methodology, while in Section 5, we discuss some interesting problem extensions and we illustrate how this methodology can be modified in order to accommodate them. In Section 6, we present extensive computational results demonstrating the performance of this methodology on a collection of both realistic as well as random problem instances. Finally, in Section 7 we summarize the present work and we point to promising directions for future research.

2. Literature review

Although there is a large number of research works that address typical airline optimization problems such as aircrew scheduling, tail assignment, fleet planning, pairing generation and disruption handling, in the related published literature there are only a few research works that address aircrew training related decision making problems such as the one that we address in this paper. One of the earliest such works is that of Shapiro (1981), who develops a three-phase solution approach for scheduling crewmen for recurrent training at American Airlines. The first phase of this approach decides the assignment of students to slots, taking into consideration only a subset of the original problem constraints. The second phase performs a feasibility check on the obtained solution, and finally, if this check fails, the third phase tries to repair the diagnosed infeasibilities using heuristics.

Haase et al. (1998, 1999) address the problem of constructing annual course schedules for aircrew training at Lufthansa's technical training center. For this problem, the authors formulate an integer programming model maximizing the airline's profit, while taking into consideration a variety of complex precedence, temporal, and resource-related constraints. In a more recent related work, Qi et al. (2004) address a class scheduling problem for pilot training at Continental Airlines. The aim is to find the minimum weighted length schedule of training classes which must be attended by crew members who have bid for changing their position, home base or fleet type. The motivation behind doing so is that this also minimizes the associated airline cost, since pilots are paid but do not provide any service while in training. The authors solve the problem with a branch and bound algorithm and a family of heuristics. The main difference that the above works exhibit with respect to the present one is that they address the class scheduling and not the trainee assignment aspect of the problem. In the problem that we address in this work, on the other hand, the schedule of each class is predetermined.

Yu et al. (1998, 2003, 2004) develop a decision support system for pilot planning and training optimization at Continental Airlines. This system is capable of determining optimal pilot transitions and training schedules subject to a variety of constraints, such as strict seniority, resource capacity, aircrew availability, etc. A related optimization model for typical airline manpower planning operations such as aircrew training and vacation allocation has been developed by Holm (2008). The main difference that this model exhibits with respect to the present one is that the training course that each crew member must attend is predetermined; thus, no related assignment decisions are involved. On the other hand, that model considers various other decisions, such as the schedule of the courses and the crew members' training and vacation plan.

Xu et al. (2006) address the flight instructor scheduling problem, which aims to schedule instructors to teach a set of pilot training events. They develop a multi-objective mathematical model for this problem, which they then convert into a single objective model using suitable weights. The authors solve the problem with a dynamic neighborhood based tabu search algorithm, and illustrate its application on a major US airline carrier. Rather than focusing on the trainees' assignment, this work addresses the trainers' scheduling aspect of the problem. Due to the fact that this problem exhibits significantly different requirements than those of our problem definition, its mathematical formulation incorporates considerably different problem parameters, such as the labor cost and the workload consistency.

The published work that seems to exhibit the most similarities with the present one is that of Sohoni et al. (2003), who develop a mathematical model for optimizing continuing-qualification-training schedules for pilots. Although that model includes trainee assignment decisions, each assignment pertains to entire schedules composed of mixed duties, reserves, off days and training days, and not to individual training sessions, as in the case of the present one. To the best of our knowledge, the present aircrew training assignment problem with special capacity, seniority, preference, and language compatibility constraints has not been addressed in the related literature. Yet, this is an important problem encountered not only in the typical operation of the commercial airline industry, but in the military aviation as well. In fact, the proposed methodology has been incorporated into AIMS' standard software suite and has already been distributed, after suitable customization, to other of its airline clients who address similar decision making problems. With this in mind, we present next the proposed methodology for addressing this problem, starting with the optimization model formulation.

3. Model development

In this section, we present the problem definition and we develop two integer programming models for the formulation of