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Aircraft schedule recovery problem – a dynamic modeling framework for daily operations

Hans-Wieger M. Vos [a], Bruno F. Santos [a,*], Thomas Omondi [a,b]

[a]*Air Transport and Operations, Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands*
[b]*Kenya Airways, Airport North Road, Embakasi, P.O. Box: 19002 00501 Nairobi, Kenya*

Abstract

In this paper we present an innovative dynamic modeling framework to the aircraft schedule recovery problem (ASRP). The ASRP can be defined as the problem of modifying the flight and aircraft schedules to compensate the presence of irregular operations that result in the temporary or permanent unavailability of aircraft. Previous works on this topic often make use of static disruption test scenarios, simulating a set of disrupted events in a single time evaluation. The modeling framework here presented, named Disruption Set Solver (DSS), is innovative because it tackles aircraft schedule disruptions in a dynamic way (i.e., the recovery problem is solved as disruptions happen, involving the solutions of new disruption but also considering decision the incumbent solution) and because it is the first time that parallel time-space networks are used to track individual aircraft in the fleet. The framework relies on the combined usage of an efficient aircraft selection algorithm and a linear-programming model based on parallel aircraft specific time-space networks. The goal of the optimization model used to solve the ASRP is to minimize costs, including operational, passengers delay and cancellation costs. The decision variables involve the cancellation of flights, the delay of flights and the swap of aircraft between flights. The validation of the framework is done applying it to a set of real disruptive days in the operation of a major African airline. The results suggest two conclusions: (1) that the traditional static approach can lead to unreliable solutions, neglecting practical challenge and underestimating the disruption costs; and (2) that the proposed dynamic DSS framework can solve real aircraft schedule disruption problems within a time-window suitable for real-time operations.

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1. Introduction

The operation of an airline requires the allocation of resources such as aircraft and crew members to air services. The allocation plan is defined in advance of the day of operations, aiming at the most efficient use of the resources available. However in practice, operations are usually associated with disturbances such as severe weather or aircraft

* Corresponding author. Tel.: +31-(0)15-2782-713
E-mail address: b.f.santos@tudelft.nl

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mechanical failure. If these disturbances are not properly managed they can cause a large impact on operations, not only locally but also through the airline network.

To minimize the effect that disruptions have on planned operations there are two approaches. The first is a proactive approach, making sure that there is enough buffer within a schedule to cope with disruptions. This approach is often referred to as robust scheduling. The second is a reactive approach, which consists on the re-planning of resources once a disruption has occurred, referred to as recovery operations. When the focus of the recovery effort is on the aircraft, the problem of recovering operations is called the aircraft schedule recovery problem (ASRP). The ASRP can be defined as the problem of modifying the flight and aircraft schedules to compensate the presence of irregular operations that result in the temporary or permanent unavailability of aircraft.

This paper is focused on ASRP and presents an innovative dynamic modeling framework to solve the problem. The modeling framework, named Disruption Set Solver (DSS), was developed by Delft University of Technology in a collaborative project with Kenya Airways Vos (2015). Dynamic modeling refers to the technique where disruption are solved as they become known, which is in fact a simulation of reality. This approach is compared to the approach where a set of disruptions is solved as if all disruptions were known at the beginning of the day of operations. To this last approach we call the static approach, which is the traditional approach in the literature. This research is based on the assumption that this traditional approach is not suitable to solve the ASRP in real world applications.

The structure of this paper is as follows. It starts with a brief summary of the literature and research trend on the topic (Section 2). Section 3 describes the DSS framework and methodology used. The framework is tested on real-life disruption cases provided by and tested at Kenya Airways. A description of the the situation at Kenya Airways and the case study used to test the proposed framework are described in Section 4. Section 5 discuss the results achieved by the created model in terms of computational performance and provides a comparison between the dynamic and the static approach. The last section summarizes the main conclusions.

2. Literature Context

The research on recovery operations problems started in the 1980's. The early research simulated the manual approach that airline operators use, splitting the recovery of aircraft, crew and passengers into separate problems and solving them sequentially (e.g., see Teodorović and Guberinić 1984 and Yan and Yang 1996 for the case of the aircraft problem). Doing so resulted in problems which were more tractable, however still required considerable simplifications in order to solve them within a reasonable time.

In the late 1990's the use of heuristics in airline recovery operations started with the research presented by Arguello et al. (1997). This research inspired other researchers to follow similar approaches. As the research moved forward new works discussed the integrated version of the recovery operations problem, combining the aircraft recovery problem with crew and passenger recovery problems. The attempt by Petersen et al. (2012) is the most comprehensive research in the integrated recovery of aircraft, crew and passengers. However, the computation times are arguably not fit for real time use. For a recent review on the recovery operations topic, please refer to Clausen et al. (2010).

It is a recent trend in the general airline operations decision-support research field to look at practical challenges in the implementation of solution techniques. That is, to consider more realistic features of the problem in the formulation of decision-support tools. This includes, for instance, the incorporation of the dynamics aspects of the problem or the improvement of the human-machine interface in the decision-support tool. Nonetheless, this is still an emerging trend in the airline recovery literature.

This papers contributes to the literature by presenting an realistic dynamic approach to the particular case of the recovery operations problem, the ASRP. Although Stojković et al. (2002) and Babić et al. (2010) have already proposed decision support tools to handle the ASRP problem in real-time, our approach is the first to model multiple aircraft types in the decisions support system.

3. Methodology

The dynamic characteristic of the modeling framework proposed is given by two key feature. The first is that in the framework the set of disruptions is not known at the beginning of the disruption scenario. Instead, the information of these disruptions is made available as they happen, with the evolution of time. This way, the ASRP problem is