A non-time segmented modeling for air-traffic flow management problem with speed dependent fuel consumption formulation

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ABSTRACT

Aircraft en-route flight planning is one of the major challenges for Air Traffic Control operations. Poor planning results in undesirable congestion in the air-traffic network, causing major economic losses for both airline companies and the public. Furthermore, heavy congestion generates flight safety risks due to increased possibility of mid-air conflict. To address these problems, this paper introduces a non-time segmented en-route flight plan formulation with rerouting options for aircrafts in a 3-dimensional (3D) capacitated airspace. Novelty of the proposed mathematical model is the non-time segmented formulation that captures exact arrival and departure times to/from each air-sector. The proposed formulation also incorporates sector capacity changes due to changing weather conditions during planning horizon. Moreover, the speed dependent fuel consumption rate is introduced as a factor in the zone-based air traffic flow management problem. In order to handle the problem sizes similar to those in real-world cases, we proposed a sequential solution heuristics. The performance of the sequential solution method is demonstrated through various test cases.

1. Introduction

Since 1980s, congestion in United States (US) air-traffic network has become an increasing problem with serious economic and social consequences (Richetta, 1995). Past three decades, the demand for air transportation around the world has precipitated a significant growth in passenger volume, as well as the number of airline companies providing service. According to International Air Transport Association (IATA) forecasts, the demand for air transportation will double over the next 20 years (IATA, 2016). Other studies further suggest that the demand for air-traffic will continue increasing (Boeing, 2011; Leal de Matos & Powell, 2003). The resulting traffic conditions will cause significant bottlenecks in most parts of the world. As a result of this augmenting demand for the air transportation, the Air Traffic Flow Management (ATFM) has been an increasingly challenging task for both academia and industry (Bertsimas, Lulli, & Odoni, 2008). Therefore, the development of new methodologies and strategies for managing air-traffic flow in densely populated airspaces and airports is vital for the future of the air transportation industry. Among various alternatives, the development of modern tools for capacity management in which the flow rate of air traffic is matched with the available capacity of air-segments and airports in the Air Traffic Control (ATC) network requires special attention from both academia and industry. The capacity management in aerospace is known as the Flow Management Problem (FMP), which is particularly important when weather conditions significantly decrease the capacity of the ATC system (Richetta, 1995).

The mathematical model proposed in this paper aims to improve the efficiency of ATC by incorporating the aircrafts’ exact arrival and departure times and ensures the avoidance of mid-air collision. While the traditional concerns, the minimization of delays and earliness represent the main body of the objective function, the cost of fuel consumption as a function of average aircraft-speed at each air-sector has successfully been introduced in the formulation. In this paper, the entire airspace is divided into capacitated air segments. The en-route flight plans for all aircrafts are determined in such way that the capacities of air-segments are upheld and mid-air conflicts are avoided. Unlike most other research work on the same topic, the described mathematical model avoids time-segmented modeling approach.

The remainder of this paper is organized as follows. First, a brief literature review in the realm of the air traffic management is provided. Next, the model and its distinctive features are discussed. In Section 4, proposed solution strategies are presented and performance gains have been demonstrated. Finally, conclusions and future work are summarized in Section 5.

2. Literature review

The ATFM problem under several different extensions has been well