Multi-Objective, Multi-Stakeholder Airport Slot Scheduling Considering Expected Delays

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Motivation and problem description

Airport congestion is caused by excess airline demand for limited airport capacity and results to delays and multi-billion costs with significant economic, societal implications affecting passengers, airlines and airports. Meanwhile, airport capacity expansions require a long-term planning and implementation horizon, as well as huge financial and spatial resources. To mitigate delays and improve the utilization of existing airport capacity, the industry has adopted administrative demand management mechanisms. The most common demand management mechanism is the Airport Slot Allocation (ASA) defined in the World Airport Scheduling Guidelines (WASG) [1]. Despite the ongoing pandemic, ASA is being applied in about 200 airports which accommodate 40% of global passenger demand [2].

Current literature and Contributions

Existing multi-objective ASA studies either assume an ad-hoc weighting/ordering of the objectives [3] that results to a single airport schedule, or generate multiple non-dominated solutions providing information on the trade-offs among the considered objectives [4]. Existing studies have provided improved decision-support through the consideration of airlines' preferences with respect to the displacement that they receive [4, 5], yet there are no studies to holistically consider the preferences of the airlines, airports, air navigation service providers and coordinators (hereafter referred to as ASA stakeholders) with respect to multiple objectives. Furthermore, none of the existing studies incorporating preferences is based on empirical data expressing the preferences of the stakeholders involved in and affected by the slot allocation process. In addition, none of the existing ASA models assesses the implications of the proposed schedules on the expected delays experienced during the most congested days of the scheduling season. The importance of expected delays has been recognized by tactical ASA models that introduce scheduling interventions a few days prior to operations [5, 6], yet we note the dearth of expected delay considerations in strategic ASA models. In this presentation, we introduce a multi-objective, multi-stakeholder ASA framework that addresses the above identified gaps through the holistic consideration of the ASA stakeholders' preferences regarding both the displacement-related performance and the operational delay characteristics of each schedule. We also present results from the application of the proposed framework using data obtained through a survey with industry experts. Our results shed light on the effect of the stakeholder preferences on slot scheduling performance.

Methodology

The proposed framework integrates a tri-objective ASA mixed integer programming model and generates the complete set of non-dominated schedules for any triplet of linear objective functions using an efficient multi-objective solution technique [7]. Having full information on the non-dominated schedules that can be achieved, the framework reduces decision-making complexity by pruning non-dominated schedules without compromising the representativeness of the alternatives offered to the stakeholders. The operational delays of each representative solution are estimated using a strategic delay estimation model, and the schedules are ranked based on the stakeholders' preferences concerning both displacement and operational delay metrics. A schematic overview of the proposed framework is provided in Figure 1.

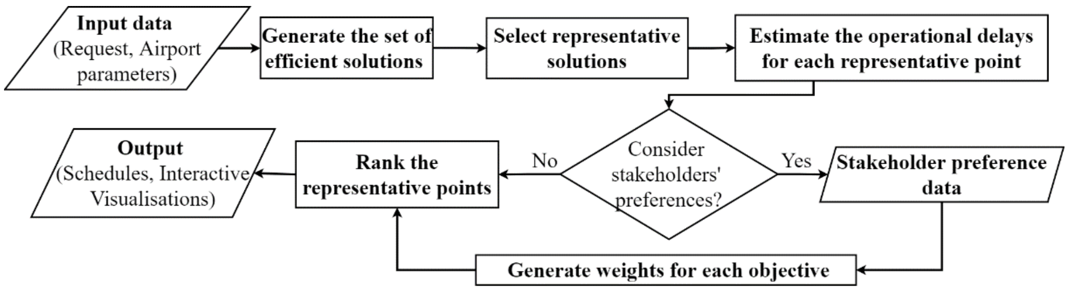

Figure 1: *Overview of the proposed framework*

Findings and decision-making implications

The proposed framework facilitates a more collaborative ASA decision-making process through the consideration of ASA stakeholders' preferences and provides more acceptable schedules with beneficial implications on airport capacity utilization. The proposed framework may facilitate the adoption of mathematical ASA models and algorithms by practice, since ASA stakeholders may experiment with alternative preference considerations and study their implications on the efficiency of the proposed airport slot schedules. We provide evidence that the schedules selected under alternative preference considerations have different characteristics and demonstrate that our framework can elicit schedules that balance the preferences of the stakeholders. In particular, for the considered instance, the proposed schedule achieves consensus among airlines, coordinators and airport authorities. Furthermore, our analyses exhibit that the consideration of expected delays not only allows stakeholders to review the impact of their preferences on the delays experienced during congested days, but also facilitates the quantification of the benefits associated with the airport's current declared capacity setting.

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