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A SIMHEURISTIC APPROACH TO SOLVE TACTICAL AIRPORT GROUND SERVICE EQUIPMENT PLANNING

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ABSTRACT

In this study we work on a tactical level airport decision problem: daily allocation of Ground Service Equipment based on the flight schedule, as well as potential foreseeable deviations from the original operations plan. We integrate simulation within an overall Simulation-Optimization framework, falling within the family of so-called Simheuristics, to deal with the uncertain factors of the problems, such as flight delays or resource availability. We contribute to the literature by proposing a feedback mechanism from simulation back to optimization. The tactical level problem is essentially a discrete combinatorial problem, where metaheuristics will be used to attack the problem in a timely manner and reach reliable solutions, the robustness of which is evaluated thanks to the inclusion of simulation at specific steps of the overall methodology.

1 INTRODUCTION

At every airport, ground services are handled to prepare every aircraft for their next departure. Ground Service Equipment (GSE) and vehicles used to perform these services include: baggage carts for baggage handling, refuelling trucks, passenger stairs for boarding/disembarking, etc. GSE play an important role as their inefficient planning could lead to departure delays. Single-GSE delays may not be as extreme, but, especially at peak times, knock-on effects between subsequent uses of the same GSE can indeed lead to serious departure delays —of which passenger dissatisfaction is but one obvious downside. The airport GSE planning problem has recently seen increased interest within the simulation and optimization communities, in line with sustained air passenger growth (Guimarans et al. 2019). Typical solution approaches include ad-hoc heuristics, as well as combinations of simulation and optimization. Following a blend of the two approaches, we propose a simheuristic methodology in which we integrate both in a systematic way. The major novelty of our approach relates to its improved feedback mechanism between the simulation phase and its subsequent search phase.

2 THE TACTICAL GSE PLANNING PROBLEM

Tactical planning of GSE can be decomposed into several Vehicle Routing Problems with Time Windows (VRPTW), one for each type of GSE. However, these VRPTWs are strongly interdependent, following the typical precedence relations between the service operations of aircraft turnarounds in which GSE are employed. Taking into account all GSE concurrently is paramount. This is why we define an overarching resource-constrained project scheduling problem (RCPSP) that provides the initial time windows (i.e., earliest and latest start times of each task) for each of the component VRPTWs.

In addition, there are sets of tasks that do not have strict precedence relationships, and hence can be performed in any order as long as they do not use the same resources simultaneously. This becomes an issue if several tasks and related GSE are scheduled independently. The scheduling design of our global approach includes this flexible aspect, which brings a novelty to the problem. Similar to practice, most approaches in the literature (e.g., Padrón et al. (2016)) assume a fixed sequence of operations for each turnaround depending on the type of aircraft being serviced. In our case, this sequence is flexible for each aircraft and dependent on the scheduling needs of each resource, aiming at improving overall performance and resource utilization across turnarounds.

Once the RCPSP is solved to minimize tardiness of operations (i.e., scheduling delays), each VRPTW is provided with the set of time windows that need to be satisfied. This allows to allocate each individual GSE or team a sequence of tasks to be performed in different aircraft turnaround. We do so by maximizing the slack between activities to increase robustness within the planning horizon to absorb minor delays, as well as trying to balance the workload across teams. Each VRPTW has specific characteristics that need to be addressed (e.g., finite capacity for catering trucks or the need for additional GSE that needs to be moved around the aerodrome). We believe the novel adoption of the two intertwined modeling approaches, that is RCPSP and VRPTW, is one of the main strengths of this study.

3 PROPOSED METHODOLOGY

We use the MiniZinc language to implement the models for the RCPSP and the VRPTWs. This allows us to exploit the advantages of constraint programming to solve scheduling and routing problems efficiently. Moreover, these models can effectively be used within a Large Neighborhood Search (LNS) metaheuristic framework to obtain high-quality solutions for large-scale problems.

To solve real-life instances of the problem, we adopt the concept of Simheuristic, as it has shown promising results in solving stochastic optimization problems where simulation is used to guide the search towards a better solution (Juan et al. 2015). Adding to this concept, we propose a ‘learning’ component, so simulation is used not only for evaluating solutions but also to infer the reason for non-improving solutions or failures. By analyzing the simulation outputs, we can identify common traits of non-desirable solutions, which can be used to systematically generate new *cuts* for the specific optimization models (i.e., adding new constraints). For example, these constraints can be used to discard specific sequences of visits in the routing problems, or to increase the lower bound on the number of resources in peak periods. This contribution would drastically enhance the performance of the simheuristic approach, improving the algorithm’s convergence by reducing the time the optimization process spends generating similar solutions to the ones already rejected by simulation.

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