Using simulation for evaluating ground handling solutions reliability under stochastic conditions

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1 Introduction

The turnaround is a critical airport process where different types of vehicles have to perform a set of interrelated services (ground handling activities) between an inbound and outbound flight. In spite of being a stochastic process in nature, most studies found in the literature use deterministic values to represent the activities completion time [1, 2] and to schedule ground handling vehicles [3]. In a previous work [3], we proposed a deterministic bi-objective optimization approach to solve the ground handling scheduling problem. Our methodology is able to obtain a set of solutions representing a trade-off between the defined objectives : minimizing the tightness of the available time windows to perform each activity (F1), and minimizing the completion time of turnarounds (F2). The aim of the current work is to use simulation to evaluate the reliability of the obtained Pareto solutions under stochastic scenarios.

We define *reliability* as the ability of a system to perform consistently well under variable circumstances. In order to determine the reliability of our solutions, we calculate the percentage of stochastic simulated scenarios in which all the scheduled turnarounds are completed on time.

To start an operation in a turnaround, two constraints need to be respected : (i) previous operations in the turnaround have to be completed, and (ii) the required vehicle for performing the task must have arrived at the parking position. Constraint Programming has been used to ensure these precedence and routing constraints. Simulating a ground handling solution in our problem consists of updating the operation schedules, i.e. the start time of all the operations involved in the turnaround, considering stochastic durations and vehicle traveling times between turnarounds. Hence, this will affect the performance of operations and is likely to have a knock-on effect on subsequent turnarounds.

2 Computational experiments and discussion

Stochastic operation durations have been generated using a triangular distribution with mode μ and range $[\mu - 1, \mu + 1]$, where μ is the deterministic duration according to the aircraft type (9 aircraft types). This distribution is used due to the difficulty to obtain comprehensive data regarding turnaround tasks [1]. A log-normal distribution ($\mu = 10$, $\sigma = 3$) has been used to represent vehicle speed and to obtain traveling times, as we consider the deterministic value an optimistic one. We use Monte Carlo simulation to evaluate solutions obtained by the algorithm, running 1000 simulations per solution. Both solving and simulation processes are implemented in Java. The Pareto solutions corresponding to a 56 scheduled flights instance from Barcelona airport and the obtained results are shown in Table 1.

The actual bi-objective approach was defined to provide better global scheduling solutions able to deal with perturbations. Solutions having lower values of F2 mean that turnarounds

F1	F2	Reliability (%)	Avg. Turnaround violations (%)	Avg. Delay (min)
7069	2173	82.7	0.92	3.395
6459	2195	89	0.97	4.318
5704	2206	77.5	2.34	11.338
5349	2497	62.7	3.44	8.654
4637	2654	64.3	1.28	2.151
4328	2677	67.8	2.28	8.409
4063	2820	65.6	3.18	7.718
3956	2840	65.1	1.95	3.177

TAB. 1 – Simulated solutions obtained for an instance from Barcelona airport with 56 scheduled turnarounds.

have been planned to be completed in the minimum possible time. If we look at the turnaround as a unique, whole process, these kind of solutions are more robust, i.e. turnarounds are more likely to finish on time in presence of disturbances. However, we have to look at each operation the turnaround is made of. When F2 is lower, operations have been planned to begin in their earliest start time. This has the effect of packing activities in a smaller time window, aiming at minimizing the makespan of the turnaround. On the other hand, this makes each operation less tolerant to complete the service later than scheduled. That is, if the duration is longer than expected, this operation is more likely to affect the beginning of successive tasks. Moreover, because vehicles performing operations are shared between turnarounds, delays are more easily propagated to other aircraft.

Regarding solutions with lower values of F1, operations have longer time windows, but they can also have longer waiting times (i.e. difference between the earliest possible starting time and the actual start time of an operation) in order to use resources more efficiently. However, this compromise has to be cautiously applied under stochastic conditions. If waiting times are too high, any small perturbation (e.g. due to longer traveling times or longer duration of previous activities) can affect the punctuality of the turnaround.

3 Conclusions

In this work we present a simulation approach to evaluate the reliability of ground handling scheduling solutions in stochastic scenarios. We do so by measuring the percentage of cases in which all turnarounds are completed on time. This is a first step to integrate simulation within the solving process. The final goal of this research is to use this evaluation to feedback the optimization process in order to improve the robustness of the deterministic solutions, e.g. by only accepting solutions able to improve the reliability criteria or defining a reliability threshold. That is, simulation is to be integrated in the optimization algorithm in order to guide the search for obtaining pseudo-optimal solutions, but robust enough to cope with the system's stochasticity.

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