Air cargo ground operations optimization: A service vehicles coordination problem

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Air transportation plays a significant role in e-commerce, whose volume of activity increases year after year and has known a real explosion in 2020 when the covid-19 crisis emerged. However, the air cargo field is mainly driven by historical "best" practices without strong coordination among the stakeholders providing the different ground service equipment. As a consequence, many challenges need to be overcome, especially at the ground operations level. Those logistical activities which are performed between the time a cargo plane lands and the time it takes off again indeed offer big rooms for improvements. In this regard, ground service equipment coordination has been identified as a common bottleneck in the operations flow and is the cause of most delays. Beyond the impact on customer satisfaction, flight delays are a financial burden for the concerned airlines and may cause additional environmental damage by increasing fuel consumption and gas emissions. It is therefore crucial to find ways to optimize the air cargo supply chain.

The present work seeks to optimize air cargo ground operations by coordinating the different ground service equipment, the idea being to develop a decision system that optimizes the journey of the different service vehicles considering the precedence and synchronization constraints that bind some ground operations or vehicles together. As each ground operation requires a fleet of vehicles to serve different clients within a defined time interval, it seems reasonable to tackle the problem as a set of vehicle routing problems with time windows, each VRPTW referring to a given ground operation. Those VRPTWs should consider capacitated and heterogeneous vehicles, deal with forbidden pairings and split deliveries, and allow both multi-trips and fleet sharing. Their complexity is further reinforced by goods transfer between vehicles, which leads to dependency between some vehicles and the use of multiple recursive processes. Precedence constraints between operations also make the problem more complex as they induce dependency between some operations. Scheduling decisions made for an operation or a vehicle therefore affect the scheduling decisions for other operations or vehicles respectively. In addition, many additional problem characteristics should be considered. These include among others the fact that some vehicles can perform different operations and must follow a specific services sequence, that some operations consist in carrying vehicles required by other operations, that some vehicles can be replenished while others cannot, that some operations entail a trip, that the number of some vehicle types is restricted in certain places, or that some operations experience a random extra operating time.

Due to the complexity induced by the numerous problem features considered, it is highly likely that exact methods would not succeed in finding an optimal solution or, at least, finding one within a time frame which is small enough to be viable in the dynamic airport environment. Indeed, since input data evolves over time and is subject to disruptions, it seems preferable to build an algorithm that is able to compute and recompute good solutions very quickly. In this regard, note that even if each sub-problem takes the form of a VRPTW, we do not try to minimize the total distance travelled or the number of vehicles in use as is often the case. Instead, we are looking for solutions that minimize the total responsiveness, that is solutions which complete operations as soon as possible, within the time window, such that both the aircraft and the different service vehicles can operate again. Such an objective function allows to increase the time left before the theoretical aircraft departures, which can be seen as a buffer that could absorb any disruptions and therefore subsequently help to minimize total aircraft delay on the time horizon considered.

Literature remains relatively sparse on that topic, with most authors focusing only on the passenger side, considering only a specific ground operation (meaning that they do not approach the prioritization problem induced by precedence constraints between operations nor the synchronization problem arising from goods transfer between vehicles), or dealing only with some of the numerous features of the problem. The originality of this work lies therefore in the fact that we are approaching the complete picture of air cargo ground operations coordination problem. In addition, the algorithm which is currently developed is designed in a way that it would be possible to use it in any application presenting the same problem structure, making this work relevant not only to the air cargo industry. The approach is thus intended to be general and applicable to different problems requiring services coordination, air cargo ground operations being only a use case to illustrate the research.

This work is part of a doctoral thesis in progress and constitutes the first step of a long-term project. So far, the first objective of this work, which is to identify and classify a range of issues related to services synchronization, is already achieved. The second objective, which is to propose a basic heuristic that is able to address the complete problem, is under development. We hope to be able to present some preliminary results by the time of the conference.