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A bi-objective approach for scheduling ground-handling vehicles in airports

Silvia Padrón [a,*,1], Daniel Guimarans [a,b,2], Juan José Ramos [a], Salma Fitouri-Trabelsi [c,3]

[a] Department Telecommunication and System Engineering, Universitat Autònoma de Barcelona, C/ Emprius, 2, 08202 Sabadell, Barcelona, Spain
[b] Optimisation Research Group, National ICT Australia (NICTA), 13 Garden Street, Eveleigh, NSW 2015, Australia
[c] Mathématiques Appliquées, Informatique et Automatique pour l'Aérien (MAIAA) & Air Transportation Department, L'Ecole Nationale de l'Aviation Civile (ENAC), 7 Avenue Édouard Belin, 31055 Toulouse Cedex 04, France

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ABSTRACT

In the present paper, we propose a new approach for scheduling ground-handling vehicles, tackling the problem with a global perspective. Preparing an aircraft for its next flight requires a set of interrelated services involving different types of vehicles. Planning decisions concerning each resource affect the scheduling of the other activities and the performance of the other resources. Considering the different operations and vehicles instead of scheduling each resource in isolation allows integrating decisions and contributing to the optimization of the overall ground-handling process. This goal is defined through two objectives: (i) minimizing the waiting time before an operation starts and the total reduction of corresponding time windows and (ii) minimizing the total completion time of the turnarounds. We combine different technologies and techniques to solve the problem efficiently. A new method to address this bi-objective optimization problem is also proposed. The approach has been tested using real data from two Spanish airports, thereby obtaining different solutions that represent a trade-off between both objectives. Experimental results permit inferring interesting criteria on how to optimize each resource, considering the effect on other operations. This outcome leads to more robust global solutions and to savings in resources utilization.

1. Introduction

The notable growth of air traffic in recent years has led to increasingly congested airports and significant flights delays. In 2012, approximately 35% of European flights were more than 5 minutes late, with an average of 30 min [1]. A more collaborative coordination among all the involved actors, such as airports, airlines, air traffic management, ground handlers, etc., and a better planning of airport resources are crucial to improve the operational efficiency of the air transportation system. Different efforts and important projects are currently being carried out to achieve this goal, such as the Airport-Collaborative Decision Making (A-CDM) and the Single European Sky ATM Research (SESAR) programs [2,3], which is particularly focused on Air Traffic Management.

Regarding turnaround, the TITAN Project [4] proposes to improve the efficiency of airport processes through sharing reliable and timely information among the concerned actors. Turnaround is defined as the period of time the aircraft is on the ramp between an inbound and outbound flight, and different ground-handling operations are performed. Ground handling comprises the activities, operations procedures, equipment requirements, and personnel necessary to prepare an aircraft for the next flight. Many aircraft delays can be attributed to overlong turnarounds due to a lack of planning integration of the different activities and an inefficient use of resources [5]. In addition, the ground tasks are very interdependent. Each operation is a potential source of delays that could be easily propagated to other ground operations and other airport processes [6,7].

Divisions of either airports or airlines have historically performed these operations. With the recent process of deregulation

* Corresponding author. Tel.: +33 61198437.
E-mail addresses: s.padron@tbs-education.fr, silvia.padron9@gmail.com (S. Padrón), d.guimarans.serrano@hva.nl (D. Guimarans), juanjose.ramos@uab.cat (J.J. Ramos), salma.fitouri.trabelsi@gmail.com (S. Fitouri-Trabelsi).
[1] Present address: Industrial Organization, Logistics & Technology Department, Toulouse Business School, 20 Boulevard Lascrosses, 31068 Toulouse, France.
[2] Present address: Aviation Academy, Amsterdam University of Applied Sciences, Amsterdam, Netherlands.
[3] Present address: Institut Supérieur des Sciences Appliquées et de Technologie de Gabès (ISSAT Gabès), Rue Omar Ibn Khattab 6029, Gabès, Tunisie.

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of the ground-handling market at European airports, a notable increase in the number of third-party companies has taken place [8]. This new scenario, with several ground handlers providing multiple services, further increases the importance of efficient scheduling of ground activities [9]. Due to the hierarchy of overall airport planning, ground handlers are generally not included in the decision making of other scheduling processes (flight scheduling, stand allocation, etc.). This means they must fit their planning around a set of hard constraints. These constraints include aircraft arrival, departure, turnaround time, and stand allocation, among others [10].

Thus, ground-handling appears an interesting and open field for research and technology transfer. In particular, logistics in ground-handling [11] and cooperative planning decisions are among the major challenges to improving the quality of ground-handling services. In this context, the development of new tools that can help with the decision making process becomes mandatory. We present a novel and efficient bi-objective approach to tackling the ground-handling scheduling problem. To the best of our knowledge, this is the first time the problem is treated as a whole in the literature. Thus far, other approaches have been developed to optimize operations in isolation [9,12,13], but they do not consider the relationships and entanglements among all the involved activities. In our approach, we do explicitly consider such relationships and entanglements to solve the problem from a global perspective. To do so, we develop a bi-objective optimization methodology and decompose the problem to apply efficient techniques. Thus, we first solve a planning problem that leads to multiple Vehicle Routing Problem with Time Windows (VRPTW) problems. These are solved individually, and decisions made on the routing are propagated to the other VRPTWs through reductions in the available time windows. This process provides a consistent method to solve the complete problem.

Ground-handling procedures are usually divided into two types: terminal and ramp. Terminal activities are performed inside the terminal buildings and concern passenger services. Ramp operations take place at the aircraft parking position between the time it arrives at the stand *(In-Blocks)* and its departure *(Off-Blocks)*. Fig. 1 shows an example of the principal activities during a typical turnaround when the aircraft is parked at a contact point (the stand is connected to the terminal via a bridge).

Because the turnaround is a very complex process, its duration depends on many different variables. These include operational variables related to the aircraft type (size, number of seats), the number of tasks, parking position at a contact or remote stand, and the service time required to carry them out (full servicing or minimum servicing). Some activities are affected by precedence constraints imposed due to security issues, space requirements or airline policy; e.g., *fueling* cannot be performed simultaneously with *deboarding/boarding*. In some cases, the precedence constraints can be violated; e.g., fueling and *deboarding* can be performed simultaneously when a fire extinguisher is available. For hygienic reasons, the *toilet* and *potable water* servicing (collect the waste and re-equip with fresh water) cannot be performed at the same time, but either of the two can be performed first. The *catering* and *cleaning* processes usually must be finished before *boarding* starts and, sometimes, they can begin only when *deboarding* ends. The end of the turnaround process is determined by the Off-Block Time (OBT), when all doors are closed, the bridge is removed, the pushback vehicle is present and the aircraft is ready for startup and push back [6]. Although this operation might not be necessary for aircraft parked at a remote position, pushing away the aircraft (pushback) is the most typical method used for leaving the parking position. For that reason, we have defined pushback as the last task of the ground-handling service in our problem.

Each operation is performed by a specific type of vehicle; therefore, different ground units or vehicles are necessary. According to the task, some vehicles with a given capacity must transport some quantity of resources to the aircraft stand (catering, fueling, or potable water operations) or collect waste from the aircraft (also catering, lavatory services or cleaning tasks).

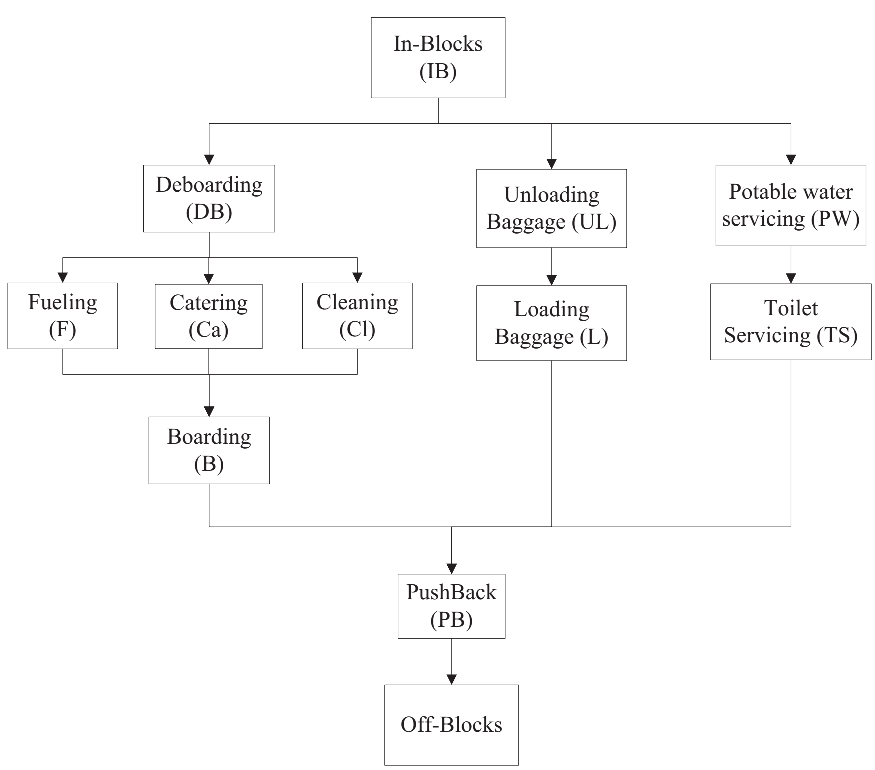

Fig. 1. Example of activity flow during a turnaround at a contact point.