Transportation Research Part E 70 (2014) 293–304

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Planning towing processes at airports more efficiently

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ARTICLE INFO

Article history:
Received 2 October 2013
Received in revised form 23 July 2014
Accepted 24 July 2014

Keywords:
Airport
Turnaround process
Towing
Vehicle routing problem
Column generation

ABSTRACT

This paper addresses the towing process of airplanes as part of the turnaround process. We introduce a VRP based MIP model which assigns different types of towing tractors to jobs with specified service time windows. The objective function minimizes operating costs subject to operational restrictions such as technical compatibility of tractor types with plane types. Our modeling approach allows for multiple depots as well as multiple trips. To solve the model we develop a column generation heuristic. Computational results show the superior behavior of the proposed heuristic compared to the original MIP formulation solved with CPLEX. In a case study we derive insights which support schedulers in their daily work. For this, we identify cost drivers and evaluate the efficiency of manual schedules in retrospect.

1. Introduction

The number of aircraft movements is expected to increase by 50% in Europe from 2012 to 2035. The capacity at airports will be the bottleneck limiting future growth. Up to 12% of the demand in 2035 will not be satisfied (see EUROCONTROL, 2013). Airports face the challenge of improving efficiency in order to cope with increasing demand while fully exploiting available resources. In the recent past, capacity constraints and cost pressure tightened flight schedules. This threatens smooth operations and punctuality. A primary source of delays are disruptions in the turnaround process. According to EUROCONTROL (2012) the turnaround process accounted for 36% of delays at European airports in 2011. Additionally, excellent operational performance has a positive impact on the cost structure of airlines which are the customers of the airport (see Zou and Hansen, 2012). This paper addresses the operational scheduling problem of towing activities as part of the turnaround process.

Planes do not have a reverse gear, so they need assistance to leave the parking position. They can use their own engines to move forward on the ground. However, over long distances towing is often more economical and ecological (see Authority Zürich Airport, 1992). Towing is distinguished between push-back, repositioning and maintenance towing.

- **Push-back**. The plane with the passengers (or cargo) on board is pushed backwards from its parking position (e.g. the gate) to the taxiway. From there the plane can move on its own to the runway for take off.
- **Repositioning**. The empty plane is towed from one parking position to another. A repositioning takes place if an occupied gate must be used by an incoming flight.
- **Maintenance towing**. The empty plane is towed to the hangar area for maintenance or repairs.

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http://dx.doi.org/10.1016/j.tre.2014.07.008
1366-5545/

There are two main categories of tractors. Towbar tractors connect with the plane via a towbar. Towless tractors raise the front part of a plane and position it on the tractor itself (see Kazda and Caves, 2007). Towbar tractors usually are more flexible with respect to compatibility with plane types and have lower maintenance and investment costs compared to towless tractors. However, each plane type requires a different tow bar. Therefore, towbar tractors must return to a depot to change the towbar between two jobs in case of different plane types. Furthermore, a second person (e.g. the pilot) must be present in the cockpit while the plane is towed by a towbar tractor.

Operating costs as well as investment costs of towing tractors are high. Investment costs can reach around 1 million Euro per tractor (see Deutsche Lufthansa AG, 2012). Therefore, using the given fleet of tractors efficiently while providing reliable services is crucial. Today, most towing service providers employ manual planning tools. We introduce a model that assigns tractors to towing jobs in order to minimize costs – taking the perspective of a towing service provider. The assignment is subject to various operational restrictions and airport dependent specifications. For instance, technical compatibility with plane types and specific variable costs are associated with different tractor types. Furthermore, the time window to start the push-back is linked to the plane departure time, i.e. services must take place during a fixed time window. Penalty costs occur if the push-back is delayed. We also consider multiple depots to which tractor drivers can return for work breaks. This implicates multiple uses of tractors in one planning period.

The two main contributions of this paper are a mixed-integer-programming (MIP) model which addresses the scheduling of towing jobs while reflecting all relevant operational specifications as well as a column generation based heuristic for solving the model. Computational experiments highlight the efficiency of our approach. Additionally, we present a real-world case study with data from a major European airport. The case study focuses on a retrospective evaluation of a manual schedule to derive insights which support schedulers in their future work. However, the model can also be applied to perform the actual scheduling task with amendments such as consideration of the current position of the tractors.

2. Literature review

The model developed in this paper is based on the vehicle routing problem (VRP). The problem considered in this paper is also referred to as the multiple traveling salesman problem (mTSP) since the capacity constraint does not apply (see Toth and Vigo, 2002). It further can be categorized as an asymmetric mTSP with time windows, multiple trips, multiple depots, and a heterogeneous fleet. In what follows we first review the literature on push-back processes and then address the literature on the VRP.

2.1. Literature on push-back

Operations research is widely applied in the air transport industry. Typical application areas are schedule design, fleet assignment and crew scheduling. Within airport operations management runway scheduling, gate assignment and check-in procedures are typical examples for problems which have been addressed in operations research. Push-back has received little attention by researchers thus far. To the best of our knowledge, there is no literature addressing the scheduling of push-back activities.

Several papers address the forecasting of ready-to-push-back-times, among others Schlegel (2010) and Carr et al. (2005). Schlegel (2010) breaks down the ground handling process into de-boarding, cleaning, catering, fueling, boarding, loading and push-back. A simulation model evaluates the impact of changes in one or more sub-processes. Furthermore, a forecasting model for predicting the ready-to-push-back-times during any step of the ground handling process is proposed. The author points out the importance of efficient and on time ground handling processes for airports and airlines. These two factors contribute to profit maximization and smooth operations. Carr et al. (2005) analyze the performance of push-back time forecasting techniques. A high quality forecast can improve the performance of decision support tools for airport surface traffic and thus reduce delays. However, the authors conclude that the stochastic nature of turnaround operations complicates precise forecasts.

The majority of push-back related literature refers to ready-to-push-back-time as an input parameter to gate assignment, taxiway optimization and runway scheduling. Cheng (1998) presents a simulation study on the ground movement of aircraft at the gate during push-back. The simulation identifies push-back conflicts which might occur when two planes at neighboring gates enter or exit at the same time and block each other on the taxiway. The author demonstrates that assessing gate assignment decisions with simulation reduces delays and increases gate utilization. Atkin et al. (2011) present models for take-off sequencing, one of which includes a push-back time allocation subproblem, which is solved after the take-off sequence has been set. The basic idea is to determine the take-off sequence first, then to calculate the push-back time using forecasts on push-back duration and taxi time. The main goal is to avoid congestion or re-sequencing at the holding area, i.e. to absorb delays at the gate and thus reduce fuel consumption. A simulation experiment shows that delay reductions of 20% or more are possible. In a more recent paper (Atkin et al., 2012) calculate push-back times after predicting departure delays. Balakrishnan and Jung (2007); Keith and Richards (2008); Lee et al. (2010) and Roling and Visser (2008) are other examples addressing the idea of gate holding or push-back control, that is giving push-back permission using up-to-date information on taxiway traffic and runway schedules.