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Flight and passenger delay assignment optimization strategies

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ABSTRACT

This paper compares different optimization strategies for the minimization of flight and passenger delays at two levels: pre-tactical, with on-ground delay at origin, and tactical, with airborne delay close to the destination airport. The optimization model is based on the ground holding problem and uses various cost functions. The scenario considered takes place in a busy European airport and includes realistic values of traffic. A passenger assignment with connections at the hub is modeled. Statistical models are used for passenger and connecting passenger allocation, minimum time required for turnaround and tactical noise; whereas uncertainty is also introduced in the model for tactical noise. Performance of the various optimization processes is presented and compared to ration by schedule results.

1. Introduction

Airports are limited in capacity by operational constraints (Bazargan et al., 2002; Gilbo, 1993; Hinton et al., 2000; Groskreutz and Munoz-Dominguez, 2015). In some cases, a significant imbalance exists between capacity and demand. Air Traffic Flow and Capacity Management (ATFCM) initiatives are then implemented to smooth traffic arrivals, transferring costly airborne delay, carried out with holdings and/or path stretching, to pre-departure on-ground delay (Carlier et al., 2007; Ivanov et al., 2017). As defined in (EUROCONTROL, 2015a), there are different phases in this capacity and demand management process: (i) strategic phase – from about one year, until one week before real time operations; (ii) pre-tactical phase – six days before real time operations, based on the demand for the day of operations; (iii) tactical phase – the day of operations: issuing on-ground delay at the airport of origin by assigning slots to flights affected by regulations.

Even if there is no particular operational limitation, the tactical capacity of the airport is limited by different factors such as traffic mix, runways in use, local weather or wake separation (Bazargan et al., 2002). This means that, tactically, controllers need to synchronize arriving flows and individual flights to meet the runway system capacity (Zelinski and Jung, 2015).

In this paper, in order to differentiate the process of on-ground delay assignment, carried out hours/minutes before take-off, from the airborne delay required to manage incoming flights at an airport, the authors refer to *pre-tactical delay* to the former and to *tactical delay* to the latter.

Current operations focus on minimizing flight arrival delay. However, beyond arrival delay, the full impact on delay and other metrics could be considered. This paper, which continues and completes the preliminary study presented in (Montlaur and Delgado, 2016), also considers passenger delay and propagation of delay through turnaround, and now includes missed

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connections. The inclusion of passengers' metrics is relevant as their experience of delay might differ from flight-centrist metrics (Cook et al., 2012). Some previous work has considered passengers' connections for allocation of slots at the pre-tactical level from an airline cost point of view (e.g. Bard and Mohan, 2008), and other studies arrival passenger delay (e.g. Manley and Sherry, 2010). In this paper, tactical allocation of slots, i.e. at the arrival manager, and passengers' metrics considering connections, such as total delay and missed connections, are also modeled. Another aspect to consider when optimizing the arrivals is that the degree of uncertainty on the actual arrival time decreases as flights approach their destination (Tielrooij et al., 2015). Hence, optimization carried out prior to departure may suffer from inefficiencies due to this traffic variability and a tactical optimization close to the arrival could be worth performing. This paper also aims to analyze these two time frames: on-ground, prior to departure, and airborne, close to the destination.

Note that this paper aims to compare different optimization strategies for the minimization of flight and passenger delays under a known scenario, in order to study if some strategies stand out and are worth implementing instead of classical Ratio by Schedule. As it will be further explained in future sections, the optimization process is done under the hypothesis of having full information about the flights, such as, for example, their number of passengers, which would not be the case in operational system, since, particularly, passenger information is not available to the ATC/ATFM at execution level. Nowadays, this information is known only by the carrier and, due to its sensitivity, it is likely to remain this way, especially when considering connecting passengers. Other studies, such as (Zanin et al., 2013, 2016), have investigated ways to exchange critical information without revealing actual values during negotiation processes. However, these considerations are out of scope of the research presented in this paper.

Section 2 presents the background information regarding the management of traffic. In Section 3, the formulations of the optimization model and of the different objectives functions considered are presented. Section 4 describes the parameters of the analyzed scenario. The main results, conclusions and further work are detailed in Sections 5 and 6 respectively.

2. Background: management of inbound flights

Delay due to capacity demand imbalance can be absorbed on-ground, as pre-tactical delay assignment, and/or in the air, as tactical delay. Other strategies, such as totally or partially absorbing the pre-tactical delay in the air, have also been suggested (Delgado et al., 2013; Delgado and Prats, 2014). Even if an ATFM regulation is implemented and flights are delayed at their origin, system uncertainty leads to the need for tactical management of flows at arrivals, i.e., demand uncertainty. Besides this demand uncertainty, the system is also affected by capacity uncertainties, which are out of scope of this paper, see for example (Buxi and Hansen, 2013; Glover and Ball, 2013). In this context, trade-offs appear between declared capacity, utilized capacity and airborne holding delay, as dynamically the tactical capacity of the airport might increase or decrease. In some cases, ATFM managers might prefer to increase the demand, in order to ensure a high utilization of the infrastructure, even at the expenses of higher holding delay. For more information regarding demand uncertainty, see Section 4.3.

2.1. Ground delay: pre-tactical optimization

When dealing with a slot assignment problem, a Ration by Schedule (RBS) prioritization of flights is the current practice (EUROCONTROL, 2015a). The required delay will be transformed into ground delay carried out prior to departure. This RBS policy is considered to be the fairest delay assignment even if economical optimum cannot be guaranteed. Other approaches to minimize delays and/or cost, rather than RBS, could be considered and extensive research has been conducted to assign the required delay in a most cost effective manner (Gilbo, 1993; Vranas et al., 1994; Dell'Olmo and Lulli, 2003; Ball et al., 2007; Bard and Mohan, 2008).

In this paper, the model developed in (Ball et al., 2007) is implemented considering different objective functions, as explained in Sections 3 and 4. RBS, being the current practice, is used as the baseline for this research.

2.2. Airborne delay: tactical optimization

When aircraft arrive to the proximity of an airport, a sequencing and merging process is required to optimize the airport utilization (Zelinski and Jung, 2015; EUROCONTROL, 2010; Hu and Chen, 2005); departures from this airport can also be considered at this stage (Bosson et al., 2015; Zammit-Mangion et al., 2012). Europe is now in the process of implementing Extended Arrival Management systems (E-AMAN). The objective of such a system is to extend the management of arrivals up to a 500 NM horizon from the airport, in order to move part of the sequencing and Terminal Maneuver Area (TMA) delay to the en-route phase. Note that the decision of the horizon extension depends on the context in which E-AMAN is applied. Controlled times of arrivals (CTAs) are issued to flights in order to manage delay, usually with speed adjustments (Jones et al., 2012). This strategy leads to reductions on fuel and emissions, along with improved en-route capacity. Airports such as Heathrow, Rome or Stockholm are already implementing this technology, with a horizon that varies from around 190 NM for Stockholm, to 250 NM for Rome and 350 NM for Heathrow, and that could be extended up to 550 NM (Bagieu, 2015).

At this tactical phase, benefits in terms of fuel, emission and noise can be obtained with procedures such as continuous descent operations (CDA) (Cao et al., 2011; Shresta et al., 2009).