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# Cruise speed reduction for ground delay programs: A case study for San Francisco International Airport arrivals

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ABSTRACT

Ground Delay Programs (GDP) are sometimes cancelled before their initial planned duration and for this reason aircraft are delayed when it is no longer needed. Recovering this delay usually leads to extra fuel consumption, since the aircraft will typically depart after having absorbed on ground their assigned delay and, therefore, they will need to cruise at more fuel consuming speeds. Past research has proposed speed reduction strategy aiming at splitting the GDP-assigned delay between ground and airborne delay, while using the same fuel as in nominal conditions. Being airborne earlier, an aircraft can speed up to nominal cruise speed and recover part of the GDP delay without incurring extra fuel consumption if the GDP is cancelled earlier than planned. In this paper, all GDP initiatives that occurred in San Francisco International Airport during 2006 are studied and characterised by a *K*-means algorithm into three different clusters. The centroids for these three clusters have been used to simulate three different GDPs at the airport by using a realistic set of inbound traffic and the Future Air Traffic Management Concepts Evaluation Tool (FACET). The amount of delay that can be recovered using this cruise speed reduction technique, as a function of the GDP cancellation time, has been computed and compared with the delay recovered with the current concept of operations. Simulations have been conducted in calm wind situation and without considering a radius of exemption. Results indicate that when aircraft depart early and fly at the slower speed they can recover additional delays, compared to current operations where all delays are absorbed prior to take-off, in the event the GDP cancels early. There is a variability of extra delay recovered, being more significant, in relative terms, for those GDPs with a relatively low amount of demand exceeding the airport capacity.



## 1. Introduction

Air traffic flow management (ATFM) aims to compensate capacity shortfalls and/or demand peaks, either at an airport or in an air traffic control (ATC) sector; and impose traffic management initiatives that delay aircraft in such a manner that airborne traffic flows do not exceed what can be handled with available resources. In the ATFM community, it is widely accepted that ground delay at origin airports is preferable than airborne delay near the congested sector/airport, from a fuel consumption (and environmental) point of view (Carlier et al., 2007). This statement assumes that airborne delays are in the form of re-routings, air holding stacks or path stretching in terminal manoeuvring areas (TMA). Airborne delay, however, can also be absorbed by slowing an aircraft from its nominal cruise speed, thus intentionally increasing the trip time.

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This speed reduction strategy, aimed at partially absorbing ATFM delays while airborne, was presented by the authors in previous publications. Prats and Hansen (2011) proposed that ground delayed aircraft could fly at the minimum fuel speed (the maximum range cruise speed). In this way, the fuel consumption (and gaseous emissions) of these flights were reduced at the same time as some ATFM delay was absorbed in the air. The impact of this strategy was quantified by analysing the historical data of all delayed flights to San Francisco International Airport (SFO) over one year. Results showed values ranging from 5% to 15% of the initially assigned delay that could have been absorbed in the air, leading to fuel savings in the order of 4–7% for each individual flight, if compared with the nominal situation.

A different strategy was proposed by Delgado and Prats (2012), where aircraft were allowed to fly at the lowest possible speed in such a way that the specific range (SR) (NM/kg fuel) remained the same as initially planned. In this case, the aircraft speed being slower than the maximum range cruise speed, higher values of delay absorbed in the air were obtained while exactly the same fuel as initially planned in the nominal situation was consumed. This strategy is interesting if we consider the fact that ATFM initiatives (as ground delay programs) can be cancelled before their initially planned ending time, as is often the case (Ball et al., 2009; Mukherjee et al., 2012; Inniss and Ball, 2002). Thus, if a GDP is cancelled, the aircraft that are already airborne can change their speed to the initially planned one and recover part of the delay at no extra fuel consumption, as shown by Delgado and Prats (2011). If weather clears (and the ground delay program is cancelled), the aircraft that are already airborne, and flying slower, can change their speed to the initially planned one and recover part of the delay at no extra fuel consumption. Thus, the suggested strategy, which can be used in conjunction with the current practise of distance-based exemptions, gives a new alternative that can be used by airlines when dealing with imposed delay due to ATFM.

In this paper, all GDP initiatives that occurred in San Francisco International Airport during 2006 are studied and characterised by a *K*-means algorithm into three different clusters. The centroids for these three clusters have been used to simulate three different GDPs at the airport by using a realistic set of inbound traffic and the Future Air Traffic Management Concepts Evaluation Tool (FACET). The amount of delay that can be recovered using this cruise speed reduction technique, as a function of the GDP cancellation time, has been computed and compared with the delay recovered with the current concept of operations. The paper is structured as follows: Section 2 discusses the required background for the paper with special focus given to explaining the ground delay program initiatives and the cruise speed reduction concept. Section 3 is devoted to explaining the different simulations that have been conducted. The different assumptions, data and architecture of the simulations is explained. Section 4 shows the application of the ground delay programs to the traffic and the results of the simulation of the GDPs with the speed reduction strategy. The introduction of abnormally slow traffic might have an impact on the air traffic control and air traffic management. Therefore, a brief assessment of the impact on the air traffic management is also performed. Finally the paper concludes with Section 5, where the conclusions are summarised and further research highlighted.

## 2. Background

Speed control for air traffic management (ATM) purposes has been the subject of several research studies and projects. The majority of the applications focus on a tactical level, where speed adjustments are used to resolve (or mitigate) aircraft conflicts (Chaloulos et al., 2010). Some other works also propose speed control as a mechanism to enable traffic synchronisation strategies (Lowther et al., 2008). In this context, Günther and Fricke (2006) proposed en-route speed reductions to prevent aircraft from performing airborne holding patterns when arriving in the congested airspace. A similar rationale is behind the ATM long-range optimal flow tool developed by Airservices Australia (Airservices Australia, 2008), where aircraft within a 1000 NM radius of Sydney Airport are proposed to reduce their flight speed in order to prevent them from arriving before the airport is open, and thereby reducing unnecessary holdings. More recently, a joint Federal Aviation Administration (FAA) and Eurocontrol study, estimated that half of the terminal area inefficiency in the system today could be recovered through speed control in the cruise phase of flight, without reducing throughput efficiency (Knorr et al., 2011).

At a pre-tactical level, some research has also been conducted considering speed control as an additional decision variable (in addition to the amount of time of ground holding) to solve the Ground Holding Problem (Bertsimas and Patterson, 1998, 2000). However, the economic impact (or solely the impact on fuel consumption) caused by these speed variations is seldom investigated. In previous publications (Prats and Hansen, 2011; Delgado and Prats, 2011, 2012, 2013), the authors have studied the impact that changes in speed may have on the fuel consumption and how different speed reduction strategies may be used to enhance ATFM initiatives. This section gives a brief overview of ground delay programs and the principal concepts that are behind the speed reduction strategy described in this paper.

### 2.1. Ground delay programs

In the US, a ground delay program (GDP) is implemented when an airport is expected to have insufficient arrival capacity to accommodate forecast arrival demand. The FAA, acting in its role as traffic flow manager, proposes a program in which flights are assigned to slots. Some flights are exempted from the FAA assigned delay. A first set of exempted flights are those airborne at the time the GDP is implemented and international non-Canadian flights. The second set is GDP dependent and exempts flights originating outside a certain radius from the affected airport (Ball and Lulli, 2004). One of the main reasons for applying this exemption policy is the uncertainty when estimating the arrival capacity of the airport. Predicted capacity