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# The Effects of the Planning Horizon on Heathrow TSAT Allocation

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## 1 Introduction and Problem Description

London Heathrow is an extremely popular two-runway airport. The runway forms the major throughput limitation for the departure system and thus increased departure delay is always expected at busy times of the day, when the demand exceeds the available capacity. A Collaborative Decision Making system has been developed by NATS and Heathrow Airport Ltd (HAL) to share information between the various partners at the airport (e.g. airlines, ground handlers, airport staff and the NATS controllers). TSAT (Target Start-up Approval Time) allocation algorithms run within the CDM system, predicting take-off times for aircraft and allocating appropriate times (the TSATs) at which each aircraft will be able to push back and start its engines. The predicted take-off times are provided to Eurocontrol, contributing to airspace capacity improvements. TSAT allocation aims to absorb at the stands some of the delay that aircraft would otherwise experience at the runway. Even a two minute reduction in fuel burn for all aircraft would save over £13M per year, along with the consequent reductions in emissions.

Minimum separations must be attained between any aircraft which use a runway. Re-sequencing can avoid larger separation requirements and improve runway utilisation and delays [3,4]. Due to the unusual constraints at Heathrow, the take-off sequencing can be very sensitive to the mix of aircraft

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which are available: only one runway can be used for take-offs at any time; downstream capacity constraints increase separations on some routes; and the airport is running close to capacity. It has been common to release aircraft from the stands as soon as possible, providing the maximal sequencing choice at the runway. Stand delays must not decrease the runway throughput.

The TSAT allocation algorithms predict the take-off sequence which a good controller would achieve at the runway and are described in [3]. Delays around the stands can be considerable, since aircraft can block each other, and have to be considered, resulting in a combination of two sequencing operations: once at the runway and one at the stands [3]. Once a take-off time has been predicted for each aircraft, an ideal pushback time is determined by considering the estimated taxi time to reach the runway from the allocated stand, the expected delays around the stands, and an 'ideal' runway hold. This 'ideal' runway hold adds slack to allow for deviations from predicted taxi times and to provide a pool of aircraft for the runway controller to choose from.

The TSAT allocation system relies upon the early provision of planned earliest pushback times (called TOBTs, Target Off-Block Times) from airlines in order to predict the earliest take-off time for each aircraft. As it is made aware of more aircraft over time, better sequences may be found, fitting new aircraft into the sequence and making small changes. It was observed in [2] that the planning horizon has a huge effect upon the runway sequencing efficiency at Heathrow. The aim of this research is to discover the extent to which this also applies when sequencing is performed at the stands in order to allocate stand holds and whether a lack of early information is likely to release inappropriate aircraft to the runway, leading to poor sequencing, and/or increased fuel burn.

## 2 Experimental details and results

The same model, parameters and objectives have been used in this research as in [4], except for the addition of a cost for larger runway delays to model the fact that a runway controller is likely to allow aircraft which have been waiting at the runway for a long time to take off earlier. This will be discussed in more detail in the full paper. The primary objective of the algorithm is to meet take-off time windows, where possible, and the secondary objective is to achieve low delay sequences which avoid excessive inequity between aircraft. The trade-off between these objectives was considered in [1].

Eighteen Heathrow datasets, provided by NATS, were tested, containing 105 consecutive take-offs each, from the same runway. The first five take-off times were fixed, to provide a take-off history. An iterated simulation was performed whereby the algorithm considered the aircraft it knew about, predicted take-off times and allocated TSATs, then advanced the time by 60 seconds, adding in new aircraft, then repeated this process. The historic pushback times were used for the TOBTs and were provided to the system $PH$ seconds before TOBT, where $PH$ is the planning horizon being investigated. TSATs were

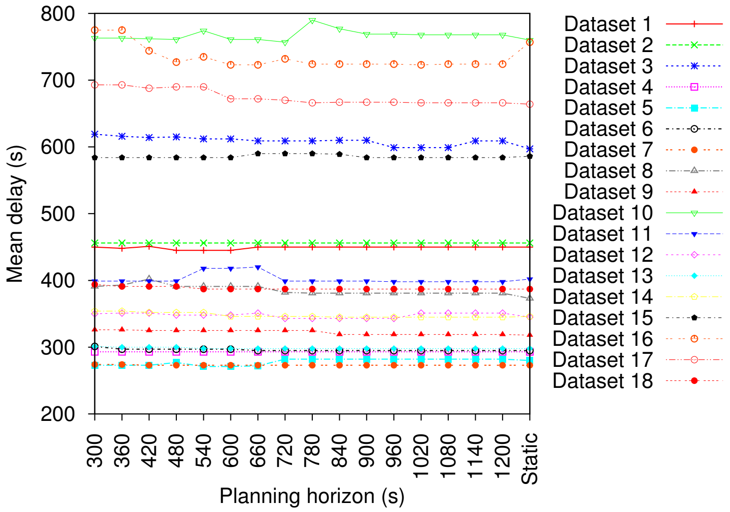

**Fig. 1** Graph of mean delay (stand hold + runway delay) vs planning horizon for all 18 datasets

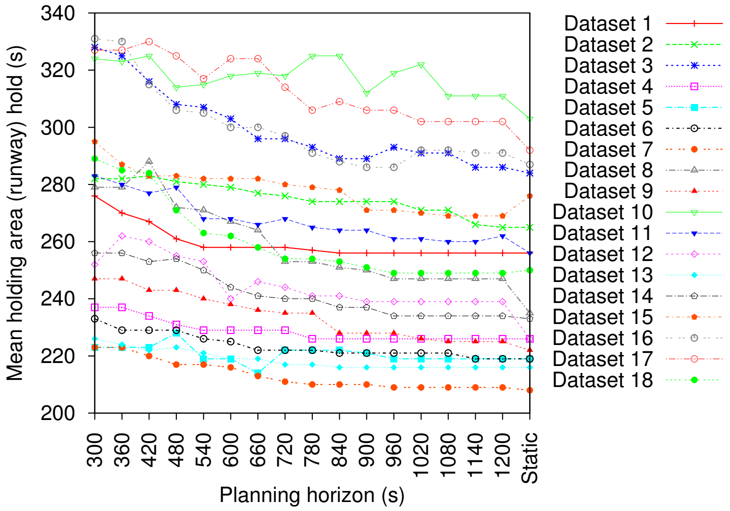

**Fig. 2** Graph of mean runway hold vs planning horizon for all 18 datasets

frozen 300 seconds before the TSAT time. No uncertainty was assumed in the predictions.

Figure 1 shows how the mean delay (on the y axis) changes as the planning horizon increases (from left to right) and compares it against the delay in the static problem (on the far right, considering all aircraft simultaneously). The delay is not greatly affected by a low planning horizon, since the system still has the potential to change the take-off sequence once the aircraft have left

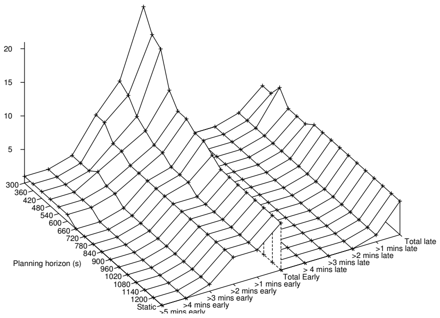

**Fig. 3** Deviation of aircraft from ideal TSATs, Dataset 1

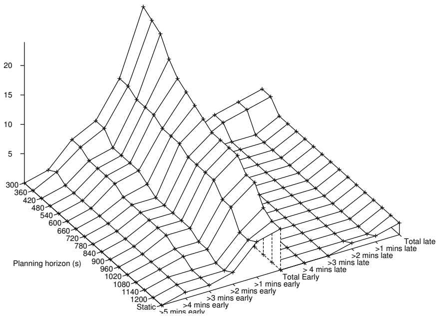

**Fig. 4** Deviation of aircraft from ideal TSATs, Dataset 2

the stands. In contrast, the runway delay is shown in Figure 2 and is much larger for lower planning horizons. This indicates that significant re-sequencing is being performed after the aircraft leave the stands and that the lack of information is leading to stand holds which would have been larger otherwise, leading to unnecessary fuel burn.

Figures 3 and 4 show, for two datasets, the deviation of the allocated TSAT from the ideal TSAT which would have been allocated based upon the final take-off sequence which was achieved. The delays around the stands mean that ideal stand holds could not be allocated to all aircraft even in the static case (the line closest to the reader). It can be observed that the system is applying shorter stand holds than ideal to some of the aircraft and that it is very rare for aircraft to be released later than ideal.

This research shows that late information from airlines may adversely affect the potential benefits of the TSAT allocation system, leading to increased airline costs and emissions. The complete consideration of the full results, the effects of the ideal stand hold, the time at which the TSAT is frozen, and the function to limit excessive runway hold are left for the full paper.

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