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A metric for the real-time evaluation of the aircraft boarding progress

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ABSTRACT

Future 4D aircraft trajectories demand the comprehensive consideration of environmental, economic, and operational constraints. A reliable prediction of all aircraft-related processes along the specific trajectories is essential for punctual operations. The uncertainties in the airborne phase only have minor impacts on the punctuality of a flight. The necessary change to an air-to-air perspective, with a specific focus on the ground operations, will provide key elements for complying with the challenging future requirements of a comprehensive 4D aircraft trajectory over the day of operations. A major task of the ground operations is to ensure a reliable and predictable departure time, which is an operational milestone for both the current and the destination airport. These mutual interdependencies between airports result in system-wide, far-reaching effects (reactionary delays). The ground trajectory of an aircraft primarily consists of the handling processes at the stand (deboarding, catering, fueling, cleaning, boarding, unloading, and loading), which are defined as the aircraft turnaround. To provide a reliable prediction of the turnaround, the critical path of processes has to be managed in a sustainable manner. The turnaround processes are mainly controlled by the ground handling, airport or airline staff, except the aircraft boarding, which is driven by the passengers' experience and willingness or ability to follow the proposed procedures.

Addressing the fact that boarding is on the critical path of the aircraft 4D trajectory and not controlled by the operators, this paper provides a scientific approach for a real-time evaluation of the boarding progress using the capabilities of a future connected cabin (e.g. sensor environment). A calibrated microscopic approach is used to model the distinct passenger behavior, where the individual movement is defined as a one-dimensional, stochastic, and time/space discrete transition process. The simulation environment is capable of covering a broad range of behaviors, boarding strategies and operational constraints and allows the integration of infrastructural changes and future technologies. The paper provides a set of indicators for depicting the real-time status of the boarding progress as a fundamental basis for the prediction of the boarding time. In this context, the aircraft seats are used as a sensor network with the capability to detect the seat status: free or occupied. The seat status is the basis for the calculation of an aircraft-wide interference potential as the major indicator for the boarding time. In combination with an integrated airline/airport information management (e.g. sequence of boarding passengers), the boarding progress will be transformed from a black box to a transparent progress with the operator's real-time ability to react to significant deviations from the planned progress. Thus, the research results provide a fundamental contribution towards the derivation of the crucial aircraft departure time.

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1. Introduction

The International Civil Aviation Organization (ICAO) provides with the Aviation System Block Upgrades (ASBU) a timeline for implementing efficient flight paths for full 4D trajectory based operations (ICAO, 2013). In the ASBU Block 0 (available) improved airport operation through Airport Collaborative Decision Making (A-CDM, see Eurocontrol, 2014) is a mandatory element. The A-CDM concept aims at an information-based decision management through real-time sharing of operational milestones among all stakeholders. It is expected that the common awareness will result in improved processes and a balanced utilization of both local and network resources. Thus, the prediction and reliability of the TOBT (Target Off Block Time, SESAR, 2014) become essential as regards the challenged high arrival punctuality at the destination (Tobaruela et al., 2014). The next ASBU Block 1 (2018–2023) necessarily demands performance improvements through the application of SWIM (System Wide Information Management, ICAO, 2016) and an increased interoperability through flight and flow information for a collaborative environment (ICAO, 2012) application before departure. Since information and data management is becoming more important for the efficiency of the global air traffic management system (ICAO, 2005), SWIM is one of the key elements of the US Next Generation Air Transportation System (NextGen) and the Single European Sky ATM Research Program (SESAR).

From an air transportation system view, a flight could be seen as a gate-to-gate or an air-to-air process. Whereas the gate-to-gate is more focused on the aircraft trajectory flown, the air-to-air process concentrates on the airport ground operations to enable efficient flight operations proving reliable departure times. Typical standard deviations for airborne flights are 30 s at 20 min before arrival (Bronsvoort et al., 2009), but could increase to 15 min when the aircraft is still on the ground (Mueller and Chatterji, 2002). As Fig. 1 demonstrates, the average time variability (measured as standard deviation) is in the flight phase (5.3 min) higher than in the taxi-out (3.8 min) and taxi-in (2.0 min) phases, but significantly lower than the variability of both variabilities departure (16.6 min) and arrival (18.6 min) (Eurocontrol, 2017). If the aircraft is departing from the airport, changes with regards to the arrival time are comparatively small (Tielrooij et al., 2015). Thus, the arrival punctuality is clearly driven by the departure punctuality (Eurocontrol, 2017).

The departure and arrival punctuality in 2016 is shown in Fig. 2, where punctuality is defined as not being later than 15 min with

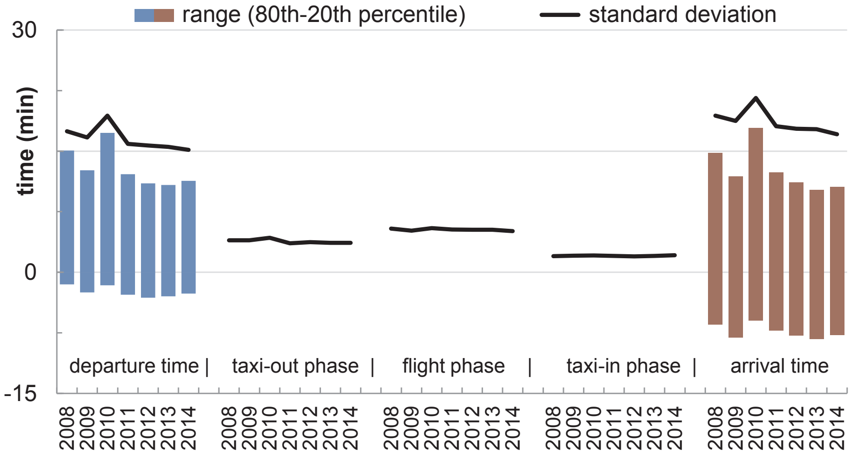

Fig. 1. Variability of time/delay at ground and flight phases on intra-European flights from 2008 to 2014 (Eurocontrol, 2017).

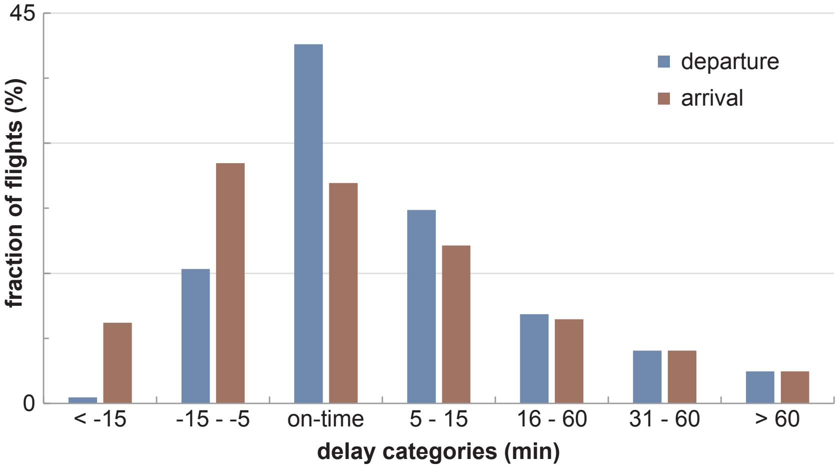

Fig. 2. Departure and arrival punctuality (Eurocontrol, 2016).