Progress in Aerospace Sciences xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Progress in Aerospace Sciences

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

A review of aircraft turnaround operations and simulations

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ARTICLE INFO

Keywords:
Ground operation
Turnaround
Passenger boarding
Aircraft cabin
Airport

ABSTRACT

The ground operational processes are the connecting element between aircraft en-route operations and airport infrastructure. An efficient aircraft turnaround is an essential component of airline success, especially for regional and short-haul operations. It is imperative that advancements in ground operations, specifically process reliability and passenger comfort, are developed while dealing with increasing passenger traffic in the next years. This paper provides an introduction to aircraft ground operations focusing on the aircraft turnaround and passenger processes. Furthermore, key challenges for current aircraft operators, such as airport capacity constraints, schedule disruptions and the increasing cost pressure, are highlighted. A review of the conducted studies and conceptual work in this field shows pathways for potential process improvements. Promising approaches attempt to reduce apron traffic and parallelize passenger processes and taxiing. The application of boarding strategies and novel cabin layouts focusing on aisle, door and seat, are options to shorten the boarding process inside the cabin. A summary of existing modeling and simulation frameworks give an insight into state-of-the-art assessment capabilities as it concerns advanced concepts. They are the prerequisite to allow a holistic assessment during the early stages of the preliminary aircraft design process and to identify benefits and drawbacks for all involved stakeholders.

1. Introduction

The aviation industry will be challenged by an annual 4.6–4.9% growth in passenger traffic in the next 20 years [1,2]. It is imperative that advancements in ground operations, specifically process reliability and passenger comfort, are developed to deal with increasing congestion at major hub airports. Current research mostly focuses on aircraft efficiency in terms of reduced carbon dioxide (CO_2), nitrogen oxides (NO_x) and noise emissions. This trend is due to ambitious goals promoted by national and international regulators, such as NASA Advanced Air Vehicle Program [3], Air Transport Action Group [4] and the Advisory Council for Aviation Research and Innovation in Europe (ACARE) [5]. However, the implementation of current research in fulfillment of the goals proposed by these regulators would require significant operational efficiency improvements, a topic which is often not addressed. The ACARE work group proposed a reduction of turnaround times by 40% in 2050 using novel handling concepts as well as actual arrival and departure times to be within one minute of scheduled times [6,7]. Especially, regional and short-to-medium haul flights are of concern as they account for the major share of global air traffic.

An efficient aircraft turnaround is an essential component of airline success, especially for regional and short-haul operations. The current ground operational procedures are highly optimized for available infrastructure and aircraft types. Further improvements can be made by refining process execution, providing better predictability for each step improving on-time performance and by reducing additional planned buffer times. In short-haul operations, passenger egress and ingress together with refueling, cleaning, and catering, are on the critical path which determines the total turnaround time. Reducing passenger boarding and disembarking time would simultaneously shorten turnaround time and free up airport capacity. Turnaround time and punctuality are not on the same level of criticality for long-haul operations since delays can be absorbed during the longer flight time and airport curfew hours can determine scheduled arrival and departure times.

The review presented here is based on the research of Schmidt et al. [8–11]. After an introduction of ground operations, focusing on the aircraft turnaround and passenger processes, the key challenges for current aircraft operators are highlighted. These comprise, amongst others, airport capacity constraints, schedule disruptions and the increasing cost pressure for aviation stakeholders. A summary of existing modeling and simulation frameworks gives insight into state-of-the-art assessment capabilities when it concerns advanced concepts. Afterwards, a review of conducted studies and conceptual work focusing on the turnaround shows pathways for potential process

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http://dx.doi.org/10.1016/j.paerosci.2017.05.002
Received 3 January 2017; Received in revised form 9 May 2017; Accepted 9 May 2017
0376-0421/

Nomenclature

Acronyms and abbreviations

ABS	Agent-based simulation
ACARE	Advisory Council for Aviation Research and Innovation in Europe
AHM	Airport Handling Manual
APU	Auxiliary power unit
CA	Cellular automaton
CAST	Comprehensive Airport Simulation Tool
CO_2	Carbon dioxide
CPM	Critical path method
DES	Discrete event simulation
CS	Certification Specification
DEL	Indira Gandhi International Airport
DOC	Direct operating cost
EWR	Newark Liberty International Airport
FAR	Federal Aviation Regulations
FRA	Frankfurt Airport
GSE	Ground support equipment
HL	Hand luggage
IATA	International Air Transport Association
IGOM	IATA Ground Operations Manual
JFK	John F. Kennedy International Airport
LCC	Low cost carrier
LHR	London Heathrow Airport
LSP	Lifting seat pan
MEX	Mexico City International Airport
NO_x	Nitrogen oxides
OEM	Original equipment manufacturer
PCA	Pre-conditioned air
PEK	Beijing Capital International Airport
SA	Single-aisle
SFS	Sideways foldable seat
TA	Twin-aisle
ULD	Unit load devices

optimization. Initial results using an agent-based passenger flow simulation are presented for promising aircraft cabin modifications. This paper concludes with a recapitulation of the current research in ground operations and proposes future research goals.

2. Overview of current aircraft ground operations

Airports have been repeatedly challenged, in terms of their operations, by the introduction of new aircraft throughout the history of aviation. Some of those aircraft were revolutionary for their time, such as the Boeing 747 (B474), Concorde and recently, the Airbus A380. Before the B747 and Concorde entered service, a thorough understanding of the terminal-related functions, ground handling characteristics and operational economics was necessary for the determination of aircraft servicing so it would not be determined by facility limitations [12]. The B747 revolutionized the cargo handling in terms of speed, through the introduction of further automation with unit load devices (ULD).[2] Prior to the entry into service of the A380, the stakeholders involved analyzed their current airport systems to identify shortcomings and requirements for area improvements [13]. Consequently, airports had to expand their runways, taxiways and gate positions to accommodate this new aircraft type. Applying modified processes in conjunction with adapted ground support equipment (GSE) allowed new aircraft types to be successfully operated at existing airports and partly improve the operation of existing aircraft types. The next generation of aircraft featuring more electric systems, hybrid-electric propulsion or non-drop-in fuels will again challenge the airport operations [14].

This section provides an overview of aircraft ground operations for contemporary single- and twin-aisle single-deck aircraft. The aircraft characteristics related to ground operation are reviewed first, proceeded by the procedures of aircraft turnaround and passenger ingress. Finally, a summary of the regulations and guidelines concerning aircraft design and ground operations currently in place is given.

2.1. General overview of aircraft ground operation

Airports are the fundamental core of all commercial passenger flights. They allow aircraft to take-off and land and provide necessary facilities to service the aircraft. Fig. 1 provides an overview of a generic airport. Airport operations are divided into 'landside processes', where passengers arrive, drop off their luggage and go through security, and 'airside processes', where passengers board and disembark planes. Airside processes cover also the take-off and landing of the aircraft, as well as taxiing procedures [15]. The focus here is on the turnaround, the connecting element between the airport and the aircraft. Turnaround can take place directly at the gate or at a remote apron position.

2.2. Aircraft characteristics related to ground operation

Aircraft are equipped with multiple interfaces, such as doors and hatches, to exchange goods, passengers or liquids during the ground service. The position of these interfaces varies depending on if the aircraft features wing-mounted or aft-fuselage-mounted engines, or if it is a low-wing or high-wing aircraft. A cluster analysis of regional and single-aisle (SA) aircraft in and out of production [11] revealed a trend shifting towards commonality, such as for the potable and waste water connector at the aft fuselage (see Fig. 2). Also, the electrical power interfaces were in general located in the forward section of the fuselage, while the fuel connector was located on the outer side from the engine. In general, passenger doors were located at each end of the passenger cabin, enabling an uninterrupted passenger cabin where passenger emergency passways do not obstruct the seat rows. This allows for a freely adjustable seating layout in terms of seat pitch[3] and class configuration. Galleys and lavatories were situated in the entrance area, enabling an easy trolley exchange through the opposite service door during the aircraft turnaround. Larger SA aircraft featured additional quarter doors in front of the wing due to their higher passenger capacity which allow for passenger egress and ingress. Due to the spatial separation of passenger boarding and cargo operations, cargo doors were, in general, located on the right side. High-wing configurations with turboprop engines allow boarding and disembarking as well as loading and unloading operations to be easily performed without the requirement of external airstairs due to the lower sill height [11].

The seating layout inside the fuselage is driven by the number of passengers transported, door positions and the operator business model. The latter determines the number of cabin classes, the targeted aircraft operation in terms of average flight distance and the seat pitch. The existence of premium cabin classes requires a higher ratio of lavatories and galleys per passenger compared to SA layouts with only

[2] A unit load device (ULD) is a standardized pallet or container used to load luggage or freight on to an aircraft.

[3] The seat pitch is defined as the distance from any point on one seat to the same point on the following seat.