Boarding Efficiency

How to enter an aircraft – the most efficient way?

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Introduction

• Michael Schultz
  • Business and Engineering degree (Dipl.-Wirtsch.-Ing.)
  • PhD in Aviation Technologies (Dr.-Ing.)

• former senior researcher at Institute of Logistics and Aviation, Technische Universität Dresden

• Currently Heading Department of Air Transportation, Institute of Flight Guidance at German Aerospace Center in Braunschweig

• Research Topics
  • model-/data based performance assessment of Air Traffic Management (ATM)
  • Performance Based Airport Management (PBAM)
  • advanced ATM concepts

• Structure of presentation: research background > turnaround > boarding modell > results
Background - Passengers at Airport Terminals

Considering of visual perception areas
- navigation to unknown locations
- information gathering and processing

Schultz et al. (2011) Managing Passenger Handling at Airport Terminal
Background - Group Dynamics

- Common group behavior also valid for airport environment

Schultz et al. (2011) *Group dynamic behavior and psychometric profiles as substantial driver for pedestrian dynamics*

Schultz (2010) *Entwicklung eines individuenbasierten Modells zur Abbildung des Bewegungsverhaltens von Passagieren im Flughafenterminal*
Background - Group Dynamics (2)

- Common constellation of pedestrians walking in groups (size of 2, 3, and 4 pedestrians)

Schultz et al. (2011) *Group dynamic behavior and psychometric profiles as substantial driver for pedestrian dynamics*, Presentation at Pedestrian and Evacuation Dynamics Conf.
Airt Transportation - Turnaround

- Connect research topics: passenger dynamics, turnaround optimization
  - increasing passenger transport capacity of aircrafts
  - demand for efficient connection between land/airside
  - ATM significantly depends on a reliable turnaround progress

- Boarding
  - always on the critical path
  - high potential of disruptions
  - robust strategies vs. highly optimized procedures
  - Passengers own the process, individual behavior drives the boarding progress

Fricke and Schultz (2009) *Delay Impacts onto Turnaround Performance*
How boarding looks like?

Szenario: Random – 1 Door

Results:
- Boarding efficiency: +0 %
- Boarding stability: +0 %

Boarding Progress: 30 %

see [http://video.air.transportation.org](http://video.air.transportation.org)
Aircraft Layout

• A320 as a reference layout

• Layouts differ
  - amount of passengers
  - number of aisles
  - config: 1st, business, eco

• Passenger process
  - enter aircraft
  - get correct aisle
  - walk to assigned seat
  - store baggage
  - seating interaction

Schultz (2013) Boarding on the critical path of the turnaround
Aircraft Layout - Modell

Schultz (2010) Entwicklung eines individuenbasierten Modells zur Abbildung des Bewegungsverhaltens von Passagieren im Flughafenterminal
Motion Model and Parameter

• Asymmetric simple exclusion process (ASEP)
  - stochastic, forward directed, one dimensional, and discrete
  - shuffled sequential update of positions at each time step
  - regular grid consists of equal cells with a size of 0.4 x 0.4 m²
  - $v_{\text{max}} = 1$ model (max 1 cell per time step)
  - pax speed of 0.8 m s$^{-1}$ at the aisle
  - time step of 0.5 s

• Additional parameter
  - individual amount baggage
  - interaction during seating (seat shuffle)
  - boarding strategy

\[ F(t) = \begin{cases} 
\frac{(t - \text{min})^2}{(\text{max} - \text{min})(\text{mode} - \text{min})}, & \text{if } \text{min} \leq t \leq \text{mode} \\
1 - \frac{(t - \text{max})^2}{(\text{max} - \text{min})(\text{max} - \text{mode})}, & \text{if } \text{mode} < t \leq \text{max.}
\end{cases} \]

Schultz (2013) Boarding on the critical path of the turnaround
Boarding Strategies

- Random (reference), Block, Back-to-Front, Outside-In

• Remarks:
  - tourist with clear trend of groups with 2 or more members (81%)
  - business travelers often travel alone (73%)
  - passengers are not altruistic (non-conformant behavior)
  - fast processes need considerable pre-sorting effort

Schultz (2013) Boarding on the critical path of the turnaround
Simulation Scenarios – Sensitivity Analyses

• Input
  - time to store baggage
  - seat shuffle: response time, interaction time
  - seat layout of aircraft: A320, B777 (2-5-2, 3-4-3, 3-3-3), A380

• Variation of input factors
  - boarding strategy/passenger sequence (default: random)
  - seat load factor (SLF) - ranging from 20% to 100% (default: 85%)
  - conformance rate (CR) - ranging from 20% to 100% (default: 85%)
  - arrival rate at aircraft (AR) - ranging from 1 to 40 pax per minute (default: 14 pax per minute)
  - one door and two door configuration (default: one)
Results (1) - Video

Szenario: Back to Front

Results:
- Boarding efficiency: -11%
- Boarding stability: -12%
- Boarding Progress: 74%

see http://video.air-transportation.org
Results (2) - Video

Szenario: Block-Boarding

Results:
- Boarding efficiency: +4 %
- Boarding stability: +4 %
- Boarding Progress: 36 %

see http://video.air-transportation.org
Results (3) - Video

Scenario: Block Boarding - Alternating

Results:
- Boarding efficiency: +16%
- Boarding stability: +14%
- Boarding Progress: 51%

See http://video.air-transportation.org
Results (4) - Video

Szenario: Outside-In

Results:
- Boarding efficiency: +19%
- Boarding stability: +22%
- Boarding Progress: 34%

see http://video.air-transportation.org
Results (5) - Video

Szenario: Reverse Pyramid

Results:
- Boarding efficiency: +23 %
- Boarding stability: +28 %
- Boarding Progress: 60 %

blocked seats

see http://video.air-transportation.org
Results (6) - Video

Scenario: Random - 2 Doors

Results:
- Boarding efficiency: +26 %
- Boarding stability: +34 %
- Boarding Progress: 29 %

see http://video.air-transportation.org
Results (A320 Sample)

Block – Sequence

Acceptance of Boarding Sequence

Schultz (2013) Boarding on the critical path of the turnaround
Results (B777, A380 Sample)

Arrival Rate (B777)

Acceptance of Boarding Sequence (A380)

Schultz (2013) Boarding on the critical path of the turnaround
Summary of Research Results

- Reliable boarding progress and delay compensation during the turnaround (A320, B777, A380)
  - additional door for the boarding process (20 - 25 % savings)
  - change of the boarding strategy (10 - 15 % savings)
  - different seat layouts (3 % savings)

- Verification/Validation
  - field trials done with Airberlin for validation of input parameters
  - reliability of the proposed stochastic aircraft boarding model against common observations
  - measurements for further improvements needed (reducing variance)

- Microscopic (individual-based) process description results in
  - identification of optimization potential of existing processes
  - stochastic boarding model to derive a benchmark methodology
  - coupling of infrastructure and procedure requirements
Next Step – New Infrastructure?

- Side-Slip-Seat - @molonlabeledesigns

First simulation results using new slide seats (preliminary results! procedures not yet verified)

- random boarding (0%, 0%)
  - efficiency + 16%
  - stability + 4%

- block boarding (16%, 14%)
  - efficiency + 25%
  - stability + 11%

- Random boarding, 2 doors (26%, 34%)
  - efficiency + 31%
  - stability + 40%
Boarding Efficiency

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