Boarding on the critical path of the turnaround

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Structure

1. Introduction - Research Motivation
2. Prior Research
3. Stochastic Model of Passenger Boarding
4. Results of Simulation Scenarios
5. Outlook
Introduction – Research Motivation

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
  - measurable input factors
  - high potential of disruptions
  - passengers have to learn
  - stabilizing strategies vs. highly optimized procedures
At a Glance

Reliable boarding progress and delay compensation during the turnaround

- additional door for the boarding process (20 - 25 % savings)
- change of the boarding strategy (10 - 15 % savings)
- different seat layouts (3 % savings).

Validation checks are performed (field trials with Air Berlin)

- high reliability of the proposed stochastic aircraft boarding model
- adapted seating procedure is planned to be introduced
- measurements for further improvements (reducing variance)

Microscopic process description

- potential of optimization of existing processes
- application for all turnaround processes, derive benchmark
- test of dynamic interactions
Modeling

“Essentially, all models are wrong, but some are useful.”
Microscopic Model of Pedestrian Behavior

Stochastic model defined by specific transition matrix: \( M = p \cdot q \)
- 3 transition states for horizontal and vertical movements \{-1, 0, +1\}

\[
\begin{align*}
\text{h}^{+1} &= \frac{1}{2} (\sigma^2 + \mu^2 + \mu) \\
\text{h}^{0} &= 1 - (\sigma^2 + \mu^2) \\
\text{h}^{-1} &= \frac{1}{2} (\sigma^2 + \mu^2 - \mu)
\end{align*}
\]

Group Size

<table>
<thead>
<tr>
<th>Group Size</th>
<th>Business</th>
<th>Tourist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73%</td>
<td>19%</td>
</tr>
<tr>
<td>2</td>
<td>23%</td>
<td>55%</td>
</tr>
<tr>
<td>3</td>
<td>4%</td>
<td>26%</td>
</tr>
</tbody>
</table>


Boarding on the critical path of the turnaround
Group Dynamics

Schultz, M., L. Rößger, H. Fricke, and B. Schlag (2012). *Group dynamic behavior and psychometric profiles as substantial driver for pedestrian dynamics*, Pedestrian and Evacuation Dynamics
Application – Passenger Dynamics

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

Aircraft Seating

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
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 ms\(^{-1}\) at the aisle
- time step of 0.5 s

Additional parameter
- individual amount \textbf{baggage}
- interaction during seating \textbf{(seat shuffle)}
- boarding \textbf{strategy}

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

Boarding on the critical path of the turnaround
Model Seat Layout

Single and twin aisle configuration

Random choice at twin aisle configuration
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
Boarding Strategies – Block Definition B777

economy section is divided into 8 equal blocks
- harmonization of the different layouts: Emirates, Cathay Pacific, Boeing
- 36 first class seats (boarded first)
- 198 (200 Emirates) seats in the center, 122 seats in the rear section
Boarding Strategies – Block Definition A380

Emirates seat layout with deck-wise separation of premium/economy class
- 399 economy seats are located on the main deck
- independent boarding progress for the upper and main deck section
Scenario Definition

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 – Boarding Progress

![Graph showing boarding progress](image)

- seat load factor reached (%)
- time (% of expected boarding time)

- 0.10 quantile
- 0.25 quantile
- expected value
- 0.75 quantile
- 0.90 quantile
Results – Block Size (A320)

The diagram illustrates the expected boarding time (%) for different boarding block sizes (number of boarding blocks) compared to various boarding sequences: back-to-front, random, block (fastest sequence), and outside-in. The graph shows that the back-to-front sequence has the highest expected boarding time, followed by random and block (fastest sequence), with outside-in having the lowest expected boarding time.
Results – Arrival Rate (B777)
Results – Conformance Rate (A320)

Boarding on the critical path of the turnaround
Results – Conformance Rate (A380)
### Boarding on the critical path of the turnaround

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Sequence</th>
<th>Expected Boarding Time (%)</th>
<th>Standard Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A320 1 door</td>
<td>random</td>
<td>100.0</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>80.9</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>back-to-front</td>
<td>110.6</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>96.1</td>
<td>6.1</td>
</tr>
<tr>
<td>2 doors</td>
<td>random</td>
<td>74.1</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>63.9</td>
<td>3.0</td>
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<tr>
<td></td>
<td>back-to-front</td>
<td>75.4</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>85.0</td>
<td>5.8</td>
</tr>
<tr>
<td>B777 1 door</td>
<td>random</td>
<td>100.0</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>86.0</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>91.0</td>
<td>2.7</td>
</tr>
<tr>
<td>2 doors</td>
<td>random</td>
<td>73.8</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>67.1</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>76.4</td>
<td>2.1</td>
</tr>
<tr>
<td>A380 1 door</td>
<td>random</td>
<td>100.0</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>85.9</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>95.9</td>
<td>5.3</td>
</tr>
<tr>
<td>2 doors</td>
<td>random</td>
<td>81.4</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>outside-in</td>
<td>73.7</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>block</td>
<td>79.1</td>
<td>3.2</td>
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At a Glance – Recap

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Thank you for your attention

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