Agent based modelling of blended wing body aircraft boarding strategies

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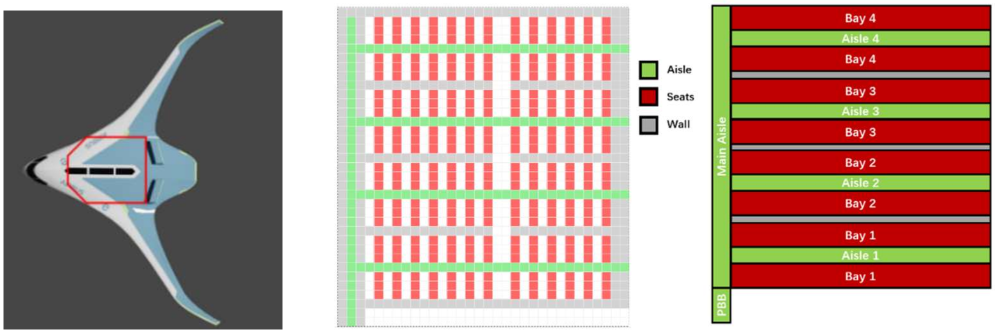
1 INTRODUCTION

For passenger aircraft, boarding constitutes a significant part of the turnaround time. Delays in the daily operation of passenger aircraft can result directly from prolonged boarding times (Schultz et al., 2013). Aircraft boarding is influenced by various factors such as the boarding strategies, passenger behaviors, and cabin layouts. To improve boarding efficiency, a particular boarding sequence can be arranged either before or after passengers pass through the boarding gate (Tanida and Nishinari, 2021). Although the boarding of conventional tube-and-wing aircraft has been extensively investigated, that of the blended-wing body (BWB) passenger aircraft has been significantly less explored. As a popular option for next-generation passenger aircraft, BWB aircraft are anticipated to fulfill the ever-increasing requirements of good fuel economy, low noise, and low emissions in civil aviation (Mody et al., 2010). Compared with conventional tube-and-wing aircraft, the BWB aircraft are expected to have distinctively different shapes. Existing studies have typically investigated the boarding process while assuming that boarding strategies are limited to simple options (Yildiz et al., 2018). This study aims to investigate new possible boarding strategies for improving the boarding efficiency of future BWB aircraft.

2 BOARDING MODEL

The cabin layout of the boarding model is shown in Figure 1. We mainly referred to N2A-HWB (Mody et al., 2010) for the cabin size. The boarding model is based on the well-tested cellular automaton (CA) model, which has been extensively used to simulate boarding processes (Schultz, 2018). The CA model discretizes space into cells, which have two states: occupied or empty. A cell can be temporarily occupied by an agent (passenger walking on aisles), or permanently occupied by obstructions (walls, seats, etc.).



(a) (b) (c)

Figure 1 – (a): 3D models of Airbus Maverick. The presumed cabin area is marked by red boxes. This image is designed to show the shape of the BWB cabin, without reliable information on "actual" sizes or cabin shapes. Original models are from ("Airbus Blended Wing Body," n.d.).

(b), (c): Overview of the boarding model. The 32 × 35 grid was designed to simulate a BWB cabin divided into four bays, each with its own aisle.

In this model, the agents' behaviors follow a set of simple rules: a) entering the aircraft through the passenger boarding bridge (generated at the entrance if the cell is vacant), b) moving from cell to cell to reach their assigned seats, c) stowing their baggage, d) taking their seats. Each timestep represents 0.5 second in real life. The simulation will finish when all agents are seated.

3 BOARDING STRATEGIES

3.1 Conventional Boarding Strategies

Four boarding strategies are adapted from those used in conventional tube-and-wing aircraft:

Random: The boarding order is randomly determined.

Back-to-Front: Agents are organized into four equally sized groups based on their seat positions in the longitudinal direction, irrespective of which bay they belong to. Agents assigned to seats at the back area of each bay board first. The boarding order within each group is random.

Outside-in: Agents are organized into three equally sized groups. The first group comprises agents assigned to window seats, and the second and third groups comprise agents assigned to middle seats and aisle seats, respectively. The boarding order for each group is random.

Double Outside-in: Similar to *Outside-in*, but each boarding group is further divided into two equal-sized groups based on their seat positions in the longitudinal direction, similar to *Back-to-Front*. This boarding strategy was introduced in (Schultz, 2018).

3.2 N-Aisles Steffen

The boarding problem was simplified by organizing 312 passengers into 48 groups, as shown in Figure 2. In each group, passengers board in a back-to-front order. Two consecutive agents in one group have a seat difference of 12. This boarding strategy is inspired by the highly efficient *Steffen Perfect*, where agents are first assigned to window seat boards in a back-to-front order while skipping one row (Steffen, 2008). A combined group is defined as two groups boarding together. Combined groups are classified into two types based on their influences on congestion:

Type A: Groups belonged to bay 1 and 2. They cause congestion near boarding gate and have a significant impact on boarding time.

Type B: Groups belonged to other bays. They cause congestion far away from the boarding gate, therefore the impact on the overall boarding time is limited.

We now introduce the boarding strategy *N-Aisles Steffen (N-Steffen)*. As shown in Figure 2, in *N-Steffen*, two type A combined groups are always separated by at least one type B combined group to reduce congestion near the boarding gate. The sequence of combined groups is not unique, and can be extended to BWB cabins with more bays and aisles.

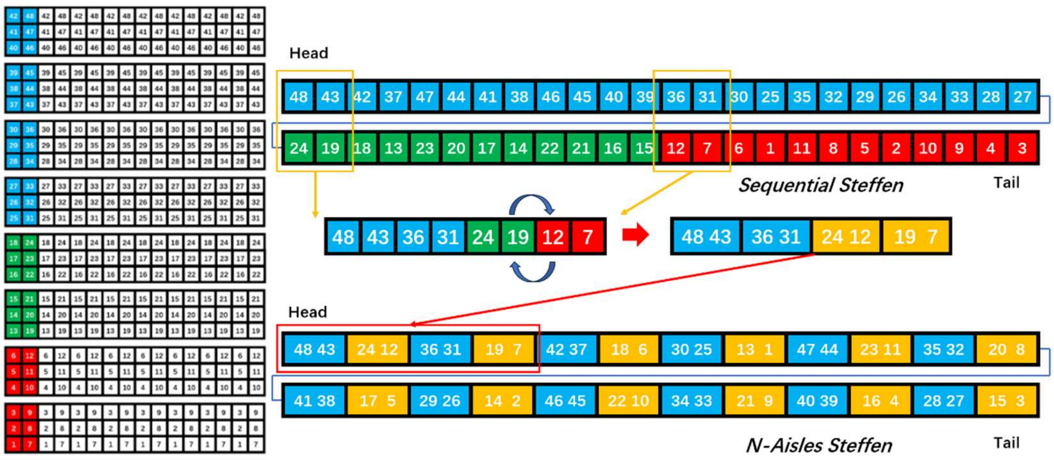


Figure 2 – Modification of *Sequential Steffen* into *N-Aisles Steffen*. *Sequential Steffen* means each bay is filled sequentially with the classic *Steffen Perfect* (Steffen, 2008). *N-Aisles Steffen* ensures that for bays 1 (red) and 2 (green), only one group will attempt to enter the corresponding aisle simultaneously. Type A combined groups are yellow and type B combined groups are blue.

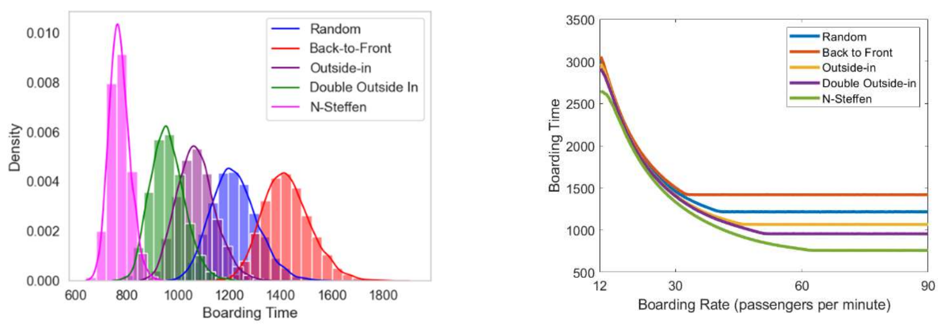


Figure 3 – Left: Kernel density distributions and histograms of all five boarding strategies when the boarding rate is 60 passengers per minute.

Right: Changes in boarding time when boarding rate gradually increases from 12 passengers per minute to 90 passenger per minute.

As shown in Figure 3, the simulation results suggest that *N-Steffen* and *Double Outside-in* offer higher boarding efficiencies than conventional boarding strategies in ideal scenarios. The average boarding time *N-Steffen* decreases to 771.02 timesteps (385.51 seconds), with a significantly lower deviation. However, the performances of boarding strategies are limited by the boarding rates.

4 Discussion

The presence of multiple aisles in the BWB boarding model enables faster boarding compared with conventional tube-and-wing aircraft, particularly when combined with appropriate boarding strategies. *N-Aisles Steffen* is a boarding strategy designed specifically to reduce congestion during the boarding of the BWB aircraft. It can reduce boarding time by approximately 36.6% (compared to *Random*) in ideal cases. On the other hand, *Double Outside-in* has emerged as a simple and reliable boarding strategy for the BWB aircraft.

For the BWB aircraft, boarding rates have become a bottleneck for improving boarding efficiencies. The ticket checking process should be more automated to allow a significantly higher boarding rate compared to modern airports. Other changes in related systems, such as the passenger boarding bridges and boarding gates, may also be necessary.

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