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Experimental analyses of airplane boarding based on interference classification

Xinhui Ren*, Xiaobing Xu**

College of Economics and Management, Civil Aviation University of China, No.2898 Jinbei Road, Tianjin, 300300, PR China

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ABSTRACT

Passenger boarding is a key activity of flight turnover. A reduction in boarding time can benefit airlines carriers, airports, and passengers in terms of economical, operational, and customer satisfaction reasons, respectively. The study classifies seat interference and aisle interference to aid in analyzing airplane boarding. A boarding experiment was conducted in a prototype cabin with forty-eight seats to evaluate six boarding strategies and explore the impact of music on boarding and passengers' perceived time. The experimental results confirm that reserve-pyramid and outside-to-inside strategies exhibit good efficiency. In addition, the back-to-front strategy used by several airlines is inefficient; and music significantly affects the perceived time and reduces the boarding time to a certain extent. The results of the study can provide a reference for airlines to select boarding strategies and improve passenger experience.

1. Introduction

Passenger boarding is a key activity in flight turnover that directly affects turn-around time. Airline carriers, airports, and passengers benefit from reduced boarding time. With respect to airline carriers, a reduction of 1 min in the turn-around can save US$30 at each turn-around (Nyquist and McFadden, 2008). A reduction in turn-around time implies that an airplane parks at a gate for a shorter time (Steffen, 2008). The airport offers more flights per day per gate by optimizing the boarding procedure. Furthermore, reduction in the total boarding time indicates reductions in the average individual boarding time, and this enhances perceived passenger relaxation (Jaehn and Neumann, 2015).

Interferences are distinguished as either seat interferences or aisle interferences (Van den Briel et al., 2003). Typically, a few models attempt to minimize the interference and increase the boarding time speed (Bazargan, 2007; Kuo, 2015; Soolaki et al., 2012; Tang et al., 2012a, 2012b). A study on airplane boarding mainly focuses on a comparison of boarding strategies (Nyquist and McFadden, 2008; Jaehn and Neumann, 2015). Simulation studies on boarding strategies include the following (although they are not limited to the following examples). Different boarding patterns are investigated to detect the extent to which boarding time is reduced (Van Landeghem and Beuselinck, 2002). Ferrari and Nagel (2005) focus on disturbances, such as boarding earlier or later, and the results support the typical back-to-front boarding strategy when passengers do not follow their boarding group.

Recently, a few studies focus on passengers' individual properties (Tang et al., 2012b), grouping characteristics (Budesca et al., 2014; Zeineddine, 2017), baggage distribution in cabin (Milne and Kelly, 2014; Milne and Salari, 2016), aircraft interior design (Bachmat et al., 2009; Chung, 2012; Schmidt et al., 2017; Schultz et al., 2013), and dynamic changes of infrastructure (Schultz, 2017). Several studies propose new boarding strategies based on the aforementioned factors. For example, Notomista et al. (2016) provide a fast airplane boarding strategy using online seat assignment according to passenger classification. Passengers are assigned to seats on airplanes based on their carry-on luggage (Milne and Kelly, 2014; Milne and Salari, 2016). Based on the outside-to-inside strategy, a new strategy developed by Ren et al. (2016) assigns passengers with several pieces of luggage to seating at the back of the aircraft. Zeineddine (2017) proposed a dynamically optimized aircraft boarding strategy. Schultz (2017) dynamically changed aircraft seat condition for fast boarding. However, only a few studies examine passengers' perception. Specifically, there is paucity of studies examining the impact of separating passengers' cliques (e.g., families, friends or traveling companions) on passenger satisfaction and even airline selection. Thus, research related to perceived time is attracting increasing attention in the field of travel behavior research. Perceived time is estimated by an individual's own perception, and affects passenger experience and satisfaction. Miura and Nishinari

* Corresponding author.
** Corresponding author.
E-mail addresses: xinhui9596@sina.com (X. Ren), xuxiaobing_cauc@163.com (X. Xu).

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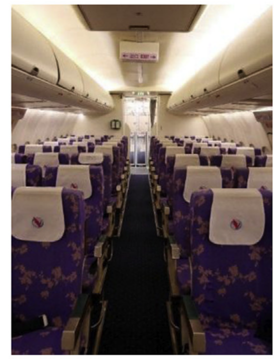
(a)



(b)

Fig. 1. Photograph of the mock-up cabin.

(2017) indicated that the ratio of perceived time to actual time corresponds to a Gaussian distribution. Load factor, seat pitch, and boarding strategies are factors that change perceived time. Based on extant studies, the present study investigates and analyzes the perceived time of boarding.

Most studies use computer simulation or mathematical methods. Most parameters correspond to empirical data and lead to few difficulties in implementation. Deviations exist between computer simulation and the real process. For example, passengers do not exhibit micro behaviors and are assumed as homogeneous in simulations, and it is impossible to obtain passenger perception in simulations. Therefore, it is necessary to perform experiments to test boarding strategies and analyze the perceptions of a passenger. A few studies involved experimental tests. Steffen and Hotchkiss (2012) conducted an experimental comparison of boarding strategies in a mock Boeing 757 fuselage and indicated the optimized Steffen strategy effectively reduces boarding time. Gwynne et al. (2018) performed a series of small-scale laboratory tests to investigate three factors as follows: seat pitch, luggage, and instructions. They then examined the significant albeit complex effect of luggage and seat pitch on performance. Qiang et al. (2017) organized passengers to board a school bus to evaluate strategies by using a surrogate experimental test. Miura and Nishinari (2017) used tables and chairs in a room and conducted boarding experiments to understand how passengers assess boarding/deboarding time and then modeled the perceived time of boarding/deboarding.

The main contributions of the present study are as follows. The study tests boarding in prototype Boeing 737–800 cabin, and it provides a reality experimental environment when compared with experiments in a school bus (Qiang et al., 2017) or a room (Miura and Nishinari, 2017). Luggage data is collected by performing surveys on approximately 20 flights at several Chinese airports. We classify and allocate luggage based on the survey results, and this increases the accuracy and realism of the experiment. The study subdivides interferences to analyze the boarding process in further detail. Furthermore, it attempts to explore whether music impacts boarding time and perceived time, which is a topic that is currently unexplored in previous studies. The aim of the study involves analyzing the interference and efficiency of boarding strategies and exploring the impact of external factors on boarding such as music. The results of the experiment are expected to aid in establishing a model of interference in subsequent studies.

The study is organized as follows. In this section, we provide an overview of the boarding problem and focus on a comparison of experimental studies. In Section 2, we discuss an appropriate experimental design based on the research question. Section 3 is dedicated to the index. Section 4 yields results and analysis. Section 5 concludes the study and reports on future studies.

2. Design of boarding experiment

The study attempts to analyze the experimental results based on interference classification and examines as to whether music significantly impacts boarding time and perceived time. Therefore, luggage is subdivided into three types based on the site investigation. Interference is classified, and music is added in the boarding strategy. The boarding experiment was performed by 96 participators in April 2017. We obtained experimental data and analyzed interferences, boarding time, and perception time. The experiment involves the following assumptions:

(1) Late arrival or early boarding is not required;
(2) A passenger boards the aircraft at the front door;
(3) The aisle in the cabin is narrow, and this allows only one passenger to pass;
(4) The load factor is 100%.

2.1. Dimension of the mock-up cabin

The experiment was conducted in a Boeing 737–800 mock-up airplane, and a photograph is shown in Fig. 1. The layout of available seats and location of camera are shown in Fig. 2, which includes 12 rows of six seats and a single central aisle. The distance between two adjacent rows is 78 cm with the exception of the first row that has a corresponding separation of 115 cm. The row of the emergency exit is 92 cm. The aisle width is 64.5 cm and only allows one passenger to pass.

The dimensions of the overhead bin and the proportion, amount, and size of carry-on luggage affect luggage stowing time. The aforementioned factors can affect the frequency and duration time of interferences, and thereby affect boarding time. The structure of interior space of the overhead bin is shown in Fig. 3. The overhead bin has a width of 63.5 and a height of 30 cm.

2.2. Characteristics of luggage

Given the different types of flights, there are differences in the number, size, and proportions of passenger carry-on luggage. Field surveys were implemented at Tianjin Binhai International Airport, Kunming Changshui International Airport, and other airports in China to collect luggage data. Based on the survey results, baggage is divided into three types as follows: trolley cases, backpacks, and hand bags, which are indicated asL_l, L_m, L_s, respectively. The baggage distribution is shown in Table 1. The dimensions of the trolley case are 50 cm * 34 cm * 20 cm, those of the backpack are 30 cm * 25 cm * 10 cm, and those of the hand bag are 15 cm * 10 cm * 5 cm as shown in Fig. 4.