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Small-scale trials on passenger microbehaviours during aircraft boarding and deplaning procedures

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ABSTRACT

NRC researchers have recently employed computational tools to simulate airline passenger movement – primarily to examine the impact of different procedures on aircraft boarding times. It was felt that the modelling techniques could be improved by the inclusion of current, relevant and refined data on passenger movement. This article outlines a series of small-scale laboratory tests performed to help quantify individual passenger boarding and deplaning movement with and without the presence of luggage. Test subjects were monitored and video recorded while participants moved through a cabin section enabling observers to quantify the performance of specific micro-behaviours that formed the deplaning and boarding process. These tests were conducted at the National Research Council of Canada's prototype cabin research facility. The trials involved a total of 35 subjects who were each observed performing a series of 12 trials inside the cabin section. These trials were formed from the manipulation of three factors: seat pitch (29 in/31 in/33 in), luggage (present/absent), and instructions (continuous flow/discrete movements). During each trial, participants performed a series of micro-behaviours that included traversing the aisle/row, stowing/collecting under-seat bags, seat belt fastening and unfastening and adopting a brace position. In addition, two trials were conducted for each participant outside of the cabin facility to establish baseline straight line movement speeds with and without luggage. The study indicated that the impact of luggage and seat pitch had a notable, but complex, effect on performance and, more importantly, generated an array of data-sets for use in future simulation efforts. For instance, seat pitch appeared to have a more consistent impact when passenger movement was perpendicular to the seat row, as opposed to along the seat row where the impact was varied. Such data collection is necessary to advance empirical support for current and future simulation efforts.

1. Introduction

Changes to airline boarding efficiency are influenced by societal changes and airline policies (http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm). These changes affect passenger experience and turnaround costs; for instance, Nyquist and McFadden estimated in 2008 that it cost an airline $30 for every minute that an aircraft was on the ground during turnaround (Nyquist and McFadden, 2008). Given that a large airline can operate thousands of flights per day, this cost spirals quickly. Airlines and airport operators routinely look for ways to improve aircraft turnaround time – effectively, the time required to unload the aircraft at the gate and ready it for takeoff (Marelli et al., 1998). Turnaround time is reliant on a number of phases related to (1) luggage/cargo handling, (2) airplane servicing and (3) cabin and passenger servicing (Marelli et al., 1998). This last element includes bridge positioning, deplaning passengers, servicing cabin and galleys, boarding passengers and removing the bridge. In this article, we present data describing passenger boarding and deplaning activities.

To discriminate between aircraft designs and boarding/deplaning designs, it is necessary to quantify their impact on passenger movement during routine/non-emergency and emergency scenarios. This becomes more important as aircraft designs become more complex (multi-aisle, novel seating configurations, etc.) and different boarding procedures are employed (WILMA, Reverse Pyramid, etc.); i.e., where it is not necessarily possible to derive results analytically.

In recent years, the impact of configuration and procedural designs on passenger performance has become of greater interest – as an indicator of passenger experience, passenger safety and as a means to establish the relative benefits of design change (Milne and Kelly, 2014;

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NTSB, 2000). This interest has required and benefitted from greater understanding of passenger performance (in both emergency and non-emergency scenarios) supported by empirical data (Marelli et al., 1998; NTSB, 2000; Júnior et al., 2008; Van den Briel et al., 2003; Iyigunlu, 2015; Soolaki et al., 2012; Steiner and Philipp, 2009; Wallace; Kalić et al., 2013; Fernandes and Pacheco, 2002; Ahmadpour et al., 2016; Tang et al., 2012a; Steffen and Hotchkiss, 2012; Bachmat et al., 2006; Bazargan, 2007a; Landeghem and Beuselinck, 2002; Nagel and Ferrari, 2005; Steffen, 2008a, 2008b; Van den Briel et al., 2005; Daamen, 2004; Galea et al., 2010; Ferrari and Nagel, 2005; Kirchner et al., 2003; Peterson et al., 1995; Tang et al., 2012b; Van Landeghem and Beuselinck, 2002; Lewis and Lieber, 2005; Mattern, 2003; Mitchell, 2008; Reed and Yu, 2006; Yu, 2006; Setti and Hutchinson, 1994; Dorton and Liu, 2016; Helkey, 2013; Office of Technology Assessment, 1993; Sun et al., 2013; Audenaert et al., 2009; Bachmat and Elkin, 2008; Ball et al., 2010; Bazargan, 2007b; Johnson, 1973, Marcus, 1997; Blethrow et al, 1977; Barker, 1996; Snow et al., 1970; Rose, 1969; Quigley, 2001; Muir, 1996a; Muir and May, 1996b; Muir and Cobbett, 1996a; Muir and Cobbett, 1996b; Muir and Cobbett, 1999; Muir et al, 1989; Muir et al, 1990; Muir et al, 1992; McLean, 2001; Marrison and Muir, 1992). However, the data are not sufficiently comprehensive (issues of scope), sufficiently detailed (issues of granularity) and are often not provided in the manner required to support intended applications (issues of format). *Gaps exist that need to be filled.*

One such application, which is particularly dependent on a variety of data-sets, is the modelling of passenger movement using computer simulation tools (Marcus, 1997; Rose, 1969; Galea et al., 2003, 2006; Blake et al., 2002; Miyoshi et al., 2012; Kirchner et al., 2003; Liu et al., 2014a; Du et al., 2016; Fang et al., 2016; Zhi-Ming et al., 2014; Hedo and Martinez-Val, 2011; Cagliostro, 1984; Hedo and Martínez-Val, 2010; Marcus, 1994a, 1994b; Folk, 1972; Court and Marcus, 1996; Garner, 1978; Schroeder and Tuttle, 1991; Liu et al., 2014b; Mackenzie et al., 2012; Sharma et al., 2008; Court, 1999) that attempt to simulate passenger movement to investigate issues such as the time to complete the check-in process, board an aircraft, or deplane from an aircraft (from an individual or aircraft perspective). However, the simulation tools are only as powerful and credible as the data and assumptions on which they are based.

Over the last few decades, there has been a significant change in the demographic make-up of passenger populations (reflecting society at large (http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm; Quigley et al., 2001)) and the level of passenger encumbrance; i.e., passengers now tend to board and deplane an aircraft with more luggage given changes to airline cabin policies (http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm; Dorton and Liu, 2016; Johnson, 1973). These demographic and encumbrance changes have driven changes in boarding rates (which might in turn affect turnaround time). Before 1970, passengers typically boarded an aircraft at a rate of 20 passengers per minute. By 1998, the boarding rate had fallen to 9 passengers per minute due in part to policies charging passengers for stowing luggage in the hold (Marelli et al., 1998; Milne and Kelly, 2014). The demographic and behavioural changes will impact passenger movement. This will not only affect non-emergency scenarios, but may also affect emergency scenarios; for instance, people choosing to collect baggage during an evacuation or rapid deplaning (http://www.cnn.com/2015/09/11/travel/ba-plane-fire-las-vegas-luggage/index.html;http://www.bbc.com/news/magazine-34191035; https://www.economist.com/blogs/gulliver/2016/08/baggage-battles;http://nationalpost.com/news/world/passengers-who-evacuated-british-airways-flight-that-caught-fire-ignored-pilot-who-told-them-to-leave-their-luggage-behind/wcm/b0b4b826-f855-40b8-af7c-7538423c1282;https://www.theguardian.com/uk-news/2015/sep/09/aeroplane-evacuations-why-people-grab-luggage-before-escaping;http://www.independent.co.uk/news/world/americas/ba-plane-fire-pilots-condemn-passengers-who-carried-baggage-from-burning-aircraft-10493667.html;http://www.independent.co.uk/travel/news-and-advice/dubai-plane-fire-video-emirates-emergency-evacuation-crash-landing-passengers-suitcases-fireball-a7171341.html;http://www.independent.co.uk/travel/news-and-advice/dubai-plane-fire-video-emirates-emergency-evacuation-crash-landing-passengers-suitcases-fireball-a7171341.html;http://www.abc.net.au/news/2016-08-04/is-it-illegal-to-take-your-bag-from-a-plane3f/7688930), moving more slowly due to an increased likelihood of physical impairment in the passenger population, etc.

The work presented in the following sections describes a set of small-scale experiments to collect data on passenger travel speeds and task completion times for typical boarding and deplaning activities for a representative single-aisle aircraft design. The intention was to collect data related to a set of passenger micro-behaviours – the individual behaviours that form the passenger boarding and deplaning experience - to gain specific insights, but also to facilitate the quantification of passenger movement and subsequent processes such as aircraft turn-around – be it through engineering analysis or through agent-based simulation. Within a simulation model, the expected tasks could be reconstituted in different ways to represent different boarding and deplaning procedures. Although the data may still require manipulation for inclusion with specific simulation tools, the data are collected and presented on the individual action level – such that it might at least be directly transposed to a simulated agent at a level of detail reflecting real-world performance. It is hoped that this effort, although provisional and simplistic, will aid in the development and application of simulation tools to the quantification of passenger movement around airports and aircraft – addressing current issues of data scope, granularity and format.

2. Boarding and deplaning

Airlines include a number of boarding and deplaning procedures to enhance efficiency and passenger comfort (Marelli et al., 1998; Van den Briel et al., 2003; Iyigunlu, 2015; Soolaki et al., 2012; Steiner and Philipp, 2009; Wallace; Kalić et al., 2013; Fernandes and Pacheco, 2002; Ahmadpour et al., 2016; Tang et al., 2012a; Steffen and Hotchkiss, 2012; Bachmat et al., 2006; Bazargan, 2007a; Landeghem and Beuselinck, 2002; Nagel and Ferrari, 2005; Steffen, 2008a, 2008b; Van den Briel et al., 2005; Daamen, 2004; Galea et al., 2010; Ferrari and Nagel, 2005; Kirchner et al., 2003; Peterson et al., 1995; Tang et al., 2012b; Van Landeghem and Beuselinck, 2002; Lewis and Lieber, 2005; Mattern, 2003; Mitchell, 2008; Reed and Yu, 2006; Yu, 2006; Setti and Hutchinson, 1994; Dorton and Liu, 2016; Helkey, 2013; Office of Technology Assessment, 1993; Sun et al., 2013; Audenaert et al., 2009; Bachmat and Elkin, 2008; Ball et al., 2010; Bazargan, 2007b; Johnson, 1973; Schmidt et al., 2016). For instance, boarding procedures include back to front, block approaches, Wilma (Tang et al., 2012a), unassigned seating and more recent developments such as the Steffen boarding procedure (Marelli et al., 1998; Van den Briel et al., 2003; Iyigunlu, 2015; Soolaki et al., 2012; Steiner and Philipp, 2009; Wallace; Kalić et al., 2013; Fernandes and Pacheco, 2002; Ahmadpour et al., 2016; Tang et al., 2012a; Steffen and Hotchkiss, 2012; Bachmat et al., 2006; Bazargan, 2007a; Landeghem and Beuselinck, 2002; Nagel and Ferrari, 2005; Steffen, 2008a, 2008b; Van den Briel et al., 2005; Daamen, 2004; Galea et al., 2010; Ferrari and Nagel, 2005; Kirchner et al., 2003; Peterson et al., 1995; Tang et al., 2012b; Van Landeghem and Beuselinck, 2002; Lewis and Lieber, 2005; Mattern, 2003; Mitchell, 2008; Reed and Yu, 2006; Yu, 2006; Setti and Hutchinson, 1994; Dorton and Liu, 2016; Helkey, 2013; Office of Technology Assessment, 1993; Sun et al., 2013; Audenaert et al., 2009; Bachmat and Elkin, 2008; Ball et al., 2010; Bazargan, 2007b; Johnson, 1973; Schmidt et al., 2016). Typically, these procedures attempt to manage the order in which passengers act and the number of passengers acting simultaneously to improve boarding efficiency. Similar approaches can be adopted for deplaning; however, given the limited opportunities for crew intervention, deplaning procedures are typically constrained by