HUMAN DECISION MAKING AND THREAT-AWARENESS RESPONSE DURING EMERGENCY AIRCRAFT EVACUATIONS

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Aircraft emergencies requiring evacuation present unique safety challenges to both crew and passengers due to the confined space and the speed at which fire, extreme heat and smoke propagate. In this scenario, where a one or two second delay can literally determine survivability, rapid evacuation is paramount. Although evacuation capability is demonstrated through required and controlled drills for aircraft certification, during a real emergency human factors affect passenger decision making, in some cases resulting in the decision to retrieve personal items during actual emergency evacuations. This may pose a significant threat to post-accident survivability. This research evaluates evacuation decision making and the associated impact on passenger exit flow, during emergency evacuation scenarios. This paper provides an update on a controlled field study using a functional CRJ-100 50-seat aircraft to explore the contributing factors affecting passenger threat awareness and decision making during aircraft evacuations.

Unpredictable or adverse passenger decision making or lack of adherence to instructions during emergency aircraft evacuations have long been identified as contributors to delayed egress and fatalities from otherwise survivable crashes (Muir & Marrison, 1990). Even a few seconds delay can result in additional and needless fatalities. While aircraft design plays a key role, human behavior and decision making can also dramatically impact exit flows and potential survivability; this has been demonstrated even in very recent aircraft incidents (McGee, 2016). A National Transportation Safety Board (NTSB) study in 2000 found that 50% of people involved in an actual emergency evacuation reported having attempted to retrieve their carry-on bag and were the most frequently cited obstruction to evacuation (NTSB, 2000). Accidents as recent as the Delta MD-88 runway excursion in 2015 involved post-accident evacuations that were hampered by hesitancy to begin evacuation by crew members and passengers (Aerossurance, 2016; NTSB, 2016). Survivor reports of passengers attempting to retrieve carry-on bags were documented for the Asiana 777 runway crash in San Francisco, the British Airways 777 engine failure in Las Vegas, and the Emirates 777 fire in Dubai; these demonstrate that baggage retrieval and hesitancy remain a threat (RAS, 2016). Clearly, passenger decision making continues to play a significant role in survivability of modern aircraft, and could contribute to fatalities in what might otherwise be a survivable aircraft accident. This exploratory study evaluates passenger emergency evacuation scenarios using a 50 passenger jet, in an effort to gain a better understanding of the passenger human factors and to identify any appropriate measures to mitigate associated potential threats.

Background

As part of a rigid certification process, regulatory requirements spell out precise configuration and testing requirements for evacuation timelines for large aircraft certification. For example, Federal Aviation Administration (FAA) regulations require aircraft with seating capacity over 44 passengers be designed for complete evacuation through half of the available exits in 90 seconds. (U.S.C.F.R.-FAA (a), 2016) including formulas for total exit time calculations (FAA (b), 2012 p. 19) and required manufacturing design, g-force load carrying capabilities and safety technologies like fire suppression (FAA (c), 2010).

Findings from one NTSB safety study on emergency evacuations indicated that although exit row passengers may be pre-screened and briefed regarding the use of emergency exits, many passengers reported that they did not actually comply with instructions to read and understand emergency exit instruction cards (NTSB, 2000). Additionally, human intuition and perception of the way things operate (right or wrong) and ease of use can be strong determinants of behavior in an aircraft evacuation.

Aircraft design engineers report that evacuation speed can be improved through the use of automatic evacuation systems, doors that are easy to operate, and seats that will stay secure and do not block the aisles (Rosenkrans, 2014). To reduce confusion reported in accident investigations, Boeing redesigned a series of its Type III overwing exit doors to hinge up and out after door handle activation; this design eliminates the issue of where to place removable exit "plug" type doors after they have been opened. This is critical since cabin flight crew members may not always be available to give instructions (NTSB, 2000).

Aircraft cabin design changes and new technologies have improved post-crash survivability and egress capabilities and have allowed airlines to meet prescribed requirements (FAA(c), 2010) As a result, the percentage of survivable accidents is increasing (Rosenkrans, 2014). However, timely aircraft evacuation also depends upon passengers leaving all items on board. Unfortunately, passengers may make inappropriate decisions that can potentially compromise their own safety, or the safety of other passengers. Passenger decisions to bring personal items with them when they evacuate or to retrieve carry-on items before exiting slow down evacuation and block the egress path for other passengers (NTSB, 2000). Examples of this are shown in Figure 1. Trying to retrieve carry-on baggage has been cited as a contributing factor for injuries and fatalities in recent crashes (McGee, 2016). Personal items and carry-on luggage may also potentially damage the aircraft evacuation slide, or cause injury to passengers.

(Gold, 2015)

Figure 1. Social media response to passengers who evacuate with luggage in London

While bringing items when evacuating is against FAA rules and many passengers consider it selfish, other passengers acknowledge they would bring items, with justifications ranging from medical need (medicine in a carry-on), to business need (computer and paperwork) or personal inconvenience (loss of personal items). Some passengers put their passport, wallet and cell phone in their pockets for takeoff and landing, so they can evacuate unimpeded but still be assured possession of their essentials (Gold, 2015). Other passengers suggest that if people want to bring carry-on items, they should be the last to evacuate (Gold, 2015); however, enforcing this framework would be difficult if not impossible. One pilot suggests that carry-on retrieval not only delays evacuation, but also increases exertion and causes greater oxygen use, when oxygen may be in limited supply during an emergency (Gold, 2015). A flight attendant notes that during a planned evacuation, passengers are asked not only to leave all items behind, but also remove high heels and eye glasses, which could potentially damage the slide and prevent others from evacuating (Gold, 2015).

Purpose

Although FAA provides a tightly regulated framework for assessing the evacuation time for an aircraft, and federal regulations advise that passengers leave items behind and follow the directions of a crew member, behavior observed in recent emergencies suggests that many passengers will bring items with them when they evacuate an aircraft in an emergency situation. The purpose of this research is to document human decision making during a controlled field test of an aircraft evacuation, including both qualitative and quantitative findings. One associated research hypothesis is that the average time to evacuate an aircraft will be longer if passengers are carrying personal items or carry-on items; the correlating null hypothesis is that evacuation times will not be longer if passengers are carrying items during evacuation. The purpose of this paper is to describe the framework and methodology, as well as present preliminary findings from pilot tests.

Methodology

This research is a controlled field study using a 50-seat Canadair Regional Jet (CRJ) 100 model manufactured in 1995. The aircraft is a single-aisle, twin engine transport category aircraft with a 3 flight crew configuration (2 flight and 1 cabin crew member). The lower deck height of this aircraft eliminates the need for emergency exit slides, however, as shown in Figure 2, in preliminary tests stairs were used to facilitate passenger exit off the wing leading edge to ensure safety, which is permitted during test certification per the regulatory guidance in Advisory Circular AC25.803 1A (FAA, 2012). ARFF responders were on-site to assist, and the evacuation activity was leveraged to support ARFF aircraft familiarity training. One fire fighter was stationed on the wing to enhance safe evacuation. This aircraft has four passenger area exits:

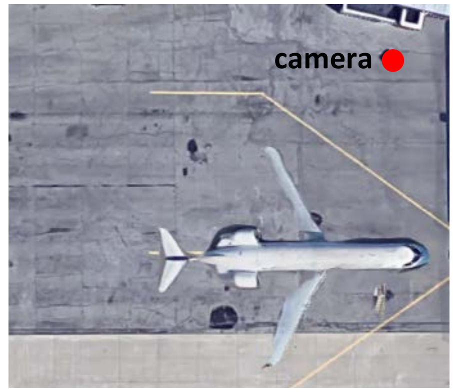
- Forward left passenger entry door (Type 1) that opens down to the ground incorporating stairs for main cabin and flight crew entry and exit.
- Forward right galley service door (Type 1) that can be used for emergency exit.
- Left side overwing removable plug (Type III) exit door.
- Right side overwing removable plug (Type III) exit door.

In preliminary tests, only the left side entry and overwing exit doors were used for consistency with FAA regulatory certification requirements to use only one half of the aircraft's doors; this also simplifies video documentation of the evacuation. Cameras were also mounted in the cabin, as shown in Figure 3. The flight deck also has an emergency escape door at the top of the fuselage, however, for safety, this was not incorporated in the initial testing. Aircraft interior seating chart is shown n Figure 4, and external dimensions of the aircraft in Figure 5.

The aircraft is functional but non-flying. Seating configuration is two seats abreast, single class configuration. All systems operate including electrical, hydraulic, pneumatic, engines, APU, interior overhead, placard and Emergency Exit Lighting. The test location was the aircraft ramp area used for parking and working on the jet as a live learning and research laboratory.

A convenience sample was used and participants were recruited from personal contacts of the researchers. Although demographic information was not collected, the sample was predominantly college students with an interest in aviation, since the study was conducted at the Purdue Airport, which serves the Purdue Aviation Technology program. The subject pool included anyone over 18 without regard to gender, ethnicity, or health status, although participants were required to be physically mobile and able to safety enter and exit the aircraft. The study was approved by the University Institutional Review Board (IRB) and the purpose of the research was explained to the participants, who signed a consent form prior to participating. After boarding the aircraft, stowing any personal items and carry-on items (some of

a. Passengers utilized the two port exits for egress



b. Camera location provided view of both port exits

Figure 2. Aircraft evacuation through port exits

Figure 3. Camera mounted in the galley provided limited field of view in the cabin

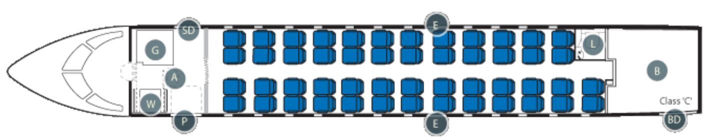


Figure 4. CRJ-100 interior seating chart (Bombardier)

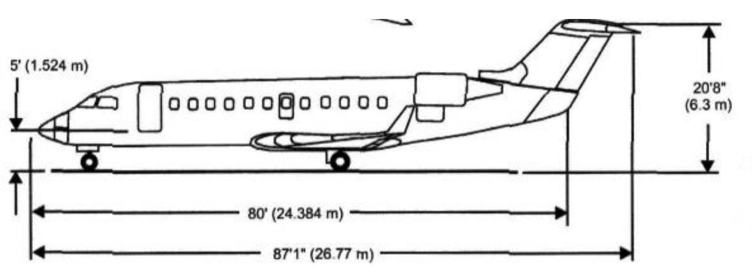


Figure 5. Exterior dimensions

which were provided by the researchers), participants sat in available seats of their choice in the aircraft. Researchers provided the flight safety briefing per the federal regulations for the CRJ aircraft, and participants were instructed to fasten seatbelts. Participants exited the aircraft via the left hand over wing emergency exit and left main entry door upon a verbal signal from a researcher on board the aircraft. Participants opened the exit and main doors using only the aircraft's actual safety information card without the assistance of researchers. Participants seated in row 8 (exit row) removed the exit door. In the first evacuation, they were instructed to place the door on their seat as they exited. Actual procedures would instruct that the door be thrown out of the aircraft, however, in the interest of safety and to protect the aircraft, in the remaining evacuation tests the door was handed to an ARFF or research personnel through the exit opening. After exiting, participants were directed to an emergency assembly area by ARFF personnel. Participants re-boarded the aircraft for another trial run but were instructed to sit in a different section of the aircraft so they would potentially exit from a different door. Trial runs included: passengers only (no items), passengers with carry-on items from below the seat in front of them or the overhead bin, and a mix of passengers with and without items.

Results

Pilot trials were held with two groups of less than ten passengers each, and with one group of 50 passengers. This allowed testing of the protocol and collection of preliminary test configuration data. The procedure generally went very well, and evacuation times were all within the 90 seconds required for a live drill. One limitation of these trials is the composition of the sample, namely able bodied aviation students who are very familiar with airplanes and are generally physically fit. The ease of evacuation within the required timeframe also suggests that the issue of retrieval of items may be more critical on larger aircraft.

Preliminary trials indicate that one potential issue is the placement of the exit door. When the door was placed in the cabin, it was an obstacle to egress (see Figure 5). Another possible challenge is the full utilization of all exits. Participants tended to use the exit closest to them, even if there was no line for the far exit. This makes sense, because the person at the front of the line wants to exit the aircraft as soon as possible, which would always be the exit right next to them. If the queue is near the window exit, it would be optimal to have half the people come to the front to exit, which flight crews are instructed to direct if able, but this is not optimal or intuitive in terms of fastest evacuation for the person at the front of the line. This imbalance would be presumably be exacerbated if there were smoke or other line of sight obstructions, or if a coordinating flight crew member were incapacitated or absent. One final observation is that, in some cases, the wing exit door was removed faster than the front door was opened. This could cause potential problems (due to an even longer ling for the wing exit) if people from both the front half and back half of the aircraft try to exit from through the wing exit.

One limitation of this study was that the stakes were low. In a real evacuation the consequences of evacuating quickly would be significant, and the stress of the situation would affect passenger decision making, which is hard to simulate in a controlled field study in which participant safety is a primary concern.

a. Exit door in cabin can be an obstacle to egress

b. Passengers evacuated through rear door only even after queue at front door cleared

Figure 5. Sample observations during preliminary trials

Recommendations and Conclusions

The human decision making element may be a more challenging factor to control in an emergency situation, based on observation of both historic data as well as very recent large aircraft accident events. Ironically the human element remains the greatest constraint in a NextGen system that has made substantial progress in terms of aircraft technologies, materials, and accident survivability. There is no question that timely and safe passenger evacuation is a critical component affecting safety and survivability following an aircraft incident or accident. Recent airline accident evacuation highlight the ongoing need to better educate passengers and develop more innovative intervention techniques to manage the passenger human factor and threat response during post-accident evacuation.

This paper presents a methodology as well as preliminary findings. These findings suggest that there is value to continued research in this area. Additional research includes additional data collection, the use of a larger aircraft, the use of a more diverse sample of passengers, and increasing the complexity of the evacuation scenario for a more accurate simulation of an actual emergency evacuation. Given the importance of this topic for passenger safety, additional research is clearly warranted to expand the understanding of the factors affecting safe and timely evacuation, and to develop educational and promotional information for passengers, as well as more detailed information regarding the cost, in terms of time as well as safety consequences, associated with passengers evacuating with items.

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