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Motivation and Egress Route Affect Simulated Emergency Aircraft Evacuations

Researchers found that subjects who were offered financial rewards tended to be among the fastest to evacuate and that the type of egress correlated with speed. Equally important, the study suggested that simulation design must include the factors that can confound experimental results.

Robert L. Koenig
Aviation Writer

Aviation regulatory authorities around the world take varying approaches in regulating emergency aircraft evacuations. That divergence in regulations has resulted partly from differing interpretations of data from research that used simulated emergency aircraft evacuations, often conducted using dissimilar techniques.

With the goal of harmonizing aircraft-egress regulations, the U.S. Federal Aviation Administration (FAA) and its regulatory equivalents worldwide are trying to identify the research techniques and data from evacuation simulations that "provide the most logical basis for regulation of the aviation industry."

As part of this effort, the FAA asked the Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma, U.S., to investigate the effects of passenger motivation on aircraft evacuations. CAMI researchers tested groups of subjects in simulations that varied evacuation routes (escape slides and platforms) and cabin visibility.

The results, described in a June 1996 report, *Aircraft Evacuations onto Escape Slides and Platforms I: Effects of Passenger Motivation*, indicated that financial incentives (and the resultant higher motivation) and the type of egress routes played "strong role[s]" in the speed of evacuations. Subjects tended to escape more quickly onto doorsill-height platforms than down escape slides.

But researchers also concluded that "findings derived from evacuation studies are very susceptible to nuances in individual subject behavior and experimental techniques/protocol."

The CAMI researchers who conducted the study and wrote the report — G. A. McLean, M. H. George, G. E. Funkhouser and C. B. Chittum — observed that varying techniques used by cabin-safety researchers at laboratories around the world had led to different opinions about the use of data generated by the simulations.

"These differences have led to divergence in the [worldwide] regulations promulgated by aviation regulatory authorities; such incongruities are troublesome to justify and often complicate operations for air carriers flying internationally," the authors wrote.

Their report warned that "combining previously studied independent variables" in evacuation research — such as the type of egress route, the smokiness of cabin air and the subjects' levels of motivation — "may produce unexpected interactions that invalidate initial assumptions about the utility of those variables in answering specific research questions."

The authors concluded by advising other evacuation researchers: "Studies intended to assess the evacuation potential of aircraft designs, configurations and operating procedures should tightly control such variables to prevent them from inadvertently confounding the experimental questions being addressed."

Although aviation researchers have been conducting simulated emergency aircraft evacuations for many years, the techniques, data and conclusions from such simulations often have not been parallel.

For example, some simulations used inflatable escape slides, and others used doorsill-height platforms. Some simulations motivated subjects by offering cash rewards to those who escaped fastest. Other simulations used no financial incentives. Some simulations introduced "theatrical smoke" into the cabins during the evacuations, but other tests did not include smoke.

To resolve some of the discrepancies, CAMI researchers set out to determine "whether the apparent disparities among data arising from previous evacuation studies could be rendered comparable within a single paradigm, using a factorial research design."

To that end, their study manipulated three factors:

- **Motivation.** The CAMI study included "experimental control of passenger motivation, using verbal instructions, flight attendant commands and financial incentives" to compare the effects of motivational differences on cabin evacuations;

- **Escape routes.** The use of two different egress routes — platform and slide — was "intended to answer questions about the willingness of passengers to deplane into the different escape devices and how each route modeled actual evacuations"; and,

- **Cabin smoke.** During the simulations, the air in the cabins was either clear or infused with theatrical smoke "to assess the effects of obscured vision on egress through floor-level [Type I] exits, as well as to investigate the interaction of motivational level with ability to see." [The U.S. Federal Aviation Regulations (FARs) Part 25.807 defines a Type I exit as "a floor-level exit with a rectangular opening of not less than (60 centimeters [24 inches]) wide by (122 centimeters [48 inches]) high, with corner radii not greater than one-third the width of the exit."]

Researchers hoped their work would lead to "a baseline for future evacuation research designs and protocols and [would] resolve questions of regulatory concern."

The CAMI researchers hypothesized that people in the cabin would escape faster onto the platform than onto the inflatable escape slide, especially when there was no smoke in the cabin. Also, they predicted that the effects of higher motivation would be greater with the platform than the slide because "competitive behavior was theorized to be more ardent" on the platform.

Researchers hoped their work would lead to "a baseline for future evacuation research designs and protocols and [would] resolve questions of regulatory concern." Also, they wanted to establish research designs and techniques that could be applied to both current and future aircraft evacuation simulations.

The 239 persons who took part in the CAMI research were between the ages of 18 and 44, and they were divided into four groups: three 60-person groups with an equal number of men and women, and one 59-person group that was 61 percent male. None of the subjects had participated previously in an aircraft evacuation.

The simulated aircraft cabin was configured as a Boeing 737, with rows of triple-seat assemblies placed six abreast. A Type I exit situated forward of the seats was fitted with an inflatable, single-lane escape slide, which was attached to the exit threshold by a girt bar.

Across the aisle, another Type I exit led to a 1.9-square meter (20-square foot) platform scaffold at doorsill height. A ramp, three meters (10 feet) wide and 10.7 meters (35 feet) long, led from the platform at a 15-degree angle to the ground.

Both cabin exits were covered with fabric "doors" that could be removed by research-team members when a buzzer signaled the beginning of the evacuation simulation. Video cameras recorded the evacuations, and in some simulations two smoke-generating machines fed theatrical smoke into the cabin.

The experimental design was 2 x 2 x 2, involving two motivational levels, two egress routes and two visibility conditions. "Two egress trials were conducted in clear air, followed by two egress trials in smoke that replicated the trial order sequence used in clear air. … The last trial in clear air was designed to highlight individual decision making, as each subject was allowed to choose his/her own egress route."

The baseline motivation for the subjects was a briefing by the principal investigator, who explained that each evacuation was intended to simulate an emergency and that passengers should exit the cabin as quickly as possible. In addition, a flight attendant at the active exit door shouted commands for passengers to unbuckle their seat belts and move forward to the exit. The other flight attendant blocked the inactive exit and redirected straying passengers to the active exit. Passengers in this group were told that the evacuation should be fast, but also cooperative.

To induce higher motivation in other test groups, researchers told them that the first 25 percent of passengers to evacuate the cabin (averaged across five egress trials) would earn a US$50 bonus. “Their briefings included no instructions to be orderly but emphasized the financial reward for fast individual egress.” They were told to use whatever technique they felt necessary (short of injuring themselves or other subjects) to exit quickly.

Evacuation times — recorded by videotapes of the evacuations and later analyzed by computer — were defined as the period from the beginning of the buzzer signal to the time that the group’s 58th passenger cleared an exit opening. Depending on the group, the last one or two passengers were left out of the analysis because experience from previous experiments showed that the last remaining passengers tended to feel less pressure and motivation to exit quickly.

The results indicated that both financial incentive (and the resultant higher motivation) and the egress route played a “strong role” in the speed of evacuations.

According to the three-way repeated-measures analysis, the type of egress route had the most significant within-group effect ($p < 0.012$). [Values for “p” indicate the probability that the results could be explained by chance. For example, “$p < 0.012$” means that there is slightly more than one chance in 100 that the results were caused by chance.] Subjects exited faster onto platforms than onto escape slides (Figure 1).

In addition, motivational level had a significant between-group effect ($p < 0.008$), with subjects exiting faster if they were promised financial incentives (Figure 2).

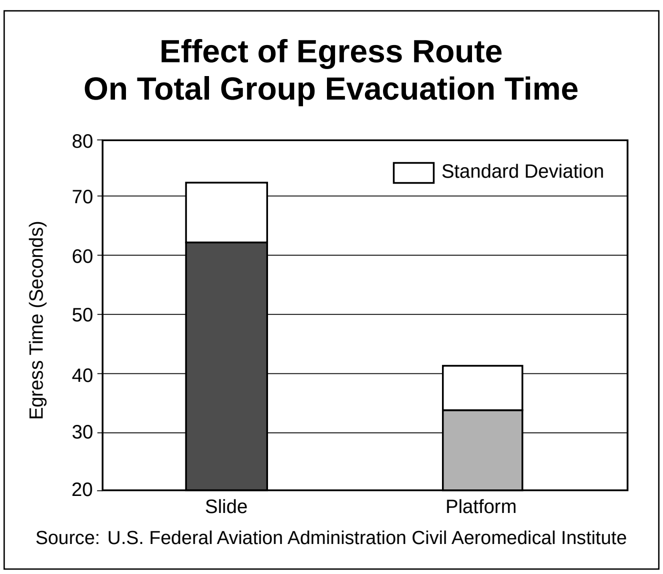

Figure 1

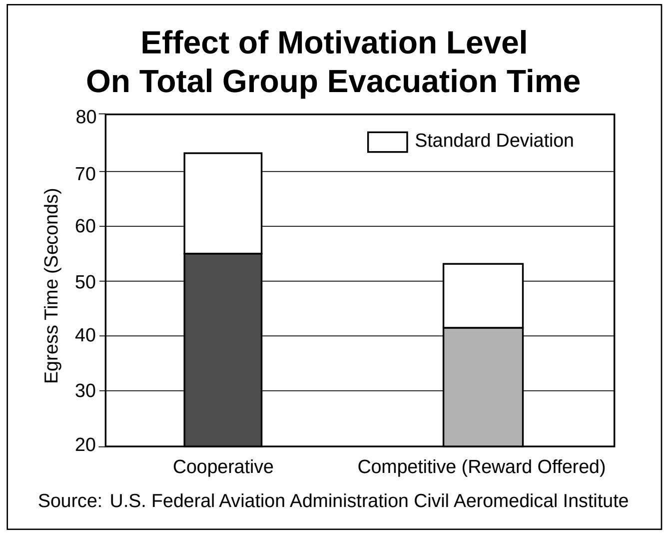

Figure 2

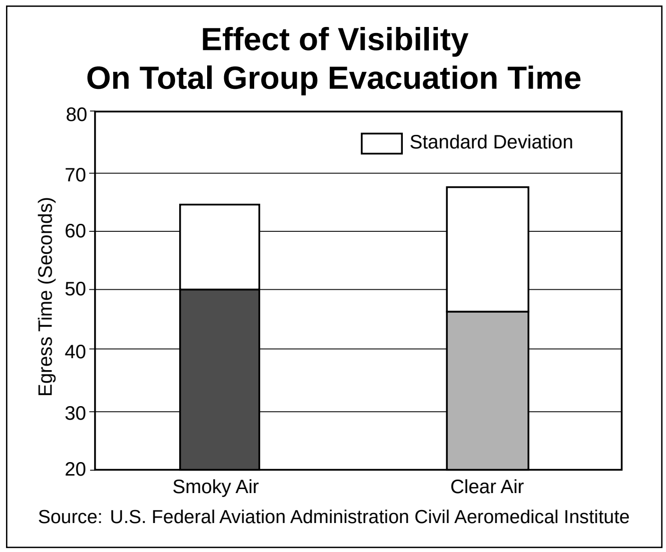

Figure 3

The smokiness of the cabin air was not found to have a within-group effect ($p < 0.45$) (Figure 3). Nevertheless, the analysis found a “hyperadditive interaction effect” for visibility by egress route ($p < 0.03$) (Figure 4, page 4). That result may have been influenced by “the effects of passenger hesitation at the Type I exit fitted with the slide,” researchers suggested.

No statistical significance was found in the motivational level by egress route ($p < 0.25$) (Figure 5, page 4); the visibility by motivational level ($p < 0.9$) (Figure 6, page 4); or the interaction of visibility, motivational level and egress route ($p < 0.2$).

“These effects reveal the strong role that financial incentives and differences in egress route had on the evacuations, especially when related to passengers’ ability to see,” the researchers wrote.

Although the CAMI experimental results showed “the potential for unanticipated findings from evacuation studies,” the report said, researchers were able to draw useful conclusions.

Platform vs. slide. It was clear that "the platform allowed much faster evacuations than the inflatable slide." The main reason: Passengers tended to hesitate a moment before using the escape slide, which required a small downward leap and "an associated leap of faith. Initially, the anxiety of having to jump onto the slide produced individual hesitations before passengers would jump; the cumulative hesitations [were] responsible for" the effect of the egress route on evacuation time.

The CAMI researchers suggested that the implication of that result for other cabin-evacuation research was clear: "Doorsill-height platforms do not model escape slides very well." The report recommended that researchers consider this when designing evacuation studies. Simulations that purport

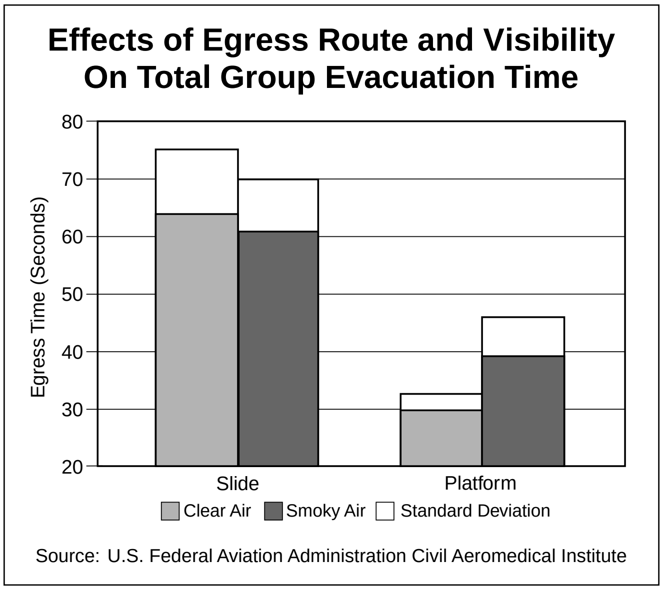

Figure 4

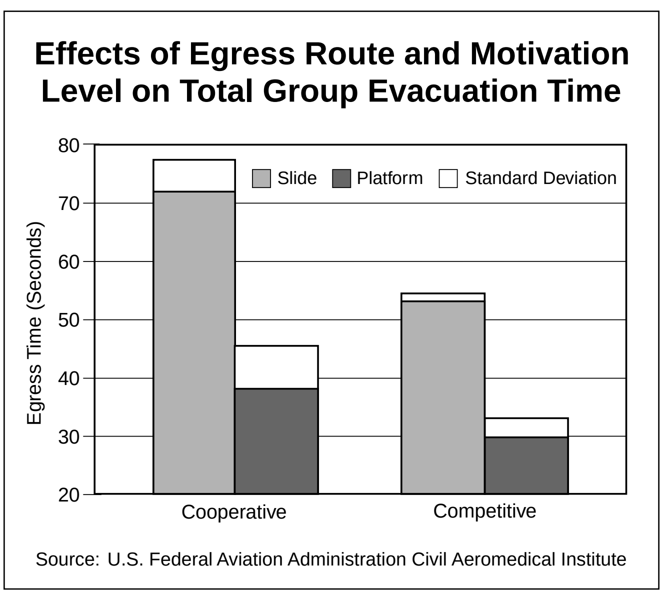

Figure 5

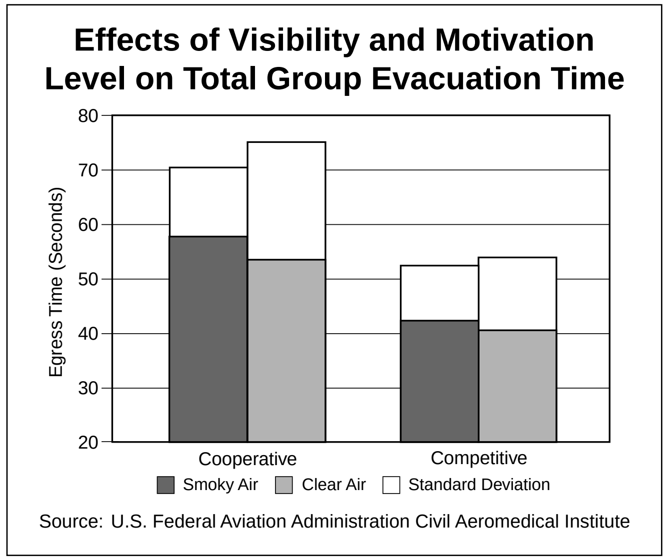

Figure 6

to model evacuations of a specific aircraft should "use the aircraft's actual means of egress to obtain the highest fidelity," the report said.

Other factors that should be considered closely in designing such simulations are exit-opening size, escape-slide angle of descent and the effect of emergency-lighting systems, the report added.

The smoke factor. On the separate issue of smoke in cabin air, researchers suggested that future simulations carefully control any manipulations of cabin visibility, because CAMI results did not indicate a consistent effect.

In previous simulations, researchers had found that smoke in the cabin had significantly delayed evacuations through overwing Type III exits. [FARs Part 25.807 defines a Type III exit as "a rectangular opening of not less than (51 centimeters [20 inches]) wide by (91 centimeters [36 inches]) high, with corner radii not greater than one-third the width of the exit, and with a step-up inside the airplane of not more than (51 centimeters [20 inches]). If the exit is located over the wing, the step-down outside the airplane may not exceed (69 centimeters [27 inches])."]

But the CAMI tests did not produce such a clear-cut result. Smoke had no effect or even a benign effect on the group speed of the slide egress, but smoke did slow egress onto the platform. Researchers speculated that smoke did not produce the expected results for one or more of the following reasons:

- Smoke may have less influence on egress through floor-level exits than it does on egress through Type III exits;
- Passengers, who always began with evacuations in smokeless cabins, may have learned the cabin layout so well that the smoke in later simulations did not slow them down as much as expected; and,

- The effects of one or more other factors in the experiment "concealed the effects of the smoke."

Further analysis led the researchers to conclude that one reason for the failure to find the expected reduction in egress times in the smoke condition was the interaction of the visibility and egress-route variables. The researchers said that using the slide required passengers to make a downward leap and that individuals' hesitations in making this leap created a queue at the door. This queuing did not happen in the platform condition because "egress onto the platform was essentially equivalent to going through a door from one room into another." Thus, passengers exiting onto the escape slide had to line up and wait for their turn to exit, which created a delay that had nothing to do with the presence of smoke and that obscured any slowing effect that the smoke might have had.

Furthermore, the trials were conducted with the smoke condition always following the no-smoke condition, enabling passengers to "[benefit] from earlier experience with the slide" during the second trial. The cumulative effect of individuals' faster egress the second time was enough to offset the effect of smoke during the second trial and shorten overall egress times for the slide-using group in the smoke condition. The implausible finding that the group using the slide was able to evacuate faster in the presence of smoke than in its absence was attributed to the difficulty of using the slide for egress compared with using the platform.

The potential for conflicting results is especially high when tests are conducted by unrelated laboratories using different equipment.

For the passengers who exited onto the platform, however, where there were no waits at the threshold, the delaying effect of cabin smoke was readily apparent in significantly longer evacuation times for this group under the smoke condition.

"This indicates that the use of ... visibility manipulations in studies employing floor-level exits ... should also be tightly controlled," the report suggested. "Likewise, the demonstrated effects of evacuation experience must be considered in these research designs."

Financial motivation. Although financial incentives clearly increased the speed of evacuations, researchers found that the facilitating effect of motivation was constant, regardless of visibility or egress route.

When no financial incentives were offered, subjects took an average of 1.25 seconds to exit the plane onto the slide (a figure reached by dividing the total group evacuation time by the number of passengers in the group). But when the $50 was offered, passengers took an average of only 0.67 second to get onto the slide. A similar effect was noted for egress times on the platform.

"These effects were produced by the competitive nature of the trials and resulted from the passengers becoming more aggressive and climbing over seats, outmaneuvering other passengers, etc., to get out quickly," the report found.

"This technique provided usable data from all passengers, enhancing the cost-benefit ratio of the study," the researchers contended, recommending that future evacuation simulations also offer such incentives.

CAMI researchers said that their finding supports the conclusion, drawn by British researchers led by Muir in 1989[1] and 1992,[2] that significantly increased motivation only impairs the performance of test subjects when the exit opening in the aircraft cabin is rather small (because passengers eager to claim their reward create blockages around the small Type III exits).

But some human factors are difficult to predict. For example, in the trials during which passengers were allowed to choose their egress route, all the financially motivated subjects chose the platform because they believed it to be faster. But only half the group that had no financial incentives chose the platform; the other half chose the slide, they said, because "it was more fun and more safe."

That perception of the escape slide as being safer "appears inconsistent with the fact that the slide was much steeper and [the] descent much faster" than on the platform, researchers said. The only injury reported in the simulations was sustained by a passenger who broke her ankle while using the escape slide.

The report suggested that the discrepancy could be related to individual motivations: Those who wanted the $50 made a decision related only to the speed of their exit, but the other subjects were motivated more "by their own internal beliefs about the value of their participation in the study, their perceptions about the potential consequences of jumping onto the slide and, thus, their willingness to use the slide at all."

The report concluded that cabin-evacuation researchers must be extremely careful in conducting simulations. The CAMI researchers warned of "the potential for unexpected, and sometimes conflicting, results in evacuation studies."

That potential for conflicting results is especially high when simulations are conducted by unrelated laboratories using different equipment. "Comparative studies done in independent laboratories, or when using [differing types of] apparatus, appear particularly susceptible to such potential confounds, and only through significant attention to detail will the meaning of results be made clear," the report said.

Reflecting on their experience, the CAMI researchers suggested that the design of evacuation simulations "should include careful assessments of all relevant variables, including the aircraft structures and equipment, crew procedures, passenger attributes and experimental treatments."

The CAMI report also advised researchers to exercise caution "not to rely too heavily on assumptions derived from similar, but untested techniques, without some measure of the differences in effects that the experimental techniques can produce."♦

Editorial note: This article was adapted from *Aircraft Evacuations onto Escape Slides and Platforms I: Effects of Passenger Motivation,* Report no. DOT/FAA/AM-96/18, June 1996. The 17-page report includes tables, charts, illustrations and a detailed reference list.

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Further Reading from FSF Publications

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About the Author

Robert L. Koenig is a Berlin, Germany-based correspondent who specializes in transportation and science issues. He has written on aviation matters for Science *magazine and the* Journal of Commerce. *Before his move to Germany, he was a Washington, D.C., newspaper correspondent for the* St. Louis Post-Dispatch, *for which he covered transportation issues. He won the National Press Club's top award for Washington correspondents in 1994. Koenig has master's degrees from the University of Missouri School of Journalism and from Tulane University in New Orleans, Louisiana.*

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