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Strengths and Weaknesses of the Emergency Evacuation Trial for Transport Airplane Certification

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Abstract
Safety has always been the key driver for aviation development, based on the permanent commitment of airworthiness authorities, airplane manufacturers, and other intervening agents. One of the established regulations requires, at airplane certification level, that all occupants must be able to abandon the aircraft and safely reach the ground in less than 90 seconds. This rule has always been a matter of debate since it does not represent any accident scenario and just one trial is not statistically meaningful, although airworthiness authorities argue that it is a practical benchmark for consistent evaluation. The research reported here describes the strengths and weaknesses of the requirements and suggests potential modifications.

1. Introduction

1.1 Aviation and safety

In less than two decades from the first flight by Wright brothers, commercial aviation became a major technical initiative that later led to the global transportation system we know today [1]. From the limited objective of controlled flight in pioneers' time, aviation has rapidly progressed through its main drivers [2,3]: safety, performance, cost and environmental respect, to which mission effectiveness can be added in combat and UAV operations.
Within this group of drivers, safety has always been the undisputed number one [4,5], based on the permanent commitment of airworthiness authorities, airplane manufacturers, airlines and other intervening agents, which has resulted in a continuous decline of aircraft accident rates [6,7].
Aviation safety has been traditionally divided into two categories: active safety, aimed at avoiding accidents; and passive safety, focussed on minimizing the probability and level of injuries of aircraft occupants once an accident has occurred. On its side, passive safety can also be divided into two parts:

a) Crashworthiness, i.e. the aircraft capability of withstanding crash loads while protecting occupants, in other words to ensure that accidents can be survivable or technically survivable.
b) Post-crashworthiness, or the aircraft capability to allow occupants to safely abandon it.

The experience accumulated through a hundred years showed that in many airplane crashes fatalities occurred not because of the impact but because of fire and toxic inner environment [8,9]. Consequently, airworthiness authorities have dictated a number of design and performance standards related to cabin evacuation [10,11] with the aim of improving post-crash survivability; these requirements that must be fulfilled by both manufacturers and operators.
To ensure an acceptable performance of airplane evacuation, and since potential scenarios are extremely varied, aviation authorities decided several decades ago to setup a benchmark based on a somewhat arbitrary situation, that will be detailed later.
Table 1 gathers the series of regulations appearing over the last decades to enforce both operators and manufacturers on aircraft evacuation capability [12-14].
Initially, it was an obligation for operators to train their crews in the evacuation of large aircraft. The trials were arranged with volunteer, simulated passengers and defined a maximum of 120 seconds to complete the evacuation. The time limitation for the experiment was related to the characteristic time of the breaking-up and propagation of fires and toxic gases. However, aviation authorities soon realised that, on the one hand, the same experiment should

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be performed by airplane manufacturers each time a new aircraft was designed and, on the second hand, that the figure should be shortened because the initial value was too generous, not on the safe side. Subsequent changes dealt with evacuation emergency exits, improvements in escape means, flame retardant materials in seats and cabin furniture, better definition of the evacuation trial, etc.

Table 1: Chronology of evacuation regulations relevant changes

Effective Date	Regulation
March 3, 1965	Amendment 121-2 required all transport-category aircraft operators to conduct demonstrations, to be completed in less than 120 seconds, for all previously built and new aircraft.
October 24, 1967	Amendment 25-15 required manufacturers to conduct a 90-second demonstration, and required that aircraft be equipped with automatically deployed egress assist devices. Amendment 121-30 revised the operators' demonstration time limit from 120 seconds to 90 seconds, and required retrofit of automatically deployed egress assist devices.
December 1, 1978	Amendments 25-46 and 121-149 revised requirements to permit manufacturers and operators to concurrently demonstrate compliance with evacuation certification requirements.
January 18, 1982	Amendment 121-176 required, if an aircraft is certified to FAR 25.803 per Amendment 25-46, the airline operator to demonstrate crew proficiency by showing that crew members can open half the exits and achieve usable slides within 15 seconds.
August 20, 1990	Amendment 25-72, placed the demonstration conditions previously listed in §25.803(c) into a new Appendix J to part 25 and amended them for consistency with part 121.
September 27, 1993	Amendment 25–79 revised the age/gender mix of passengers for performing emergency evacuation demonstration and allowed the use of stands/ramps for overwing evacuation. Amendment 121–233, revised §121.291 to allow demonstrations in compliance with §25.803 to satisfy the requirements of §121.291.
December 9, 1996	Amendment 25-88 redefined and completed emergency exit types and assist means.
July 29, 1997	Amendment 25-91 included: asymmetry, uniformity, and location requirements for exits.
March 25, 1998	Amendment 25-94 reintroduced the maximum distance between exits of 60 foot and requirements for flight deck emergency exits.
June 2, 2004	Amendment 25-114 included more stringent erection times for escape slides and requirements for passageways acceding type III exits.
December 2004	Amendment 25-117 included the requirement of viewing the exterior of each exit and a means to retain the exit open.

1.2 Current rules

Certification Specifications for Large Aeroplanes CS-25 [10] (FAR 25 [11] is almost identical) states that:

> "(a) Each crew and passenger area must have emergency means to allow rapid evacuation in crash landings, with the landing gear extended as well as with the landing gear retracted, considering the possibility of the aeroplane being on fire.
>
> (b) Reserved.
>
> (c) For aeroplanes having a seating capacity of more than 44 passengers, it must be shown that the maximum seating capacity, including the number of crew members required by the operating rules for which certification is requested, can be evacuated from the aeroplane to the ground under simulated emergency conditions within 90 seconds. Compliance with this requirement must be shown by actual demonstration using the test criteria outlined in Appendix J of this CS--25 unless the Agency finds that a combination of analysis and testing will provide data equivalent to that which would be obtained by actual demonstration."

A full-scale actual evacuation demonstration is a trial in which a real fuselage with an all tourist or high-density cabin full of passengers and the corresponding crewmembers is evacuated using assist means under the conditions specified in Appendix J. Such conditions are summarized in Table 2 [14]. For obvious reasons, the simulated passengers cannot be children, minor neither disabled persons.

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Table 2: Test criteria of emergency evacuation demonstration

Sec.	**Matter under consideration**
(a)	Limitation of outdoor lighting.
(b)	Airplane in normal attitude and with landing gear extended
(c)	Authorized means of descent to the ground from the wing
(d)	Interior illumination only provided by emergency lighting of the airplane
(e)	Exclusive use of standard aircraft emergency equipment
(f)	Interior doors and curtains in take-off configuration
(g)	Crew positioned as take-off and retained until start
(h)	Selection of passengers by minimum fractions of gender and age
(i)	Prohibition of assigning specific seats to passengers
(j)	Belts and harnesses fastened at the beginning
(k)	Blankets, pillows and luggage obstructing escape routes
(l)	Prohibition of prior assignment of exits to occupants
(m)	Prohibition of explaining, training or practicing the test
(n)	Passengers obey crewmembers and pre-flight evacuation instructions
(o)	Prohibition of prior disclosure of active emergency exits to participants
(p)	Obligation to use a representative selection of exits and slides
(q)	Mandatory use of equipment descent means
(r)	Mandatory use of approved procedures and passive role of flight crew
(s)	Evacuation time period definition

1.3 Purpose of the present work

Former regulations have always been a matter of debate since they do not represent any accident scenario and just one trial is not statistically meaningful. Nevertheless, airworthiness authorities argue that the trial is a robust, practical benchmark for consistent evaluation.
The research reported here summarizes the strengths (consistent benchmark and well-established procedures) and weaknesses (lack of real passenger mix representation, lack of statistical meaningfulness, etc) of the requirements and suggests some modifications of the certification regulation.

2. Strengths and weaknesses of the current airworthiness requirements

2.1 Advantages of the rule

The main strength of the current procedure is that it provides a benchmark by which FAA or EASA can systematically evaluate the evacuation capability of any new or highly modified transport airplane with its corresponding seating and exit configuration.
Since the regulations establish uniform standards for conducting evacuation demonstrations, results are directly comparable to each other. All transport airplanes seating more than 44 passengers must show its evacuation performance by means of evacuation trials with the same clearly defined rules during the certification process. Such evacuation competence is supervised by officials and certification engineers who depend on the Certification Authority.

2.2 Weaknesses of the rule

In spite of the aforementioned advantage, that is widely recognized, the adequacy of emergency evacuation regulations has been questioned by experts and third parties since its inception in the mid-sixties of the last century [8, 15]. Many shortcomings and disadvantages have been pointed out over the years, related to risks, cost/duration, lack of statistical meaningfulness, age-gender mix non-representative of actual passengers, etc. The major criticisms are listed below.
From the first evacuation trials, it was seen that such demonstrations were dangerous experiments [15], with several risky steps, the most problematic one being the transit along the scape slide between cabin and ground. In average 6% of participants were injured during tests [8], although very few with severe burns or fractures. To avoid this

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danger becoming a major public health issue, Airworthiness Authorities have established a marked bias toward the safety of test participants against the realism of emergency situations.
Another important drawback is the high cost of trials, associated to evacuation demonstration planning, preparation of demonstration scenario (complete aircraft or complete fuselage), incentives and insurance fees for participants... The cost of conducting a certification demonstration has been estimated to be a few million US dollars [8], more or less proportional to the size of the aircraft. For example, the MD-11 demonstration test in 1992, with 410 passengers and the corresponding crewmembers, amounted to around $1.3 million, besides the fuselage cost.
Besides this cost issue, a parallel topic is the long duration required to prepare and carry out the tests, due to the planning work needed by the type certificate applicant, the study of the proposal by the Certification Authority, the date agreed for the demonstration with a sufficient margin to complete all pertinent matters.
On another side, the age-gender population pyramid used in the emergency evacuation demonstration is not representative of actual flights, because of the absence of children, elderly people, persons with disabilities, non-English speaking passengers, etc.
Of particular relevance is the fact that a single demonstration, although successful, has no statistical significance and impedes estimating any kind of parameter. The total evacuation time resulted from a demonstration is a combination of several periods with random duration and, therefore, it does not provide manufacturers an adequate opportunity to observe flaws or wrong design features.
Last, the full-scale certification demonstration does not represent evacuation in real scenarios.
In summary, the requirement to completely evacuate the airplane within 90 seconds is not an appropriate performance standard for measuring actual evacuation capabilities. Additionally, it does hardly encourage new technology development for its conservative, inflexible criteria, although some improvements have been achieved in interior materials and scape slides.

Figure 1: Evacuation experiment with scape slides for crew training.

3. Evacuation tests and simulations

3.1 Evacuations tests

There are many facilities dedicated to cabin safety training, because airlines are obliged to train their crew members to face emergency evacuation manoeuvres (see Fig. 1). These facilities are usually mock-ups of cabin parts where manual exit opening, slide deployment and other manoeuvres are repeated as part of the training. But there are very few research and development centres in the world related to airplane evacuation, because these facilities are complex and expensive. The most important ones are those of the Federal Aviation Administration (FAA) in USA and the British Civil Aviation Authority (CAA).

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With respect to FAA, most research and testing is carried out by two institutions:

- FAA Technical Center, based in Atlantic City, a laboratory focused on crashworthiness and fire safety, among many other air transportation issues;
- FAA Civil Aerospace Medical Institute (CAMI), based in Oklahoma City, responsible for evacuation research and other human factor issues. The CAMI Cabin Safety Research Team (CSRT) performs research on aircraft emergency evacuation to support regulatory and airworthiness functions. Full-scale cabin simulators are used to study issues such that seating density, exit size and location, passenger flow rates and human behaviour. At present CSRT has got two facilities:
  - The Flexible Aircraft Cabin Research Facility (FlexSim), a fully reconfigurable, computer controlled single aisle aircraft cabin facility introduced in 2014 for researching on cabin safety and evacuation;
  - The Aircraft Environment Research Facility (AERF) is a full sized wide-body cabin of B747-100 adapted for researching on cabin safety, environment, and evacuation.

Among the many results obtained by CSRT it is possible to mention the flow rate through overwing type III exits, exit preparation time, or egress efficiency for different seating arrangements. The Cabin Safety Research Team also explores the use of computer simulation to support certification evacuation and accident investigation projects.
On its side, CAA has worked on the influence of nontoxic smoke on the evacuation rates, passenger competition, seat spacing effects on egress rates, crew personality impact on evacuation performance, etc.

3.2 Computer models for evacuation simulation

Computer modelling of cabin evacuation have been attempted during the last decades, once hardware and software were capable of reproducing and handling the main characteristics of both the cabin and the humans' movements. The simulation scenario is always a more or less detailed cabin planview, such as the one shown in Fig. 2, corresponding to Douglas DC-8-61 (the longest and most crowded narrow body ever built).

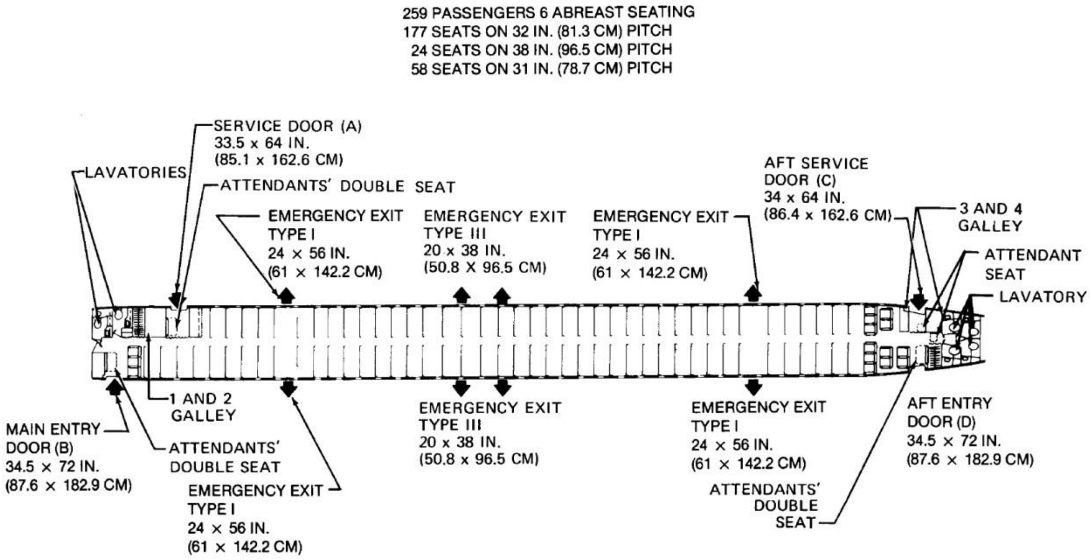

Figure 2: Sketch of DC-8-61 cabin showing all seat blocks, exits, toilets, wardrobe and galleys.

Table 3 lists, in chronological order, a set of relevant models, which will be briefly discussed. As it will be shown, most models have been developed under the auspices of airworthiness authorities or aviation related entities.
FAA's CAMI undertook the task of developing the GPSS model in the late 1970s [16, 17], intended to simulate the evacuation trials in certification scenarios. It was a network rule-based passenger behaviour model, programmed in GPSS, an IBM simulation language. Its main drawbacks were the uniformity of passenger attributes, the lack of graphical interface, and a great dispersion of evacuation times.
Some years later, NASA sponsored the FIREVAC model [18], developed by Victor E. Middleton, from the University of Dayton Research Institute. The purpose of this model was to assess passenger survival during post-crash evacuation of transport airplanes. It was also a network model that included simple physiological effects of intoxicants. The software was programmed in FORTRAN, and the passengers had preassigned optimal routes that

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could be modified depending on the evolving circumstances. It was tested for verification but never validated because of the lack of data.
Following an FAA initiative, Gourary Associates developed the GA model [19, 20], again of a network type, to simulate realistic accident scenarios. It incorporated a graphical interface and ran in near-real time, but it had important operational limitations. No validation results were published in open literature.
The aircraft evacuation (AIREVAC) model [21, 22] was developed by the South West Research Institute under the Air Transport Association's sponsorship, to simulate real emergency evacuations. It was very slow, did not include occupants' features, and had too many parameters. The project was later renamed ARCEVAC [23] and improved to run in real time, but it achieved no meaningful success.
The Fire Safety Evacuation Group of Greenwich University applied his extensive knowledge of building evacuation to develop the airEXODUS model [24–26], with the financial support of the British Civil Aviation Authority. This ambitious software package is intended for aircraft design, certification testing, crew training, and accident investigation. It is programmed in C++ and may run on a variety of PCs and workstations. The model is of a network type with single-occupancy cells and rule-based behaviour. It incorporates four submodules: movement, behavioural, hazard, and toxicity. The simulated passengers are assigned to the nearest available exit, unless redirected by crew or local conditions. It has been validated with Cranfield University partial trials and data from the Boeing B767-300ER certification test. Its main disadvantages are a cumbersome geometric definition and difficulty in interpreting the results.
Macey and Cordey-Hayes developed, with financial support from CAA, the risk assessment model (RAM) [27, 28] at Cranfield University. Again, it was a network, deterministic model, with rule-based behaviour, conceived to analyse actual as well as certification evacuations. Fire and other hazards were probabilistically introduced in the scenario. It had a graphical user interface and a large airplane database. The model was validated with two narrow-body actual certification trials, but the simulated evacuation times were always overestimated, as a result of a suboptimal evacuation.
The Oklahoma object-oriented model [29] was conceived as a join initiative by Oklahoma University and the FAA's Civil Aerospace Medical Institute to create a framework to handle evacuation simulation software models, both for real emergency cases and for certification trials. However, it was never fully implemented nor validated.
Robbins and McKee, from Strathclyde University, developed the discrete element method (DEM) [30] aimed at simulating certification trials and real emergency evacuations. It is a deterministic model based on an analogy between passengers evacuating an airplane and spheres moving through pipes. The motion of spheres is solved, including friction and inertia forces and torque. In the analogy, the spheres were individually pulled by the exits. The validation tests were performed with B737-300 certification trial data, providing 81s against the actual 75s. Apart from just showing promising results, the functional analogy was questionable, and the validation of parameters lacked physical meaning.

Table 3: Emergency evacuation software models

Name	Years	Institution	Purpose
GPSS [16, 17]	1978–1980	CAMI	Certification
FIREVAC [18]	1984	NASA/Univ. Dayton	Fire accident reconstruction
GA [19, 20]	1987–1992	FAA/Gourary Associates	Accident reconstruction
AIREVAC [21, 22] AIRCEVAC [23]	1991–1994	ATA/South West Research Institute	Certification
airEXODUS [24–26]	1993–	FSEG-Greenwich University	Certification and accident reconstruction
RAM [27, 28]	1994–1996	Cranfield University	Certification and accident reconstr.
OOO [29]	1996–1997	CAMI/Oklahoma University	Theoretical model
DEM [30]	2001–	Strathclyde University	Certification and accident reconstr.
AvatarSim [31, 32]	2008-	Bowie State University	Certification and accident reconstr.
Vacate [33] VacateAir [34, 35]	2008–	State University of New York at Buffalo	Certification (psychological aspects)
ETSIA [9, 38-40]	2009–	Universidad Politécnica de Madrid	Certification and design
[36, 37]	2012-	University of Electronic Science and Technology of China	Certification (physical aspects) and accident reconstruction

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AvatarSim [31, 32] is a multi-agent software developed to simulate battlefields scenarios and emergency situations like building and airplane evacuations. Its main objective is to capture the impact of human behavioural characteristics (panic, stress, anger, etc) on human movements and waiting times. It combines various techniques such as geometric modelling, social force modelling, and fuzzy human behaviour modelling into a single simulator. It is programmed in JAVA language and runs as an applet in a web browser. Regarding airplane evacuation, it seems to underestimate evacuation demonstration time, where panic and anger have no influence. But it will be difficult to tune behavioural parameters for other applications without genuine emergency data.

Following a former model developed by the State University of New York at Buffalo for individual and crowd fire emergency evacuations, called Vacate [33], a new, specific application to simulate both certification and real evacuation situations of transport airplanes was elaborated under the name of VacateAir [34, 35]. It is an optimization model validated with data from Cranfield University evacuation trials. The model considers that occupants move grouped, like flocks. Apart from this unrealistic performance, the model does not reproduce certification results with enough precision.

An unnamed simulator has been developed at the University of Electronic Science and Technology of China. Its basic purpose is to assess the influence of occupants' physical features in evacuation performance [36, 37]. It is an agent-based model and uses mesh discretization, but some cells are so large that they can be occupied by more than one person. Because of the graphics interface characteristics, the model uses a rather gross discretization of the cabin, which is common to other mesh type simulators. Moreover, the algorithm of cell occupancy in the simulation produces a congestion of passengers that does not seem very realistic. It has been checked with the actual emergency evacuation data, with all exits available, of a hard-landed B737-800 happened at Beograd (Serbia) on October 18, 2008 after an engine fire in flight. No verification neither validation has been published in open literature.

The last computer model described here, although not the last one chronologically, has been created by the same authors of this paper. ETSIA (acronym for Evacuation Test Simulation and Investigation Algorithm), has been presented in detail in previous papers [38-40]. It is an agent-based computer model, conceived to simulate evacuation trials for certification, developed in NetLogo [41]. The model is structured in four submodels: geometric subdomain, human subdomain, time subdomain and kinematic subdomain; and has been coded, validated and verified for narrow body aircraft, but it could be extended to wide bodies, multi-deck airplanes, and unconventional configurations, such as blended wing bodies. It can provide a variety of results, both at individual or complete cabin level; for example, seat to exit distance, time to reach the ground, etc. Thus, Figure 3 shows the chronoline (number of evacuees as a function of time) for a simulated evacuation of Fokker F100 cabin with 107 passengers and 6 crewmembers. The auxiliary lines appearing are related to two performance rate indexes: i.e. raw and net average evacuation rates (evacuees per second).

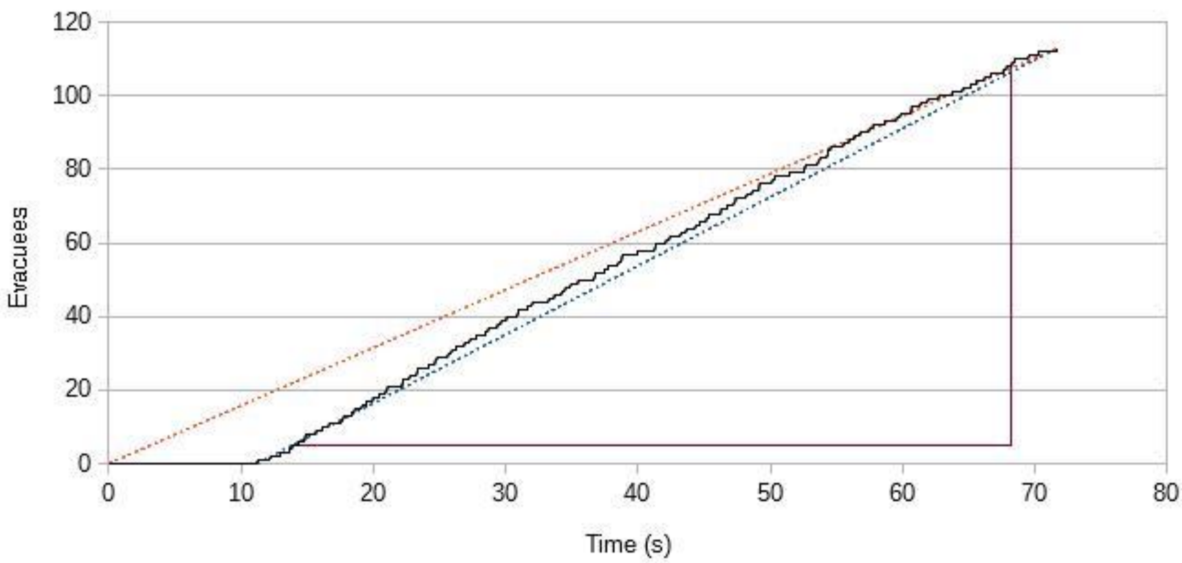

Figure 3: Evacuation performance of Fokker F100 cabin.
Raw and net average evacuation rates (ev/sec) are also shown.

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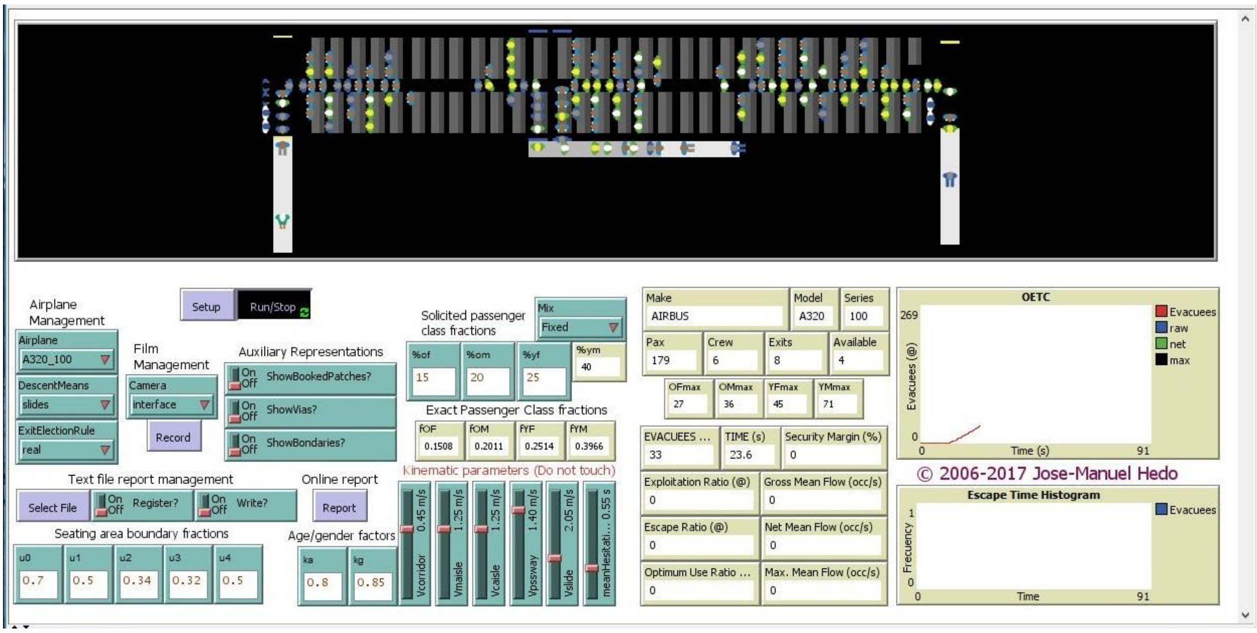

Figure 4: Computer screen during the simulation of A320-100 with actual airplane cabin (modified from [40]).

Figure 4 contains the complete screen view of the ETSIA graphical user interface, where it is possible to perceive the airplane cabin identification, occupants position, age-gender fractions, kinematic factors intervening in determining displacement speed, accumulated evacuation performance, etc. In this case, the airplane is the A320-100 in the actual arrangement used at its certification trial. The five categories of simulated occupants (young women, young men, elder women, elder men and crewmembers) can be distinguished by hair and body colour. Occupants may use all port board (left side) exits: i.e. doors at both ends of the cabin and two close overwing window exits, all of them equipped with slide ramps.

ETSIA model is capable of assessing any modified cabin, including major changes in seating arrangement or in emergency exits location and size. Thus, Fig. 5 depicts again the A320-100 cabin, but with a major modification, since all conventional exits have been suppressed and substituted by two large doors closer to the cabin centre. Although this cabin is highly uncommon, it is much more efficient in terms of evacuation, because large doors with double lane slides are fed from both sides decreasing the total evacuation time from 81.4 seconds in the actual trial to 80.8 seconds in the modified cabin.

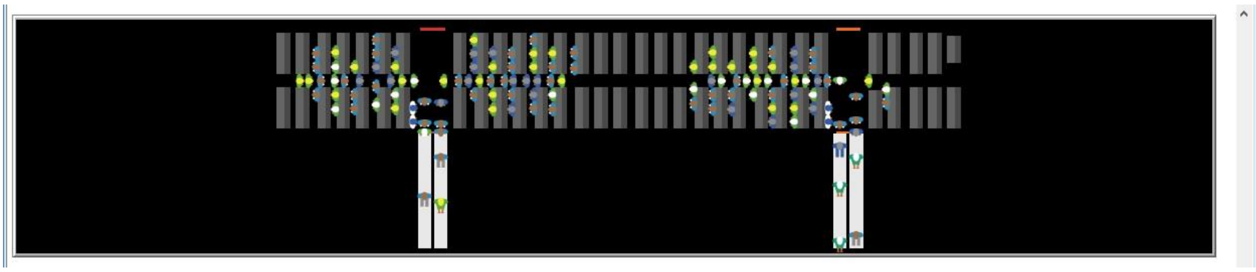

Figure 5: Cabin and slide details during the simulation of A320-100 with modified size and location of exits [40].

Another factor that has been easily tested with ETSIA is the adequacy of the prescribed age-gender mix and its impact on evacuation performance. FAA and CS regulations state that the percentage of volunteer passengers taking part in the evacuation trial must obey certain thresholds: women older than 50 yrs ≥15%; men plus women older than 50 yrs ≥35%; women ≥40%; younger men the rest. If these fractions are varied, the evacuation takes longer or shorter, depending upon the mix of each case. Thus, Table 4 shows the average of 1000 simulation runs for each one of the 27 cases of age-gender mix analysed, with Fokker F100 cabin. Even in this airplane, with a relatively easy evacuation, the differences are remarkable among the cases.

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Table 4: Mean evacuation time (in seconds) in terms of age-gender group fractions for Fokker F100. Subscripts meaning: OF, old females; YF young females; OM, old males.

f_{OF} ↓	f_{YF} ↓ ‖ f_{OM} →	0.1588	0.2056	0.2523
0.1033	0.2056	70.37	70.80	71.23
	0.2523	70.57	71.05	71.46
	0.3084	70.93	71.17	71.65
0.1588	0.2056	71.44	71.63	71.85
	0.2523	71.91	**72.03**	72.32
	0.3084	72.24	72.43	72.67
0.2056	0.2056	72.28	72.55	72.88
	0.2523	72.83	72.95	73.09
	0.3084	73.07	73.21	73.46

4. Final considerations and suggestions on the evacuation trial for certification

The current way of showing compliance with emergency evacuation requirements at airplane certification stage, i.e. an actual evacuation with volunteers, exhibits many drawbacks and shortcomings. Furthermore, such problems are so relevant that largely counterbalance the recognized rule's strength. Therefore, in spite of the highly conservative character of airworthiness regulations, some initiatives should be undertaken to modify the emergency evacuation requirements in such a way that, while keeping the key aim of assessing the evacuation performance, would do the task much more efficiently and meaningfully. As a matter of fact, the airworthiness requirements recognise the existence of alternatives in the wording "Compliance with this requirement must be shown by actual demonstration using the test criteria outlined in Appendix J of this CS--25 *unless the Agency finds that a combination of analysis and testing will provide data equivalent to that which would be obtained by actual demonstration*."

Since the former section has presented the enormous possibilities of computer models for accident analysis as well as to reproduce certification trials, a feasible initiative, given the tremendous power achieved by computers and the development of dedicated software for whichever purpose, would be to accept as proof of compliance of emergency evacuation performance the results of validated computer models. As a matter of fact, Airworthiness Authorities have already accepted analysis instead of actual evacuation trials in some limited cases (new versions of well-known aircraft), but the proposal presented here is much more ambitious and would end up in the complete cancellation of evacuation trials for certification. The development of this initiative could be arranged as described below.

An important limitation of computer models is the lack of a wide, reliable data base of crucial variables: passengers' reaction times (unfasten seat belts, hesitation time at the door, etc); speed in side (between seat rows) and longitudinal (aisles) movements; and so on. Similar comments can be applied to evacuation means, like door opening, slide deployment, etc. However, airplane manufacturers and Airworthiness Authorities on one side, and some research centres on the other side have collected a large amount of such data. The information on evacuation demonstrations and testing is proprietary and the results are not available to the public; so, nobody can take advantage of the invaluable information collected.

The authors propose to free all these data and make them available for the research community, at least in statistical form (average and standard deviation as a function of age, gender and girth, for example). In situations where data are scarce or unreliable, new evacuation experiments could be performed in controlled scenarios to avoid or minimize risks. All these data would be crucial in formulating sufficiently approximate mathematical models of human attributes as well as those of devices involved.

At present, computer models can accurately simulate evacuation trials for airplane certification, and are capable of reconstructing many accident scenarios with suitable matching of real conditions. Besides these capabilities, evacuation computer models may also be helpful in assessing cabin design for both conventional and unconventional aircraft configurations.

It must be recalled that airplane evacuation has its own requirements and specificities and cannot be properly analysed with models based on evacuation of buildings, vessels or other transport vehicles.

In the mid-long term, computer models for evacuation simulation could thus serve as an acceptable analysis procedure as mentioned in the regulations, and achieve a similar status as complex software used for structural analysis in airplane certification.

To keep, or even improve, the current safety level, aviation authorities should support the development of a number of models in such a way as to ensure the possibility of using two or more independent software in each airplane certification process, for redundancy and more reliable inference of results.

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