THE INFLUENCE OF AIRCRAFT CABIN CONFIGURATION ON PASSENGER EVACUATION BEHAVIOUR

Helen Muir MA PhD, Claire Marrison BA MSc
Applied Psychology Unit, College of Aeronautics
Cranfield Institute of Technology
Bedford, MK43 0AL, UK

Abstract

In 1987 the United Kingdom Civil Aviation Authority, commissioned Cranfield Institute of Technology to conduct an experimental programme of research into passenger behaviour in aircraft emergencies. The main objective was to investigate the influence of changes to the cabin configuration involving access to the emergency exits, on the rate at which passengers could evacuate an aircraft. The configurations evaluated involved a range of widths for the passageway through a bulkhead aperture leading to floor level exits, and a range of seating configurations adjacent to a Type III overwing exit. The configurations were evaluated (a) when passengers were competing to evacuate the aircraft, as can happen in an accident when the conditions in the cabin become life threatening, and (b) when passengers were evacuating in an orderly manner as occurs in aircraft certification evacuations and in some accidents.

Volunteers were recruited from the public in groups of approximately 60, to perform a series of emergency evacuations. A total of 2,262 volunteers took part in the evacuations from a Trident aircraft parked on the airfield at Cranfield.

The results suggested that the blockages known to occur in some emergency evacuations, can be significantly reduced when the passageway through a bulkhead is greater than 30 inches. The minimum seating configurations specified by the Civil Aviation Authority in Airworthiness Notice No. 79 in 1986 were shown to have significantly increased the rate at which passengers can evacuate through a Type III overwing exit in an emergency. Blockages were also found to occur in evacuations involving a three inch vertical projection between the seats (pre AN79). The six inch vertical projection with the outboard seat removed (an AN79 alternate) led to a rapid evacuation flow rate but had a tendency to give rise to blockages and the opening and disposing of the exit was found to be more difficult in this configuration.

The results suggested that the optimum distance between the seat rows either side of the exit would involve a vertical seat projection of between 13" and 25". A Technical Report (Ref 1) is available in which a full description of the methodology and results obtained from the programme of competitive evacuations is included.

Introduction

Recently in the UK, a number of steps have been taken by the Civil Aviation Authority to increase the probability of survival in an aircraft accident. These have included regulations relating to the introduction of fire blocking materials for aircraft seats, floor proximity lighting, smoke detectors in the toilet compartments, crew rest areas and cargo holds, together with additional access at the overwing exits. The objective to improve passenger survival rates has also led to a demand for human factors evaluations of new and existing safety provisions. It is hoped that if we had a better understanding of behaviour, in conditions which for many people are highly stressful and disorientating, we could determine which additional steps should be taken to improve the probability of a successful evacuation of all passengers from the aircraft.

From the reports of a number of accidents it is possible to learn from the similarities and differences between their causes, their location and the environmental conditions present, the types of passengers onboard and their responses to the emergency. For instance, there were many similarities between the accident which occurred at Manchester in 1985 and the one which occurred at Calgary in 1984, in that they were both caused by an engine fire at take off. However, they differed in one important respect, namely that at Manchester there were 55 fatalities whereas in Calgary everyone survived. We know that in some aircraft accidents everyone files out of the plane in a rapid although orderly manner. For example, in the evacuation of a British Airways 747 at Los Angeles in 1987 as a result of a bomb scare. In other accidents however, the orderly process is not adhered to and confusion in the cabin can lead to blockages in the aisles and at exits, with a consequent loss of life.

In an emergency where there is smoke and fire, we know passengers exit by their nearest door, as would be expected. However we also know that other passengers do not exit by their nearest available door but travel for considerable distances along the cabin, e.g. extreme cases of back to front. Why and in which circumstances do they choose to do this? Other passengers apparently near exits, do not survive. Do they panic and freeze, give up, get crushed by other people from behind or around? Do they have their seat backs pushed onto them? We also know that blockage can occur in the aisles and at exits in some accidents, when this does not occur in evacuation demonstrations for certifications.

There are in fact a great many questions which as yet we are not able to answer about the behaviour of people in emergencies, including the important question of why in some accidents the passengers evacuate in an orderly manner, and in other accidents the behaviour is disorderly.

It is suggested that one of the primary reasons for the differences in behaviour, between the orderly and disorderly situations must rest with the individual motivation of the passengers. In some accidents as in the aircraft certification evacuations, all of the passengers assume that the objective is get everyone out of the aircraft as quickly as possible, and they therefore all work collaboratively. In other emergencies, however, the motivation of individual passengers may be very different, especially in the presence of smoke and fire. In a situation where an immediate threat to life is perceived, rather than all passengers being motivated to help each other, the main objective which will govern their behaviour will be survival for themselves, and in some instances, members of their family. In this situation when the primary survival instinct takes over, people do not work collaboratively. The evacuation can become very disorganised, with some individuals competing to get through the exits. The behaviour observed in the accident which occurred at Manchester, and other accidents in the UK, including the fire at the Bradford City football stadium and the Zeebruggee ferry disaster, supports this theory. In fact in the Zebrugge disaster some adults pulled children off life rafts in order to survive.

The cabin safety research programme at Cranfield has been sponsored by the Uk Civil Aviation Authority (CAA) and was initiated in 1986.

The CAA commissioned Cranfield to conduct an experimental programme, to investigate the influence of certain cabin configurational factors on the behaviour of passengers in situations where the evacuation process had become disorderly. The objective of the research was to assess the effect on passenger behaviour and flow rates during simulated emergency evacuations of:

(a) The influence of increasing the width of the passageway through the floor to ceiling bulkhead leading to floor level Type I exits, on the time taken for passengers to evacuate the aircraft.

(b) The extent to which an increased distance between the seat rows adjacent to the overwing exit, or the removal of the outboard seat beside the overwing exit, would improve the rate at which passengers could pass through the exit in an emergency.

In any research programme in which the objective is to investigate accident or emergency escape behaviour (from either fires in aircraft, motor vehicles, fires in buildings, etc.) there is a primary dilemma: how to introduce sufficient realism into the experimental programme, whilst at the same time not putting people at serious physical and perhaps mental risk? It is the trade-off between safety and realism which is always the challenge for researchers faced with the task of investigating the human response to safety provisions for use in emergency situations, such as fire on aircraft.

For both ethical and practical reasons it is not possible to put members of the public in a situation of fear and threat for the purpose of research. However, a technique used in laboratory work in behavioural science is to offer an incentive payment to volunteers. This is done in an attempt to influence the motivation and performance of individuals either individually or in groups.

Two independent series of evacuation trials were conducted which included tests of all of the configurations under consideration. In the first test series, a system of bonus payments was introduced in order to increase the individual motivation of the volunteers to get out of the aircraft as quickly as possible. In the second test series all of the volunteers were simply told to evacuate the aircraft as quickly as possible and no bonus payments were made. The bonus payments were introduced in order to simulate experimentally the competition which is known to occur between people trapped in a confined space fighting for their lives. The second test series (in which no incentive payments were made) was conducted in order that comparisons could be made between the evacuation rates for the configurations being evaluated in the first test series and the evacuations conducted by the airframe manufacturers at the time of aircraft certification.

It was anticipated that with the data from the experimental programme of evacuations, it would be possible to determine whether there was an optimum aisle width through the bulkhead leading to the Type I exit, or an optimum seating configuration adjacent to the Type III exit.

Method

A Trident Three aircraft permanently sited on the airfield at Cranfield Institute of Technology was used for the evacuations. Volunteers from the public were recruited in groups of approximately sixty to take part in evacuations from the Trident. The aircraft provided an element of realism which was considered necessary. Additionally, the aircraft had a similar cabin layout, to many of the narrow bodied aircraft in operation at the time of the investigation.

Evacuations through the bulhead

The following configurations were assessed:

(i) The international minimum, a width between the galley units of 20 inches (51 cm)

(ii) A bulkhead which is typically seen on aircraft, a width between the galley units of 24 inches (61 cm)

(iii) A width between the galley units of 27 inches (68 cm)

(iv) A width between the galley units of 30 inches (76 cm)

(v) A width between the galley units of 36 inches (91 cm)

(vi) Port galley totally removed

The flow of volunteers through the bulkhead was of prime importance in the evaluation of the optimum width between the galley units. It was therefore important that the number of volunteers attempting to reach the bulkhead was not influenced by a blockage at an exit downstream of the bulkhead. Consequently, both of the port Type I exits forward of the vestibule were utilised in all of the evacuations through the bulkhead.

In order to direct the volunteers in a way which would ensure that the only restriction to the rate of evacuation was that of the bulkhead, a member of cabin staff was positioned in the vestibule area forward of the bulkhead in order to direct passengers to the exits.

In order to avoid any interaction between the seating configuration at the overwing exit and the evaluation of the impact of the width between the bulkheads, the seating layout through the aircraft remained constant during all of the evacuations through the bulkheads.

The behaviour of passengers using evacuation chutes and their associated flow rate was not within the scope of this investigation. The use of ramps, rather than chutes, eliminated this variable from the design. It also removed the risk of volunteers being injured whilst using the chutes.

Evacuations through the Type III overwing exit

The following configurations were assessed:

(i) The minimum configuration complying with CAA standards prior to Airworthiness Notice No.79, which is also the FAA minimum standard, with a seat pitch of 29 inches (73 cm) and a vertical projection between the seat rows of 3 inches (7.6 cm). The outboard seats in the rows bounding the exit were modified to allow minimal recline and break-forward movement.

In conditions (ii) to (vii), the movement of the backs of the seats in the rows bounding the routes to both the port and starboard, Type III exits were restricted. The limited recline and break-forward of seats, ensured that the configurations were in accordance with the specifications of Airworthiness Notice No.79. The configurations are illustrated in Appendix C.

(ii) A configuration in which the access to the exit between the seat rows was 3 inches (7.6 cm) with a corresponding seat pitch of 29 inches (73 cm).

(iii) The CAA standard in Airworthiness Notice No.79 paragraph 4.1.2 (1) in which 'Seats may only be located beyond the centre line of the Type III exit provided there is a space immediately adjacent to the exit which projects inboard from the exit a distance no less than the width of a passenger seat and the seats are so arranged as to provide two access routes between seat rows from the cabin aisle to the exit'. In the research programme the seat row adjacent to the exit had the outboard seat removed and the seat rows fore and aft of the Type III exit were at a seat pitch of approximately 32 inches (81.2 cm), with the vertical projection between the seat rows being 6 inches (15.2 cm).

(iv) The CAA standard, specified in Airworthiness Notice No.79, paragraph 4.1.1(1), in which 'All forward or aft facing seats are arranged such that there is a single access route between seat rows from the aisle to a Type III exit, the access shall be of sufficient width and located fore and aft so that no part of any seat which is beneath the exit extends beyond the exit centre line and the access width between seat rows vertically projected shall not be less than half the exit hatch width including any trim, or 10 inches, whichever is the greater'. In the research programme the seats fore and aft of the Type III exit were at a seat pitch of approximately 39 inches (99 cm), with the vertical projection between the seat rows being 13 inches (33 cm).

(v) A configuration in which the access between the seat rows vertically projected was approximately 18 inches (46.1 cm), with a corresponding seat pitch of 44 inches (111 cm).

(vi) A configuration in which the seat pitch between the seat row fore and aft of the exit was 51 inches (129.5 cm). The resultant vertical projection between the seat rows was 25 inches (63.5 cm).

(vii) A configuration in which all of the seats located in line with the exit were removed, leaving a pitch of approximately 60 inches (152 cm) between the seats fore and aft of the exit. The resultant vertical projection between the seat rows was 34 inches (86.3 cm).

In all of the evaluations of the seating configurations adjacent to the Type III exit, the egress took place through the port overwing exit. (See Appendix B.) Although it had initially been suggested that there might be differences between the ease of egress through the port and starboard exits, data which had been collected by the FAA indicated that laterality of exits did not affect the rate of evacuation(2). The FAA report indicated that an interaction was obtained between the method of opening the Type III exit and the seat configuration on egress rate. To remove this interaction, the method of opening the exit was held constant throughout the trials. This was achieved by a member of the research team being employed to open the exit and hand it to a trained observer on the wing.

Procedure

As has already been indicated, the experimental programme comprised two separate series of evacuations involving volunteer members of the public. The first series included making bonus payments to the first half of the volunteers to evacuate the aircraft (competitive evacuations). In the second series no bonus payments were made and the procedure for the volunteers was the same as in an aircraft certification test (non-competitive evacuations). The procedure for each of the test series will be described separately.

Competitive Evacuations

Volunteers were recruited in groups to take part in an experimental session which comprised four evacuations from the Trident aircraft. In two of the evacuations all of the volunteers passed through the bulkhead and evacuated through the Type I exits and in two of the evacuations all of the volunteers evacuated through the port Type III overwing exit. The configurations were all tested on a minimum of eight occasions, with the exception of the configuration (b)(ii) above. This was considered to be of secondary importance and was tested on four occasions.

The test programme involved 28 separate test days of four evacuations. In order to account for the effects of fatigue and practice the order in which the configurations under review were tested, was systematically varied using a counterbalanced design based on a latin square. Although the volunteers were told that they would be required to take part in some evacuations from the aircraft, they were not given any information about the configurations under review, or the order in which the evacuations would be performed.

The volunteers were members of the public. They were recruited by local advertising and were told that they would be paid a £10 attendance fee after they had completed four evacuations. The volunteers were instructed that their task was to evacuate the aircraft as quickly as possible once the exits had been opened by the Cranfield staff. In addition a £5 bonus would be paid to the first half of the volunteers to pass through the exits which were used on each evacuation.

The bonus payments were made immediately after each evacuation. The seating plans which were developed for the volunteers on the four successive evacuations from the aircraft, gave each volunteer an equal chance of receiving the monetary incentive. Volunteers were not allowed to take part in a test session more than once in any six month period (this requirement is also specified for volunteers taking part in evacuation for aircraft certification).

The safety of volunteers was an important consideration. To this end, only volunteers who claimed to be reasonably fit and were between the ages of 20-50 were recruited. On arrival all volunteers were given a medical examination. They were also asked to complete a questionnaire indicating that (i) they had fully understood the purpose of the trails, (ii) the medical information which they had supplied was correct and (iii) that they were satisfied with the insurance cover. A doctor and the airfield fire service were present at all times. A system of alarms was employed to stop any evacuation should a real emergency occur or should there be concern for the safety of any volunteer.

In order to introduce as much realism as possible, not only did the evacuation take place from a real aircraft, but on their arrival at the airfield the volunteers were met by members of the research team trained and dressed as cabin staff. After boarding the aircraft, they were given a standard pre-flight briefing by the cabin staff, they then heard a sound recording of an aircraft starting up and taxiing to a runway. This sequence of recording lasted for approximately five minutes before giving way to the simulated sounds of an aborted take-off. This sequence was subsequently followed by a period of silence, in which time the pilots were supposedly shutting down engines and liaising with the cabin staff. The shut down period was predetermined for each evacuation, being either 7 or 25 seconds. The variation ensured that the subjects could not anticipate the precise time at which the call to evacuate would be given. On the command 'Undo your seatbelts and get out', the appropriate exits were opened by research personnel and the volunteers evacuated the aircraft.

After each evacuation all of the volunteers were required to complete a questionnaire indicating the route which they had taken from their seat to the exit, whether any person or object had hindered their progress and their assessment on a scale of 1 to 10 of the difficulty of their evacuation. Additional questions were included on the questionnaire completed after the fourth evacuation asking volunteers for information about whether they had adopted or changed their strategy for egress during the course of the evacuations. Demographic information relating to each volunteer's age, sex, height and weight was also collected.

Non-competitive Evacuations

Volunteers were recruited in groups of approximately sixty to take part in one experimental session which comprised two evacuations from the Trident aircraft. In one of the evacuations all of the volunteers passed through the bulkhead and evacuated from the aircraft through either of the two Type I exits. In the other evacuation, all of the volunteers evacuated through the port Type III overwing exit.

The six bulkhead configurations at the entrance to the galley unit and the overwing seating configuration (ii)-(vii) which were tested in the competitive evacuations, were each tested on two occasions. The test programme involved 12 separate test days of two evacuations. In order to account for the possible effect of practice, the order in which configurations under review were tested was systematically varied using a counterbalanced design. As in the competitive evacuations, the volunteers were told that they would be required to take part in some evacuations from the aircraft, but they were not given any information about the configuration under review, or the order in which the evacuations would be performed. On arriving at Cranfield they were told that they would be paid a £10 attendance fee after they had completed the two evacuations. The volunteers were instructed that their task was to evacuate the aircraft as quickly as possible once the exit(s) had been opened by the Cranfield staff.

After the competitive and non-competitive evacuation, before the volunteers left the site they were given a debriefing in which they were reminded of the safety of air travel and advised that they should get back in touch with Cranfield if they experienced any physical or mental problems as a result of the evacuations. At the end of the test programme the volunteers were invited to return to Cranfield to attend a lecture about the work in which they had participated. This feedback to volunteers proved to be very popular and was a useful source of volunteers for other investigations.

A report including a description, methods and results may be obtained from the UK Civil Aviation Authority(3).

Results

Competitive Evacuations

In the test series of competitive trials the final data base included information from 110 evacuations, of which 56 were through the bulkhead and 54 were through the overwing exit. Deteriorating weather conditions, poor quality video recording and damage to seating during preceding evacuations caused four evacuations to be omitted from the programme. Five evacuations were abandoned because of blockages of people in the overwing exit caused the safety officer to consider it to be dangerous to continue. Two evacuations through the bulkhead were terminated when a volunteer fell and would have been trampled upon if the evacuation had continued. Thus data was not obtained from eleven of the planned evacuations. Over the trial series 1558 volunteers took part with an average of 55 participants on each test day. The mean age of the participants was 28.8 years and 71% were male.

Evacuations through the Bulkhead Aperture

Passenger flow rates through the exits were obtained from the video recordings. The evacuation times have been compared for the first thirty volunteers to pass through the exits used. These times were used as the criteria for determining the evacuation flow rate for each of the configurations tested. Since the bonus payments were only available to the first half of the volunteers to reach the exits, (approximately thirty), it was assumed that many of the volunteers reaching the exits in the latter half of the group had realised that they would not receive payments and had therefore stopped competing. For this reason their data was not included in the analysis.

TABLE 1: MEAN EVACUATION TIME FOR THE THIRTIETH INDIVIDUAL (time in seconds)

Bulkhead	Competitve Evacuations		Non-competitive Evacuations	
Aperture	Mean	SD	Mean	SD
20"	26.3	2.9	25.1	2.0
24"	24.5	5.8	21.8	1.4
27"	23.2	7.1	23.7	2.7
30"	18.4	1.9	23.4	0.0
36"	17.2	3.1	21.4	3.4
PGR	14.7	1.4	17.6	0.5

SD = Standard deviation associated with the mean
PGR = Port galley removed

As the means for the competitive evacuations indicate (see Table 1), statistical treatment of the data suggested that as the aperture in the bulkhead was increased, the evacuation rate increased, leading to a reduction in the time for the first thirty individuals to evacuate the aircraft ($F511 = 10.5$ $p < 0.001$*). There was no significant difference between the times for the first or second evacuations through the bulkheads which the individual groups of volunteers completed ($F1,11 = 0.001$NS). The individual comparisons of means indicated that there was a significant difference between the mean times when the aperture in the bulkhead was 27" or less, and the mean times when this aperture was 30" or greater.

Evacuations through the Overwing Type III Exits

As in the analysis of the evacuation times through the bulkhead, the evacuation times for the first thirty volunteers to pass through the exit have been compared for the range of configurations tested.

TABLE 2: MEAN EVACUATION TIME FOR THE THIRTIETH INDIVIDUAL (time in seconds)

Vertical	Competitive Evacuations		Non-competitive Evacuations	
Projection	Mean	SD	Mean	SD
3"	71.4	15.0	53.2	1.8
6"(OBR)	53.2	10.0	39.6	2.5
13"	55.9	10.3	39.9	3.3
18"	53.7	8.2	37.2	0.2
25"	54.9	11.5	40.8	2.7
34"	62.3	8.1	35.3	0.6

SD = The standard deviation associated with the mean
OBR = Outboard seat removed

Note: In conditions (ii) to (vii) - all the seats in the rows adjacent to access to the exit had limited recline and break-forward but, in condition (i) the movement of only outboard seat backs was restricted.

Blockages led to the abandonment of certain of the evacuations through configurations (i) and (iii). As a result the data for the second evacuation conducted on each test day are based on a sample of one for condition (i) and a sample of 2 for condition (iii).

As the means suggest, the statistical treatment of the data indicated that the seating configuration had a significant effect on the mean evacuation times ($F6,1 = 7.0p < 0.001$). Comparisons for the first and second evacuation times were not significantly different ($F6,1 = 0.9$NS).

Individual comparison of means indicated that the time for the first thirty volunteers to egress through the configuration involving a 3" vertical projection (ie pre Airworthiness Notice No.79), was significantly longer than the evacuation times for all of the other configurations.

The data from the configuration with the 6" vertical projection (condition (iii)) has not been included in this figure. In this condition the removal of the outboard seat meant that rather than being a single aisle with a 6" vertical projection adjacent to the exit which would be comparable with the other configurations tested there were two aisles with 6" vertical projections leading to the exits.

The Non-competitive Evacuations

In the test series of evacuations not involving bonus payments, the final data base included information from 24 evacuations. Twelve evacuations were through the bulkhead (2 evacuations were conducted for each of the 6 configurations tested) and 12 evacuations were conducted through the Type III overwing exit (2 evacuations for each of the configurations tested). Over the series of trials 704 volunteers took part. The volunteers were aged between 20 and 50 and 63% were male. All of the planned evacuations were successfully completed as it did not become necessary to halt any of the evacuations as a result of blockages, damage to the equipment or concern for the safety of volunteers.

As in the competitive evacuations, passenger flow rates through the exits were obtained from the video recordings. Comparisons between the mean evacuation times for the configurations tested were conducted for the first thirty individuals through the exits. This was in order that the analyses would be comparable with those carried out for the competitive evacuations.

The results for the evacuations through the bulkhead aperture (see Table 1) at first sight seem to suggest that increasing the width of the aperture leads to a small reduction in the evacuation times. However, statistically there was no significant difference between the mean evacuation times for the first thirty volunteers to evacuate the aircraft ($F_{5,11} = 3.2$NS) through the six configurations tested. However, this result may have been due to the fact that only two evacuations were conducted through each configuration.

Statistical treatment of the results from the evacuations through the overwing Type III exits (see Table 2) indicated a significant difference between the mean evacuation rates for the various configurations ($F_{5,11} = 16.84$ $p < 0.01$). Individual comparisons of means indicated that the seating configuration involving a 3" vertical projection gave rise to significantly increased evacuation times when compared to any of the other configurations.

Comparison between the Competitive and non-Competitive Evacuations

For the evacuations through the bulkhead aperture, the means show that for the 20" and 24" bulkhead apertures the times for thirty people to exit were a little faster in the non-competitive trials (see Table 1). For the remaining widths, the times were faster in the competitive trials. Statistical analysis indicated that there was an overall difference between the means for the six configurations ($F_{5,1} = 11.87$ $p < 0.01$). The total of 12 non-competitive evacuations as opposed to 56 competitive evacuations meant that no significant difference was found between the means for the competitive and non-competitive evacuations ($F_{5,1} = 0.2$NS).

As can be seen from the mean evacuation rates through the Type III overwing exit (see Table 2), the times to evacuate thirty passengers were slower in the competitive trials for all of the configurations tested ($F_{5,1} = 37.99$ $p < 0.001$). There was also an overall significant difference between the means for the six configurations ($F_{5,1} = 9.28$ $p < 0.001$).

Conclusions

1. The experimental programme successfully met the objective to produce a series of simulated emergency evacuations in order to explore the influence of changes to the aircraft configuration on passenger evacuation behaviour.

2. The results from the programme of evacuations involving competition between passengers suggested that increasing the width of the aperture through the bulkhead will lead to an increase in the speed at which passengers can evacuate the aircraft in an emergency.

3. The results from the evacuations through the Type III overwing exit, indicated that changes to the distances between the seat rows either side of the exit will influence the speed of the evacuation.

4. The results from a comparison of the video data from the competitive and non-competitive evacuations indicated that the non-competitive evacuations provided an effective simulation of passenger behaviour in precautionary evacuations, and in aircraft evacuations when the physical conditions in the cabin have not deteriorated.

5. The introduction of incentive payments to volunteers, successfully induced a simulation of the behaviour reported to occur among passengers, when conditions in the cabin are perceived to be life threatening.

6. The use of incentive payments to produce a competitive evacuation has been shown to have the potential to provide both the behavioural and statistical data required for the assessment of design options or safety procedures for use in emergency evacuations which maximise the degree of realism. Nevertheless the technique should be used sparingly since it can be potentially hazardous for volunteers.

References

1. Airworthiness Notice No.79 "Access to and Opening of Type III and Type IV Emergency Exits" Published by the Civil Aviation Authority, 1986.

2. Rasmussen P.G. and Chiltum C.B., "The Effect of Proximal Seating Configuration on Door Removal Time and Flow Rates Through Type III Emergency Exits" Memorandum No AAM-119-86-8 Federal Aviation Admininstration, 1986.

3. Muir, H.C., Marrison, C. and Evans, A. "Aircraft Evacuations: The Effect of Passengers Motivation and Cabin Configuration Adjacent to the Exit" Civil Aviation Authority, Paper 89019.