Report on analysis conducted by FSEG of Video Footage derived from the VERRES evacuation tests conducted at Cranfield on the 25 Jan and 1 Feb 2003

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EXECUTIVE SUMMARY

This report concerns the analysis undertaken by the University of Greenwich (UoG) on the evacuation data collected as part of the EU funded VERRES project (GMA2/2000/32039). This data primarily concerns the passenger use of the stairs and passenger exit hesitation time analysis for the upper deck slide.

Unfortunately, the trials did not proceed in the controlled manner that was originally planned and so the analysis did not yield the detailed information that was originally hoped. The main difficulties associated with these trials were:

1) CC did not behave as originally intended. This meant that it was not possible to (a) measure the propensity of passengers to freely elect to use the staircase and (b) it was not possible to estimate impact of crew influence on passenger stair efficiency and flow rates. It was apparent that in all the trials, crew played some role in managing the passenger flow on the stairs.
2) The camera angle for cameras intended to show the passenger stair behaviour on the first day trials were such that three separate cameras would need to be used to investigate passenger performance and behaviour on the stairs. Furthermore, even using these three cameras, a central portion of the stair was missing from view. While this difficulty was corrected for the second day's trials, this meant that much of the video footage collected on the first day was either extremely difficult to analyse or not appropriate for analysis.
3) While the upper deck slide is considerably different to that expected to be used in actual VLTA such as the A380, the passenger exit hesitation times are of interest in aiding our understanding of passenger behaviour. As these were the first trials to make use of the upper deck slides, the Cranfield crew that staffed the exit exhibited great caution and as such the majority of crew behaviour at the upper deck exits can be described as extremely non-assertive. This crew behaviour significantly biases the behaviour and hence performance of the passengers. It is thus not clear if the resultant passenger behaviour is a result of the sill height and slide length or the lack of assertiveness of the crew.

However, it is clear from these trials that crew can exert an influence on the performance of passenger stair usage. Passenger behaviour in utilising the staircase is both rich and complex and warrants further investigation. These trials support the view that for crew to consistently make appropriate or optimal redirection command decisions that include the possibility of using the stairs as part of the evacuation route, they must have sufficient situational awareness. Equally, passengers can only make appropriate or optimal redirection decisions if they too have sufficient situational awareness. This situational awareness may need to extend between decks.

Passengers were also noted to make heavy use of the central handrail while both descending and ascending the stairs. The presence of the central HR effectively created two staircases. By effectively separating the crowding on the stairs, reducing passenger-passenger conflicts and providing an additional means of passenger stability, it is postulated that the stair flow rates may be positively influence through the presence of the central HR. Flow rates in the UPWARDS direction was found to be greater than flow rates in the DOWNWARDS direction. This was thought to be due to the packing densities on the stairs which is a function of the motivation of the passengers, the travel speeds of the passengers and the feed and discharge

characteristics of the staircase and surrounding geometry. It was also noted that the average unit flow rate in the DOWNWARDS direction was equivalent to that specified in the UK Building Regulations. Clearly, most of the parameters can be influenced by both crew procedures and cabin layout.

Concerning the passenger exit hesitation times for the higher sill height, the trials produced inconclusive results. While the exit flow rates are lower and the passenger exit delay times are longer than would be expected for a normal Type-A exit, it is clear that the extreme unassertiveness of the cabin crew positioned at the exits and the lack of motivation of the passengers exerted a strong influence on the data produced. The reaction of the passengers in these trials was to be expected as the trials were not performed under competitive conditions and the reaction of the cabin crew could also be understood as safety concerns were paramount given that these were the first trials of their type to be conducted at Cranfield.

Finally, due to the small number of data points provided by these trials, there is insufficient data upon which to claim statistical significance for any of the observations.

Clearly, much more work is required in order to generate essential data to improve our understanding of passenger performance, passenger-crew interaction and passenger-structure interaction within VLTA configurations.

CONTENTS

1 Introduction

This document reports on research work undertaken for the European Commission funded study GMA2/2000/32039 Very Large Transport Aircraft (VLTA) Emergency Requirements Research Evacuation Study (VERRES). The purpose of VERRES was to investigate a number of issues relating to post-accident survivability of future large aircraft. A particular focus was on evacuation issues and several large-scale evacuation trials were conducted in the CRANFIELD simulator. This document addresses part of the research undertaken for Work Package 3 by FSEG with a focus on the analysis of the data concerning passenger use of stairs and passenger exit hesitation time analysis for upper deck slides.

The trials were conducted over two days, the first taking place on the 25th January and the second on the 1st February 2003. The trials consisted of a series of four separate tests to be conducted on each of the two days. On each day a fresh cohort of test subjects would be utilised for each of the four tests. In this way two data points would be derived for each of the four tests. The tests were primarily intended to investigate the behaviour and performance of passengers utilising the main staircase. In addition, as an upper deck exit with slide was to be used during the trials, passenger exit hesitation times could also be usefully collected for the upper deck slide. As each cohort of volunteers would undertake four different trials, the ordering of the trials was designed to limit the learning influence on the outcome of the results (see Table 1).

Table 1: Planned test matrix for trials

Day	Trial	Exits used	Participant direction on stairs	Crew with responsibility for stairs
1	1	UPPER DECK: **UR1** LOWER DECK: **LR2**, **LL2**	Free choice* (DOWN)	NO
1	2	UPPER DECK: **None** LOWER DECK: **LR2**, **LL2**	DOWN	NO
1	3	UPPER DECK: **UR1**, **UL1** LOWER DECK: **None**	UP	**YES**
1	4	UPPER DECK: **None** LOWER DECK: **LR2**, **LL2**	DOWN	**YES**
2	1	UPPER DECK: **None** LOWER DECK: **LR2**, **LL2**	DOWN	**YES**
2	2	UPPER DECK: **UR1**, **UL1** LOWER DECK: **None**	UP	NO
2	3	UPPER DECK: **None** LOWER DECK: **LR2**, **LL2**	DOWN	NO
2	4	UPPER DECK: **UR1** LOWER DECK: **LR2**, **LL2**	Free choice* (DOWN)	NO

*'Free choice' refers to Upper Deck participants who could egress via either the Upper Deck exit or the stairs then a Lower Deck exit.

The trials were intended to explore various aspects of aircraft evacuation in which passengers made use of the main stairs linking the upper and lower deck. In particular

the following aspects were highlighted by the consortium for investigation and were to be part of the University of Greenwich analysis. Other aspects of the evacuation were investigated by other members of the consortium.

1) Given a free choice (i.e. without direct intervention of Cabin Crew (CC)), how many passengers on the upper deck would elect to use the stairs to evacuate via the exits on the lower deck. The analysis would involve not only the numbers of passengers but also consider the circumstances and motivations influencing the decision to use the stairs.
2) Note the behaviour of passengers utilising the staircase.
3) Measure flow rates achieved by passengers using the stairs in both the upward and downward directions.
4) Measure the population densities on the staircase.
5) Measure the frequency of passengers utilising the hand rails (HR).
6) Explore the efficiency of staircase usage with zero or two CC managing the staircase flow.

Unfortunately, the trials did not proceed as anticipated. This means that not all of the objectives highlighted above can be satisfied. In summary, the main difficulties associated with these trials preventing the intended data analysis are as follows:

1) CC did not behave as originally expected. For example, in the first trial were free choice was intended, crew at the forward exits on the upper deck directed passengers to use the stairs and exit via the lower deck exits. This meant that it was not possible to (a) measure the propensity of passengers to elect to use the staircase and (b) it was not possible to estimate the passenger stair efficiency and flow rates without crew directing them downstairs. In other trials, crew directed passengers down the stairs when the trial was intended to measure the flow rates and stair efficiencies for passengers travelling upstairs (from the lower deck to the upper deck). It was apparent that in all the trials, crew played some role in managing the passenger flow on the stairs (see Table 2). It should be noted that CC were not given any special instructions as to how to control passengers on stairs and this type of behaviour is not a normal part of their training.
2) The camera angle for cameras intended to show the passenger stair behaviour on the first day trials were such that three separate cameras would need to be used to investigate passenger performance and behaviour on the stairs. Furthermore, even using these three cameras, a central portion of the stair was missing from view. While this difficulty was corrected for the second day's trials, this meant that much of the video footage collected on the first day was either extremely difficult to analyse or not appropriate for analysis.
3) While the upper deck slide is considerably different to that expected to be used in actual VLTA such as the A380, the passenger exit hesitation times are of interest in aiding our understanding of passenger behaviour.
4) As these were the first trials to make use of the upper deck slides, the Cranfield crew that staffed the exit exhibited great caution and as such the majority of crew behaviour at the upper deck exits can be described as extremely non-assertive. This crew behaviour significantly biases the behaviour and hence performance of the passengers. It is thus not clear if the

resultant passenger behaviour is a result of the sill height and slide length or the lack of assertiveness of the crew.

Given the actual behaviour that occurred during the experiments and based on the video footage provided the following data could be collected:

1. Average stair flow rates, i.e. flow rates that include periods of non-flow and/or obstructed flow, etc.
2. HR usage was determined using camera 13 and was consequently only calculated for Day 2.
3. Stair data was measured for both the left and right lanes (when looking up the stairs). Combination data could be derived from the Left and Right data as desired.
4. It was also possible to measure passenger exit hesitation times and generate a distribution of these, including identification of participants who sat at the exit.

Table 2: Planned and actual experimental goals

	Planned behaviour		**Actual behaviour (unanticipated behaviour underlined)**	
	Participant direction on stairs	**Crew with responsibility for stairs**	**Participant direction on stairs**	**Crew assumed responsibility for stairs**
Day 1 Trial 1	Free choice (DOWN)	NO	Free choice then **Crew directed DOWN**	**YES**
Day 1 Trial 2	DOWN	NO	DOWN	**YES**
Day 1 Trial 3	UP	YES	**DOWN then UP**	YES
Day 1 Trial 4	DOWN	YES	DOWN	YES
Day 2 Trial 1	DOWN	YES	DOWN	YES
Day 2 Trial 2	UP	NO	**DOWN then UP**	**YES**
Day 2 Trial 3	DOWN	NO	DOWN	**YES**
Day 2 Trial 4	Free choice (DOWN)	NO	Free choice then **Crew directed** DOWN	**YES**

Given the actual behaviour that occurred during the experiments and based on using the video footage provided the following data could **NOT** be collected:

1. It was *not* possible to measure the average flow rates for the Day 1 trails from the above stairs angle, due to camera positioning (camera 13 was not in place on Day 1, see Table 3).
2. It was not possible to measure average flow rates for **ALL** participants during Day 1 Trial 3 and Day 2 Trial 2 due to the unexpected crew intervention. Recall that in these trials some upper deck participants initially descended the

stairs, and that those downstairs did not initially go upstairs. In Day 2 Trial 2 flow rate calculations were begun ONLY once participants began using stairs in the desired direction (i.e. upwards).

3. It not possible to comment on any relationship between the performance of the stairs and CC performance, as there appear to be discrepancies between the agreed protocol and the manner in which the trials were conducted as evident on the video footage.
4. It is not possible to come to any firm conclusion regarding the nature of the passenger exit hesitation time distribution and its relationship to sill height as CC performance at the exits are extremely non-assertive.

The data that could be generated from the trials is summarised in Table 3.

Table 3: Summary of data that could be extracted by UoG from the video footage

	Collected Data		
	Exit hesitation delays	**Handrail use**	**Stair flow rates**
Day 1	YES	NO	YES
Day 2	YES	YES	YES

2 Staircase performance

The planned matrix of experimental trials is presented in Table 1. This shows the intended direction of participant stair movement and CC action per trial.

Table 4: Summary description of participant and CC behaviour during trials

Trial	Participant Direction on Stairs	CC activity at top of stairs
Day 1 Trial 1	Four participants descend stairs before CC arrives. Most participants who then descend stairs were re-directed to them by CC.	Arrives at 36 s and directs participants downstairs then departs to re-direct participants downstairs from Forward Upper exit.
Day 1 Trial 2	Approx 20 participants voluntarily descend stairs before the majority realise only the stairs are available, or were redirected by CC, and turn away from the Upper exit queue to descend stairs.	No CC at stairs until last 7 participants. During evacuation CC verbally re-direct participants downstairs from Forward Upper cabin.
Day 1 Trial 3	Participant procedural confusion. Initially descend stairs causing chaos at base of stairs. Correct upstairs movement only due to intervention of Lower deck CC. 32 participants descended or were beginning to descend stairs before error corrected at 16 s	CC directed participants downstairs instead of forward to Upper exit. This was corrected when participants started to ascend stairs
Day 1 Trial 4	Seven participants ignore CC and correctly descend stairs before CC allows stair descent by all remaining participants	CC blocks participants from descending stairs. Attempts to send them to Upper exit. Then changes to encouraging stair descent.
Day 2 Trial 1	Eight participants ignore CC and descend stairs before CC allows stair descent by all remaining participants	CC blocks participants from descending stairs. Attempts to send them to Upper exit. Then changes to encouraging stair descent after a 13 s dry-up on the stairs
Day 2 Trial 2	Participant procedural confusion. Initially descend stairs causing chaos at base of stairs. Correct upstairs movement only due to intervention of Lower deck CC. 30 participants descended stairs before error	CC arrives at stairs after 37 s when all Upper Deck participants are out and correct flow from downstairs is occurring.

	corrected at 17 s	
Day 2 Trial 3	Eleven participants voluntarily descend stairs before the majority realise only the stairs are available, or were redirected by CC, and turn away from the Upper exit queue to descend stairs	No CC at stairs until last 8 participants. During evacuation CC verbally re-direct participants from Forward Upper cabin to descend stairs
Day 2 Trial 4	Thirteen participants voluntarily descend stairs before others start to redirect to descend stairs from Upper exit queue. Redirection due to CC further back.	CC directs participants to descend stairs from further back. Arrives at stairs at 23 s and directs participants downstairs then departs to re-direct participants downstairs from Forward Upper exit.

The actual participant stair movement and CC behaviour is presented in Table 2 and further in Table 15. As already described in the introduction, the trials did not proceed as intended and this had an impact on the nature of the data that could be analysed. Throughout the trials, lower deck CC invariably dealt with lower deck participants first and those descending the stairs only when free. In both trials in which participants were intended to travel UPSTAIRS, trails participants initially descended stairs.

2.1 Behaviour on Stairs

Several types of participant action where noted on the stairs that will have implications for flow rates. These behaviours occurred within the staircase ***lanes*** defined by the free space between the HRs. The staircase in the Cranfield simulator consists of two distinct lanes (see Figure 1 and Figure 2).

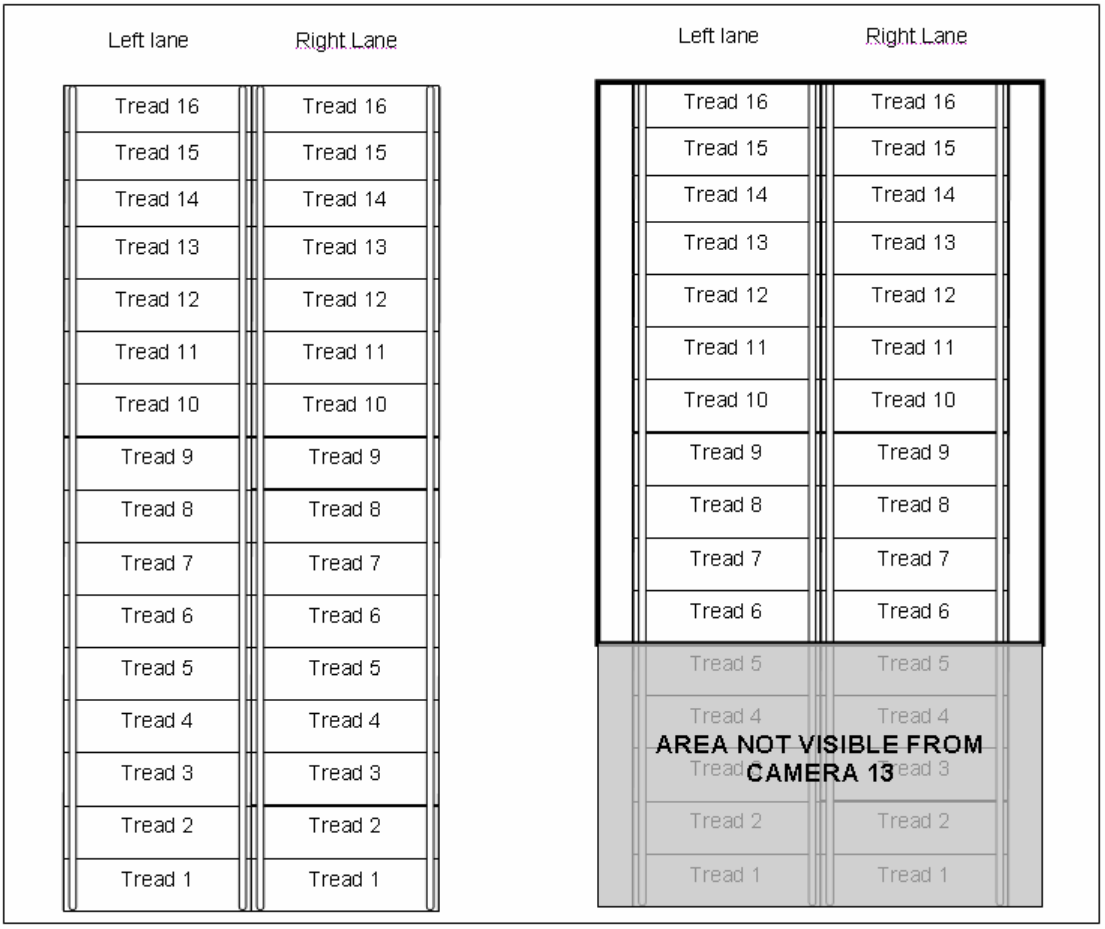


Figure 1: Description of stair configuration and portion of the staircase visible from camera 13

2.1.1 Definition of frequently used descriptive terms

For clarity the staircase is defined as follows:

- The stair consisted of two distinct passenger lanes separated by a central HR.
- The width of the left lane (as measured from the centre of each HR) was 76.8 cms.
- The width of the right lane (as measured from the centre of each HR) was 75.8 cms.
- The width of the left lane (as measured from outermost portion of the HRs) was 73 cms.
- The width of the right lane (as measured from outermost portion of the HRs) was 72 cms
- The effective width of the left lane (allowing for 9 cms from each HR) was 58.8 m.
- The effective width of the left lane (allowing for 9 cms from each HR) was 57.8 m.
- The riser height was 17.8 m.
- The tread depth was 26 cms.

- There were 16 stairs from bottom to top (excluding the floor of each deck).
- Using camera 13, 11 of the 16 stairs were visible (see Figure 2).
- There were 11 visible steps from camera 13.

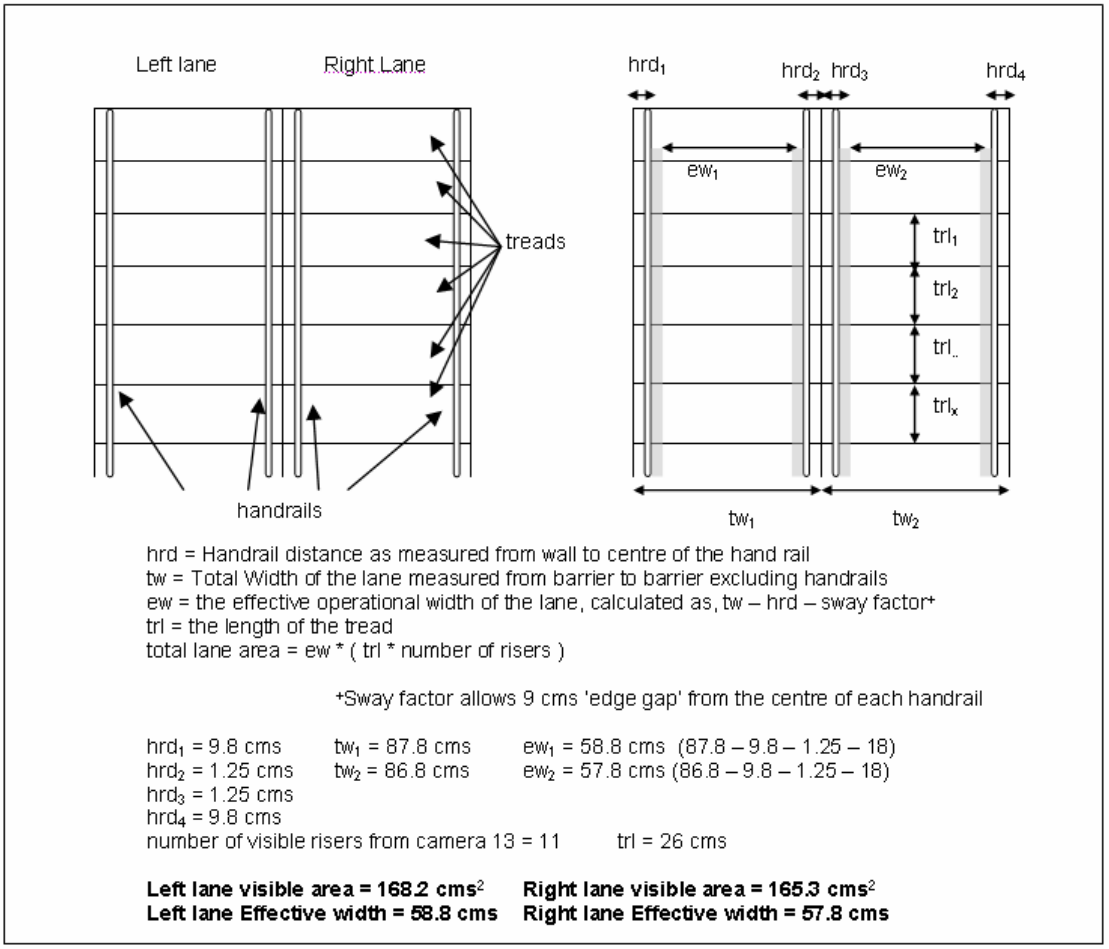


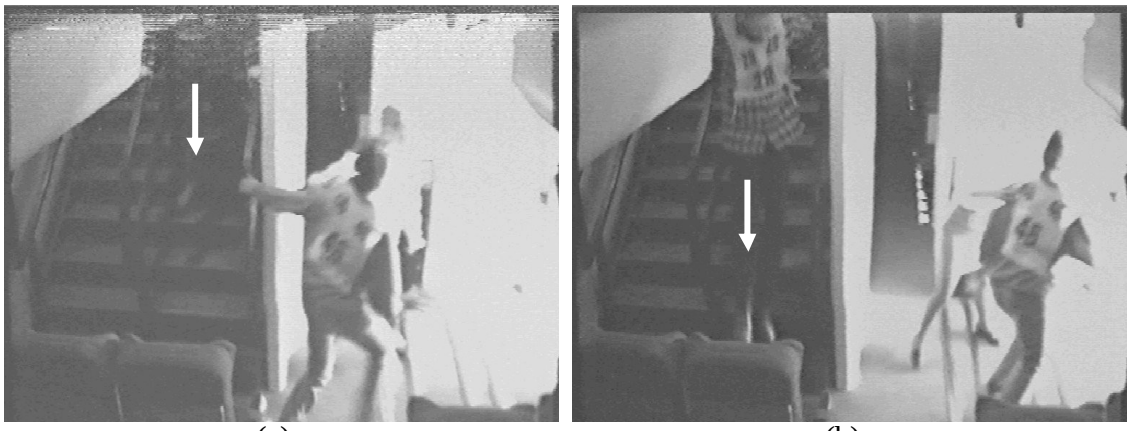
Figure 2: Description of stair geometry

Terms frequently used to describe the behaviour of the participants in this document will now be defined. HR use was characterised by participant holding or touching; (a) both hand rails, (b) only the side hand rail or (c) only the centre hand rail. `Use' was taken to mean any contact at any point in the camera shot from which measures were being taken. Many participants used the side HR to swing around to the exit during DOWN stairs movement (Figure 3(a)). Some participants used a 2 handed grip, probably due to CC exhortation to hasten (Figure 3(b)).

(a) (b)

Figure 3: Participants using the side HR to swing around to an exit during DOWN stairs movement with (a) one handed and (b) 2 handed grips

The term 'Single file' in this report refers to participants filing down / up the stairs in a single line i.e. one person per lane. In single file, free flow conditions and unhurried, less urgent conditions e.g. Trial 1.1 participants tried to maintain personal space between others. When flow was more urgent and congested, particularly in upstairs flows, close staggering / dual usage and occasionally overtaking occurred. The term 'vaulting' refers to participants who put all their body weight on their arms holding side and centre HRs, and then jump across several treads in one action (Figure 4(a) followed by Figure 4(b)). This only occurred during free flow conditions and may possibly occur with greater frequency during more 'urgent' evacuations involving passenger motivation.



(a) (b)

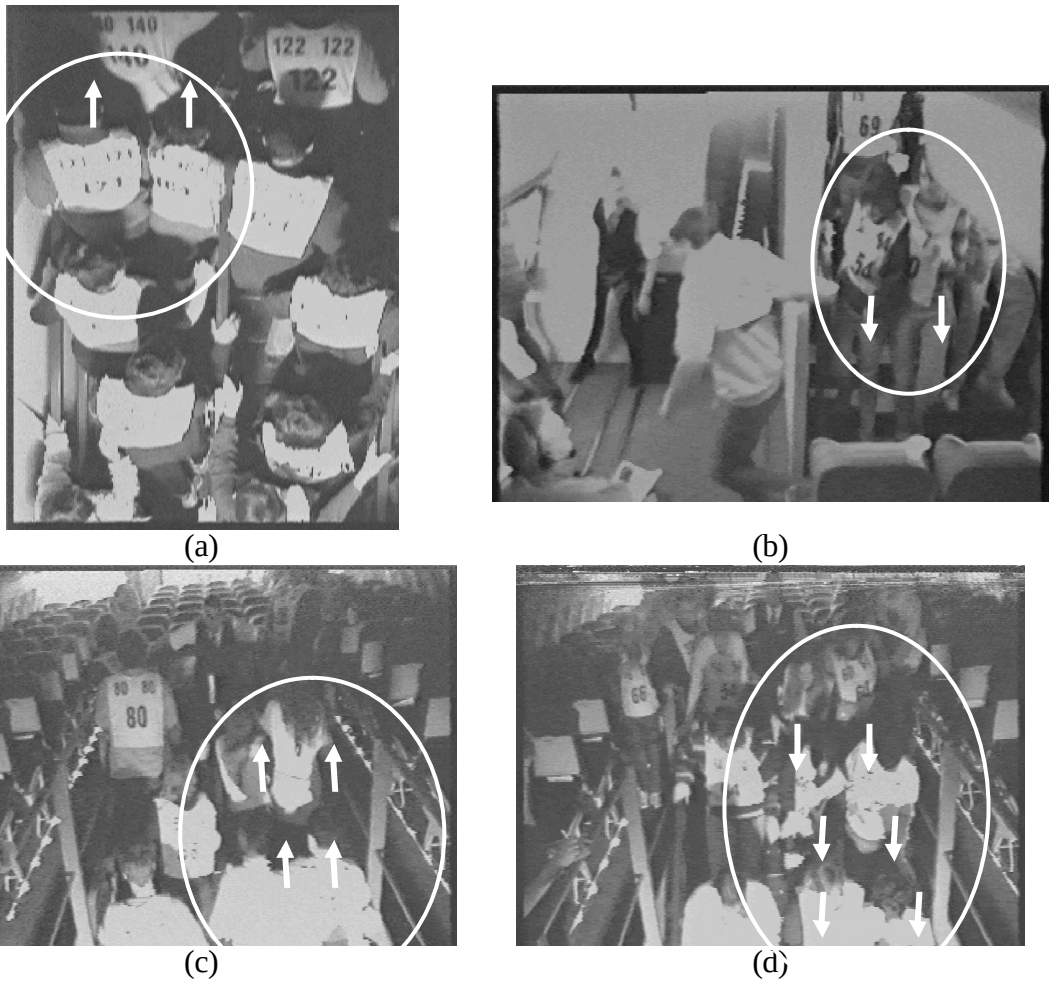
Figure 4: (a) Commencement and (b) the completion of a vault across several treads during DOWN stairs movement

'Overtaking' refers to a participant passing a slower participate located within the same lane (Figure 5(a) followed by Figure 5(b)).

(a) (b)

Figure 5: (a) Commencement of and (b) over-taking during DOWN stairs movement

'Dual usage' refers to a flow condition in which two participants move side-by-side for any period of time. This behaviour was witnessed during upwards (Figure 6(a)) and downwards stair movement (Figure 6(b)).



(a) (b)

(c) (d)

Figure 6: Examples of Dual usage of a tread by participants

'Dual flow' refers to consecutive dual usage by more than one pair of participants. Again this occurred during both upwards (Figure 6 (c)) and downwards movement (Figure 6(d)).

'Close staggering' refers to flow which that was almost dual flow but without participants sharing the same tread. In this flow condition participants bunched together to the point of being packed / dual flow. Close staggering occurred during upwards (Figure 7(a)) and downwards movement (Figure 7(b).

(a) (b)

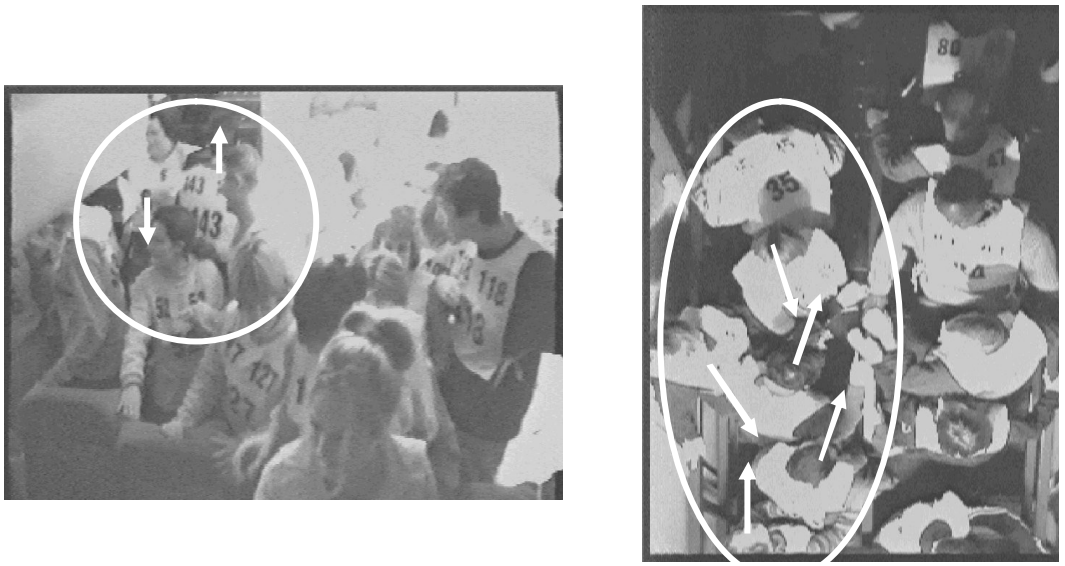
Figure 7: Close staggered participant movement (a) up and (b) down the stairs

2.1.2 Description of stair behaviours

On occasions participants were witnessed conflicting for space on the stairs. This usually occurred on the Upper and Lower deck landings whilst attempting to access the stairs. The situation was typically resolved by a participant stopping to let the other go ahead, or alternatively both used the stairs and a dual flow condition occurred.

As the CC did not which exits were to be made available, the trials on Day 1 Trial 3 and Day 2 Trial 2 were characterised by confusion on the part of the CC relating to the direction of stair use, i.e. UP or DOWN. This confusion typically prevailed for the first 16-17 seconds of these evacuations. In these trials participants at first attempted to descend the stairs. After 16-17 had elapsed the flow turned and went in the intended direction of the experimental design (see Table 1). The initial periods of these trials were however subjected to a large degree of disorganisation on the stairs. Two examples can be seen in (Figure 8(a) and (Figure 8(b)).

Another behaviour that was noted was that at the start of some trials (i.e. Day 2 Trial 1) Upper deck participants had to queue on the stairs while lower deck participants evacuated (Figure 9). Whilst at the start of others (i.e. Day 1 Trial 4) some Upper deck participants disobeyed the CC that was attempting to block the use of the stair use.



(a) (b)

Figure 8: Disorganisation and resulting confluences on stairs
NOTE: the direction of travel according the experimental design was upwards.

During Day 2 Trial 2 the experimental design dictated that passengers should descend the stairs to evacuate via lower deck exits as none of the upper deck exits were available. During the early stages of this evacuation the CC at the stairs on the upper deck deliberately stopped passengers from using the stairs. This action was taken as the CC was waiting to see if any of the upper deck exits were operable CC (see Figure 10). During this period the CC appeared to be advocating the use of Upper Forward exits. Despite this, some participants were observed to disobey the CC and use the stairs (see Figure 10).

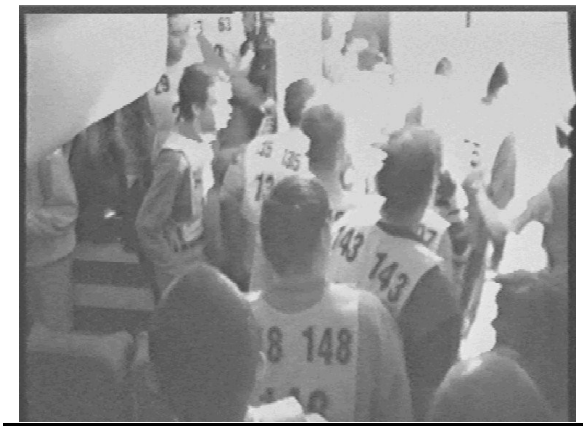


Figure 9: Participants queue DOWN right lane of stairs

Figure 10: Two participants disobeying CC (in centre with back to camera, telling participants to go forward) during DOWN stairs movement

The modal class of behaviour from those described was free flowing / single file movement. The second most typically flow condition was close staggering. Close staggering was usually coupled with higher densities on the stairs. In one of the downwards and both upwards movement trails, densities were higher and the flow was characterised as being dual usage

A more detailed breakdown of the behaviour that occurred in these trials can be found in Appendix A.

2.2 Stair population densities

Stair population densities could not be determined from the trials on Day 1 due to camera positioning and so only densities associated with Day 2 are presented here. The density on the stairs was measured using Camera 13 and calculated for the visible portion of the stairs only (see Figure 1 and Figure 2). The video footage was stopped every two seconds and the number of visible participants recorded. From this the density was calculated using the effective width [1] across the number of visible treads (see Figure 2). To aid the discussion some hypothetical densities based on various stair behaviours can be seen in Table 5.

The stair densities as a function of time are displayed in Figure 11 to Figure 14. From these figures it is clear that the stair densities in the UPWARD direction is greater than that in the DOWNWARD direction and that maximum stair density recorded approached 5 passengers/metre^2. This was recorded during Day 2 Trial 2 and involved passengers moving upwards. In this trial the flow condition was characterised as being dual / dual staggered. Note that it is thought that the high density observed on Day 2 Trial 2 did not result from the disorganisation at the start of the trial (recall that initially passengers descended the stairs) as the highest densities occur once the flow has begun moving upwards.

Lower densities occurred in all of the DOWNWARDS movement trials performed on Day 2. These trials typically generated densities between 2.5 and 3.5 passengers/metre^2. These densities are broadly equivalent to having one passenger located every other tread, i.e. a single file flow.

Table 5: Hypothetical densities based on imposed packing densities

	Number of passengers		Density (passengers/metre^2)	
	Left lane	**Right lane**	**Left lane**	**Right lane**
1 passenger per tread	11	11	6.5	6.7
1 passenger every other tread	5.5	5.5	3.3	3.3
2 passengers per tread	22	22	13.1	13.3
2 passengers every other tread	11	11	6.5	6.7

While average individual stair speeds were not measured, it is hypothesised that the average upward travel speed of the participants is slightly less than the average downwards travel speed leading to a greater degree of bunching in the UPWARDS direction. This hypothesis is supported by evidence from the building industry, where the average stair speed in the UPWARD direction is generally accepted as being lower than the DOWNWARD speed. Another possible explanation for the difference in the observed packing densities could involve the nature of the discharge from the stairs in both cases. In situations with an UPWARD movement, the upper discharge from the stairs consists of two passenger aisles leading forward. In the DOWNWARDS movement trials, the discharge from the stairs can be fed by four aisles, (2 moving forwards and 2 moving aft wards). In the UPWARDS case there is

greater potential for a bottleneck or slower discharge resulting in the higher observed densities.

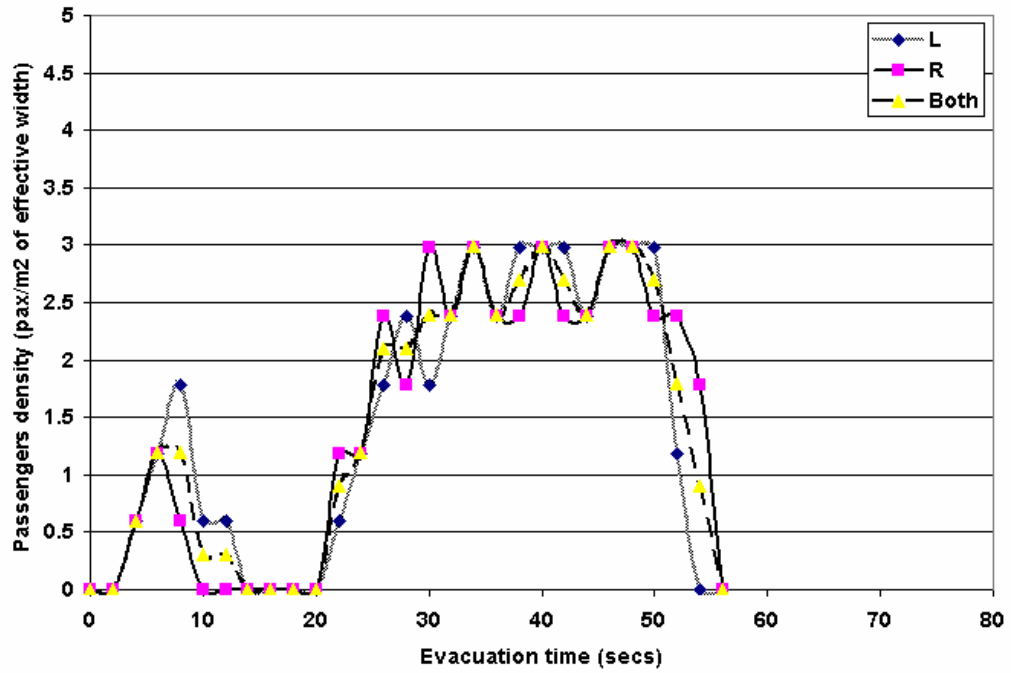


Figure 11: Density in visible portion of stairway during Trial 2.1 (DOWNWARDS TRAVEL)

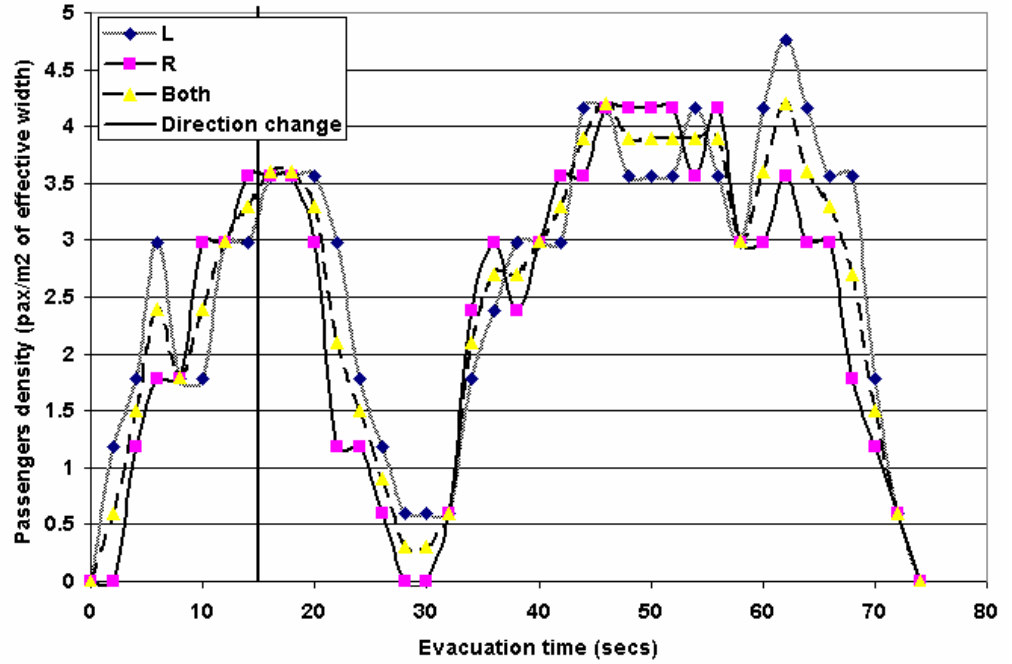


Figure 12: Density in visible portion of stairway during Trial 2.2 (DOWNWARDS and then UPWARDS TRAVEL)

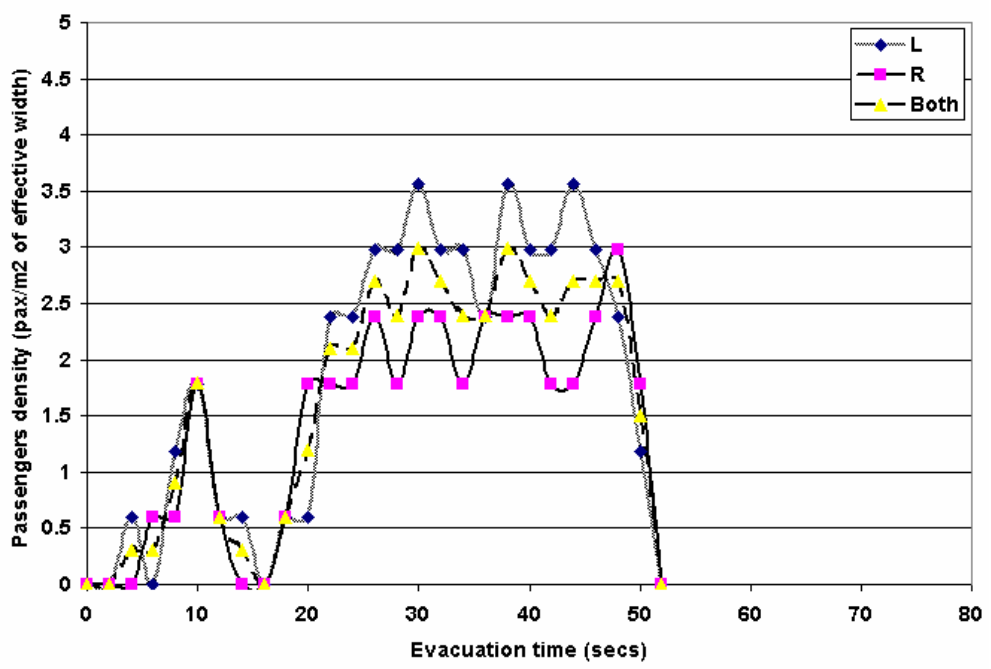


Figure 13: Density in visible portion of stairway during Trial 2.3 (UPWARDS TRAVEL)

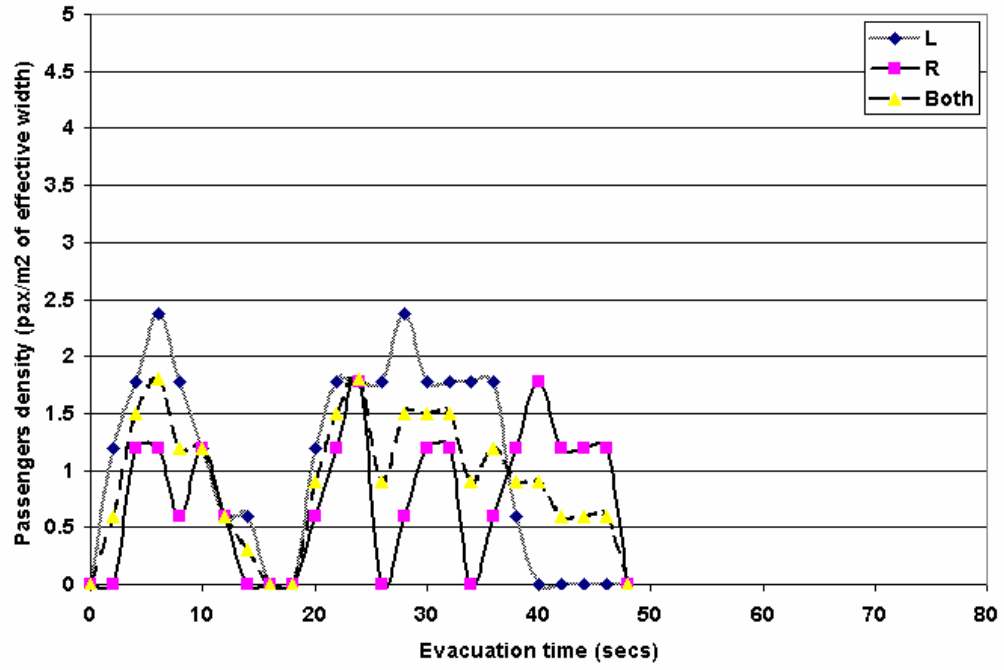


Figure 14: Density in visible portion of stairway during Trial 2.4 (DOWNWARDS TRAVEL)

It is also worth noting that the maximum density of 5 passengers/metre^2 is less than what would be expected if we had achieved one passenger per tread or two passengers every other tread (6 passengers/metre^2) and greater than if we had one passenger every other treed (3.3 passengers/metre^2). Thus, while the packing densities are high, they are not as high as could be achieved.

2.3 Stair flow rates

2.3.1 Calculation of Stair flow rates

During the first pass at video analysis it became apparent that the central HR effectively created two separate staircases, with no participant ever crossing the central HR. The decision was made to analyse the left lane and right lane separately and then to combine the data. Average flow rates (AFR) – measured in paxs/minute - were calculated for the total period of passenger usage - this may include periods of no-flow (i.e. 'dry-ups') and periods of blocked discharge. During day 1 cameras 2, 4 and 12 were used. These measurements are extremely difficult and subject to error due to the use of several different cameras. Also, some important information is not recorded by these cameras. ***Thus, data from day 1 should not be considered very reliable.*** Trials for the second day were analysed using camera 13. Flow termination was determined at the visible point of discharge, i.e. the top of the stairs when ascending, and the bottom when descending. Similarly flow inception was determined using the point of flow initiation, depending upon the direction of travel this was the upper or lower most visible tread.

In detail, the first stage was to calculate Stair Use time. In Day 1 Trials cameras 2, 4 and 12 were used. For DOWN trails (1, 2 and 4) Stair Use time commenced (Figure 15(a)) with the time at which the first participant placed a foot on the first USED tread at the top of the stairs. `Used' covers the situation where a participant vaults more than one tread at a time. Stair Use time ended when the last participant placed a foot on the lower deck landing (Figure 15(b)). Again this is to include those participants who leap the last few treads. The start of the UP trial (Day 1 Trial 3) was characterised by unintended descent by Upper deck participants, who then turned to ascend the stairs.

(a) (b)

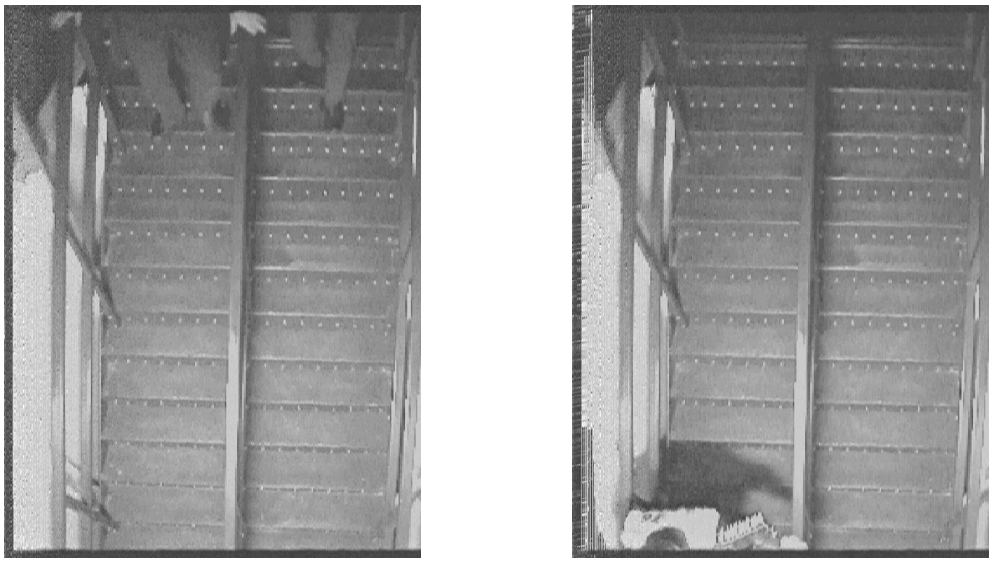
Figure 15: (a) commencement and (b) termination markers used for calculating stair flow rates on day 1 during DOWNWARDS movement

Discounting these Upper deck participants and measuring only Lower deck participants correctly ascending was the ideal. However no break in flow occurred to enable a reliable commencement of the UP measure to be made of Stair Use time. For the UP commencement marker, the first participants on the stairs to visibly turn to face UP were used (Figure 16(a)). The same end point as DOWN was used but was measured on the upper not lower deck landing (Figure 16(b)).

(a) (b)

Figure 16: (a) commencement (in this example taken as first participant moving in correct direction) and (b) termination markers used for calculating stair flow rates on day 1 during DOWNWARDS movement

In Day 2 Trials camera 13 was used. For DOWN stairs conditions this commenced with the time at which the first participant began to enter the camera 13 shot and ended when the last participant disappeared from the camera 13 shot. Figure 17(a) and Figure 17(b) show the first and last participants in shot for illustrative purposes. In reality the moment the participant begins to enter and has disappeared from shot were used.

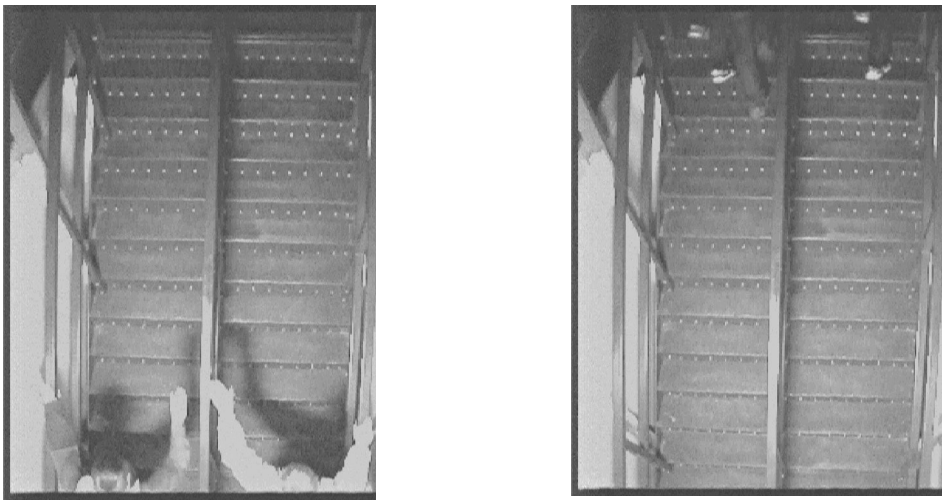


(a) (b)

Figure 17: (a) commencement and (b) termination markers used for calculating stair flow rates on day 2 during DOWNWARDS movement

This procedure was used for Day 2 Trials 1, 3 and 4. The 'first participant' in the UP stairs trial (D2T2) was deemed to be the first lower deck participant to appear following a break in stair use, following the unintended descent of Upper deck participants at the start of the trial, after they had retreated upstairs and disappeared from view. Stair Use time commenced with the time at which the first participant began to enter the camera 13 shot (lowest point visible on stairs) and ended when the last participant placed a foot on the Upper landing, which is visible in the camera 13

shot. Figure 18(a) and Figure 18(b) show the first and last participants in shot for illustrative purposes.



(a) (b)

Figure 18: (a) commencement and (b) termination markers used for calculating stair flow rates on day 2 during UPWARDS movement

Stair Use time reflects periods of non-use of the stairs following the first participant, periods of waiting and queuing on the stairs, periods of free flow and periods of dense flow and congestion. Average flow rate was calculated by dividing Stair Use time into the number of participants who used the stairs, then multiplying by 60 gives a persons per minute flow rate, for both lanes then in combination. For the 2 UP conditions only those moving as intended were used in Stair Use and AFR calculations.

2.3.2 Stair flow rates

Before turning to an analysis of measured average stair flow rates, a brief discussion of behaviours that are relevant to the flow rate calculations is presented (see Section 2.1 for descriptions of participant behaviour). A more detailed description of passenger behaviour may be found in Appendix A.

Trial 1.1: Free Flow conditions. The trial commenced with a 22 seconds delay in participants beginning to use stairs. Flow was single file with no dual usage or over-taking. Flow was unhurried with no crowding, no over-taking, no dual flowing or close staggering.

Trial 1.2: Flow DOWN stairs. Participants queued in Left lane from 9-17 seconds due to congestion from lower deck participants at the lower deck exit. When free flow gathered momentum it was single file and unhurried with no crowding, no over-taking, no dual flowing or close staggering. In Right lane participant 130 stops on stairs and slows up flow behind even though there was room ahead of him to keep moving. This causes others behind him to stop altogether. Flow rate gathered momentum when main flow started. This correlated with CC downstairs facing the stairs and shouting orders and pushing participants.

Trial 1.3: Flow UP stairs. Participant procedures were confused. Upstairs participants went downstairs, turned and were joined by participants from downstairs

sent up. Slow congested flow throughout. Correct upstairs flow started at 16 s into the trial and was high density throughout.

Trial 1.4: Flow DOWN stairs. Left lane flow was unhurried and single file with 2 or 3 incidences of close staggered flow. Only one CC who remained at the Assist Space (AS) throughout. Flow may have been slower due to this. Right lane movement is initially slow then at 18 seconds participant 52 descends stairs at crawl speed. He may have been injured or disabled and held other participants up behind him. When flow down stairs gathered momentum CC were positioned either side of the exit. Flow was unhurried and mostly single file, but some close staggered flow plus 4 seconds of dual flow occurred.

Trial 2.1: Flow DOWN stairs. Left lane, participants queued on stairs initially. Dual usage occurred at 45 seconds. Half a dozen participants over-took at the top of the stairs. Bunching and close staggering occurred in the middle of the stairs. Right lane, also some bunching and close staggering in middle of stairs and dual usage occurred at 45 seconds.

Trial 2.2: Flow UP stairs. Base of stairs was disorganised at the beginning of the trial with participants crossing each other on stairs, and descending then back tracking up the stairs. Correct upstairs flow started at 17 s into the trial and was high density throughout. Use of BOTH handrails coincided with less congestion during the main use phase (38-72 seconds in) and use of Centre or Side HR only coincided with peak congestion where flow was `staggered dual flow'.

Trial 2.3: DOWN. 10 -15 seconds into the trial participants had to wait/queue on stairs. Thereafter flow was unhurried and less urgent than other trails. The paradoxically high flow rate achieved in Table 6 reflects a near optimal combination of free flow and little dry up in flow compared to other trials.

Trial 2.4: Free Flow conditions. Left lane exhausts 9 seconds before right. This was due to Cabin Crew redirecting participants from the Upper deck exit queue to the stairs. Dry ups on both lanes due to Upper participants exit choice indecision. Flow was unhurried with no crowding, over-taking or dual flowing or close staggering.

The average stair flow rates measured in the trials is presented in Table 6. As can be seen from these results, the mean flow rate in the UPWARD direction is greater than the mean flow rate in the DOWNWARDS direction. The average stair flow rate (per unit width) is a function of the average packing density and the average travel speed. For a given width stair, the stair flow rate may be increased by either increasing the stair flow rate or increasing the average travel speed. The higher flow rates when travelling UPWARDS are thought to originate from the higher packing densities that were witnessed on the stairs during these trials. It is suggested that while the average UPWARDS travel speed has been hypothesised to be less than the average DOWNWARDS travel speed, the increase in packing density compensates for this reduction, resulting in a greater flow rate.

The flow rates presented here are less than what may be expected to be achieved in emergency situations. Two reasons for this concern the calculation technique adopted and the nature of the trials. With regards the calculation technique, as an average

flow rate was calculated, periods of non-flow were included in the flow rate calculations. This will result in the calculated flow rate being less than the actual achieved flow rate during periods of passenger flow. With regards to the trial conditions, it has already been noted in Section 2.2 that the stair packing densities were less than what could be expected. A possible explanation for this relates to the procedures adopted in the trial. The level of participant urgency was low for these trials and this could have resulted in the low levels of packing densities. In most trials participants were unhurried with gaps of one or more treads between them. In others, particularly those ascending the stairs, higher densities were apparent. CC activity on the lower deck may also have effected stair flow rates.

Another aspect that could influence stair flow rates concern the physical layout of the aircraft. When considering the evacuation efficiency of aircraft design, much can be learned about the potential performance of the aircraft layout by considering the aircraft as an escape system made up of a series of sub-components. These sub-components have a supply and discharge capability that must be balanced in order to achieve an efficient evacuation performance. Thus, the physical layout of the stairs, the cabin layout in the immediate vicinity of the stairs, the approach to the stairs finally the exits must be considered as an entire system. Each component will influence the performance of the system as a whole.

Table 6: Average stair flow rates for all trials

		Left lane		Right lane		Combined	
Trial	**Direction**	**Flow rate (pax/minute)**	**Users**	**Flow Rate (pax/minute)**	**Users**	**Flow rate (pax/minute)**	**Users**
1.1 *	DOWN	45.1	24	36.8	28	68.3	52
1.2 *	DOWN	45.6	39	53.2	46	97.7	85
1.3 *	UP #	63.4	56	60.6	58	119.2	114
1.4 *	DOWN	50.0	42	51.1	42	108.4	84
2.1 $	DOWN	48.2	41	49.4	44	95.1	85
2.2 $	UP ##	68.3	47	64.1	44	132.2	91
2.3 $	DOWN	54.8	44	52.2	41	105.2	85
2.4 $	DOWN	40.4	26	30.3	23	62.3	49
MEAN	**DOWN**	47.4	36.0	45.5	37.3	89.5	73.3
MEAN	**UP**	65.9	51.5	62.4	51.0	125.7	102.5

* Cameras 2, 4 and 12 used
$ Camera 13 used
# flow measure includes participants undertaking incorrect procedure
flow measured from point at which correct procedure occurred

2.3.3 Comparison of Stair flow rates with building evacuations

The unit flow rate capacity for a standard stair as specified in the UK Building Code [2] is 80 people/metre/minute. This equates to 1.33 people/metre/second. The unit flow rates measured in these trials together with the equivalent value as specified in the building regulations are displayed in Table 7. From Table 7 it is apparent the DOWNWARDS flow rates that were generated during the trials are broadly equivalent to those expressed in building regulations. However, for UPWARDS movement the flow rates generated by the trials are 35% higher than those prescribed in building regulations. It should however be noted that the UK Building Code does

not specify a unique value for stair ascent. It is assumed that stair movement is in the DOWNWARDS direction.

Table 7: Flow rates expressed per unit of effective width

		Flow rate (passengers/metre of effective width/second)		Flow rate (passengers/metre/ second
		Left Lane	Right Lane	Building codes
1.1 *	DOWN	1.28	1.06	1.33
1.2 *	DOWN	1.29	1.53	1.33
1.3 *	UP#	1.80	1.75	1.33
1.4 *	DOWN	1.42	1.47	1.33
2.1 $	DOWN	1.37	1.42	1.33
2.2 $	UP##	1.94	1.85	1.33
2.3 $	DOWN	1.55	1.51	1.33
2.4 $	DOWN	1.15	0.87	1.33
Mean	DOWN	1.34	1.31	1.33
Mean	UP	1.87	1.80	1.33

* Cameras 2, 4 and 12 used
$ Camera 13 used
# flow measure includes participants undertaking incorrect procedure
flow measured from point at which correct procedure occurred

2.4 Stair Hand Rail usage

Determining HR usage was very difficult for day 1 trials due to the poor camera angles. HR usage was therefore only estimated for the day 2 trials using camera 13. HR use was categorised as either, 'side-only', 'middle-only', 'both' or 'none' (see Table 8). The term 'Side-only' represents passengers that ONLY used the HR located on the left or right hand side of the stairs. 'Middle-only' represents passengers that ONLY used the central HR. 'Both' represents passengers that used BOTH the side and central HR. Finally, 'None' represents passengers that did not use either HR. For the purposes of this analysis use is defined as a passenger making any visible contact with a HR. This may represent a light touch or the use of the HR to propel oneself using both arms. In addition use may occur at any point along the length of the HR and for any contact duration.

Table 8: Day 2 participant's HR use, determined from camera 13

Trial	Direction	Side only	Middle only	Both	None
2.1	DOWN	10/85 (12%)	7/85 (8%)	68/85 (80%)	0/85 (0%)
2.2[+]	DOWN	34/112 (30%)	34/112 (30%)	44/112 (39%)	0/112 (0%)
2.3	UP	12/85 (14%)	3/85 (4%)	69/85 (81%)	1/85 (1%)
2.4	DOWN	3/49 (6%)	0/49 (0%)	45/49 (92%)	1/49 (2%)

[+]Could not be determined for one passenger via camera 13

It is clear from these trials that the majority of passengers made use of the HRs in some form. The majority of passengers either made use of only the central HR or

used both the central and side HRs. It would be interesting to note from participant questionnaires if the central HR was cited as providing assistance during the evacuation.

3 Passenger Exit Delay Time distributions

3.1 General considerations

Only one exit was used that had a slide attached, this was the Upper right number 1 exit. Evacuation via the Upper exit and slide was only undertaken in Trials 1.1, 1.3, 2.2 and 2.4. The sill height for these experiments was 8 metres and the slide length was 16 metres. The exit is a standard dual lane Type A exit measuring 42 inches in width and 72 inches in height. The slide is also dual lane. Exit delay times were recorded from a video machine measuring 25 frames per second. Each participant's number of frames multiplied by 0.04 (one frame = 0.04 s) gives that participant's exit delay time in 100ths of seconds.

3.2 Extraction technique

The Passenger Exit Delay Time is a combination of passenger exit hesitation time and passenger exit negotiation time. Hesitation refers to participants' reluctance to quickly vacate the exit for whatever reason and negotiation is the physical act of using the exit. Passenger Exit Delay Time is the time difference between two events. The time at which the participant breaks contact with exit system minus the time at which the participant starts his/her last steps to the exit door sill when the exit is free to use. In other words the period of time expended physically moving through the exit plus time expended hesitating when he/she *could* have moved if the exit was free. 'Starts Last Steps to Sill' is defined as the beginning of the approach to the door sill with the intention of exiting, rather than shuffling forward in a queue. If the participant 'goes' immediately after the previous participant no hesitation occurs and only negotiation time is measured. 'Exit free to use' is defined as the time from the moment the previous participant has broken contact with the exit system sufficiently enough for the next participant to step up and commence exit negotiation. 'Breaks contact with exit system' is the time at which the participant has effectively passed through the exit, which usually means letting go of the last exit sill foothold when through the door, or the last foothold on the thickness of the top of the slide. This assumes the participant jumps, leaps, hops or vaults from the exit (usually the case). Some participants sit at the exit before descending the slide. Here 'buttock hold' is used instead of foothold as the exit negotiation time end marker i.e. exit contact is broken when the participant can be seen to have disengaged his/her seat from the exit sill base or the thickness of the top of the slide, as appropriate.

The assertiveness of the CC at the exit is of paramount importance to the degree of participant hesitation displayed at the exit. The purpose of CC 'assertiveness' is to expedite passenger flow and minimise passenger hesitation at the exit, assuming an emergency evacuation or other time-critical event e.g. 90 second certification trial. Here, assertive CC are taken to be crew who displayed a vocal and physical assertiveness during the majority of the participant flow through their exit. Vocal assertiveness is taken to mean crew members who continuously yelled clear instructions to the participants and physical assertiveness is represented by CC who made physical contact with the participants during their egress, in particular pushing

passengers out of the exit. Unassertive CC crew are those who fail to display either vocal or physical assertiveness for the majority of the evacuation.

3.3 Raw data and qualitative features

3.3.1 Trial 1.1

In Trial 1.1 two CC worked the exit and 33 participants evacuated. Participants appeared to wait for the previous participant to be some distance down or off the slide before they jumped. There were long intervals between participants ('long' in terms of the behaviour that was being measured). Data in Table 9 does not reflect inter-participant delays. Participant exit during this trial is thought to resemble a precautionary evacuation in which extreme care is taken with respect to minimising injuries. For the first 66 seconds the exit door was not fully open / fastened.

The FSEG team would classify the CC behaviour at the exit as significantly less than Unassertive. The CC during the trials neither physically or verbally expedited participant exit flow. Indeed, in several cases CC are seen to actively prevent participants from exiting. The CC did not appear to treat the trial as time critical, but more safety critical. As these were the first trials to make use of the upper deck slides, the Cranfield crew that staffed the exit exhibited great caution and as such the majority of crew behaviour at the upper deck exits can be described as extremely non-assertive.

Table 9: Raw exit delay times (s) extracted from trial 1.1

1.56	3.68	3.88	3.24	2.72
3.52	2.96	3.52	3.52^{+}	
3.56	3.36	2.88	7.36^{+}	
3.4	2.4	3.64	6.88^{+}	
2.6	2.52	4.6^{+}	4.36^{+}	
2.08	2.8	4.36	5.56	
3.4	2.68	3.12	4.68^{+}	
2.72	3.48	2.6	5.2^{+}	

$^{+}$denotes sitter

One CC was located in the AS either side of the exit. They called for participants to form two lines on approach to the Type A exit. But at the exit participants evacuated one at a time, cued by CC, who took turns at saying "go" once the CC thought a 'safe' amount of time had elapsed since the last evacuee had descended the slide. On several occasions CC stopped participants from evacuating too soon. In these cases the participants either jumped from the exit or sat and slid down the slide on their own initiative. CC did not push participants or throw them out. Only the longest 'sitters' appeared to receive any assistance from the CC. The only physical contact which CC undertook was to take hold of a participant's arm, step them up to the exit sill and pull them to one side so that two participants were at the sill, ready for CC to take turns at saying "go". However, it should be noted that this behaviour was the exception not the rule.

3.3.2 Trial 1.2

Not applicable. No evacuation slide used

3.3.3 Trial 1.3

In this trial 48 participants exited via the slide. As in Trial 1.1, the CC were classified as less than Unassertive. Participant behaviour in this trial appeared to be more motivated than in Trial 1.1 however, this was despite rather than because of CC activity.

Table 10: Raw exit delay times (s) extracted from trial 1.3

1.28	1.2	2.6	1.52	1.64	2.84
2.68	3.08	2.88	2.56+	2.12	3.24
1.64+	2.36	1.08	1.68+	2.08+	2.24
2.4	5.16+	0.76	1.76	3.56+	1.4
2.92+	3.96+	1.68+	1.24	3.32+	1.76
2.64	1.36	1.2	2.04	1.96	1.6
4.36+	2.24	0.72	1.32	2.76	1.04
3.52+	1.88	2	3.48+	4.08	1.92

+denotes sitter

3.3.4 Trial 1.4

Not applicable. No evacuation slide used

3.3.5 Trial 2.1

Not applicable. No evacuation slide used

3.3.6 Trial 2.2

In this trial 56 participants made use of the slide. Again CC were less than Unassertive. At approximately 17 seconds into the trial the door partially closes, which temporarily impeded participants. Participants behaviour in this trial appeared to be more motivated than in Trial 1.1, but this was despite rather than because of CC activity. CC appeared to tap participants on the shoulder, telling them when to go.

Table 11: Raw exit delay times (s) extracted from trial 2.3

1.04	2.32+	1.08	2.56	2.6	3+	1.8
1.84	1.4+	1.96	1.92	1.72	2.52	2.8
0.8	2.48	1.92	2.44	3.16+	1.36	2.48+
0.64	2.52	2.2	0.8	2.44+	3.4+	2.16
2.44	2.64	2.36	2.4	2.4	3.8+	2.4
1.92	1.16	1.72	1.68	2	1.84	1.8
3.44	1.8	3.2	2.08	1.2+	3.36+	2.68+
2.52+	2.72	1.28	1.96	2.16	3.28	2.92

+denotes sitter

3.3.7 Trial 2.3

Not applicable. No evacuation slide used

3.3.8 Trial 2.4

In this trial 36 participants made use of the slide. Similar to the other trials the CC were classified as being less than Unassertive during this trial. Participants in this trial appeared to display the highest levels of motivation, but again this was despite rather than because of CC activity. The reason for this participant motivation is not

clear from the video evidence but it did not appear to be a reflection of CC instructions or assertiveness.

Table 12: Raw exit delay times (s) extracted from trial 2.4

3.36+	1.28	1.36	2.12	1.6
3	2.76	1.72	1.48	2.44
1.24	1.72	1.4	2.12	1.4
1.72	1.12	1.44+	1.08	1.08+
1.2	2.36+	1.96	1.56	
1.76	0.8	1.36+	2	
1.64	2+	2.2	1.6	
1.72	2.28	1.68+	0.76	

+denotes sitter

3.4 Converting the data to exit delay distributions

As all four sets of data refer to unassertive cabin crew, the intention was to combine these curves to produce a single smoothed probability distribution representing the distribution of expected passenger exit hesitation times.

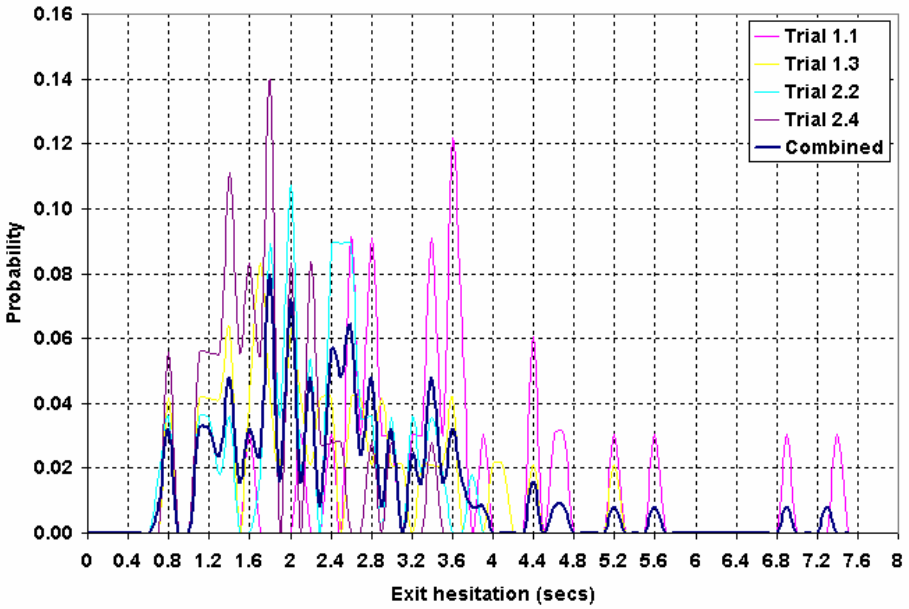
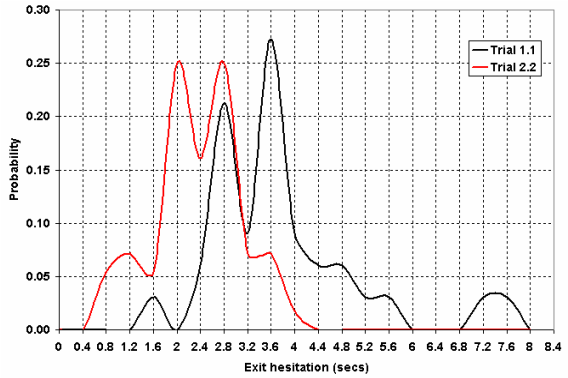
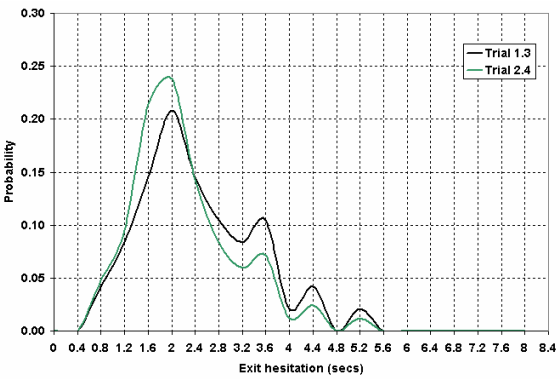


Figure 19: Uniform probability curves using a bin size of 0.1s

The data was smoothed (using a bin size of 0.4 seconds) and the resulting curves indicated significant differences between the first evacuations undertaken on each day (see Figure 20(a)) and the second evacuations undertaken on each day (see Figure 20(b)). The first and second trials on each day were then combined (see Figure 21).

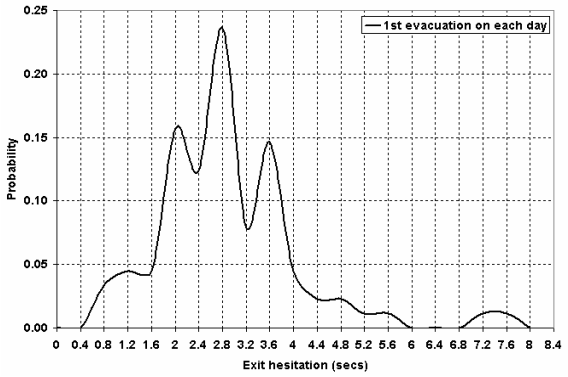


(a)

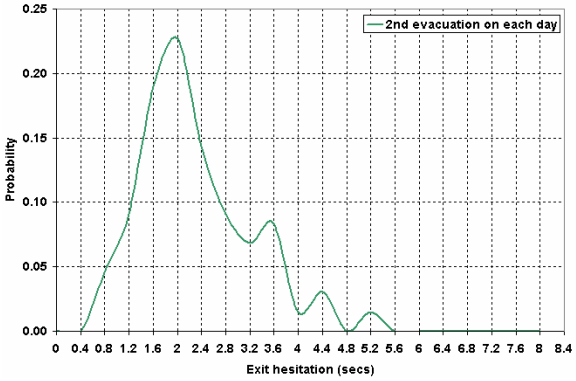


(b)

Figure 20: Exit Hesitation Probabilities from (a) the first trials on days 1 and 2, and (b) the second trials on both days 1 and 2



(a)



(b)

Figure 21: Combined Exit Hesitation Probabilities from (a) the first trials on days 1 and 2, and (b) the second trials on both days 1 and 2

Overlaying the curves for the first and second trials on each day (see Figure 22) indicates that the second trials on each day are offset to the left, i.e. generated faster evacuation times. This finding is substantiated by examination of the means that were generated (see Table 13).

Table 13: Summary of raw Passenger Exit Hesitation Times (secs)

	Hesitation (secs)					
	Trial 1.1	Trial 1.3	Trial 2.2	Trial 2.4	Trials 1.1 and 2.2 combined	Trials 1.3 and 2.4 combined
Min	1.6	0.7	0.6	0.8	1.6	0.7
Mean	3.6	2.2	2.0	1.7	3.6	2.2
Max	7.4	5.2	3.4	3.4	7.4	5.2
Standard deviation	1.25	1.05	0.69	0.58	1.25	1.05

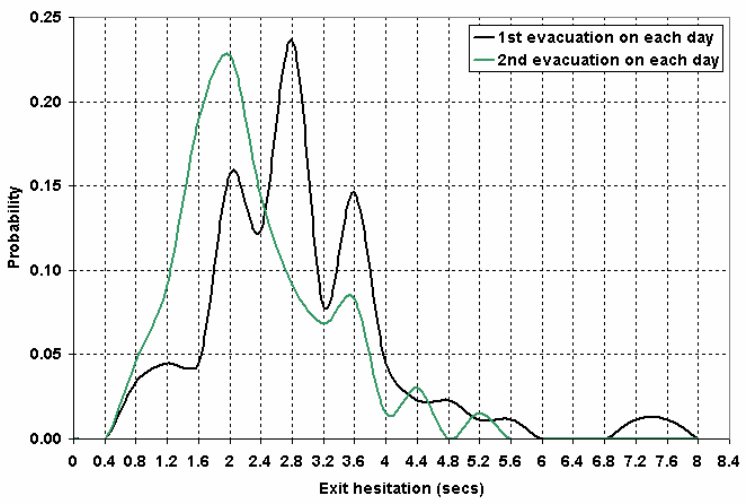


Figure 22: Combined Exit Hesitation Probabilities from the first trials on days 1 and 2 and the second trials on both days 1 and 2

Based on this analysis the following conclusions are made,

1. The first trial undertaken was particularly slow. This could be due to the extreme caution with which the CC approached the first trial. Indeed the first trial generated both the longest minimum times and the longest maximum times. This suggests that both the jumpers and the sitters were quite slow on this day.

2. The first trials undertaken on each day generated longer hesitation times than those generated by the second trials on each day. These differences are thought to originate from,
    a) the safety concerns of the CC leading to extremely unassertive behaviour, especially in the first trials that were undertaken on each day, and
    b) relative increases to both passenger and crew confidence in the second trials of each day.

These results can be compared with the data generated by FSEG from the analysis of passenger exit hesitation time behaviour at main deck Type-A exits with assertive cabin crew.

FSEG have analysed the exit hesitation time distribution produced from a large number of Certification Trial evacuations for a range of exit types. In particular, FSEG have analysed data from 11 previous certification tests involving Type-A exits with assertive cabin crew. The aircraft from which these exits were drawn included Boeing, Airbus and Douglas. It is also worth noting that three of the aircraft failed to meet the FAR part 25.803 certification requirements. In total, passenger exit delay time data from 20 exits representing some 2078 passengers was used to determine the passenger exit distribution. For each exit meeting the selection criteria (i.e. Type-A, main deck, assertive crew) a frequency distribution curve of passenger exit delay time can be generated. The shape of these distributions are remarkably similar, resembling an exponential/poisson distribution that peaks at the low end of the delay time

distribution and tails off towards the higher end of the distribution. This suggests that the majority of the passengers display a short delay time (associated with a rapid jump onto the slide) while a sizeable number of passengers have a relatively long delay time (associated with sitters). On the whole, the slowest passengers exit delay times are associated with personal attributes of being elderly and being female. From this data we note that the minimum delay time is approximately 0.2 seconds and the maximum delay time is 4.7 seconds. The typical distribution of delay times for main deck Type-A exits with assertive crew is depicted in Figure 23. The shape of the curve for unassertive crew is similar to that shown in Figure 23 with the fastest times being unaffected but with more passengers displaying the slower times.

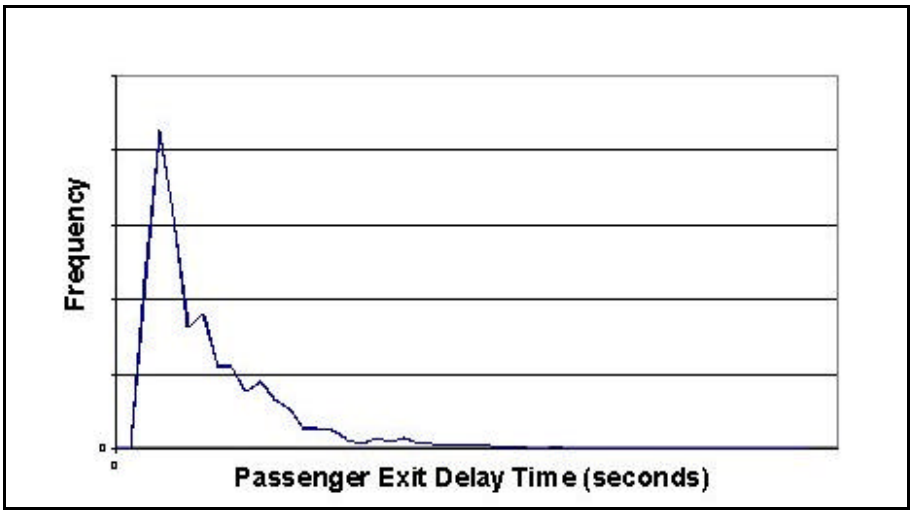


Figure 23: Passenger Exit Delay Time distribution for main deck Type-A exits with assertive crew.

The shape of the passenger exit hesitation time distribution generated from the second trials conducted on days 1 and 2 resemble Figure 23. However, the mean exit hesitation times generated by the first trials on each day are approximately 6 times longer than those typically found for Type-A exits with assertive cabin crew. The mean of the second trials on each day are approximately 4 times longer than those found for Type-A with assertive cabin crew.

3.5 Participant Average Exit Flow Rates

Participant average exit flow rates were measured by dividing flow time into the number of participants per trial. This is then multiplied by 60 to give participant per minute rate. 'Flow time' commenced when the first participant to exit stepped up to the exit door sill and commenced his/her exit hesitation. It finished when the last participant broke final foot contact with the exit system or thick edge of top of slide, as appropriate. These flow rates include any periods of dry-up in exit flow.

Results in Table 14 confirm the point made in Section 3.3 and the means presented in Table 13. Participant exit delay time diminishes progressively through the trials. It should be re-iterated that the reason for this is not clear, but it was not through any assertive intervention by CC. whilst the AFR in Trial 2.4 is double that in Trial 1.1 the figure presented is considerably slower than would occur in a 90 second certification trials using assertive CC, which average 120 passengers/minute.

Table 14: Participant average exit flow rates

Trial	Participants	Average flow rate (passengers/minute)
1.1	33	31.13
1.3	48	43.70
2.2	56	44.97
2.4	36	63.34

4 Conclusions

While the trials did not proceed in the controlled manner that was originally planned, much has been learned from theses trials.

It is clear from these trials that crew can exert an influence on the performance of passenger stair usage. Passenger behaviour in utilising the staircase is both rich and complex and warrants further investigation. These trials support the view that for crew to consistently make appropriate or optimal redirection command decisions that include the possibility of using the stairs as part of the evacuation route, they must have sufficient situational awareness. Equally, passengers can only make appropriate or optimal redirection decisions if they too have sufficient situational awareness. This situational awareness may need to extend between decks.

Passengers were also noted to make heavy use of the central handrail while both descending and ascending the stairs. The presence of the central HR effectively created two staircases. By effectively separating the crowding on the stairs, reducing passenger-passenger conflicts and providing an additional means of passenger stability, it is postulated that the stair flow rates may be positively influence through the presence of the central HR. Flow rates in the UPWARDS direction were found to be greater than flow rates in the DOWNWARDS direction. This was thought to be due to the packing densities on the stairs which is a function of the motivation of the passengers, the travel speeds of the passengers and the feed and discharge characteristics of the staircase and surrounding geometry. It was also noted that the average unit flow rate in the DOWNWARDS direction was equivalent to that specified in the UK Building Regulations. Clearly, most of the parameters can be influenced by both crew procedures and cabin layout.

Concerning the passenger exit hesitation times for the higher sill height, the trials produced inconclusive results. While the measured exit flow rates are lower and the passenger exit delay times are longer than would be expected for a normal Type-A exit, it is clear that the extreme unassertiveness of the cabin crew positioned at the exits and the lack of motivation of the passengers exerted a strong influence on the data produced. The reaction of the passengers in these trials was to be expected as the trials were not performed under competitive conditions and the reaction of the cabin crew could also be understood as safety concerns were paramount given that these were the first trials of their type to be conducted at Cranfield.

Finally, due to the small number of data points provided by these trials, there is insufficient data upon which to claim statistical significance for any of the observations.

Clearly, much more work is required in order to generate essential data to improve our understanding of passenger performance, passenger-crew interaction and passenger-structure interaction within VLTA configurations.

5 References

1. Pauls, J. Chapter in The SFPE handbook of fire Protection Engineering, published by the Nation Fire Protection Association, 2nd Edition , 1995, ISBN 0-87765-354-2

2 HMSO, The building Regulations 1991, Approved Document B, Section B1, HMSO Publications, London.

6 Appendix A – Qualitative notes

6.1 Trial 1.1

This was a Free Choice trial. Cameras 2, 4 and 12 were used for data collection. No Camera 13 `bird's eye' view of the stairs was available Upper deck participants either used the Upper deck exit or descended the stairs. A total of 52 participants used both lanes. There was a delay of 22 seconds before participants began to make use of the stairs. Four participants voluntarily descend stairs before CC arrived. They went straight to the stairs from their seats. It is however unclear how many other participants would have freely elected to use the stairs as the CC intervened and directed participants down the stairs. It is clear from this trial that at least some passengers will elect to use the staircase if given the option. Most participants who subsequently descend stairs were re-directed to them by CC from much further back in the cabin. CC follows the line of redirected participants to the stairs. Flow down the stairs was not urgent with no dual usage, dual flow or over-taking (concepts defined in Section 2.1). The Upper landing immediately in front of the stairs was the location of many participant stair access conflicts. Participants occupying this space can choose either lane and clash with others already entering the stairs. Delay in commencing stair use and punctuated, slow flow was the result of participants initially opting for upstairs exits, only switching to the stair descent under CC instruction.

Left Lane

View from camera at base of stairs: The first participant does not appear until 34 seconds into the evacuation. He (vest 1) vaults the last five treads, launching himself from both HRs. Then he does not know which way to go and crosses-over to the right exit. A dry up of the main flow down the stairs occurs until the main flow restarts at approximately 40 seconds. Initially, ALL the main flow participants cross-over to the right exit. They only start using their nearest exit when the CC comes across and redirects them. CC only repositions to be any value to participants descending stairs after 43 seconds. Thereafter only one participant crosses over Left lane to Right exit. After CC begins to provide direction, participants start to use side HR at bottom of stairs to `swing' around to left exit. Flow was unhurried with no crowding, no over-taking, no dual flowing or close staggering. No participants grabbed the side HR with both hands to accelerate the `swing' around to left exit at the base of the stairs.

View from camera at top of stairs: Vest 1 also vaults down the stairs from the top. Participants 31 and 49 and 4 and 64 vie for stair access on the top landing. Dry ups and punctuated flow occur. Flow was unhurried with no crowding, over-taking, dual flowing or close staggering. All flow was single file.

Right Lane

View from camera at base of stairs: Only one participant used only the centre HR. He crossed over Right lane to Left exit. The first participant does not appear until 25 seconds into the evacuation. The main flow down stairs only starts at 30 seconds in and has two periods in which the flow dries-up for approximately 5 seconds. The Lower deck Right exit CC leaves AS at 29 seconds but does not position herself to be visible/audible to the participants descending the stairs until 59 seconds, when only two participants are left. Only two participants cross over from the right lane to left

exit. Every participant made use of the side HR at bottom of stairs to `swing' around to right exit once main flow started after 36 seconds. Flow was unhurried with no crowding, over-taking or dual flowing or close staggering. No participants grabbed the side HR with both hands to accelerate the `swing' around to right exit at the base of the stairs. At one point many participants crossed over from the left lane to exit via the right exit. Apparently this did not impede egress from the right lane.

View from camera at top of stairs: Participant 57 catches his vest on centre HR causing him and participant 82 to dual use the stairs momentarily. Otherwise all flow down the stairs was single file and punctuated by dry-ups.

6.2 Trial 1.2

This was a Down stairs trial. Cameras 2, 4 and 12 were used for data collection. No Camera 13 `bird's eye' view of the stairs was available A total of 85 participants used both lanes. Approx 20 participants voluntarily descend the stairs before the majority of participants realised only the stairs were available, and turn away from the Upper exit queue to descend stairs, or were redirected by CC. Most participants who then descend stairs were re-directed to them by CC. It is likely that many more participants would NOT have used the stairs but for it being the only route and the exhortations of CC. Lower deck CC were absent opposite stairs (as they were at their AS) then present from 49 s. Upper deck CC verbally re-directed participants downstairs from Forward Upper cabin until only stragglers were left the stairs. After some initial congestion preventing free flow off the stairs, flow was single file with no crowding, over-taking, dual flowing or close staggering apparent.

Left lane
View from camera at base of stairs: Participants queued on stairs from 9-17 seconds due to LL2 exit congestion by lower deck participants. Nobody participant swapped the left lane for the right exit at this stage. One participant did so at 25 seconds after flow commenced. Another did soon after. At 32 s participants 116 and 141 were a close staggered pairing, as were 152 and 153 soon afterwards. Other than these 2 instances flow was single file, non-urgent, no crowding, over-taking, dual flowing or close staggering. Once main flow started after 20 seconds every participant used the side HR to swing around to the exit. While the CC was still at the AS participant 143 crosses to the right exit. A string of participants follow this until CC arrives to the point opposite the stairs, and directs participants to their nearest exit. CC exhorts participants to hasten but not did not assertively push. Participants involved in this appeared faster than when CC was at the AS but not as fast as the right lane after the other CC started shoving participants towards the exit.

View from camera at top of stairs: Indecision by Participant 129 impedes 179 from getting onto the first tread. This in turn delays participants behind him. Between 16 and 30 seconds into the trial flow is very slow. Participants step down one step at a time. Participants push up on each other but density was still one participant per tread. This is probably a knock on effect from the Base shot queue 9-17 seconds into the trial. When free flow commences it is single file, non-urgent, no crowding, over-taking, dual flowing or close staggering. Participant 101 takes a big leap round about the middle of the stairs.

Right lane

View from camera at base of stairs: The first participants cross over from the right lane to the left exit. Others follow. At 11 seconds participants 130 stops on stairs and slows up flow behind even though there was room ahead of him to keep going. This causes others behind him to stop altogether. It may have looked congested ahead of him but there was no reason to stop moving. He caused others to wait on the stairs behind him. At 22 seconds participants 110 and 159 are nearly a dual usage. Other than these 2 participants, flow was single file, non-urgent, with no crowding, over-taking, dual flowing or close staggering. CC relocates from the LLR exit AS at 39 seconds but is not visible to all participants descending stairs. She starts assertively pushing participants from base of stairs. Flow appeared to be fastest when she initially moved from the AS so that participants could hear her then again when she relocated to opposite the stairs and could be seen and heard by those on the last few steps. Their acceleration prompted those behind to copy. They also sped up when she started to manhandle participants on the lower landing. Once the initial half a dozen participants who switched to the Left exit had evacuated, the main flow started and was characterised by side hand rail use to swing around to the right exit.

View from camera at top of stairs: Participants 129 spends several seconds on the Upper landing indecisive about whether to go exit or stairs, then which lane to use. The halt in flow at the base of the stairs causes the same at the top from about 11-16 seconds in. Flow was single file, non-urgent, no crowding, over-taking, dual flowing or close staggering. Flow appeared to speed up when the main flow started. This correlated with lower deck CC facing the stairs shouting orders and pushing participants, and lower deck CC arriving at the stairs to expedite the last few participants down the stairs.

6.3 Trial 1.3

This was an Up stairs trial. Cameras 2, 4 and 12 were used for data collection. No Camera 13 `bird's eye' view of the stairs was available A total of 114 participants used both lanes. The trial was characterised by participant procedural confusion. It should be remembered that neither crew nor participants knew which exits were available during the trials. The trial commenced with severe crowd congestion on the Lower deck landing which impinged onto the stairs, as Lower deck participants who could not find a Lower deck exit clashed with Upper deck participants flowing downstairs. Participants initially descend the stairs causing chaos at base of stairs. Correct upstairs movement was only established following the intervention of Lower deck CC. 32 participants descended or were beginning to descend the stairs before the error was corrected at 16 s and the Upper deck CC started to encourage participants upstairs. Initially he directed Upper deck participants downstairs instead of forward to Upper exit. He only realised the error when participants started to ascend stairs. After 16 s correct upstairs flow commenced and was congested throughout, mostly close staggered but with some dual flow as well. This trial achieved a high flow rate due to packed stairs at the moment participants turned to ascend and a constant supply of participants to the stairs. Without the intervention of Lower deck CC it is likely that all Upper deck participants would have descended the stairs and no Lower deck participants would have ascended the stairs.

Left lane

View from camera at base of stairs: Disorganisation until 15-16 seconds into the trial. Participants descend stairs and wait/queue on the stairs, then turn around and head back up stairs. Down stairs participants were sent upstairs. The stairs were congested throughout excluding the last 3 stragglers. At 21 s the crowd sways on the lower deck landing and first treads. There was no CC involvement at the base of the stairs. When UP stairs flow commenced it was slow and congested with many instances of close staggering and some dual usage.

View from camera at top of stairs: As per base shot. Participants 13 climbed 2 treads at a time as he is last participants with room to.

Right lane
View from camera at base of stairs: Disorganisation until 14 seconds into the trial. Participants come downstairs and wait/queue on the stairs, then turn around and head back up stairs. Down stairs participants were sent upstairs. CC arrived at base of stairs after 58 seconds. Flow was congested throughout with many instances of close staggering and some dual usage.

View from camera at top of stairs: As per base shot.

6.4 Trial 1.4

This was a Down stairs trial. Cameras 2, 4 and 12 were used for data collection. No Camera 13 `bird's eye' view of the stairs was available A total of 84 participants used both lanes. CC on the Upper deck blocks participants from descending stairs and attempted to send participants to the Upper exit. Seven participants ignore CC and descend stairs before CC allows stair descent by all remaining participants.

Left lane
View from camera at base of stairs: Up to 30 seconds into the trial 3 participants have crossed to the Right exit. At 32 seconds participants 24 and 73 dual use the last few steps. Throughout flow is unhurried and single file with only 2 or 3 incidences of close staggering. There was only one Lower deck CC who remained at AS throughout. Every participant used the side HR to swing around to the Left exit excluding the participants who crossed over and close stagger participants in the outside lane (they use centre HR).

View from camera at top of stairs: Participants 2 and 9 are the first to the stairs. Participant 2 overtakes on the inside lane causing participant 9 to wait on the first 2 treads including the landing. Then a dry up occurred, caused by Upper deck CC guarding the stairs to stop participants using them. CC then lets participants use the left lane. At 20 seconds participant 61 `freezes' on the top landing outside lane while 82 passes her. Participant 57 momentarily blocks 56 from using the top of the stairs as he ponders which lane to use. At 30 seconds participant 68 unsuccessfully attempts to overtake down the outside lane. Between 40-46 seconds there was a flow of close staggered participants. Prior to these, flow throughout was unhurried and single file.

Right lane
View from camera at base of stairs: Participants have to wait momentarily at 12 seconds due to Lower deck participants ahead of them at exit LR2. Movement is

initially slow then at 18 seconds participant 52 descends stairs at crawl speed. He may have been injured or disabled. He used both handrail as a prosthetic and held other participants up behind him. By the time flow gathers momentum down the stairs there are CC either side of the right exit. At 23 seconds all Lower deck participants have evacuated. CC at the AS beckoned participants off the stairs, but they could not have seen him until they were off the stairs. But his exhortations did expedite flow. At 43 seconds participant 48 overtakes participant 47. Flow is otherwise unhurried and mostly single file, but some incidences of close staggering. Tall participants appear to have to bend forward as they reach the base of the stairs. Once flow gathers momentum every participant uses the side HR to swing around to the Right exit, including one participant using the 2 handed grip.

View from camera at top of stairs: At the commencement of the trial CC try to block the stairs. One participant disregards CC and descends the stairs. Then a dry up in flow occurs until 3 participants another 3 participants disobey CC and use the stairs. At 11 seconds CC allows stair use proper. Participant 52 is slow getting onto the stairs and participant 40 overtakes him on the outside lane. Once participant 52 gets onto the stairs he looks very slow and hesitant. Flow throughout was unhurried and single file until 25 seconds. Then a spate of incidences of close staggering occur until 29 seconds. Participants 1 (tall male) appears to vault 2 or 3 treads when flow frees up. At 35 seconds a dual flow starts until 39 seconds.

6.5 Trial 2.1

This was a Down stairs trial. Camera 13 `bird's eye' view of the stairs was used. A total of 85 participants used both lanes. A third lane is apparent in the CC space on the Upper landing and was used by over-takers. Upper deck CC blocks participants from descending the stairs. He attempts to send participants to the Upper exit. Then he changes to encouraging stair descent after a 13 s dry-up on the stairs. Eight participants ignore CC and descend stairs before CC allows stair descent by all remaining participants

Left lane
View from camera above stairs: Participants queued on stairs initially. Participants 79 overtakes at 35 s. A dual usage occurs on the stairs at 45 seconds. Half a dozen participants over-take at the top of the stairs. Considerable bunching and incidences of close staggering occur in mid stairs

Right lane
View from camera above stairs: Participants 85, 5 and 49 over-took at other participants at the top of the stairs. Some bunching and incidences of close staggering occur in mid stairs. A dual usage at occurs 45 seconds.

6.6 Trial 2.2

This was an Up stairs trial. Camera 13 `bird's eye' view of the stairs was used. Lower deck cameras 2 and 4 were also used. A total of 113 participants used both lanes. The trial was characterised by participant procedural confusion. The trial commenced with severe crowd congestion on the Lower deck landing which impinged onto the stairs, as Lower deck participants who could not find a Lower deck exit clashed with Upper deck participants flowing downstairs. Participants initially descend the stairs causing chaos at base of stairs. Upstairs movement was only established following the

intervention of Lower deck CC. 30 participants descended stairs before the error was corrected at 17 s. CC arrived at the UP stairs position after 37 s when all Upper Deck participants had evacuated and correct flow from downstairs is occurring i.e. CC actions did not impact on crowd control and it was not intended that they manage the stairs anyway. Only Upstairs flow and behaviour was recorded, from point at which correct participant movement occurred i.e. largely discounting Upper deck participants who initially descended the stairs and only measuring Lower deck participants who ascended the stairs. Without the intervention of Lower deck CC it is likely that all Upper deck participants would have descended the stairs and no Lower deck participants would have ascended the stairs.

Left lane
View from camera at base of stairs: The beginning of the trial was chaotic with participants crossing each other on stairs and descending then back tracking up the stairs. Lower deck CC ordered redirection UP at 14.2 seconds. There were 3 flows into left lane (forward cabin, mid cabin and across central seats) once `correct' upstairs movement commenced, with participants overlooking the right lane. Participants barge each other on the Lower landing.

View from camera above stairs: Very bunched, staggered flow occurred including some overtaking 38-72 seconds in. Participant 136 reaches up to use the balustrade as a handrail. Dual usage at occurred at 46.3 and 56.0 seconds into the trial. Use of BOTH handrails coincided with less congestion during the main flow phase (38-72 seconds into the trial). Use of Centre or Side HR only coincided with peak congestion where flow consisted of incidences of close staggered and dual flow.

Right lane
View from camera at base of stairs: Two participants pass each other on stairs at 23 seconds, indicative of the confusions occurring. Stair access jostling also occurred.

View from camera above stairs: Bunched, closely staggered behaviour was the norm (but not as congested as the left lane) including some overtaking 42-72 seconds into the trial. Participants 162 pushes the back of participant 137 for reasons unknown. Dual flow at 43.2 to 46.0 seconds into the trial and dual usage occurred at 54.3 and 58.0 seconds into the trail. One participant cuts across another, swapping `lanes' within this right lane.

6.7 Trial 2.3

This was a Down stairs trial. Camera 13 `bird's eye' view of the stairs was used. Lower deck cameras 2 and 4 and Upper deck camera 12 were also used. A total of 85 participants used both lanes. Eleven participants voluntarily descend stairs before the majority realise only the stairs were available, or were redirected by CC, and turn away from the Upper exit queue to descend the stairs. No CC were at the top of the stairs until the last 8 participants. During the trial CC verbally re-direct participants from Forward Upper cabin to descend stairs. Without CC redirection from deep into the Upper deck stair descent would either have not occurred in the majority of instances or would have been delayed. Flow was unhurried, free flowing and single file throughout. There was no over-taking, incidences of close staggering or dual flowing. The paradoxically high flow rate achieved in Table 6 reflects a near optimal combination of free flow and little dry up in flow compared to other trials. The Upper

landing again appeared important in terms of participants vying for access to the stairs.

Left lane
View from camera at base of stairs: Flow was unhurried, no crowding, over-taking or dual flowing. Most participants used side hand rail to swing around to the exit, including some participants using 2 handed holds. Half way through the trial CC moves from the AS in order to be audible/visible to participants descending the stairs. This cajoled participants into using the nearest exit off the stairs instead of the opposite further exit. SEVERAL participants crossed over from the Left Lane to the Right exit prior to this CC relocation.

View from camera at top of stairs: Flow as per base shot. Participant 121 hurdles seats in order to access the stairs, forcing another participant to give way. Dual usage occurs between participants 102 and 152 at 39 seconds into the trial.

View from camera above stairs: Dual usage between 2 participants 36 seconds into the trial. Four instances of close staggered flow occurred but otherwise flow was unhurried. Interpersonal space on the stairs was maintained.

Right lane
View from camera at base of stairs: 10-15 seconds into the trial participants had to wait/queue on stairs Every participants bar one used side handrail at bottom of stairs to swing around to right exit. Flow was unhurried with no crowding, over-taking or dual flowing. Half way through the trial CC moves from AS across to the stairs and is audible/visible to participants descending the stairs. ZERO participants crossed over from the Right Lane to the Left exit

View from camera at top of stairs: Participant 164 overtakes 108 at top of stairs as does 144 over 154 and 126 over 168. Flow as per base shot, unhurried and fairly spacious.

View from camera above stairs: Flow was all single file with no incidences of close staggering or dual flow.

6.8 Trial 2.4

This was a Free Choice trial. Camera 13 `bird's eye' view of the stairs was used. Lower deck cameras 2 and 4 and Upper deck camera 12 were also used. Upper deck participants either used the Upper deck exit or descended the stairs. A total of 49 participants used both lanes. Thirteen participants voluntarily descend stairs before other participants start to redirect to descend stairs from Upper exit queue. These participants went straight to the stairs from their seats. Upper deck CC directed participants to descend stairs from further back. CC arrived at the stairs at 23 s and directed participants downstairs, then departed to re-direct participants downstairs from Forward Upper exit. It is unclear how many participants would have freely elected to use the stairs as the CC intervened and directed participants down the stairs. Without CC intervention many participants in all likelihood would have continued to queue for the Upper exit. It is clear from this trial that at least some passengers will elect to use the staircase if given the option. Most participants who subsequently descend stairs were re-directed to them by CC from much further back in the cabin.

CC follows the line of redirected participants to the stairs. The Left lane exhausted 9 seconds before right. This was due to CC redirecting participants from the Upper Right exit queue to the stairs. Participants simply used the nearest stair lane. Dry ups occurred on both lanes due to Upper deck participants exit choice indecision. Some participants waited, pondering which route to go and others first opted for Upper Right slide then changed to stairs. This punctuated stair use. Flow was unhurried with no crowding, over-taking, dual flowing or close staggering.

Left lane
View from camera at base of stairs: Participants waited/queued at on last few steps 6-17 seconds into the trial. Every participant used the side handrail at the bottom of the stairs to swing around to the Left exit once the main flow started after 22 seconds. Dry ups occurred and flow was unhurried with no crowding, over-taking or dual flowing or incidences of close staggering. Half way through CC moved from AS across to the stairs and was audible/visible to participants descending the stairs. This did NOT expedite flow as by this point flow into Upper left lane was drying up. CC continued to encourage participants down the stairs but soon only the right lane was in use. Only 1 participant crossed over from the Left Lane to the Right exit.

View from camera at top of stairs: 2 seconds into the trial participant 160 walks straight into the centre HR causing 125 to stop momentarily. Flow was unhurried with no crowding, over-taking, dual flowing or close staggering. At 24.8 seconds into the trial Upper deck CC relocated to the other side of the Upper landing. This inhibited participant 116 from stair access for a second.

View from camera above stairs: 10 seconds into the trial a female participant stands on the stairs, due to the wait by predecessors. Flow was slow and spaced out almost throughout the trial, as reflected in Table 6. Treads between participants were visible almost throughout. Participant 148 vaulted 2 treads at a time all the way down the stairs.

Right lane
View from camera at base of stairs: Participants queued on last few treads 11-17 seconds into the trial. Every participant used the side handrail at the bottom of the stairs to swing around to the Right exit once the main flow started after 17 seconds. At least one participant used a 2 handed grip on the side rail. Dry ups occurred and flow was unhurried with no crowding, over-taking or dual flowing or incidences of close staggering. Half way through CC moved from AS across to the stairs and was audible/visible to participants descending the stairs. This appeared to expedite flow. Many participants leapt the last few steps. NO participants crossed over from the Right Lane to the Left exit.

View from camera at top of stairs: Dry ups occurred and flow was unhurried with no crowding, over-taking, dual flowing or incidences of close staggering. Most participants were redirected from Upper exit. Participants 170 and 105 vie for access on the Upper landing at 22 seconds into the trial.

View from camera above stairs: Participants 154 and 112 vaulted 2 treads at a time all the way down the stairs.

7 Appendix B – Cabin Crew action in relation to the stairs during the trial

Table 15: Cabin Crew action in relation to stairs from video evidence

		LEFT LANE		RIGHT LANE	
		CABIN CREW BEHAVIOUR		CABIN CREW BEHAVIOUR	
TRIAL	**PARTICIPANT MOVEMENT**	**UPPER DECK**	**LOWER DECK**	**UPPER DECK**	**LOWER DECK**
Day 1 Trial 1	Free Choice (DOWN)	CC arrives at 36 s and directs participants downstairs 36 to 46 s. Leaves for forward Upper cabin at 46 s to redirect participants from Forward Upper exit. Follows re-directed participants downstairs.	Directs participants off stairs after approx 44s	No involvement	Directs participants off stairs from opposite the exit after approx 39s
Day 1 Trial 2	DOWN	No CC at stairs until last 7 participants. During evacuation CC verbally re-direct participants from Forward Upper cabin.	Directs participants off stairs after approx 44s	See `left lane'	Directs participants off stairs from opposite stairs after approx 39s
Day 1 Trial 3	UP	CC arrives at Centre HRs at 4 s. Directs participants downstairs. Realises need to change direction when participants start coming back up due to lower deck CC redirection. Then he directs participants upstairs.	CC positioned at AS directs participants upstairs throughout	See `left lane'	CC positioned adjacent to stairs directs participants upstairs after approx 58s
Day 1 Trial 4	DOWN	CC arrives at Centre HRs at 3 s. Blocks stair descent from 3 to 12 s, coaxing participants to the Upper Forward exit. From 12 s to the end he unassertively guides participants onto the stairs.	No involvement. Remains at AS throughout	2 CC follow participants from Forward Upper cabin through the aisle to the stairs	2 CC located in AS direct participants off stairs after approx 23s. CC did NOT re-locate to opposite stairs
Day 2 Trial 1	Free Choice (DOWN)	CC arrives at Centre HRs at 3 s. Blocks stair descent from 3 to 21 s, coaxing participants to the Upper Forward exit. From 21 s to the end he `in-between assertion' guided participants onto the stairs.	CC calls participants from AS ONLY. He had minimal impact	2 CC follow participants from Forward Upper cabin through the aisle to the stairs	2 CC located in AS direct participants off stairs 28-33s. From approx 33s to end, one CC directs participants from location opposite stairs
Day 2 Trial 2	UP	CC arrives at left balustrade at 37 s when all Upper deck participants have departed. Verbally directs lower deck participants upstairs until end	CC directs participants upstairs from AS. After approx 52s moves to base of stairs and unassertively guides participants to stairs	No CC	CC directs upstairs from AS after approx 28 s. Moves adjacent to stairs at 49s and assertively urges participants onto stairs.
Day 2 Trial 3	DOWN	One CC arrives at left balustrade at 42 s after verbally redirecting participants to stairs from much further back. Only 8 participants	Coaxes participants from the forward then	1 CC followed participants along the aisle and down the	CC directs participants off stairs from opposite stairs after approx 31s

		were yet to use the stairs when he arrived.	aft AS until 41 s. Then unassertively directs participants off stairs from opposite stairs	stairs from the Upper forward exit	
Day 2 Trial 4	DOWN (FC)	CC arrives at left balustrade at 23 s after verbally redirecting participants to stairs from much further back. Verbally cajoles participants onto the stairs 23-29 s then moves forward to follow the line of participants down the stairs.	Coaxes participants from the forward then aft AS until 37 s. Then unassertively directs participants off stairs from opposite stairs	No CC	CC unassertively directs participants off stairs from opposite stairs after approx 31s