THE AASK DATABASE V4.0: AIRCRAFT ACCIDENT STATISTICS AND KNOWLEDGE

A Database to Record Human Experience of Evacuation in Aviation Accidents

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ABSTRACT

This paper describes the AASK database. The AASK database is unique as it is a record of human behaviour during survivable aviation accidents. The AASK database is compiled from interview data compiled by agencies such as the NTSB and the AAIB. The database can be found on the website http://fseg.gre.ac.uk

1 INTRODUCTION

The Aircraft Accident Statistics and Knowledge (AASK) database is a repository of survivor accounts from aviation accidents [1-3]. Its main purpose is to store observational and anecdotal data from the actual interviews of the occupants involved in aircraft accidents. The database has wide application to aviation safety analysis, being a source of factual data regarding the evacuation process. In their recent report to the Committee of Transportation and Infrastructure, US House of Representatives [4], the US Government Audit Office (GAO) recommended that the FAA,

"….develop a complete autopsy database that would allow them [FAA researchers] to look for common trends in accidents, among other things. In addition, the researchers would like to know where survivors sat on the airplane, what routes they took to exit, what problems they encountered, and what injuries they sustained. This information would help the researchers analyse factors that might have an impact on survival."

This is precisely what the AASK database is intended to do. It is also key to the development of aircraft evacuation models such as airEXODUS [5-8], where insight into how people actually behave during evacuation from survivable aircraft crashes is required. With support from the UK CAA (project 277/SRG/R&AD), AASK V3.0 was developed [3]. This was an on-line prototype system available over the internet to selected users and included a significantly increased number of passenger accounts, the introduction of cabin crew accounts, the introduction of fatality information and improved functionality through the seat plan viewer utility.

The most recently completed AASK project (project 560/SRG/R+AD) involved four main components:

(i) analysis of the data collected in V3.0,
(ii) continued collection and entry of data into AASK,
(iii) maintenance and functional development of the AASK database, and
(iv) user feedback survey.

All four components have been pursued and completed in this two-year project. The current version developed in the last year of the project is referred to as AASK V4.0.

This paper summarises this work, interested readers will find a fuller account of AASK V4.0 and the analyses undertaken using the data base in the UK CAA report [24].

2 DATA COLLECTION AND ENTRY INTO AASK

During this project a total of 50 accidents, accounts from 622 passengers and 45 crew and data relating to 11 fatalities were added to the database. A complete listing of accidents in AASK V4.0 can be found in Appendix B. The primary source of additional data entered into AASK was provided by the US NTSB. The accidents included in AASK V4.0 cover the period 04/04/77 – 23/09/99 and consists of:

- 105 accidents,
- 1917 individual passenger records from survivors,
- 155 records referring to cabin crew interview transcripts, and
- 338 records of fatalities (passenger and crew).

The majority of the additional data was derived from the NTSB study covering the period September 1997 to June 1999 [10]. This involved 46 evacuations, 2,651 passengers and 18 different types of aircraft. Of the 46 evacuations, one was considered an emergency evacuation while 45 were considered to be precautionary evacuations. Due to the nature of this data it was considered necessary to modify the data categorisation within AASK. These modifications resulted in the creation of new categories to represent the type of evacuation. Some 28 of the 46 new NTSB accidents were found to have no passenger or cabin crew information. This was primarily due to the NTSB not attempting to collect passenger data from accidents involving non-American-registered airlines. In addition, some airlines did not provide sufficient information to track passengers.

3 ANALYSIS OF DATA IN AASK V4.0

The AASK database can be used for a variety of purposes. The type of analysis performed is dependent on the nature of the questions posed to the database. Thus, the uses of AASK are far greater than those originally envisaged by its developers. In this section, several analyses performed using the AASK database will be presented. All analysis and results must be carefully considered within the context of the database. Reply rates vary considerably from accident to accident and the analysis conducted using AASK is based on passenger accounts from those passengers who "responded" to the request for information. For certain types of questions, knowledge of such statistics may be vital in order to establish whether or not the data represents a fair cross-section of all the data. For example, a proportion of the survivors who fail to return questionnaires may have exhibited behaviour that greatly influenced the outcome of the evacuation.

In earlier publications based on AASK [11, 12, 13] several key analyses were conducted. The first concerned an analysis of the data set in AASK V3.0. This study focused on, survivor and reply rate, age and gender distribution, nearest exit usage, seat belt usage and difficulty, direction and distances travelled by evacuating passengers and exit distribution and availability. This study was conducted to determine whether findings made using earlier versions of the database remain valid after the introduction of the additional data. This study reported to the CAA in September 2002 that the results were still valid [12]. This analysis was then extended to include new aspects of the AASK V3.0 data set not previously reported with a particular focus on data relating to cabin crew [11,13]. Here we will briefly describe some of the new analysis however, interested readers are referred to the UKCAA report for full details [24].

Of the 105 accidents entered into AASK V4.0, 49 have detailed passenger and crew accounts and so are suitable for analysis. This compares with 31 accidents from the previous analysis [11, 12, 13]. Note that the reply rate, for the 48 aircraft for which we also have the number on board, varies from 3% to 95%. The average reply rate for these 48 is 45%, and in 22 accidents there are replies from at least 50% of the survivors. Within AASK V4.0, data is available from 42 % of the survivors of these accidents.

3.1 Group Behaviour

An important aspect of behaviour that has been practically ignored in aviation safety research is the influence of social bonds on evacuation behaviour. The industry standard 90-second evacuation certification trial assumes that each passenger is socially unconnected to other passengers, and the majority of experimental trials that have been conducted have also been based on individuals. Passenger behaviour during evacuation may be influenced by the presence of travelling companions and the nature of the social bond that exists between travelling companions. From the 1917 passenger reports in AASK, 49.5% (947) were entered into the database as travelling with a ‘companion’. As with all data reported in AASK and other accident surveys, it should be noted that this data only corresponds to those passengers who have agreed to complete a survey. However, as this corresponds to approximately 10% of the passengers on board, it suggests that we can expect an appreciable number of socially bonded passengers on aircraft. As AASK suggests that a significant number of social groupings are likely to exist on flights, it is essential to take this into consideration when determining likely behavioural responses of passengers.

3.1.1 Type of companion

The term ‘companion’ refers to two or more passengers that are connected through virtue of being a family member, friend, work colleague or other socially connected travelling associate. Family groups were further broken down into subcategories of spouse, child, infant, parent, sibling, relation, etc.

The vast majority of the companion relationships were family related (65% or 616/947), with spouse being the most common form of companion, represented in 40% (369/947) of the companion relationships. This is consistent with the early results quoted for AASK V3.0 [11, 12, 13]. The breakdown of these companions by type is shown in Figure 1. It should be noted that these categories are not exclusive and that a passenger who was travelling with a spouse and two children will make a contribution to both of the categories (although only once for the inclusion of children). Hence 1048 companion references were made by 947 passengers. It should also be noted that the term ‘partner’ is ambiguous as there is at least one case of a pairing where the term spouse is used by one and partner by the other.

The co-worker (business associate) category has seen a major increase (650%) in AASK V4.0 when compared to AASK V3.0. The majority of co-workers included in AASK V4.0 were derived from the NTSB study (85%). This is possibly due to the type of flight considered in the NTSB study which consisted of a large number of smaller commuter flights (for example the Canadian Regional Jet). The size of the companion group also varies considerably with groups being made up of two or more travelling companions. The largest companion group recorded was a family of 11 (consisting of three generations of one family), the next largest being eight, with groups of six and five also occurring. The average size companion grouping was 2.4 with the most common group size consisting of two people. The size of the average companion grouping has decreased slightly from 2.7 in AASK V3.0.

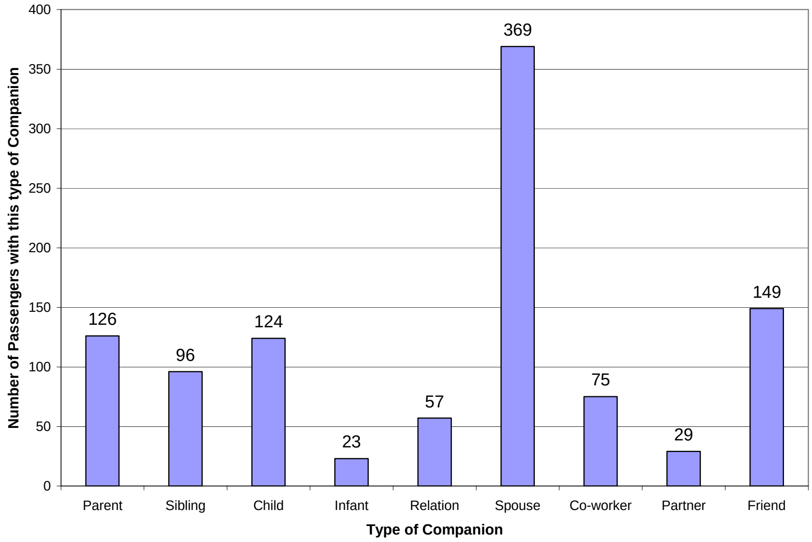

Figure 1: Types of companion relationships found amongst the 947 passengers in AASK stating that they travelled with a companion

3.1.2 Assistance to companions

Within AASK V4.0, 1490 companion relationships were cited by the 947 passengers claiming to be accompanied by at least one other passenger. The difference in numbers can be explained as follows. A passenger who cited a spouse, an infant and two children as her companions cited four relationships. Of these 1490 passengers cited as companions, there were 104 instances of rendering assistance to a travelling companion during the course of the evacuation. For example if a father helps his wife, son, other son and daughter, this is regarded as four instances of assistance being rendered by one passenger. The purpose was to measure behavioural complexity, hence instances of assistance were identified not simply the number of individuals rendering assistance. The 104 instances are produced by 87 individual passengers (of 947/1917 passengers in V4.0 travelling with a companion). All of these 87 passengers (104 instances of companion assistance) were involved in planned or unplanned emergency evacuations.

Care should be taken when interpreting this data as this does not imply that 104 passengers received assistance. The results here refer to those passengers who have stated that they rendered this service to a companion. In some situations it is possible for more than one member of a travelling group to lend assistance to a single companion, for example two parents assisting one child. Also a passenger can render assistance to more than one type of companion, such as helping both spouse and child, and can help two or more children, or friends etc.

The number of individual passengers rendering assistance as a percentage of all passengers travelling with a companion, is lower in AASK V4.0 (87/947, 9%) than the corresponding figure found in AASK V3.0 (81/621, 13%). The reason for this is a large number of the companions added to AASK V4.0 were adult business travellers on smaller aircraft, and a number of precautionary evacuations was added to V4.0. These raise the number of passengers travelling with a companion to 947 from 621, but assistance was less likely to be necessary on board the aircraft added to V4.0 than all the planned and unplanned emergency evacuations of larger aircraft, with more families, in V3.0. Many new companions are found among the precautionary evacuations but no assistance occurred.

The type of person who rendered assistance is presented in Table 1. This shows the 87 unique passengers who provided assistance. Of these 17 passengers provided assistance to multiple passengers which makes up the 104 passengers reported in Table 1. Males are disproportionately represented in the role of care givers to companions with 65% (68/104) of care giving incidents being by a male. The most common cases of assistance involve children, closely followed by the assistance given to a spouse. It should be noted that the number of spouses exceeded the number of children by a factor of three to one (see Figure 1). As the spouses received an equal degree of assistance to the children, this suggests that children are disproportionately receiving assistance. It is also interesting to note that in the role of care giver to infants, children and other family members, females are the dominant gender rendering assistance. In contrast, in cases where a spouse is assisted, the male almost always assists the female. These results appear to support common gender based roles i.e. females caring for family and children and males assisting females. It should be recalled that this analysis is based only on accounts from 87 passengers and in the case of assistance rendered by a spouse, the 24 cases cited only represent approximately 6.5% (24/369) of those who mentioned travelling with a spouse.

Table 1: Companion type of those who were rendered assistance

Companion type to whom assistance was rendered.	**Number of incidences of passengers rendering assistance in this category.**	**For those giving assistance, details of their relationship to the companion, where stated.**	**Gender of those giving assistance**	
			Female	**Male**
Infant < 2 years old	7	6 mothers, 1 father	6	1
Child	31	11 mothers, 15 fathers, 5 females	16	15
Sibling	6	1 sister, 5 brothers	1	5
Parent	6	1 daughters, 5 sons	1	5
Spouse	24	1 wife, 23 husbands	1	23
Partner	5	1 female, 4 males	1	4
Relation	8	1 grand-daughter, 2 aunts, 3 females, 2 male	6	2
Friend	14	3 females, 11 males	3	11
Unknown relationship	3	1 female, 2 males	1	2
TOTAL	**104**		**36**	**68**

From Table 1 we note that business associates are not cited as requiring assistance. All examples of assistance cited in AASK V3.0 and V4.0 was familial or extra-familial, from planned and unplanned evacuations. This can be interpreted as meaning business associates either required no help as the accident was not severe enough, required help but were not socially bonded enough to receive it, required help but were perceived to be able enough to cope alone or required and received help, which was not reported. The first three interpretations are consistent with the social model of evacuation implicit in Table 1. The latter interpretation is somewhat unlikely as for every other type of companionship, including `unknown relationship’, assistance WAS reported.

3.1.3 Family groups

Passengers travelling in family groups make up some 32% (609/1917) of the passengers in AASK. Clearly family units represent a significant proportion of the travelling public and so their likely behavioural response to aviation accidents must be understood. As part of a study of human behaviour in severe life threatening conditions occurring during building evacuation scenarios, Johnson et al [19] analysed in detail a fatal fire and evacuation from a large hotel/night club in which 165 people lost their lives. On the night of the fire there were 2,500 patrons dispersed in various rooms of the night club. In their analysis, Johnson et al found that almost all the patrons were bound by social ties to others present – primarily spouses or dating couples - and many were embedded in networks with multiple bonds. From their analysis they concluded that the evacuation from the building was not individualistic, but that patrons fled as member of groups, often hesitating in their flight to ensure that others to whom they were socially bonded were also exiting. Furthermore, as the threat of entrapment increased, greater concern for group members was expressed. The results from this study suggest the importance of social bonds in determining behaviour during evacuation.

Clearly, further data and analysis is needed to fully understand the response of family units and other social groupings. The analysis of family group behaviour is difficult as passengers do not always explicitly identify family members within their interview transcript. It is therefore impossible to determine with certainty that all behaviour representative of the various family groupings has been collected and analysed. However, a family group analysis that has been undertaken considered family groups consisting of two adults and two children, 16 of which were found in the AASK database. These family units display a variety of evacuation behaviours. In some of these the male adult directs and leads the family, in others it is a joint operation. However the most common behaviour is for each parent to assume responsibility of a child (often with the female adult carrying an infant). The analysis reveals that 10 families stayed together while six family groups split.

In each of the 16 cases, the family groups had a variety of viable exits available to them. Regarding the six family groups who split, in two cases, the male adult and one child went through one exit, while the female adult and the other child used the other exit of the exit pair. In a third case, two adult females evacuated two children. One adult and one child used an exit before the slide malfunctioned, causing the other pair to use a different exit. In a further two cases the family split so that one parent took both children through an exit whist the other adult went through the other exit in the exit pair. In one case it was a male leading in the other it was the female who took the responsibility for the children. In the final case a parent and two children were seated in one cabin section with the mother in a different section. In this case the family did not attempt to reunite prior to evacuation. The mother used one exit and the father took the two children out of a different exit much further up the cabin.

The results from this family analysis support the findings of Johnson et al [19] and suggest that the family should be treated most commonly as a unit staying and evacuating together. However, this is not to say that the family or companion bond will be maintained indefinitely throughout the evacuation, for example, consider the following quotations extracted from AASK:

A 40 year old female "unsuccessfully tried to rescue grand mother from seat before exiting"
An "infant was fatally thrown during impact sequence"
A 58 female who had a "friend killed ….informed her of nearest exit".

The existence of group dynamics has significant ramifications for crew procedures developed using 90 second certification analysis as a justification. One commonly practised procedure is that of crew initiated exit by-pass, where crew members direct some passengers away from a functioning exit to another nearby functioning exit. While these procedures may be efficient under certification conditions – where social bonds play no significant role – in actual evacuations where social bonds become relevant, they may cause disruption resulting in inefficient evacuation.

3.2 Analysis of Exit Usage

In this section we consider nearest exit usage. The full report [24] contains a study of the following issues: Distance and direction travelled by survivors during egress, Distribution of exits used in evacuation's involving aircraft with three exits pairs, Individual exit availability analysis, Total Exit Availability and a Comparison of AASK and 90 second trial exit usage. While not discussed here, this information is extremely useful as it provides information as to the type of exit combinations that occur in survivable crashes.

Within the aviation industry it was a commonly held belief that most of passengers evacuate via their most familiar exit, thereby ignoring closer but unfamiliar emergency exits. As is quoted in an aviation safety report [14],

'Passengers will often try to exit the aircraft via the same door they entered, regardless of better options'

Analysis using AASK V3.0 [11, 12, 13] suggested that this was not the case and that overwhelmingly (i.e. 70%), passengers tended to use their nearest serviceable exit. The results from the analysis using AASK V4.0 confirm this observation with 85% of passengers who report their exit usage making use of the nearest available exit.

3.3 Comparison of Survivor and Fatality Distance Travelled

One of the first systematic studies into human behaviour issues associated with aircraft evacuations was conducted by Snow et al [18]. The study was based on the investigation of three fatal crashes involving: a DC-8 on 11 July 1961 with 114 passengers of which 17 died, a B727 on 11 November 1965 with 85 passengers of which 43 died, and a B707 on 23 November 1964 with 62 passengers of which 45 passengers and 5 crew died. All three incidents involved fire. One of the central aspects of the study was an investigation of the exits used by survivors and the travel distance taken to those exits. Across the three accidents, the survivors were located on average 2.94 seat rows from their nearest available exit while fatalities were seated some 3.99 seat rows. Their findings suggested that on average, survivors sat closer to potentially usable exits than fatalities. It is worth noting that the aircraft involved in these three accidents were built prior to the establishment of the regulation limiting exit separation to no more 60 feet [23].

It should be noted when comparing the results presented in this section with earlier publications [11, 12, 13] that several changes have occurred. Firstly, additional data is available for several of the accidents. Secondly and more importantly, in one accident (B737-236) an exit (aft right exit) was originally classified as open and available. On closer examination it was realised that while the exit was opened and slide deployed, fire conditions immediately opposite the exit made this exit unusable. In fact no passengers attempted to use this exit. In this analysis, the exit is reclassified as being unavailable. This will have an impact on the analysis previously presented for this data.

The distance calculations were based on the number of seat rows between the passenger seat location and the exit. A similar technique is used in AASK to calculate distance. Four accidents in AASK were found with sufficient numbers of survivors and fatalities (excluding in-lap infants) and with appropriate starting locations to undertake a similar comparison to that of Snow. In this analysis, only passenger fatalities are considered. The four aircraft were: B737-300 (63 Survivors and 20 fatalities), DC 9-20 (33 Survivors and 7 fatalities), DC 9-32 (18 Survivors and 23 fatalities) and B737-236 (76 Survivors and 52 fatalities, excluding infants). As in the Snow study, all of these cases involved fire and all four cases are narrow body aircraft. As can be seen in Table 2, the maximum travel distance to an exit for these four aircraft varies from 4 to 7 seats rows. In two accidents at least one exit from each of the exit pairs was available, hence maximum distance to a viable exit and maximum distance to an exit are identical. However when *pairs* of exits, or exit *positions* (such as a Tailcone exit) are taken out by fire/smoke, the maximum distance to a viable exit can increase dramatically (see Table 2).

Table 2: Comparison of maximum distance (as measured by seat rows) to the nearest available viable exit and nearest exit for four aircraft involved in fatal accidents

Aircraft	Maximum distance to viable exit	Maximum distance to an exit
B737 300	6	6
DC 9 32	7	7
DC 9 20	7	4
B737 236	12	6

In this analysis, the theoretical travel distance refers to distance from the passenger's starting location (seat row) to the nearest *available viable* exit. In the case of the survivors, this may not be the distance they actually travelled to exit, but it does represent the optimal distance to exit. All distances were calculated in terms of seat rows for each passenger and averaged over the number of passengers involved per aircraft (see Table 3). Not all passengers in the database were used in this analysis, as there were anomalies with the data relating to several of the survivors. Also presented in Table 3 is the maximum travel distance actually travelled by a passenger on board the various aircraft.

In each case, survivors are located on average closer to viable exits than fatalities. The overall mean theoretical travel distance for survivors (based on a weighted mean) in these accidents is 2.89 seat rows, while the theoretical mean travel distance for fatalities is 5.31 seat rows (assuming passengers attempted to use their nearest viable exit). These values are consistent with those of Snow and suggest that on average, survivors are located closer to viable exits than fatalities. It is interesting to note that for these aircraft, had the aircraft been fully loaded the weighted average distance of a seated passenger from an exit would be 2.88 seat rows, while the weighted average distance from a viable exit would have been 3.54 seat rows. Thus the survivors were seated on average closer to a viable exit and the fatalities further from a viable exit than would be expected by the average passenger. To put these numbers into perspective, the furthest a passenger actually travelled to a viable exit was 15 seat rows (see Table 3).

Table 3: Comparison of theoretical average distance to the nearest viable exit for survivors and fatalities (for which data is available within AASK) from four aircraft accidents

Survivors		Aircraft	Fatalities	
Number of survivors	Theoretical mean travel distance	Maximum actual travel distance for a seated passenger	Theoretical mean travel distance	Number of fatalities
40	3.03	B737 300 / 6.0	3.50	20
15	2.20	DC 9 20 / 11.0	3.17	6
17	2.06	DC 9 32 / 8.0	4.14	22
76*	3.14	B737 236 / 15.0	6.75	52*

*in lap infants discounted

For these four accidents, it is also possible to consider the likelihood of being a survivor or a fatality (excluding infants) based on seating location. To achieve this, data from the four accidents was combined and the likelihood determined for surviving or perishing depending on the number of seat rows from a viable exit. This was determined simply by taking the total number of survivors (or fatalities) in each row across all four aircraft and dividing by the total number of passengers on board the four aircraft (for which there is data within AASK). The results from this analysis are displayed in Figure 2. As the aircraft in these accidents were not fully loaded, it is not advisable to draw conclusions from cross comparisons between rows. This is because as not all of the seats were fully occupied this may bias one seat location compared to another. However, it is justifiable to compare the number of survivor's verses the number of fatalities within a given row.

This data suggests that for these accidents there are three critical seating zones. In the first zone, identified from 0 to 1 seat rows from a viable exit, the number of survivors far outweighs the number of fatalities. This suggests that passengers seated this close to an exit are most likely to survive. In the second zone, identified from 2 to 5 seat rows from a viable exit, while passengers are more likely to survive than perish, the difference between surviving and perishing is greatly reduced. Finally, the third zone is identified as being 6 or more seat rows from a viable exit. Here, the chances of perishing far outweigh that of surviving.

Another analysis that can be made using this data concerns the difference between survival rates for aisle seated and non-aisled seated passengers. In each accident, the number of survivors for each seating location is compared with the total number of people seated in that location. As can be seen from Table 4, while there is some variation between the four accidents, on average, being seated on the aisle provides only a marginally higher chance of survival than not sitting on the aisle.

A similar comparison can be made between those seated in the front rows of the aircraft and those seated in the rear. Each of the four cabins is divided into a forward and a rear section at the mid seating row. The survival rate is then determined for the two sections (see Table 5). As in the previous analysis, on average there appears to be little difference between the two options however, variability between accidents is pronounced. On average, passengers seated in the front of the aircraft have a slightly higher survival rate than those seated in the rear.

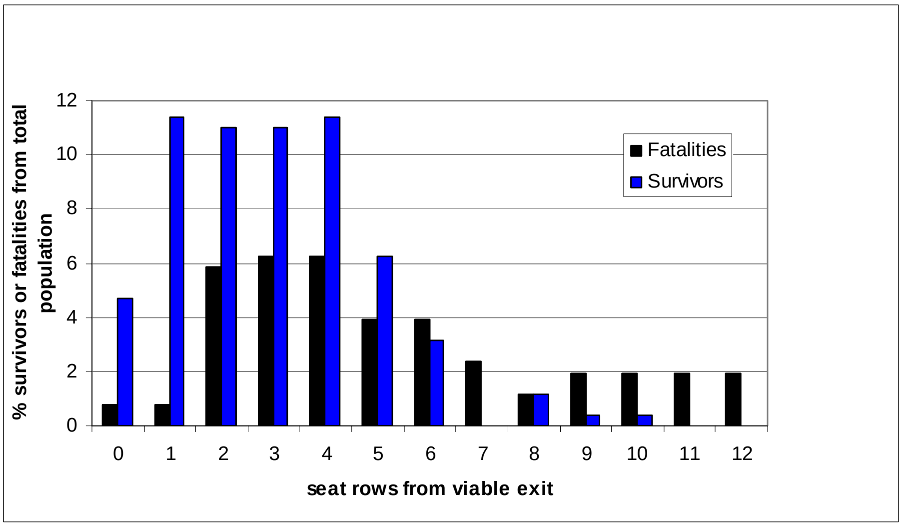

Figure 2: **The distribution of rows to nearest viable exits for survivors and fatalities**

Table 4: Survival rate for aisle seated and non-aisle seated passengers

Aircraft	Survival Rate of Aisle Seated Passengers	Survival Rate of Non-Aisle Seated Passengers
DC9-32	38%	48%
B737-236	62%	57%
B737-300	86%	61%
DC9-20	71%	70%
AVERAGE	64%	58%

While there are 323 passenger fatalities held in AASK, only 32 (from five accidents) list both the starting location and the location where the body of the deceased passenger was found, discounting accidents with ruptures. It is thus difficult to repeat the Snow analysis to determine the likely distance that the deceased passenger would have travelled to their intended exit.

Table 5: Survival rate for front and rear seated passengers

Aircraft	Survival Rate of Front Seated Passengers	Survival Rate of Rear Seated Passengers
DC9-32	33%	100%
B737-236	87%	30%
B737-300	53%	89%
DC9-20	75%	67%
AVERAGE	65%	53%

These findings are also in support of the earlier findings of Snow and suggested that on average, survivors sat closer to potentially usable exits than fatalities, both survivors and fatalities tended to sacrifice some of their location advantage by ignoring nearby exits in favour of more distant exits, and the tendency towards less effective exit utilisation was more pronounced among the fatalities. It should be noted that this result does not contradict the earlier finding that the majority of passengers tend to use their nearest exit or have a good reason for not using their nearest exit. This analysis is based only on one accident that was also a severe fire case.

3.4 Analysis Based on the Cabin Crew Component of AASK

The cabin crew component of AASK provides a view of the developing evacuation situation as seen by the cabin safety ‘professionals’ that were involved in the accident. As such considerable insight can be gained concerning both passenger behaviour and the effectiveness of both operational procedures and emergency equipment. Here several analyses using the cabin crew data are considered, the first attempts simply to identify the number of crew that are available to assist in the evacuation, the second attempts to correlate the number of active crew with the average distance travelled by passengers while the third investigates the frequency of exit and slide malfunction.

3.4.1 Cabin Crew Staffing Levels

An issue currently attracting considerable attention concerns cabin crew staffing levels and in particular the ratio of cabin crew to passengers. Of particular interest is the ratio of crew to passengers required for the safe operation of commercial aircraft. This is a complex issue involving many factors. Here we simply investigate several accidents and determine the theoretical and actual passenger to crew ratio for each of the aircraft involved in the cited accidents. For this analysis accidents were selected in which the theoretical maximum and actual number of passengers and crew on board were known. This resulted in a set of 87 accidents suitable for analysis. In some cases full details of maximum passenger loading were not included in the data supplied so the known loading from an identical model has been used.

The key statistic in this analysis is the ratio of passengers to crew. Around the world the accepted crewing level varies from around 36:1 to 50:1 passengers per cabin crew member. Here we define several ratios of interest, the first being the seating capacity of the aircraft to the total number of cabin crew on board or put more simply, maximum passengers (i.e. number of seats on board) / total cabin crew. This is the ***theoretical*** maximum passenger to crew ratio. The second ratio addresses the ***actual*** passenger to cabin crew ratio that existed at the time of the accident. It is defined as the number of passengers on board to the number of operational cabin crew. Here we define the operational cabin crew as those cabin crew who actually took an active part in managing the evacuation. It has been assumed that crew not listed as dead or seriously injured took part in managing the evacuation. The final ratio considered is defined as the ***worst case*** scenario. It assumes that the maximum passenger load is present while only the effective cabin crew are available to manage the evacuation.

Depicted in Figure 3 is a comparison of the ***theoretical*** and ***actual*** passenger to cabin crew ratio in each of the 87 accidents. As is to be expected, the ***theoretical*** ratio varies from just under 30:1 to 50:1. In contrast, the ***actual*** passenger to cabin crew ratio varies from 2:1 (BAe 31 JETSTREAM with 2 passengers on board and one cabin crew) to 139:1 (MD-82 with 139 passengers on board and only 1 uninjured member from the 4 original cabin crew). The left portion of the graph shows accidents for which the aircraft did not have a full load and all cabin crew were available so that the ***actual*** ratio is better (i.e. smaller) than the ***theoretical*** ratio. In total there were 12 accidents in which the ***actual*** passenger crew ratio was greater than the ***theoretical*** limit (towards the right end of the figure) and a further 6 accidents where the two ratios were equal. In these accidents there were a total of 22 cabin crew fatalities or injuries so severe as to leave the crew unable to take any part in the evacuation. Furthermore, we note that nine accidents resulted in the partial loss of cabin crew. While many accidents involve aircraft with less than a full load of passengers – thereby improving the ***actual*** passenger to crew ratio, a significant number of accidents occur in which the passenger to crew ratio is adversely affected by the nature of the accident.

Depicted in Figure 4 is a comparison of the ***theoretical*** and ***worst case*** passenger to crew ratios. In this figure, all 88 aircraft are assumed to have a full passenger load. In 13 of the cases crew would have been expected to cope with worse than the ***theoretical*** passenger crew ratio and in 11 of the cases the ratio is in excess of 50:1 – the maximum accepted value for the ratio. In five accidents the ***worst case*** scenario results in a doubling of the theoretical passenger to crew ratio. This may have profound implications for the effectiveness of the evacuation with potential fatal consequences for passengers that survive the initial impact trauma. Clearly, from a safety viewpoint, it is desirable to maintain a passenger crew ratio that is as low as practical as in the event of a serious accident; it is possible that some cabin crew will be unable to assist in the evacuation.

3.4.2 Correlation between number of Active Cabin Crew and Average Distance Travelled by Passengers to Exit

Here we attempt to investigate the relationship between the number of operational cabin crew and the efficiency of the evacuation. There are many ways in which the evacuation efficiency can be defined, for example, time required to evacuate, number of injuries/fatalities incurred during evacuation, distance travelled by passengers, exit flow rates achieved, passenger distribution between available exits, etc. Here we simply consider the average distance travelled by passengers during the evacuation as an indication of the efficiency of the evacuation. It is assumed that the shorter the average distance travelled by passengers, the more efficient the evacuation. Within AASK, 44 aircraft were found to have information concerning both the number of cabin crew and the distance travelled by passengers. These cases were further filtered to remove situations involving cabin ruptures leaving 35 accidents with 1015 passengers.

As in previous analyses, distance calculations are based on seat rows, taking into account the starting seat row of the passenger and the number of seat rows either to the exit used or the nearest usable exit. The number of operational cabin crew was determined by considering not the number of cabin crew present on the aircraft, but the number of cabin crew that could have been actively involved in managing the evacuation. This eliminated cabin crew that may have been originally counted in the crew contingent but were killed or severely injured in the accident. Thus, the number of operational crew was defined as those crew who were uninjured or who sustained only minor injuries. The ratio of passengers on board to operational cabin crew was then determined and this was plotted against the average distance travelled by survivors.

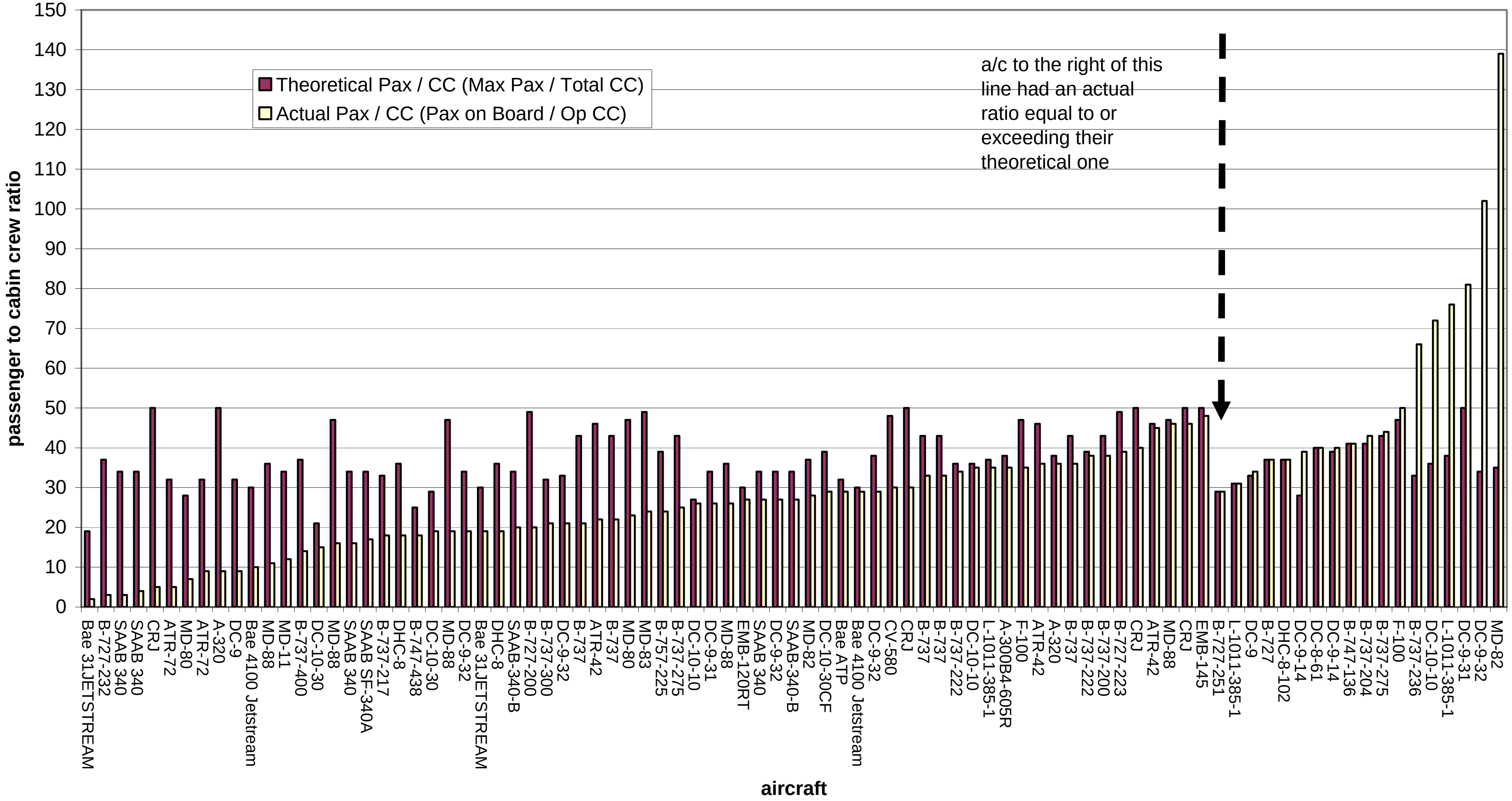

Figure 3: Comparison of theoretical and actual passenger crew ratios in the 87 cited accidents.

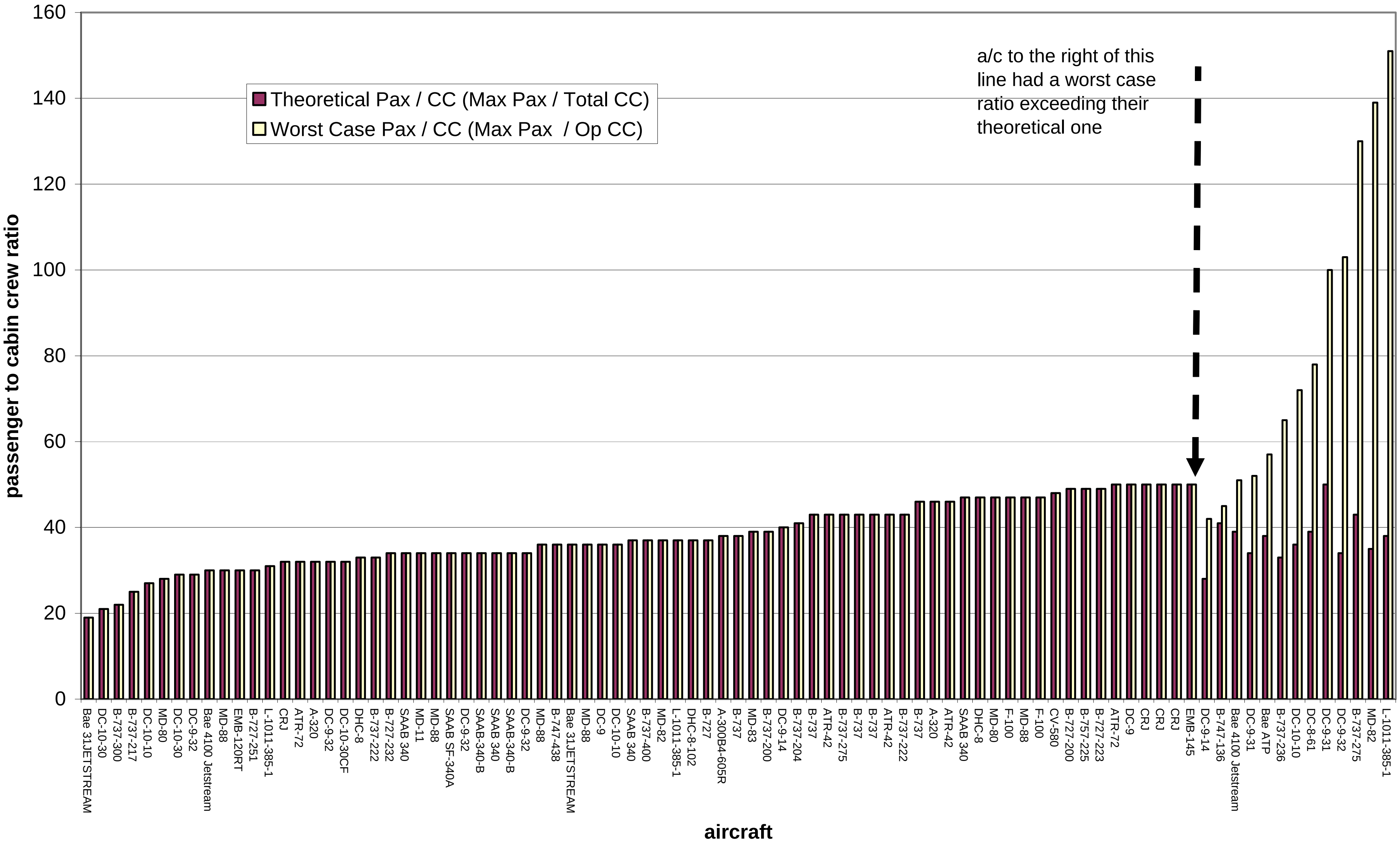

Figure 4: Comparison of theoretical and worst possible passenger crew ratios in the 87 cited accidents.

Simply using this information fails to identify any correlation between the passenger to operational cabin crew present and the distance travelled by passengers (correlation coefficient for line of best fit is r =-0.066). In precautionary and deplaning incidents, crew often direct passengers to use a particular exit for safety and convenience rather than for speed and efficiency of evacuation. This could bias the results and so these results should be removed from the analysis. If the precautionary and deplaning incidents are removed from the sample leaving only the emergency incidents, we again fail to find a significant trend between passenger crew ratio and distance travelled (correlation coefficient for line of best fit is r =-0.2338).

This is because other influential factors such as the number of available exits and size of aircraft have not been factored into the analysis. For example, it is likely that passengers in an accident involving a large wide-bodied aircraft will need to travel further than passengers in an accident involved a small commuter aircraft, irrespective of the number of cabin crew present. Furthermore, the number of exits that are available to the passengers will also have an impact on the travel distance, and this is dependent on the nature of the aircraft configuration and the accident details.

In an attempt to overcome these difficulties two representative distances are defined that take into consideration both the nature of the aircraft and the accident scenario. The first distance is calculated assuming that all passengers use their nearest *available* exit. This is then averaged for each aircraft and identified as the Theoretical Shortest Distance (TSD) for the aircraft. The second representative distance is the Actual Distance Travelled (ADT) and is the average actual distance travelled by each passenger in evacuating the aircraft. The ratio, ADT/TSD is a measure of the additional travel distance incurred by the passengers due to sub-optimal exit choice. Here we simply define the Evacuation Efficiency (EE) as TSD/ADT * 100%. An EE of 100% indicates that all the passengers made use of their nearest viable exits whereas values less 100% indicate that not all of the passengers made use of their optimal exits. It is assumed here that the crew play a vital role in managing the evacuation of passengers. This role includes guiding passengers to their exits as well as speeding their passage through the exit. Therefore, the more (well trained and active) crew that are available to direct the passengers, the more likely the passengers are of utilising their optimal exit.

Table 6: Evacuation efficiency ratio for six aircraft satisfying the selection criteria

Aircraft	Max passengers	Passengers on board	Cabin Crew on board	Operational cabin crew	Theoretical pax/cc ratio	Actual pax/cc ratio	Evacuation Efficiency
DC-9-32	100	41	3	2	33	21	68%
SAAB-340-B	34	20	1	1	34	20	34%
B-737-300	128	83	4	3	32	28	91%
DC-9-20	78	40	2	1	39	40	43%
B-737-236	130	131	4	2	33	66	58%
B-727-223	146	116	3	3	49	39	96%

To be truly representative, the distance calculations used to determine ADT/TSD must be based on a sample involving a significant number of passengers. Aircraft with small loading numbers or accidents with poor survey replies were thus excluded from this analysis. In order to filter out unrepresentative data the following acceptance criteria was used:

- Aircraft with less than 50% loading were excluded,

- Accidents with less than 50% passenger reply rate were excluded,
- Small commuter aircraft with a capacity of less than 30 passengers were excluded, and
- Aircraft with ruptures providing alternative means of escape were excluded.

Due to these rigorous criteria only six accidents were found suitable for this analysis (see Table 6). Without exception, all the aircraft involved in this analysis were single aisle aircraft and information from 247 passengers relating to exit usage was available in AASK. For each of these accidents the cabin crew accounts were studied in detail to determine the role played by each active crewmember during the evacuation. In particular the third member of the B737-300 cabin crew, although seriously injured and so not regarded as operational by our criteria in the AASK V3.0 analysis, actually took an active part in the evacuation and so is counted in this analysis.

For these six accidents there appears to be no apparent correlation between the evacuation efficiency and the actual passenger to operational cabin crew ratio (correlation coefficient for line of best fit is r =0.009). However, there does appear to be a strong relationship (correlation coefficient for line of best fit is r = 0.98) between simply the number of operational cabin crew and the evacuation efficiency (see Figure 5). For the six accidents considered here we note that when there are a small number of crew available to control the evacuation, passengers tend to fail to make use of their optimal exits and tend to travel significantly further than is necessary in order to evacuate.

In cases where only a single crewmember is available, passengers have travelled as much as three times further than was theoretically necessary, whereas when three crewmembers are available, passengers travelled on average only 1.1 times further than was theoretically necessary (see Figure 5). Furthermore, as can be seen from Figure 5, as the number of available crew increase, the Evacuation Efficiency – as measured by the average distance travelled - increases.

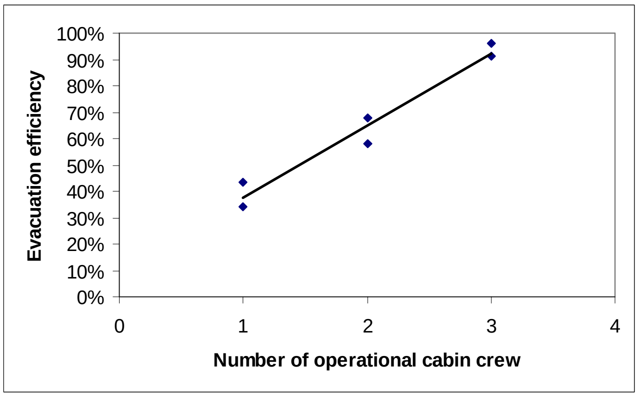

Figure 5: Relationship between Evacuation Efficiency (EE) and the number of operational cabin crew for the five narrow body accidents

From the results presented in Figure 5 it is clear that it is possible for the number of operational crew able to assist in the evacuation to be less than the number of crew normally staffing the aircraft. If the relationship between evacuation efficiency and cabin crew numbers suggested by Figure 5 can be generalised then the loss of even a single cabin crewmember may have serious implications for passenger safety. This will be particularly relevant in evacuation situations where any extra time spent in egress will compromise the survival chances of the passengers, such as situations involving fire.

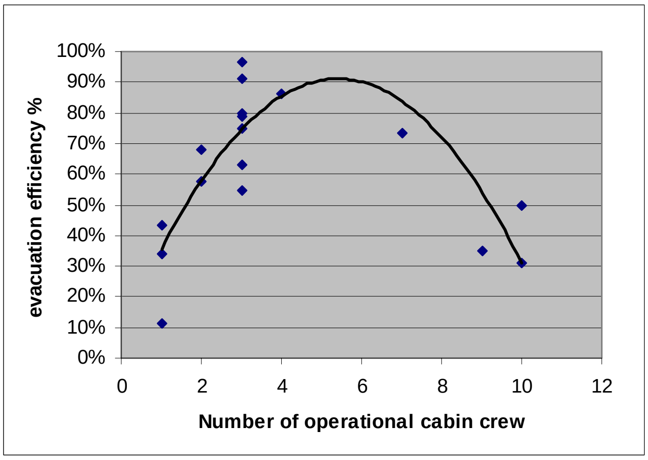

Figure 6: Tentative relationship between Evacuation Efficiency (EE) and the number of operational cabin crew for 17 accidents

While these results appear to support the hypothesis that as the number of active crew increases, the efficiency of the evacuation increases it is important to note several points. Firstly, only a small number of accidents are taken into account in this analysis. These accidents may also not be generally representative of likely accident situations. In addition, the accidents considered here are only representative of small narrow body aircraft. Different trends may occur if wide body or larger narrow body aircraft are considered. Furthermore, evacuation efficiency is a complex parameter based on a number of variables, not simply the distance travelled to exit. If other evacuation efficiency measures are considered the correlation between evacuation efficiency and crew numbers may not persist. Finally, other factors may play a more important role in passenger exit selection then simply the presence of cabin crew.

In an effort to address some of these issues additional accidents were introduced into the analysis. This was achieved by relaxing the accident selection criteria. The only selection criteria that was enforced was that the aircraft had a 50% passenger loading. In this analysis cabin crew are considered to take an active part in the evacuation if they are not reported as dead or seriously injured. Using these relaxed criteria allows 17 accidents to be considered for analysis of which four are wide body aircraft. Based on the above definition of evacuation efficiency, preliminary analysis of this data suggests that for large wide body aircraft, higher numbers of operational crew may lead to declines in evacuation efficiency as defined here (see Figure 6). This is thought to be due to more instances of passenger redirection and exit bypass resulting in passengers travelling further than the theoretical minimum distance, suggesting that for these aircraft, perhaps the efficiency ratio as defined may be inappropriate. For the additional narrow body aircraft, the original correlation between increased evacuation efficiency with increased crew numbers is maintained. All the preliminary analysis on evacuation efficiency reported has been confirmed with these extra aircraft, however these observations are only tentative as they are based on insufficient data.

3.4.3 Slide and Exit Malfunction

From the 155 cabin crew accounts held in AASK, 43 mention difficulties with exit doors, slides or both. In one instance the difficulty concerned the crewmember's indecision as to whether it was necessary to deploy the slide as the exit was only five or six feet above the ground. However, in all other cases equipment failure was cited. In some cases it is possible to have several crew members reporting the same fault. Such cases of multiple reporting of the same incident have not been included in this analysis.

Of the 105 accidents in AASK, exit or slide malfunctions were mentioned in 28 accidents and Figure 7 shows the nature of these malfunctions, and suggests that in approximately 27% (one-quarter of the accidents in AASK), a door or a slide failed to operate as intended. With the large increase in accidents entered into AASK V4.0 we find that frequency of exit/slide malfunctions has decreased from that previously found using AASK V3.0.

The majority of incidents mentioned involved doors jamming while the remainder were concerned with poor slide performance. Problems with crew operated cabin doors were cited in 22 accidents by 30 crew members, representing 31 distinct exits. Within AASK, there are 258 crew operated exits on the 105 accident aircraft (70 Type-A exits, 5 Type-B exits, 149 Type-I exits, 4 Type-II exits with Assist Means (greater than 6 feet sill height), 9 Type-II exits below this criterion but installed as secondary cabin crew operated exits, 16 Tailcone exits with slides and 5 ventral exits with airstairs instead of slides). This suggests that there were problems with 12% (one in eight) of the crew operated exits.

However, of the 258 crew operated exits, only 174 were actually opened or attempted to be opened by crew members (i.e. one exit in accident 51 is discounted as CC played no role its operation; no information is available for six exits regarding whether or not an attempt to operate was made; CC did not attempt to operate 42 exits due to crash conditions (e.g. fire, slope etc) and CC were ordered not to attempt to operate 35 exits (e.g. precautionary evacuations, such as accident 81)). Hence 31 distinct exits were problematic out of 174 attempted (i.e. 17.8%), a failure rate approaching a fifth of attempted exits.

Slide difficulties (including slide failure to inflate, slow inflation time, or failed after initial deployment) were cited in 20 cabin crew accounts and involved 20 slides from 17 accidents. This suggests that 8% of the accidents cited in AASK involved some form of slide malfunction. Associated with each of the 258 crew operated exits are 226 slides. Thus across the 105 aircraft in AASK V4.0, 20 problematic slides from a total of 226 available slides produces a slide malfunction rate of 8.9%.

However, of these 226 slides, only 137 were deployed or attempted to be deployed (i.e. one slide in accident 51 is discounted as CC played no role its operation; no information is available for 5 slides regarding whether or not an attempt to operate was made; CC did not attempt to operate 47 slides due to conditions; CC were ordered not to attempt to operate 33 slides (e.g. precautionary evacuations, such as accident 81); CC decided not to deploy one slide due to the sill height being low enough following a crash and another two could not have been deployed as the accident happened). Hence 20 distinct slides were problematic out of 137 attempted, a malfunction or problem rate of 15%.

That there should be such a relatively high incidence of problems associated with the exiting systems on board aircraft is cause for concern and requires further investigation.

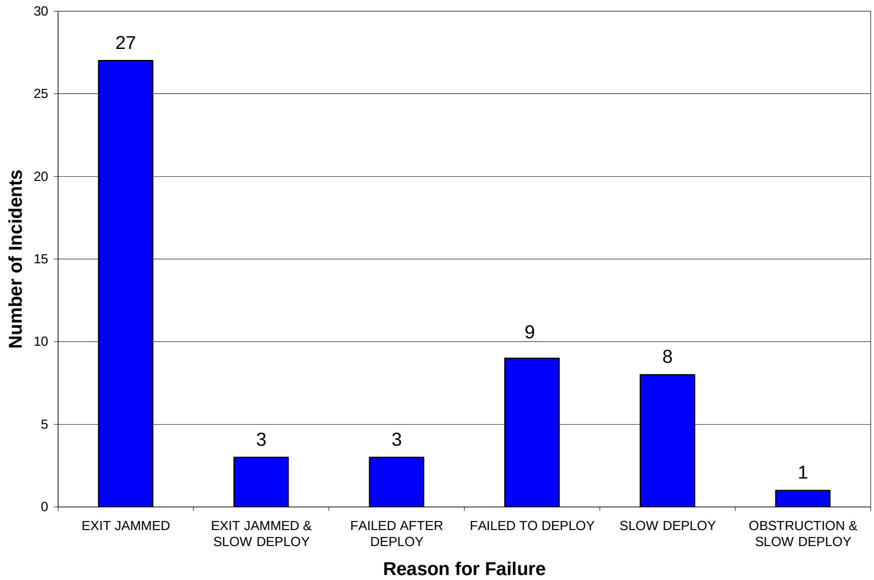

Figure 7: Common exit and slide failures reported by cabin crew members

4 CONCLUSIONS

The AASK database is a unique resource containing data from over 2000 passenger and crew accounts from 105 survivable accidents. The data in AASK is extracted from accident investigation transcripts supplied by the Air Accident Investigation Branch in the UK, the National Transportation Safety Board in the US and the Australian ATSB. AASK V4.0 is currently available online over the internet at http://aask.gre.ac.uk.

With the development of AASK V4.0, it is possible to access detailed survivor (passenger and crew) information as well as information concerning fatalities. The cabin crew component has become a significant aspect of the database providing insight into cabin conditions and passenger behaviour as seen from professionally trained cabin specialists. The fatalities component holds data for all fatalities documented in the accident reports while the Seat Plan Viewer graphically displays the starting locations of all the passengers – both survivors and fatalities - as well as the exits used by the survivors.

While AASK contains much data, the majority of this data is qualitative in nature. As such, conclusions drawn from the database must be treated with caution and with full knowledge of the implications of the questions posed and the nature of the data used to provide the responses. However, as more data is added to the database, more confidence in performing quantitative analysis is established.

A considerable proportion of the analysis undertaken with AASK V4.0 was intended to reproduce earlier investigations. To this end the initial analysis undertaken with AASK V4.0 concentrated on eight main areas: Survival and reply rates, Age distribution, Seatbelt difficulty, Seat Climbing reasons, Direction and distance travelled, Exit usage, Exit availability and Group Behaviour. It is reassuring to note that much of this analysis has confirmed earlier analysis performed using smaller data sets.

In addition the analysis was extended to include new aspects of the AASK V4.0 data set not previously reported, with a particular focus on data relating to cabin crew. The cabin crew component of AASK provides a view of the developing evacuation situation as seen by the cabin safety 'professionals' that were involved in the accident. As such considerable insight can be gained concerning both passenger behaviour and the effectiveness of both operational procedures and emergency equipment. Several analyses using the cabin crew data are considered, the first attempts simply to identify the number of crew that are available to assist in the evacuation, the second attempts to correlate the number of active crew with the average distance travelled by passengers while the third investigates the frequency of exit and slide malfunction.

While AASK was originally conceived as a tool to assist in the development of aircraft evacuation models, its uses go far beyond this. AASK is shedding light on what really happens during aircraft emergency evacuations and as such is helping to dispel some of the myths that pervade aviation safety. AASK can also be used to assist in setting up plausible and realistic scenarios for use in performance based analysis of aircraft evacuation capabilities.

Finally, the AASK database has undergone testing and validation as part of this project. However, for a system as complex as this, further testing and validation is desirable. It is hoped that this will be accomplished through field trials. It is also hoped that AASK will be further extended by the inclusion of additional survivor data and the expansion of the fatality database, in-line with the US GAO recommendations [4]. In addition to the studies and applications investigated in this report, the AASK system could also be used as an aid to accident investigators during the survivor interview process. The difficulties associated with the collection of data from survivors of aircraft accidents are not easily resolved. However, once survivors have been identified and have agreed to share their experiences, a more thorough and standardised approach could be adopted when eliciting and recording their testimonies. The AASK database provides a possible basis for forming such an approach, and as such, also provides a useful framework for the purposes of cross-accident analysis. This type of analysis is vital if trends in passenger behaviour are to be understood and ultimately used to improve passenger safety.

Further suggested development work on the AASK database includes:

(i) Analysis of data collected.
Undertake a detailed analysis of passenger and crew data, this analysis should include issues raised by the CAA/JAA and other approved interested parties.

(ii) Continued collection and entry of data into AASK,
Collect and enter data from other authorities such as Canada and Australia. In addition, develop suggestions to improve passenger questionnaires used by accident investigation authorities. In addition, the fatalities database should be expanded in line with the recommendation from the US GAO.

(iii) Maintenance and functional development of the AASK database,
A number of developments are suggested to improve usability of the database.

(iv) User feedback.
Issues concerning errors or inconsistency in data, requests for assistance in either the use of AASK or in interpreting the results generated by AASK should be followed up. Issues concerning ease of use and improved functionality should be monitored.

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