Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2006/01

A Database to Record Human Experience of Evacuation in Aviation Accidents

The Aircraft Accident Statistics and Knowledge Database (AASK)

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The Aircraft Accident Statistics and Knowledge Database (AASK)

Prepared for the CAA by Fire Safety Engineering Group, University of Greenwich
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A Database to Record Human Experience of Evacuation in Aviation Accidents

1 Executive Summary

1.1 This report concerns the development of the AASK V4.0 database (CAA Project 560/SRG/R+AD). AASK is the Aircraft Accident Statistics and Knowledge database, which is a repository of survivor accounts from aviation accidents.

1.2 With support from the UK CAA (Project 277/SRG/R&AD), AASK V3.0 was developed. This was an on-line prototype system available over the internet to selected users and included an increased number of passenger accounts compared with earlier versions, the introduction of cabin crew accounts, the introduction of fatality information and improved functionality. The completed project has led to the development of AASK V4.0. The aims of this project were four-fold, namely to:

a) maintain and improve functionality of AASK;

b) continue collection and entry of data into AASK;

c) undertake a limited analysis of the data collected in V4.0; and

d) measure user feedback.

1.2.1 All four components have been successfully completed in this two-year project. The current version of the database available over the internet (AASK is available online at http://aask.gre.ac.uk) is referred to as AASK V4.0. Summarised below are the key components of these developments.

a) Maintenance and functional development of the AASK database:

The AASK database has undergone significant modification and development during the lifetime of the project. These developments can be categorised into the following four broad areas:

i) Data Structure:

Four new accident categories have been defined. These are:

- Emergency Evacuation;
- Unplanned Emergency;
- Precautionary Evacuation and;
- Post Incident Deplaning.

ii) Database presentation:

- Dedicated server installation, setup and testing;
- On-line help facility provided;
- Database structure improved;
- Database component selection included;
- Database performance improvements; and
- Database security improved.

iii) Query Engine Developments:
- Query simplification and confirmation;
- Inclusion of pre-constructed queries;
- Cutting and pasting query results included; and
- Support for aggregate functions.

iv) Seat Plan Viewer (SPV) Developments:

A host of new features were developed for the SPV. The following is a list of key features:
- availability of SPV via Web;
- accident information such as accident dates, identity number and aircraft type is displayed;
- graphical output of seats and exits;
- exits used by each passenger easily seen by colour coding;
- viewing of either survivors or fatalities or both;
- passenger information – information displayed for each passenger consists of: gender, age, survivor/fatality, exit used, and seat label;
- information concerning travelling companions displayed; and
- exits used – all passengers who used an exit are highlighted.

b) Continued collection and entry of data into AASK:

Data entered into the AASK database was extracted from the transcripts supplied by the Air Accident Investigation Branch in the UK, the National Transportation Safety Board in the US and the Australian ATSB. The quality and quantity of the data was very variable ranging from short summary reports of the accidents, to boxes of individual accounts from passengers, crew and investigators.

c) Initial analysis of the data collected in V4.0:

The AASK database provides a versatile aid in the analysis of human experience in aircraft evacuations. While much data exists for input to the database, the data is limited in scope in that the qualitative aspects of the data far outweigh the quantitative. 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. It is reassuring to note that much of the analysis undertaken with the expanded database has confirmed earlier analysis performed using smaller data sets.

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, Seat belt difficulty, Seat climbing reasons, Direction and distance travelled, Exit usage, Exit availability and Group behaviour.

This analysis was then 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.

d) User feedback survey:

AASK V4.0 is available over the internet and at the time of completing this project, there were over 30 registered users from nine countries. Several means were pursued to gauge user interest in AASK. The first was the provision of an on-line questionnaire. At the time of writing, too few replies had been received to form any conclusions. In addition, two workshops were organised in conjunction with the UK CAA in order to present the work of this project to a wider audience. The first was to an audience at the UK CAA in January 2003 and the second was an open workshop in April 2003. The latter attracted some 17 delegates from UK, USA, Norway and France. They were drawn from the aircraft manufacturing industry, airlines, safety specialists and the regulatory community and between them they represented: Association of Flight Attendants (US); British Mediterranean Airways; Boeing; AMSAFE Aviation; DGAC; AAIB; ERA; CAA; Norwegian Cabin Crew Union; Cranfield University; and UK Flight Safety Committee. Feedback from these organisations was very positive. It was noted that many uses of AASK were suggested by the delegates going beyond the issues investigated in this report.

1.3 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.

1.4 Further suggested development work on the AASK database includes:

a) 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.

b) 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. Furthermore, the fatalities database should be expanded in line with the recommendation from the US GAO (see 2).

c) Maintenance and functional development of the AASK database:

A number of developments are suggested to improve usability of the database.

d) 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.

2 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 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 report to the Committee of Transportation and Infrastructure, US House of Representatives [4], the US Government Accountability 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 compared with earlier versions, 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:

a) analysis of the data collected in V3.0;

b) continued collection and entry of data into AASK;

c) maintenance and functional development of the AASK database; and

d) 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 report provides summaries of the work done and the results obtained in relation to the project deliverables. The relevant extract from the project proposal is provided in Appendix A.

3 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 accident information included in AASK V4.0 covers 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).

3.1 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 (see 4.1). As can be seen from Table 25 (Appendix B), 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.

3.2 Other new data was derived from a variety of sources:

a) The Australian ATSB provided data relating to a single accident.

b) Additional data relating to an accident which already existed in AASK V3.0 was derived from the internet resource. This led to information relating to 64 passengers.

c) Data relating to two accidents was located on the internet. This information related simply to the accident description, with no passenger or cabin crew accounts available.

d) Information relating to 17 passengers in various AASK V3.0 accidents became available and were entered into AASK.

e) Additional data relating to 14 cabin crew from three accidents already existing in AASK V3.0 was added to the database.

f) Using the seat plan viewer, additional data was inferred for some passengers already entered into AASK 3.0.

4 Maintenance and Functional Development

Developments undergone during the lifetime of the current project can be categorised under the following areas:

- Data Structure;
- Database presentation;
- Query Engine Developments;
- Seat Plan Viewer Developments.

The developments in each of these areas will briefly be discussed.

4.1 Data Structure

The majority of data added to AASK from the NTSB was classified as 'precautionary'. Such a classification did not previously exist within AASK. In analysing evacuation data it may be desirable to separate emergency evacuations from precautionary evacuations and so a new evacuation categorisation was developed for AASK. While AASK already had a categorisation referring to 'planned' and 'unplanned' emergency evacuations, the NTSB data used these terms in relation to precautionary evacuations. Furthermore, from the perspective of the passengers or the cabin crew, some of the NTSB precautionary evacuation situations bordered on near emergencies, with smoke in the cabin or damage to the aircraft. To accommodate this range of evacuation types, a new field named 'Type of Evacuation' was added to the database.

The 'Type of Evacuation' can be categorised into the following sections:

4.1.1 **Emergency Evacuation**: exemplar accidents 66 and 70. Here we define emergency as an incident resulting in a perceived or actual life threat to crew and/or passengers that is anticipated to grow unless crew/passengers are speedily removed from the aircraft. There are two types of Emergency Evacuation:

a) Planned emergency: exemplar accident 66. In these incidents Cabin Crew (CC) have a long period of time – usually measured in minutes – to rehearse checklists, brief passengers and converse with each other. Passengers also have a period of time to mentally prepare for evacuation. Planned emergency evacuations usually follow a serious in-flight incident, such as a fire in a cargo hold.

b) Unplanned emergency: exemplar accident 70. In these incidents CC have very little warning before the emergency, little or no time to rehearse checklists, brief passengers and converse with each other. Passengers also have little or no time to prepare for evacuation.

4.1.2 **Precautionary Evacuation**: exemplar accident 78. Here CC and passengers have preparation time equivalent to the planned emergency, but there is no immediate emergency. In precautionary evacuation situations, the passengers, crew and/or aircraft are not exposed to life-threatening conditions however; the crew anticipate that potentially life-threatening conditions may develop. This is usually the result of for example a bomb scare or a smell of fuel in the cabin. In these incidents, crew must balance the risks of not evacuating with the risks associated with evacuating. While life-threatening conditions have not yet developed, in the expectation that this could soon occur, passengers are usually evacuated. Usually in precautionary evacuations, time is not as critical as in emergency incidents. As a result, passengers are often told to 'sit and slide' at the exit instead of jumping. Passengers may even be instructed to use a single exit such as ventral airstairs. More often than not, precautionary evacuations are planned.

4.1.3 **Post-incident Deplaning**: exemplar accident 15. In these situations some untoward event has occurred within the cabin or to the aircraft, possibly causing serious damage to the aircraft or even resulting in loss of life on-board the aircraft. The decision is taken to remove passengers from the aircraft even though there appears to be no immediate threat to passengers resulting in an unscheduled disembarkation onto the tarmac. This may result from, for example, an aborted take-off (accident 15) causing substantial damage to the aircraft but no post-incident threat to the passengers. In the majority of cases, CC prepare passengers for deplaning, hence all unscheduled deplaning following an incident are seen as 'planned'.

4.2 Database Presentation

4.2.1 Server and hardware installation, set up and testing

A dedicated PC (Pentium III 1.0 GHz, 1GB SDRam and 20GB hard drive) with Netscape Enterprise web server was purchased and setup to serve the AASK database. In addition, a version of JDataConnect Java Database Connectivity (JDBC) Type 3 driver software product used by the Query Builder and SPV for the database connection allowing unlimited simultaneous users was purchased and installed.

4.2.2 On-line help facilities

An online help facility was developed that includes a complete description of the AASK database and its structure. Also included are a number of examples of how to construct queries using the Query Builder. Furthermore, a description of hardware/ software requirements for running the Query Builder and SPV is also included. Online help is only available to registered visitors. Part of the online help is a graphical structure of the database.

4.2.3 Database structure

While the database designers and regular users of the database soon become familiar with the structure of the database, occasional users may have difficulty in formulating queries and using the database if they do not understand the overall structure of the database. To overcome this difficulty, a graphical representation of the database structure was developed (see Figure 1). This is particularly relevant when constructing queries. A complete description of each table is also provided. In order to view the description the user must click on the item to reveal a complete description of all the associated fields (see Figure 2).

4.2.4 Database component selection

A database component selection feature has been added (see Figure 3). This feature allows users to select a particular part of the AASK database and query the data. For instance users can select components such as 'Accident' or 'Accident and Passenger'. This feature improves the performance of the database by allowing the user to load and run a smaller amount of data.

4.2.5 Performance

Performance improvement techniques such as Round Trip Reduction (RTR) technology, Java Threads, and database connection pooling have been included.

RTR technology provides performance improvements for Java applets operating on lower bandwidth connections such as Internet dial up access. On a typical low bandwidth connection the client-to-server-to-client round trip time is often a significant factor degrading JDBC performance. RTR technology reduces the number of round trips between the Java applet and the database server by batching multiple JDBC requests into a single transmission. [9]

Java Threads enhance performance and functionality by allowing a program to efficiently perform multiple tasks simultaneously. Connection pooling provides performance improvement by reducing the time taken to connect to the database. Without pooling, new physical connections must always be established which is time consuming and expensive on the database engine. [9]

4.2.6 Security

AASK is available online at http://aask.gre.ac.uk on its own dedicated server. The AASK Database is only available for authorised users. An authorised user can gain access to the database by providing his/her user id and password. Information about the authorised users is stored in a separate database. In addition, the AASK database online help is only available to registered visitors.

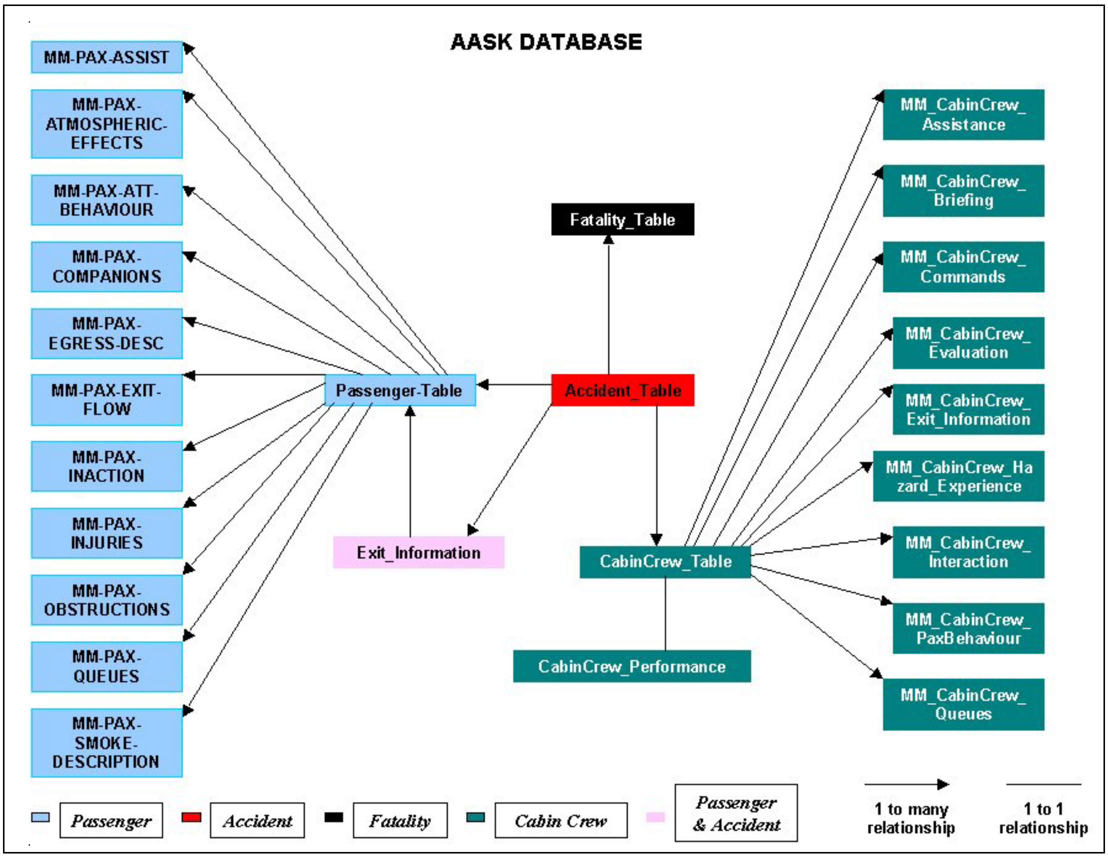

Figure 1 The diagram of data relationships in AASK V4.0

accident_table

Field Name	Data Type	Description
accident-id	AutoNumber	internal accident id
accident-date	Date/Time	date of accident
flight-number	Text	Flight Number
accident-index	Text	Calculated Field for external reference
accident-location-id	Text	Place where accident occured
accident-time	Date/Time	Time at which accident occured - local time
aircraft-operator-id	Text	Aircraft operator
accident-flight-position-id	Text	At which point of flight that accident occured
hull-position-id	Text	Resting position of hull in respect to airport - on runway etc.
accident-category-id	Text	FSEG category for accident
accident-aircraft-id	Text	Aircraft type
accident-manufacturer	Text	Manufacturer of aircraft
aircraft-orientation-id	Text	Aircraft Orientation Desciption
orientation-angle	Number	angle of hull relative to the orientation table!
accident-flight-type-id	Text	Flight Type Either scheduled or chartered
flight-destination-id	Text	reference to flight destination table - either domestic or international
accident-investigation-author	Text	Organisation in charge of investigation
accident-designation	Text	accident designation given by investigation authority
accident-report-date	Date/Time	report date
report-author-id	Text	Author of accident report
passenger-load	Number	maximum passenger load
accident-summary	Memo	accident summary + additional notes
fatal-fc	Number	injury table data
fatal-fa	Number	injury table data
fatal-pax	Number	injury table data
fatal-other	Number	injury table data
serious-fc	Number	injury table data
serious-fa	Number	injury table data
serious-pax	Number	injury table data
serious-other	Number	injury table data
minor-fc	Number	injury table data
minor-fa	Number	injury table data
minor-pax	Number	injury table data
minor-other	Number	injury table data
none-fc	Number	injury table data
none-fa	Number	injury table data
none-pax	Number	injury table data
none-other	Number	injury table data

Figure 2 Click on the accident table to reveal the field descriptions shown above

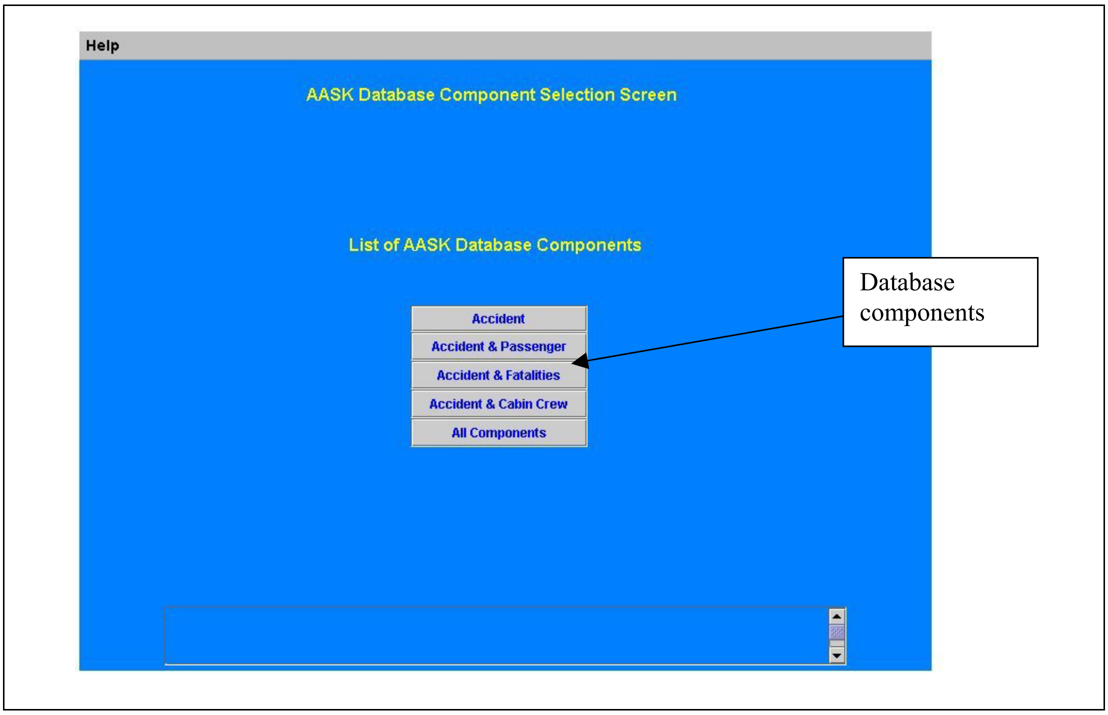

Figure 3 The component selection screen

4.3 Query Builder

The code written for the Query Builder has been completely restructured. This was done in order to improve the ease with which additional query features could be added to the database. This will also improve maintainability of the Query Builder. The user interface has been improved and now has a better layout and further functionality. Further testing was carried out and new information/error messages which are more user-friendly have now been inserted – the major changes are described below.

4.3.1 Query simplification and confirmation

A query confirmation feature has been added both to the generated Structured Query Language (SQL) code and the easier to read structured English translation of the code. All the main keywords are also highlighted for easier reading. This gives the user a check before running the query that is particularly useful if the uses of the logical functions AND/ OR have been misunderstood (see Figure 4). In addition, if the selected fields are from two tables that are not linked in the database, the user is asked to modify the query.

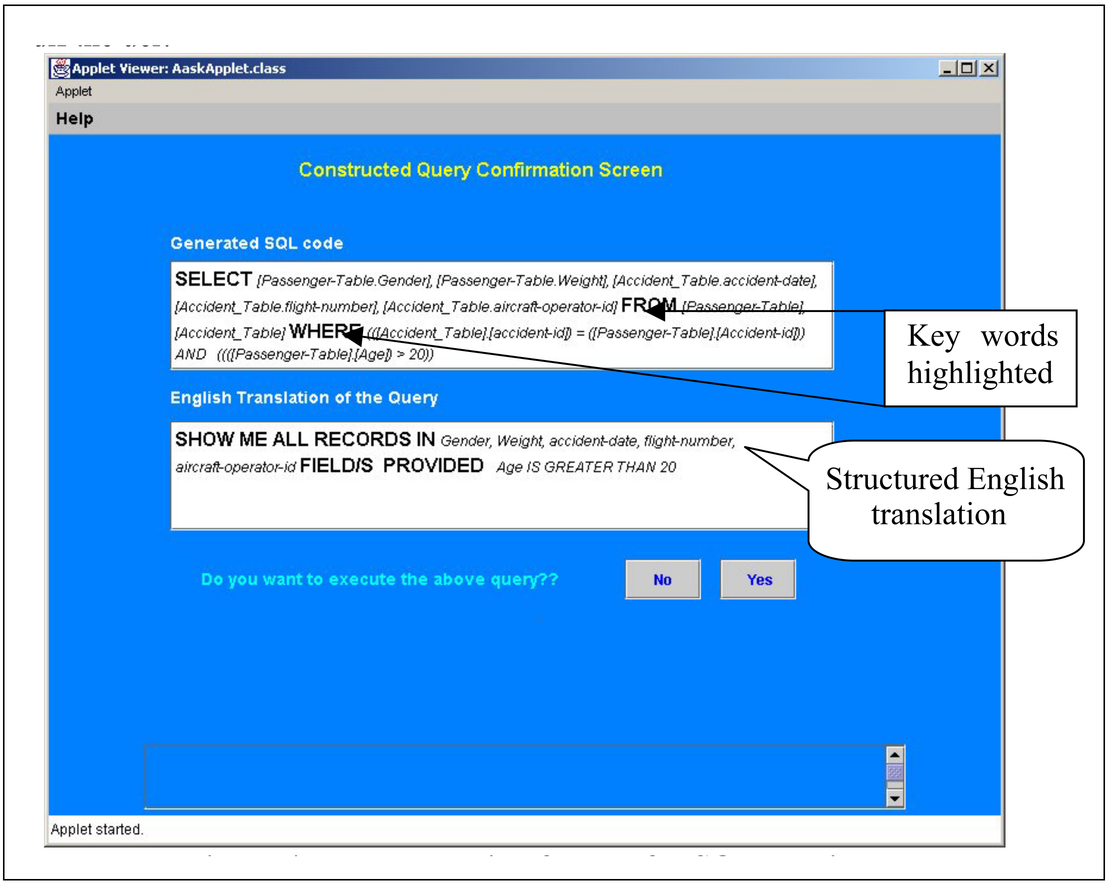

Figure 4 The translation feature for SQL queries

4.3.2 Inclusion of pre-constructed queries feature

This feature allows users to select a previously constructed query and run it. Two types of pre-constructed queries are included, namely non-modifiable and modifiable queries. Users can select and execute non-modifiable queries but they cannot modify them. On the other hand, in the case of modifiable queries, users can modify values of query constraint fields. This new feature is very useful and easy to use. All the pre-constructed queries are stored in the database and are loaded in the Query Builder upon successful user login.

4.3.3 Cutting and pasting query results

A number of potential and existing problems with the copy and paste facility have been rectified. These problems arose due to security issues relating to AASK using an operation to store data on the user's computer clipboard. Users now follow download instructions that are consistent with the access permissions. When data is copied from the results of a query to the user clipboard this is confirmed by a message as shown in Figure 5. Once placed on the user's clipboard, the query results can be analysed using any appropriate software such as MS Excel.

4.3.4 Support for aggregate functions.

For users who only require a simple statistical result the database standard Structured Query Language (SQL) aggregate functions are used to determine various statistics on sets of values. The following aggregate functions are included in the Query Builder:

- COUNT: Counts the number of rows containing not null values for the given column.

- SUM: Outputs the sum of all values in a given column.
- AVG: Outputs the mean or average of a given column.
- MIN: Outputs the minimum value in a given column.
- MAX: Outputs the maximum value for a given column.

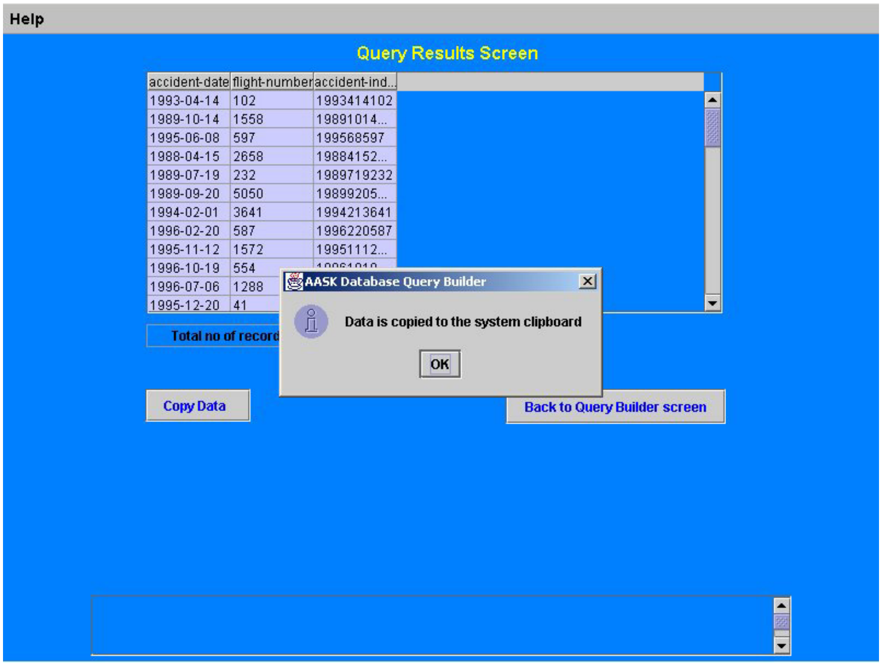

Figure 5 The cutting and pasting operation for query results

4.3.5 Support for SQL 'GROUP BY' and 'HAVING' clauses

This SQL clause specifies the groups into which output rows are to be placed and, if aggregate functions are included, calculates a summary value for each group. In other words the GROUP BY clause is used to combine rows with the same column values into a single row. The criterion for combining rows is based on the values in the columns specified in the GROUP BY clause.

The HAVING clause complements the GROUP BY clause by applying one or more conditions to groups after they are formed, which is similar to the way the WHERE clause applies constraints to individual rows. However, unlike in the case of the 'WHERE' clause, query constraints can have aggregate functions fields in the HAVING clause. In other words, the WHERE clause is used to exclude unwanted rows before they are grouped whilst the HAVING clause is used to filter records after they have been grouped.

4.4 Seat Plan Viewer

A major part of the AASK development has involved the upgrading of the Seat Plan Viewer (SPV). The SPV is a graphical tool that allows users to view a plan of the aircraft. Information concerning the exits, passengers and exits used by each passenger is also displayed. All the necessary data comes from the AASK database. The previous version of the database could only access the SPV when AASK was used in the stand-alone format (i.e. not through the Web). This was considered to be a considerable limitation of AASK as the SPV allowed for easier interpretation of AASK data. The stand-alone version of the SPV – written in Visual C++ – has been re-written in Java to make it accessible on the Web. As well as including all the previous functionality, the new Web-Based version includes additional functionality and a new user guide to starting the SPV was written.

The Seat Plan Viewer can be used independently of the Query Builder and is also only available to authorised users. The main features of the SPV are:

- Password protection – only available to authorised users;
- Accident information such as accident dates, identity number and aircraft type is displayed;
- Graphical output of seats and exits;
- Exit information – exit labels are provided to assist users to easily identify the position of each exit;
- Exits used by each passenger easily seen by colour coding;
- Viewing of either survivors or fatalities or both;
- Zoom in and zoom out facility – the plan for wide bodied aircraft can be quite crowded if it is to fit into one screen, so this zoom feature provides for improved legibility;
- Aircraft plan print facility;
- Passenger information – where available, the information displayed for each passenger consists of: gender, age, survivor / fatality, exit used, and seat label;
- Information about the travelling companions;
- Exits used – all the passengers who used an exit are highlighted.

Three of the most useful new features are now described in more detail:

4.4.1 Seat labels

Due to the large variety of cabin configurations, even within the same manufacturer's model, seat labelling is not at all obvious. In AASK V3.0 it was only possible to highlight the gender and age of the passenger sitting in a particular seat. In AASK V4.0, it is also possible to provide the seat label. This is especially useful as passengers often refer to one another by terms such as 'the man in 5A' or 'my wife was in 32 B'. It is illustrated in use in Figure 6.

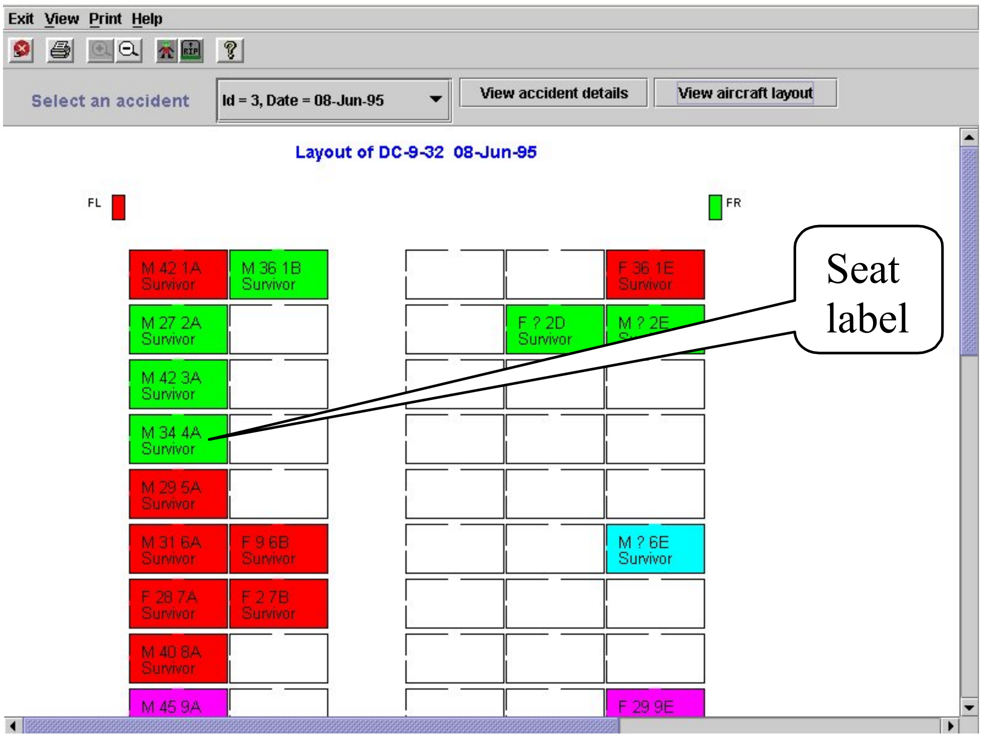

Figure 6 Seat labels shown by the SPV

4.4.2 Travelling companion information

This feature allows information relating to a passenger's companions to be highlighted. The information is also displayed in a message box. This not only provides quick and useful information about the passengers but also has been very effective in doing companion data validation. An example is illustrated in Figure 7.

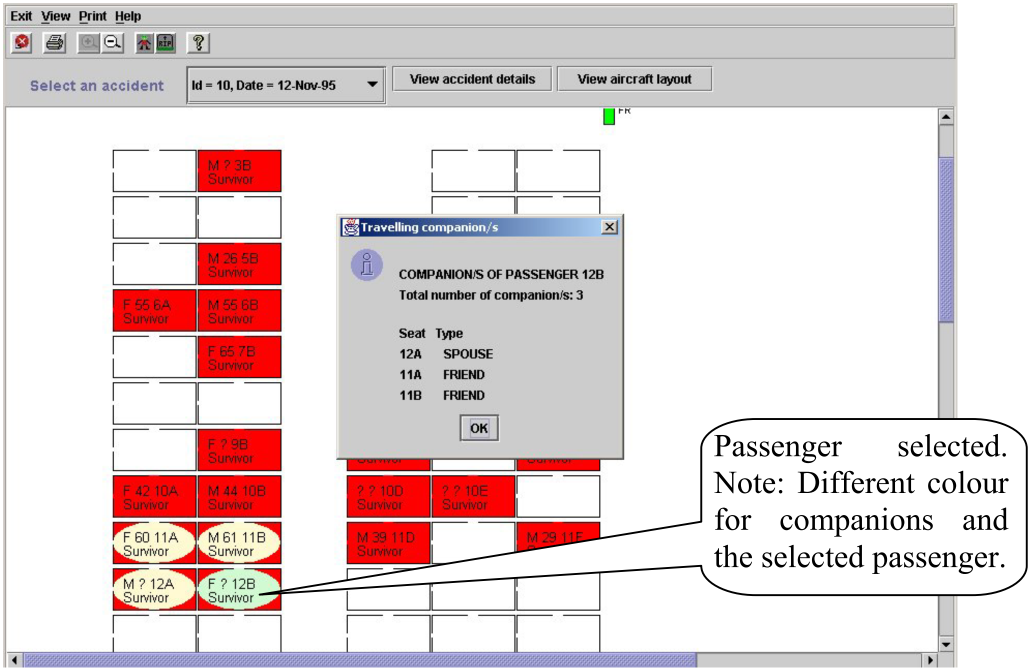

Figure 7 Companion relationships given graphic illustration in the SPV

4.4.3 Exits used

With this feature the user can click on an exit and view all the passengers that made use of the exit. When an exit is selected, all the passengers who used the exit are highlighted and the total number of passengers using the exit is displayed in a message box.

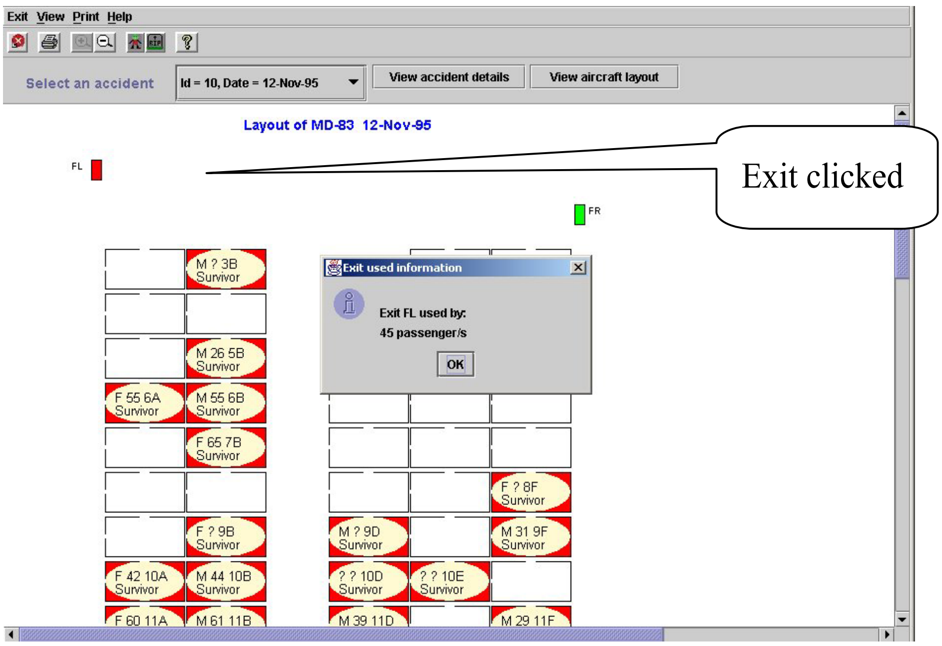

Figure 8 Graphic illustration of exit selection from the SPV

5 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 analyses 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 go on to extend the analysis to include the data from AASK V4.0 (see section 5.8).

The following analysis is a repeat of the analysis reported in [11,13] utilising the new database in AASK V4.0. The analysis will utilise different subsets of the data available within the database. Of the 105 accidents entered into AASK V4.0, 49 have detailed passenger and crew accounts and so are suitable for analysis (see Table 1 and Appendix B). 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 the 49 accidents.

5.1 Survival Rates

The survival rates – as determined from those accidents in which we have detailed passenger and crew data i.e. the 49 accidents shown in Table 1 – ranged from 24% to 100%. There were 35 accidents in which all passengers survived, however, it should be noted that some of these accidents are classed as precautionary evacuations.

Table 1: Survivor and reply rate analysis

ID	Date	Aircraft	Location	Pax on Bd	Max Pax	*Pax Load%	Survivors	Survivor%	Reply%	Entered%	Category of accident
1	14/04/93	DC-10-30	Dallas/Fort Worth Int A/P Texas	189	290	65.17	189	100.00	37.57	59.26	intact external fire
2	14/10/89	B-727-232	Salt Lake City Int A/P	12	148	8.11	12	100.00	58.33	91.67	intact internal fire
3	08/06/95	DC-9-32	Hartsfield Int A/P, Atlanta, Ga	57	113	50.44	57	100.00	61.40	63.16	intact external fire
4	15/04/88	DHC-8-102	Seattle-Tacoma Int A/P	37	37	100.00	37	100.00	89.19	100.00	ruptured external fire
6	19/07/89	DC-10-10	Sioux Gateway A/P, Iowa	286	287	99.65	176	61.54	37.50	48.30	ruptured external fire
7	20/09/89	B-737-400	Laguardia A/P NY	57	146	39.04	55	96.49	58.18	80.00	ruptured in water
8	01/02/94	SAAB-340-B	False River Air Park, Louisiana	20	34	58.82	20	100.00	90.00	95.00	intact external fire
10	12/11/95	MD-83	Bradley A/P, Connecticut	73	148	49.32	73	100.00	54.79	73.97	intact external fire
17	29/09/88	B-757-225	San Jose, Costa Rica	121	193	62.69	121	100.00	11.57	11.57	intact no fire
18	02/04/95	MD-11	John F. Kennedy Int A/P	37	271	13.65	37	100.00	27.03	32.43	intact external fire
19	30/01/91	Bae 31 Jetstream	Raleigh County Memorial A/P, Wv	17	19	89.47	17	100.00	76.47	82.35	intact external fire
30	30/07/92	L-1011-385-1	John F. Kennedy Int A/P	280	275	101.82	280	100.00	12.14	13.93	intact external fire
41	04/04/77	DC-9-31	New Hope, Georgia	81	100	81.00	21	25.93	85.71	100.00	ruptured external fire
42	29/12/80	DC-8-61	Sky Harbour Int A/P, Phoenix, Arizona	238	241	98.76	238	100.00	5.46	5.88	intact external fire
43	10/08/88	B-737-222	Little Rock, Arkansas	102	109	93.58	102	100.00	22.55	25.49	intact external fire
45	27/06/85	DC-10-10	Luis Munoz Marin Int A/P, Puerto Rico	257	268	95.90	257	100.00	15.95	18.29	intact in water
46	30/12/89	B-737-204	Tucson Int A/P	128	122	104.92	128	100.00	20.31	27.34	intact external fire
49	01/02/91	B-737-300	Los Angeles Int A/P	83	128	64.84	63	75.90	68.25	69.84	ground collision
51	03/12/90	DC-9-14	Detroit Metro A/P, Michigan	40	78	51.28	33	82.50	51.52	51.52	ground collision
52	03/12/90	B-727-251	Detroit Metro A/P, Michigan	146	146	100.00	146	100.00	9.59	9.59	ground collision
53	28/02/84	DC-10-30	John F. Kennedy Int A/P	163	229	71.18	163	100.00	9.20	11.66	intact in water
54	23/01/82	DC-10-30CF	Logan Int A/P Boston	200	354	56.50	198	99.00	27.78	29.80	ruptured in water
55	31/08/88	B-727-232	Dallas/Fort Worth Int A/P Texas	101	148	68.24	89	88.12	74.16	98.88	ruptured external fire
59	25/10/86	B-737-222	Charlotte Douglas Int A/P, Nc	114	118	96.61	114	100.00	2.63	100.00	intact no fire
60	09/01/83	CV-580	Brainerd A/P, Minnesota	30	48	62.50	29	96.67	65.52	75.86	intact no fire
61	15/11/87	DC-9-14	Stapleton Int A/P, Colorado	77	83	92.77	52	67.53	73.08	100.00	rupture no fire
62	08/03/98	DC-10	Manchester A/P England	N/D		N/D				127/0	intact external fire
65	29/04/93	EMB-120RT	Pine Bluff A/P, Arkansas	27	30	90.00	27	100.00	77.78	88.89	intact no fire
66	02/06/83	DC-9-32	Greater Cincinnati Int A/P, Kentucky	41	100	41.00	18	43.90	77.78	100.00	intact internal fire
67	02/07/94	DC-9-31	Charlotte, North Carolina	52	103	50.49	15	28.85	60.00	93.33	ruptured external fire
70	22/08/85	B-737-236	Manchester A/P England	131	130	100.77	78	59.54	94.87	100.00	intact external fire
72	13/08/98	CRJ	Knoxville, Tennessee, USA	46	50	92.00	46	100.00	39.13	45.65	intact no fire
75	25/04/98	DC-9	Detroit Metro A/P, Michigan	26	0	N/D	26	100.00	26.92	26.92	intact external fire
78	06/06/98	Bae 31 Jetstream	Evansville A/P, Indiana, USA	19	30	63.33	19	100.00	57.89	63.16	intact no fire
79	09/07/98	A-300B4-605R	Luis Munoz Marin Int A/P, Puerto Rico	243	267	91.01	243	100.00	20.99	27.57	intact external fire
80	09/02/98	B-727-223	O'Hare Int A/P, Chicago	116	146	79.45	116	100.00	61.21	63.79	intact no fire
81	27/08/98	MD-82	Phoenix A/P, Arizona, USA	75	142	52.82	75	100.00	32.00	34.67	intact no fire
84	19/01/99	ATR-72	St Louis A/P, Missouri, USA	17	64	26.56	17	100.00	41.18	41.18	intact external fire
87	01/11/98	B-737	Atlanta A/P, Georgia, USA	100	128	78.13	100	100.00	27.00	31.00	intact external fire
89	12/11/98	DHC-8	Boston A/P, Massachusetts, USA	18	36	50.00	18	100.00	11.11	11.11	intact no fire
90	26/12/98	MD-88	Dallas/Fort Worth Int A/P Texas	45	142	31.69	45	100.00	35.56	40.00	intact external fire
92	08/01/99	CRJ	Covington A/P, Kentucky, USA	5	50	10.00	5	100.00	80.00	80.00	intact no fire
95	29/07/98	B-737	Newark A/P, New Jersey, USA	109	128	85.16	109	100.00	25.69	33.03	intact no fire
96	20/04/98	B-727	O'hare Int A/P, Chicago, USA	149	146	102.05	149	100.00	40.94	53.69	intact external fire
98	17/02/99	A-320	Columbus, Ohio, USA	26	150	17.33	26	100.00	30.77	30.77	intact no fire
99	08/05/99	SAAB-340-B	John F. Kennedy Int A/P	27	34	79.41	27	100.00	44.44	62.96	intact no fire
100	01/06/99	MD-82	Little Rock, Arkansas	139	139	100.00	129	92.81	69.77	87.60	ruptured external fire
101	22/06/99	B-737	Scotsbluff, Nebraska, USA	63	128	49.22	63	100.00	34.92	39.68	in flight fire
110	27/03/98	DC-9	O'hare Int A/P, Chicago, USA	27	96	28.13	27	100.00	3.70	3.70	intact internal fire

*Pax loading that exceeds 100% is due to infants not requiring seats

5.2 Gender and Age Distribution

Of the 1859 records of passengers in AASK V 4.0 the age is given for 1288 (69%). Of these, 721 (55.98%) were male and 558 (43.32%) were female, the remainder being passengers where gender was not recorded. The average age of all survivors where age and gender is known is 40.3 yrs with the average age of females slightly lower at 39.9 yrs and the average age of males slightly higher at 40.8 yrs. Table 2 shows the breakdown of the survivors by gender and age. Compared with the data in AASK V3.0, we find the average age of the survivors has increased slightly. The oldest surviving female was 86 years old while the oldest surviving male was 80 years old.

Table 2: Breakdown of survivors by gender and age

Gender	# Pax	# Pax >18	# Pax with no age data	Mean Age (years)	Mean Age (years)*
MALE	721	670	200	40.8	43.2
FEMALE	558	512	202	39.9	42.8
N/D	9	3	169	15.2	42.3
All Pax	1288	1185	571	40.3	43.0

*Passengers less than 18 years excluded

The age distributions follow a bell shaped curve with low numbers in the under 18 age group being matched by low numbers in the over 70 age group as shown in Figure 9.

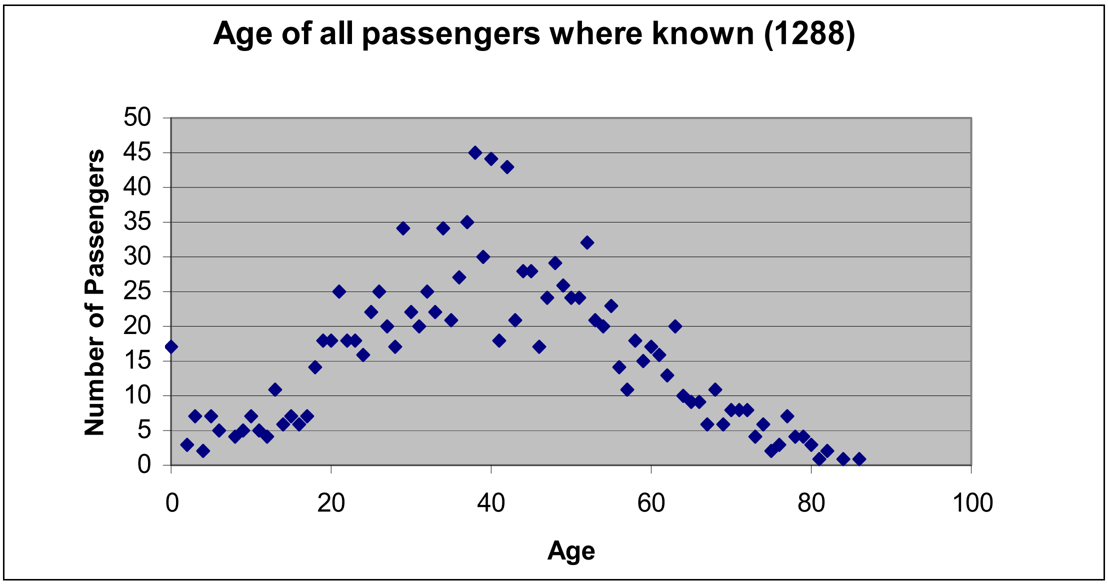

Figure 9 The age distribution of all passengers where age is known

When the age distribution is broken down by gender there is a large disparity in the numbers travelling in the 35 - 55 age groups as can be seen in Table 3. This difference can also be graphically illustrated in Figure 10. The difference is thought to represent the gender difference in the professions travelling.

Table 3:

Age	<2	2 - 12	13 - 18	19-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90
F	7	22	24	69	64	58	57	44	50	51	34	28	17	15	13	4	1
M	5	26	27	66	53	64	124	93	70	68	41	40	23	13	8		

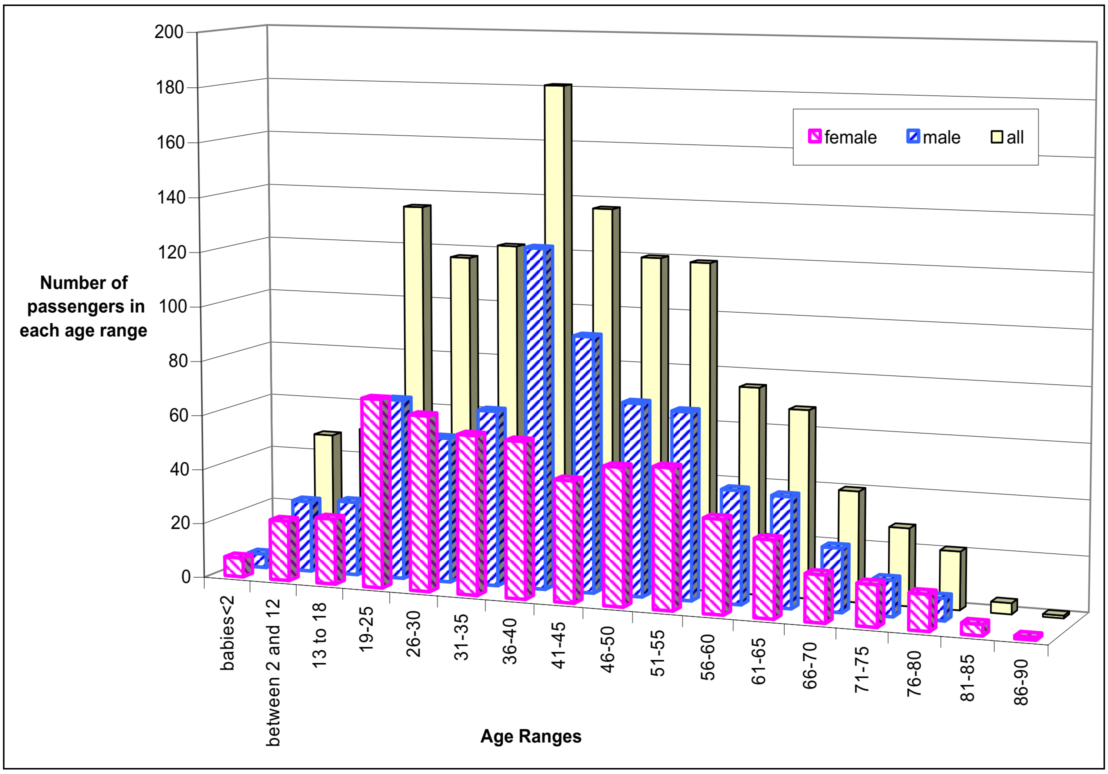

Figure 10 The age and gender distribution of passengers where known

5.3 Seat Belt Difficulty

This analysis concerns one of the most crucial aspects in an evacuation, the response time of the passengers, i.e. how quickly the passengers responded to the call to evacuate. In aircraft evacuations the response time of passengers tends to be relatively short, as there is a high degree of apparent awareness of the seriousness of the incident. However, some passengers, despite a short response time, are unable to commence their evacuation due to difficulties leaving their seat, either due to the aisle being full of passengers, or simply because they had difficulties releasing their seat belt. In this example analysis, the latter of these cases is investigated.

In AASK there are five possible answers to the seat belt difficulty field, two are for null responses (data not available/no difficulty) and the other three describe the kind of difficulty encountered. The first level is "PROVIDED HELP TO OTHER PAX" – indicating that the passenger aided at least one other passenger with their seat belt (further fields allow a description of who and where). The second level is "DIFFICULTY – REQUIRED NO HELP" – indicating that the passenger did encounter a difficulty releasing the seat belt, but was eventually able to undo it without any external assistance. The final level is "DIFFICULTY – REQUIRED HELP", indicating that the passenger experienced some kind of difficulty and required external assistance in order to release the seat belt (further fields allow a description of who/how).

In total, there are 111 passengers associated with a seat belt difficulty falling into one of these three categories. This compares to 81 in the earlier analysis. A simple analysis based on age and gender for each of the three categories is shown in Table 4. It should be noted that this analysis has collected all passengers that have experienced some kind of difficulty with releasing their seat belt, irrespective of the nature of the difficulty. For instance, included in this analysis are those passengers who did not know how to release their belts, those who were unable to release their belts because of environmental conditions e.g. could not see the seat belt release mechanism, those who could not release their belts because of injury e.g. unconscious, fractures, burns, etc.

As reported above, the average age of the survivors is 40.3 years, while the average age of the males and females is 40.8 years and 39.9 years respectively. In comparison to the figures shown in Table 4, this suggests that there is little difference in ages between the general survivor and those experiencing seat belt difficulty.

Table 4: Seat Belt Difficulty – Age and Gender Breakdown

Category	Gender	Number	Mean Age (yrs)	No Age Data
PROVIDED HELP TO OTHER PAX	Male	18	42.4[1](40.4)	3
	Female	8	38.9	1
DIFFICULTY – REQUIRED NO HELP	Male	33	43.8	10
	Female	22	43.2*(41.5)	2
DIFFICULTY – REQUIRED HELP	Male	10	44.0*(39.3)	3
	Female	20	44.7*(40.4)	1
All AASK Passengers	Male	921	43.2*(40.8)	200
	Female	760	42.8*(39.9)	202
	Unknown	178	42.3*(15.2)	169

1. Children (<18 years) excluded, number in brackets indicates mean age including children's data.

5.3.1 Gender analysis relating to seat belt difficulty

The passenger seat belt difficulties analysis is broken down by gender into three categories; those passengers who helped others, those passengers who received assistance and those passengers who managed alone. The number of passengers in these categories is such that statistical analysis is possible. From the initial analysis it appears that there is a difference in the observed numbers of passengers in these categories and those expected from the distribution of the general database population where there were 921 males and 760 females (see section 5.2). This observation is consistent with that made using AASK V3.0 and is illustrated in Figure 11.

From this distribution, it is clear that males have fewer problems with seat belts than females and that males are also more likely to render assistance to others than females. Furthermore, the number of males who rendered assistance or who managed alone is more than would be expected from the overall gender proportions. Similarly, the number of females who managed alone or who helped others is significantly less than would be expected from the overall gender mix. Finally, the number of males who received help is significantly less than would be expected from the overall gender mix, while the number of females who received help is significantly greater.

Within the category of those experiencing seat belt difficulty, whether requiring help or not, are mutually exclusive cases making it possible to estimate the significance of the gender in each case. A test was conducted on this data to test the hypothesis that gender and seat belt assistance are related. The resulting value of 5.52 was found to be significant at the 5% level implying that in the situation where a passenger gets into difficulty with their seat belt there is a link between the gender of the passenger and whether they require help.

This gender bias could be due to a number of factors, including:

- Males may be physically stronger than females and therefore are more able to deal with buckle difficulties.
- Males may be less prepared to seek assistance than females and so they continue to struggle with the buckle and eventually succeed in releasing the belt.

- In partners travelling together it may be more likely that the male will assist the female.

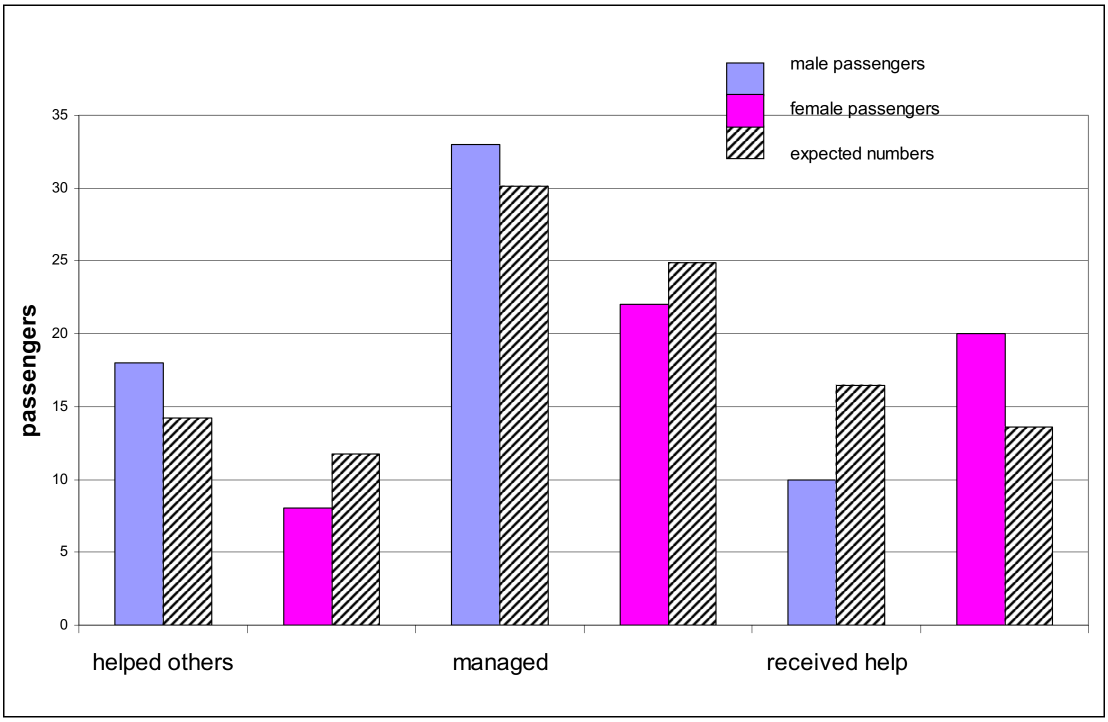

Figure 11 Comparison of expected and observed values for gender numbers in seat belt difficulty categories

5.3.2 Age analysis relating to seat belt difficulty

It is possible to further refine the analysis of the seat belt difficulty cases to consider the age of the person experiencing the difficulty. This analysis requires that the passengers in the first category (i.e. provided help to others) are removed from consideration. The remaining records must be further sorted with reference to the field "seat belt info".

From this analysis, three categories of seat belt difficulty were accepted for consideration. These are:

- Unfamiliar with buckle release mechanism:

  e.g. "It took him 5 to 6 seconds to determine how to undo his seat belt."

- Environmental related complications excluding immersion in water:

  e.g. "could not release seat belt due to smoke reduced visibility problems. Erroneously tugged on the buckle instead of undoing it."

- Buckle location:

  e.g. "thought seat belt buckle was at side as in a car not in centre."

Using these criteria, the number of passengers experiencing difficulty with seat belt release is reduced to 69. The age distribution of passengers experiencing difficulties with releasing the seat belt is depicted in Figure 12. The age distribution suggests that older passengers appear to be more likely to experience difficulties with seat belts than younger passengers. In this Figure it can be seen that the general population distribution is somewhat skewed to the left (younger passengers) whereas the distribution for those involved with seat belt difficulties has higher values to the right (older passengers). However, the mean age of those experiencing seat belt difficulties is 41.8 years, while the average age for the entire population is 40.3 years. This suggests that there is not a significant difference between the mean age of the general population and those experiencing seat belt difficulties.

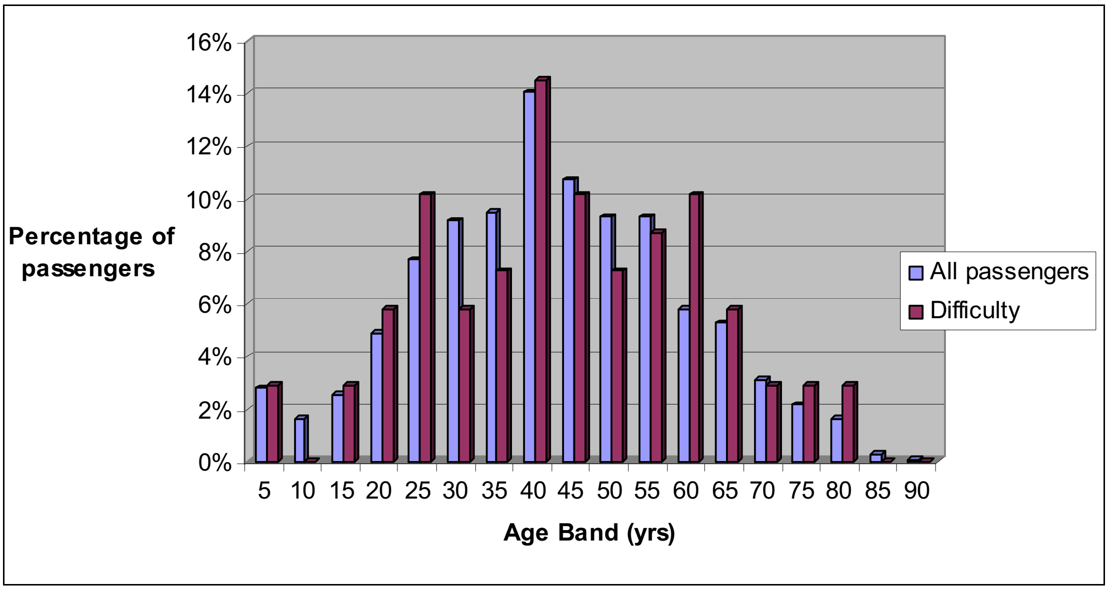

Figure 12 Age distribution of passengers involved in seat belt difficulty.

5.4 Seat Climbing

From the data in AASK V3.0, 40 passengers were recorded as climbing seats [11, 12, 13] as part of their exiting behaviour, whereas in AASK V4.0 there are 91 passengers exhibiting this behaviour. It is important to note here that generally, passenger accident questionnaires do not contain explicit questions regarding seat jumping. This information is extracted from the survivor interview transcripts. Whether or not this information is mentioned is therefore left to the passenger making the statement. If they do not feel that this is relevant information, then no mention is likely to be made of this behaviour, even if it did occur. However, for the data entered into AASK V4.0 based on the NTSB evacuation study [10], passengers were specifically asked about their own and other passengers' seat climbing. This resulted in an increase in the number of reports of seat climbing.

Four accidents (B-737-236 at Manchester (ID 70), B-727-232 at Dallas/Fort Worth (ID 55), B-737-300 at Los Angeles (ID 49) and MD-82 at Little Rock (ID 100)) accounted for 73 citations of seat climbing. These incidents all involved serious fires and damage to the aircraft and consequently had very full accident reports which may have led to a higher probability of this behaviour being noted.

Table 5 Number of seats involved in seat climbing incident

Number of passengers	Number of seats climbed
23	1
4	2
4	3
2	5
1	13
57	No information

Of the 91 passengers that reported climbing over seats, 85 passengers reported both their age and gender and of these, 41% were male and 59% were female. In the earlier study there appeared to be no age bias for this activity, however, the more recent results suggest that females may have a greater tendency to climb seats. However, it should be noted that of the 51 new seat climbing accounts, 43 were from a single accident (the MD-82 at Little Rock). Furthermore, in this accident amongst the passengers was a large choir group and the population distribution consisted of a minimum of 25% female adult passengers. This may explain the increase in female seat climbing compared to the earlier analysis.

The mean age for the passengers providing age and gender information who reported that they were involved in seat climbing activities is 32.9 years, significantly less than the mean age of the overall population of survivors (mean age 40.3 years). This may suggest that younger passengers have a greater tendency to climb over seats. Furthermore, the mean age of the male passengers involved in this activity is 35.5 years, while the mean age of the female passengers is 31.1 years. The mean age for female seat climbers has increased significantly from that in AASK V3.0 (which was previously 22.7 years), while the mean age for males has remained virtually unchanged. In the female population reporting seat climbing, nine were aged 46 years and over. For the remaining 41 females (82% of all females both climbing seats and providing age), the average age is 25.4 years. These results suggest that there are more females climbing seats of various ages than previously estimated, but largely only younger females are prepared or able to tackle this task.

The number of seats reportedly climbed by passengers is noted in Table 5. Of the 91 passengers who reported climbing over seats, 34 cited the number of seats they went over. Of these, the majority (23 passengers) only attempted to climb over a single seat (67.6%), with only 11 passengers (32.3%) attempting to climb over more than two seats. One individual reported climbing over 13 seats! The small number of seats being climbed suggests that the passengers are simply attempting to get around a local obstruction in the aisle. However, analysis of the starting positions of seat climbing passengers suggests that those passengers seated within two rows of an exit will be much more likely to attempt this behaviour. This may imply that passengers seated close to a viable exit but who are caught in their seats due to aisle congestion are likely to climb over seats to get to a viable exit. This may result in further congestion within the exit row as passengers climbing over seats force their way into the exit row.

Of the 91 passengers that reported climbing seats, 42 passengers provided a reason for jumping the seats, as shown in Table 6. Of those providing reasons for climbing over seats, 41% (17/42) claimed that it was their shortest route to an exit, while 24% (10/42) cited congestion in the aisle or slow moving queues as an explanation.

The specific reasons cited by passengers are also very revealing, for example;

"I first started to go across the aisle but this exit was blocked with passengers. I then decided to climb over a couple of seats and try to go out of the front".

"Once the plane crashed and we were ordered to evacuate by the pilot, we were unable to get to the aisle. It was too crowded with people waiting to exit. We finally climbed over the seat".

"People were filled in the aisle. The person next to me hurdled the chairs, so I followed him".

"I went to the end of my row of seats and waited to get into the aisle, the aircraft stopped about this time……..I couldn't get into the aisle [because of the crowd] so I decided to go over the seats, the middle was flat and down, so I climbed over them and made my way to the front….".

Table 6 Reasons cited by passengers for climbing over seats

Reason Cited	No. Males	No. Females
N/D (no reason given)	19	29
Shortest route to exit	12	5
Aisle too congested	4	5
Aisle blocked by accident damage	1	3
Queue moving too slowly	1	0
Route to aisle blocked by pax	0	3
Environmental (e.g. smoke)	0	3
Aisle blocked by debris	1	4

5.5 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 had 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.

5.5.1 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 13. 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.

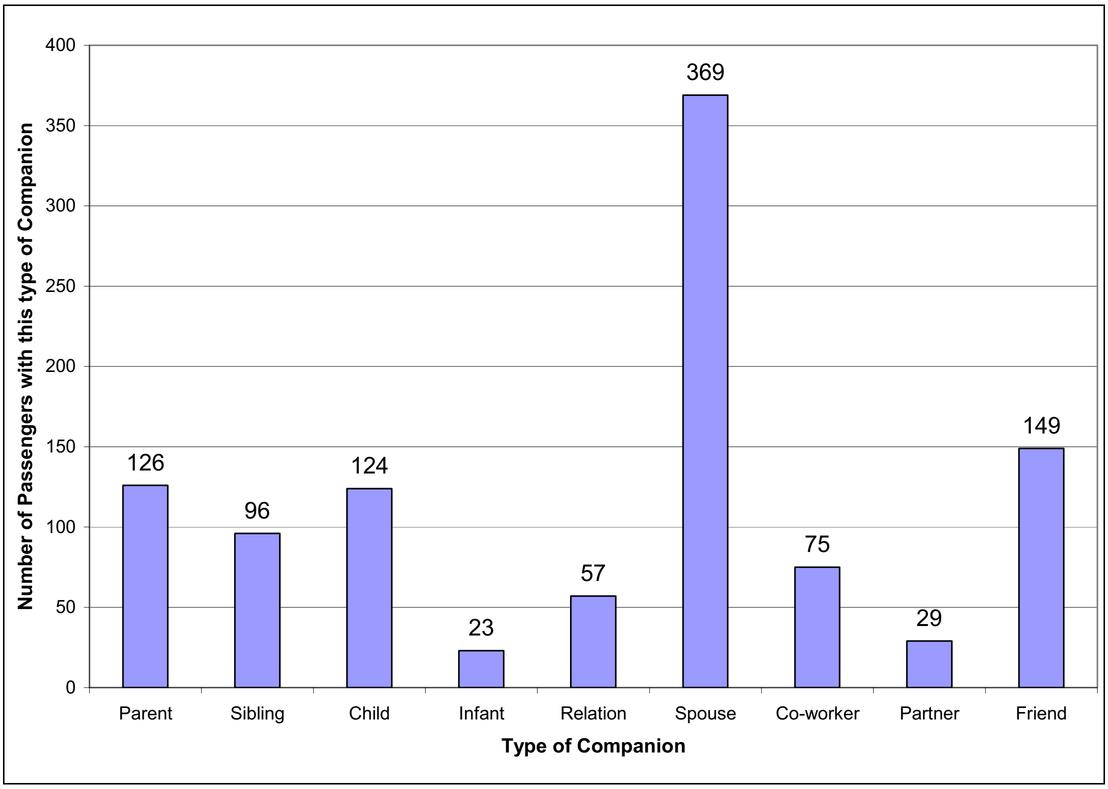

Figure 13 Types of companion relationships found amongst the 947 passengers in AASK stating that they travelled with a companion

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.

5.5.2 **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 by 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 7. 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 7. 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 13). 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.

From Table 7 we note that business associates are not cited as requiring assistance. All examples of assistance cited in AASK V3.0 and V4.0 were 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 7. The latter interpretation is somewhat unlikely as for every other type of companionship, including 'unknown relationship', assistance WAS reported.

Table 7 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 daughter, 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 males	6	2
Friend	14	3 females, 11 males	3	11
Unknown relationship	3	1 female, 2 males	1	2
TOTAL	**104**		**36**	**68**

5.5.3 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 members 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 year old 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.

5.6 Analysis of Exit Usage

Here we consider nearest exit usage, overall exit availability, a comparison between certification and accident exit usage and the relative location of fatalities and survivors with regard to exit positioning.

5.6.1 Nearest exit usage

Within the aviation industry it was a commonly held belief that most passengers evacuate via their most familiar exit, thereby ignoring closer but unfamiliar emergency exits. As is quoted in an aviation safety report [16],

'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 (see Table 8). This analysis is based on passenger accounts that clearly state both the seating location and exit used by the passenger. However, in some cases either the seat location or exit used is not clearly stated by the passenger. In most of these cases, the missing information can be inferred from other information such as other passenger accounts. Both results are presented, values appearing after the "/" include inferred data.

The AASK database reveals that 879 passengers reported both their starting location and exit usage (46% of those replying), as shown in Table 8. If inferred information is included, this number increases to 1441 passengers (75% of those replying). Of these, only 291/503 passengers (15% / 26%) did not use their nearest serviceable exit (see Table 8). Of the 291/503 passengers that did not use their nearest exit, 190/268 passengers supplied reasons for their actions. Examination of the explanations supplied by these passengers revealed the reasons given in Table 9.

Table 8 Passenger use of nearest exit. Note values after the "/" include passengers where exit use and/or seat location is inferred.

Category	**Result**
Pax reporting exit usage	879/1441
Pax not using nearest available exit	291/503
% of Pax with reported exit usage not using nearest available exit	15.2% / 26.2%
Pax not using actual nearest exit (available or not)	355/598

Table 9 Reasons for exit choice given by those passengers NOT using nearest exit. Note values after the "/" include pax where exit use and/or seat location is inferred.

Reason for Exit Choice	**Number of Passengers**
N/D	98/230
N/A (e.g rescued)	3/5
Nearest exit was/became unavailable	35/54
Followed Cabin Crew instructions	53/72
Followed other passengers	27/38
Shorter queue than other exits	16/20
Choice made before egress	11/16
Passenger thought this was his/her nearest exit (when it was not)	27/37
Found exit during egress	9/12
Followed emergency lights	4/4
Only available exit	5/6
Followed companion	2/2
Helped through exit	1/7

While by no means complete, this analysis suggests that an overwhelming 89% of those passengers reporting their exit usage, either used or had a reason not to use their nearest exit. (If the passengers with inferred data is included, this figure becomes 84%). The remaining 11% / 16% did not supply any reason for not using their nearest exit, however, this is not to say that they did not have a reason for their actions.

5.6.2 Distance and direction traveled by survivors during egress

It is also interesting to consider the direction travelled by the passengers when evacuating. Shown in Table 10 is the direction of travel for the 879/1441 passengers for which we know the direction of travel. The results suggest that 60% / 60% travelled forward, 34% / 35% travelled towards the rear, while the remainder were situated within an exit row. These results may suggest that passengers have a propensity for travelling forward.

Table 10 Direction of travel and distance travelled (seat rows) for passengers, where starting locations and exit usage is known or inferred. Note values after the "/" include pax where exit use and/or seat location is inferred.

Direction	# Passengers	Travelled Min. Distance?	# Passengers	Mean Distance
Forward	530 / 866	Yes	339 / 540	4.4 / 4.5
		No	191 / 326	11.3/ 12.4
Aft	300 / 511	Yes	200 / 334	5.1 / 4.9
		No	100 / 177	10.7 / 11.3
Exit Row	49 / 64	Yes	49 / 64	0

However, of those passengers choosing to travel forward, 64% / 62% have selected their nearest exit, while for those choosing to travel towards the aft, 67% / 65% have selected their nearest exit. This suggests that the overriding inclination of the passengers is to exit via their nearest exit, rather than to travel forward. In addition, this further suggests that exit selection is based on a rational decision, at least for the survivors.

The mean distance travelled (in terms of seat rows) by survivors in evacuating is 6.5/ 7.0 seat rows. This compares with 6.1/6.3 seat rows found in the study using AASK V3.0 [11, 12, 13]. Furthermore, those passengers who select their nearest exit – excluding those in exit rows – travel approximately 4.7/4.7 seat rows regardless of whether they travel forward or aft, while those who do not travel towards their nearest exit travel at least twice as far.

It is interesting to compare these values with data generated in a study conducted by Snow et al. [18] in 1970. The mean travel distance for survivors determined by Snow et al. in his sample of three accidents was 4.1 seat rows. The difference between the average distance travelled by survivors in the two studies could be due to a number of factors such as the small number of accidents in the Snow sample, the gradual increase in aircraft size since the earlier Snow study, improvements to survivability characteristics of aircraft since the Snow study, the severity of the accident conditions in the Snow study etc.

This type of analysis provides essential insight to computer modellers attempting to simulate the evacuation process. It also provides a means for challenging the "myth" concerning exit usage. Most importantly however, this type of analysis is extremely valuable in aiding our understanding of the behaviour of people in real accidents.

The finding concerning exit usage may have implications for cabin crew procedures. It is known that cabin crew are able to exert a considerable influence on passenger behaviour during an evacuation under controlled experimental conditions [20,21,22]. However, in real emergency situations, where passengers may have a choice of directions in which to escape, they may ultimately ignore crew commands and attempt to use their nearest exit. This is an area requiring further investigation both through the historical record and through controlled experimentation.

5.6.3 Distribution of exits used in evacuations involving aircraft with three exit pairs

As an extension to the previous analysis, it is possible to examine the exit usage in terms of exit location. This analysis is restricted to aircraft with three exit pairs (see Figure 14) where at least one exit from each pair was available. This was compared with the results from two equivalent aircraft evacuation certification trials [15]. An analysis of this type would highlight how closely exit usage in these trials represents that found in actual accidents. It is important to note that the 90-second certification trial is intended to be an industry benchmark against which aircraft designs are compared and tested. However, the 90-second certification trial scenario is not intended to represent a real life situation.

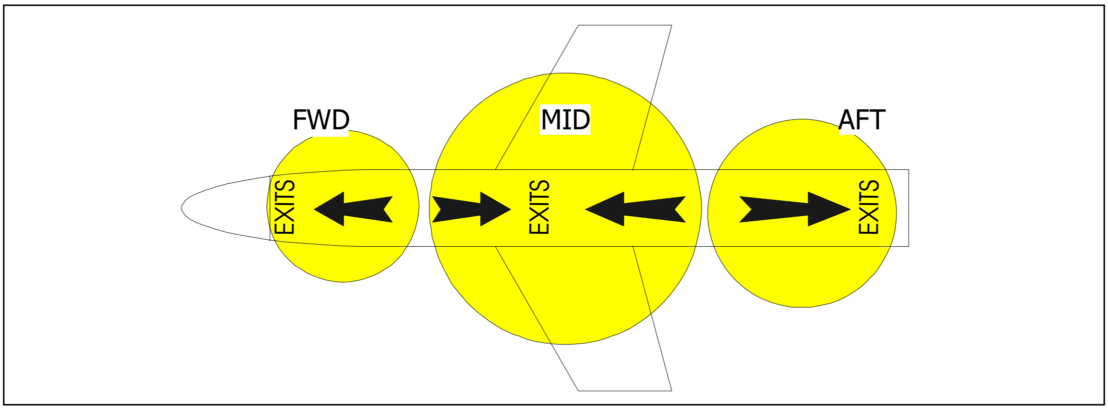

Figure 14 Likely exit usage distribution for an aircraft with three exit pairs

Of the accidents in AASK, eight accidents with three exit pairs were found to be suitable for analysis (see Table 11). The selection criteria required that at least one exit of each exit pair in the aircraft be available during the evacuation. Only three exit pair aircraft with seating capacities exceeding 44 seats (the 90 second trial criterion), were considered. The results from the analysis were normalised so that the percentages shown represent the percentage of the total passengers where exit usage is known for each aircraft. It is important to note that with the exception of accident 7, no passenger fatalities were reported in these accidents. There were two fatalities in accident 7. These passengers were killed by crash trauma while still seated. Emergency personnel extricated five other passengers via a fuselage break. In all the other cases, passengers self-evacuated via exits.

This analysis shows that unlike the behaviour noted in certification trials (see Table 12), on average, the majority of passengers tend to utilise the central Type III exits. However, this trend is reduced when compared to the analysis undertaken using AASK V3.0 [11, 12, 13], with only 38.8% of passengers utilising the centre exit compared with 49.6% in the earlier study. In the V3.0 analysis, the analysis was restricted to only three suitable aircraft involved in accidents, while in this study, the number of aircraft has increased to eight.

Table 11 Exit usage in terms of percentage of passengers using each generalised exit position. Information in square brackets identifies exit type.

Accident reference Appendix B	Pax Loading	Fwd (%)	Mid (%)	Aft (%)
(7)	39.0%	44.7 [I]	50.0 [III]	5.3 [I]
(43)	93.6%	19.2 [I]	61.5 [III]	19.2 [I]
(59)	96.6%	39.5 [I]	37.2 [III]	23.3 [I]
(80)	79.5%	23.6 [I]	58.3 [III]	18.1 [I]
(87)	78.1%	17.3 [I]	48.3 [III]	34.5 [I]
(90)	31.7%	27.8 [I]	16.7 [III]	55.6 [I]
(95)	85.2%	38.9 [I]	27.7 [III]	33.3 [I]
(96)	102.0%	6.3 [I]	11.3 [III]	82.5 [I]
Mean	**75.8%**	**27.2**	**38.8**	**34.0**

However on closer examination, not all the accidents included in this analysis are appropriate and so these should be discarded from the analysis. Accident reference 7 had a passenger loading of only 39%, while accident reference 90 had a passenger loading of only 31% of which less than half provided exiting information. These aircraft should be discarded due to the low numbers of passengers for which we have exit usage as they do not provide an appropriate basis for comparison with certification conditions. Accident reference 95 should be discarded from this analysis because it included many passengers who, while intending to use the mid Type III exit, were forced to relocate forward and aft exits due to passengers on the wing backing up to the exit. Accident reference 96 should also be discarded because it was a passenger-initiated unplanned emergency evacuation in which the flight crew halted and ordered a deplaning via the rear tailcone exit.

Table 12 Generalised passenger exit usage for aircraft with three exit pairs in 90-second certification trials.

Aircraft	Fwd %	Mid %	Aft %
1	40	20	40
2	27	37	36
Mean (%)	**33.5**	**28.5**	**38**

Several other possible candidate aircraft were excluded from the above analysis. This was due to the circumstances of the incidents. In one case all passengers exited from the tailcone exit, in another incident, one of the exits was jammed and was only made available late in the accident sequence, while in a third incident one of the available exits was not used due to smoke.

When these accidents are removed from the analysis, a different picture emerges (see Table 13). The trend to utilise the central exits is shown to be much stronger in accidents than in the certification trial. The average number of people using the centre Type III exits has increased to 51.3% (see Table 13) compared to 28.5% (see Table 12) observed in certification trials. However, it is important to note that results presented in Table 13 only refer to four accidents.

In accidents, there appears to be a biased trend for exit usage in the midsections (i.e. the nearest exit for the majority of passengers) of the aircraft. Yet in the certification trials, the mean load on each exit pair is far more even and furthermore, in one aircraft fewer passengers use the midsection exits, the reverse of that seen in accidents. The most probable reason for this lies in the behaviour of the passengers. Essentially, in an accident, the passengers have a higher motivation to escape and tend to do so by what they perceive to be the most direct method – their nearest exit. Cabin crew procedures used in certification trials work quite well and achieve a well-balanced evacuation with most of the exits working in an efficient manner. However, in these circumstances, the passengers are working in a highly co-operative manner as opposed to the competitive behaviour likely to be exhibited by passengers in life threatening situations. This suggests that formulating cabin crew procedures on the basis of certification experience may be misleading in terms of their actual effectiveness.

Table 13 Exit usage in terms of percentage of passengers using each generalised exit position during higher loaded, authorised evacuations with minimal exit redirection.

Accident reference Appendix B	Pax Loading	Fwd (%)	Mid (%)	Aft (%)
(43)	93.6%	19.2 [I]	61.5 [III]	19.2 [I]
(59)	96.6%	39.5 [I]	37.2 [III]	23.3 [I]
(80)	79.5%	23.6 [I]	58.3 [III]	18.1 [I]
(87)	78.1%	17.3 [I]	48.3 [III]	34.5 [I]
Mean	**87.0%**	**24.9** [I]	**51.3** [III]	**23.8** [I]

5.6.4 Individual exit availability analysis

In the previous analyses, exit usage has been examined from a passenger perspective. In this analysis, the exits that are actually available for use during the accident are examined. The accidents used in this analysis ignore all those where the aircraft ended up in water or where substantial damage occurred to the aircraft fuselage, i.e. cases where there were significant breaks in the fuselage, and include only those accidents where information is known about all the exits. Unless passengers actually used an exit, the exit is only considered to be 'available' when the exit and its evacuation assist means are physically and fully/safely functional, and passengers are permitted to use it by cabin crew.

Table 14 Aircraft used in three exit pair aircraft exit availability analyses

Accident reference	Aircraft	Type of evacuation
2	B727-232	Unplanned Emergency
16	MD-82	Unplanned Emergency
43	B737-222	Unplanned Emergency
46	B737-204	Unplanned Emergency
49	B737-300	Unplanned Emergency
52	B727-251	Post-Incident Deplaning
59	B737-222	Unplanned Emergency
70	B737-236	Unplanned Emergency
73	MD-88	Planned Emergency
80	B727-223	Unplanned Emergency
81	MD-82	Precautionary
87	B737	Unplanned Emergency
90	MD-88	Unplanned Emergency
95	B737	Planned Emergency
96	B727	Unplanned Emergency
98	A-320	Planned Emergency
101	B737	Planned Emergency
102	B737	Planned Emergency
105	MD-80	Unplanned Emergency

In accident 46 for example, aft exits were successfully opened but the slides were not deployed due to orientation of the fuselage, and in accident 70 an aft exit and slide were successfully deployed but smoke prohibited their use. Passengers in either accident did not use these exits. Exits not used due to the prevailing conditions or through specific crew instruction are considered unavailable. Using this definition, 19 accidents were selected, each one involving an aircraft with three pairs of exits (see Table 14). All cases included here have exit pairs in forward, mid and aft positions.

The frequency of exit availability for the aircraft involved in these 19 accidents is displayed in Table 15. This analysis reveals a very different result from that conducted using the AASK V3.0 database [3] – which involved seven aircraft (accidents 2,43,46,49,52,59 and 70 in Table 14). Here we find that at the FWD generalised location, one exit is available in the majority of cases (47.3%) with both exits available being next most likely (36.5%). In the case of MID positioned exits, the results suggest that in most cases (42.1% of the time) both exits are available, while 31.6% of the time one exit is available. Finally, the AFT positioned exits show that having no exits available is the most likely (42.1%) while having both exits available is next most likely (31.6%).

As part of the 90-second certification exercise, the trial criteria stipulate that only half of the available exits can be used. Without exception, where aircraft have exit pairs, only one exit of each pair is selected. If this scenario represented reality, we would expect to see the highest percentages in the "One Exit" column of Table 15. While the exit availability found using AASK V4.0 is different to that found using AASK V3.0, both consistently show that the exit configuration used in the 90 second certification exercise does not correspond to the exit availability suggested by real accidents.

Table 15 Proportion of exit availability in terms of generalised exit positions for three-exit pair aircraft, AASK V4.0.

	Availability (%) of exit in exit pair		
Exit Position	**No Exits**	**One Exit**	**Both Exits**
FWD	15.8%	47.3%	36.5%
MID	26.3%	31.6%	42.1%
AFT	42.1%	26.3%	31.6%

The additional data included in this analysis contains data derived from a precautionary evacuation and a post-incident deplaning (incidents 81 and 52 respectively) as well as several other orchestrated evacuations. The later group of evacuations are those in which the crew order the passengers to use particular exits in order to minimise the risks to passengers of using slides and to avoid the use of off-wing exits. Accidents 73, 98 and 102 entailed all passengers using one exit under flight crew orders. In accident 101 passengers were ordered to deplane via two exit positions, but using airport ladders, not the aircraft's escape assistance means, even though the accident scenario was far more serious than a precautionary evacuation. What characterises all these accidents is the wilful avoidance of available exits due to crew intervention. Finally, accident 96 was an unauthorised, passenger-driven evacuation. Part way through this incident, the crew intervened and instructed all the passengers to evacuate via the tailcone exit. Discounting these accidents, the remaining 12 accidents are presented in Table 16.

Table 16 Proportion of exit availability in terms of generalised exit positions for three-exit pair aircraft, discounting orchestrated artificial conditions

	Availability (%) of exit in exit pair		
Exit Position	**No Exits**	**One Exit**	**Both Exits**
FWD	8.3%	41.7%	50.0%
MID	8.3%	33.3%	58.3%
AFT	25.0%	33.3%	41.6%

If the artificial evacuation situations are removed, we now find that the most common situation is to have both exits available in each exit position. This again is very different to the scenario demonstrated in certification trials.

The same analyses can be undertaken for aircraft with four exit pairs. Using the same selection criteria as that used for aircraft with three exit pairs we find the seven suitable aircraft (see Table 17).

Table 17 Aircraft used in four exit pair aircraft exit availability analyses

Accident reference	Aircraft	Type of evacuation
1	DC-10-30	Unplanned Emergency
9	A-300-B4	Unplanned Emergency
17	B757-225	Unplanned Emergency
18	MD-11	Unplanned Emergency
30	L-1011-385-1	Unplanned Emergency
62	DC-10	Unplanned Emergency
79	A-300B4-605R	Planned Emergency

Here we find that the most common combination is to have both exits in an exit pair available in the FWD position, both exits in the MID-FWD position, and one exit in the MID-AFT position and one exit in the AFT position (see Table 18).

Table 18 Proportion of exit avalibility in terms of generalised exit positions for four-exit pair aircraft

	Availability (%) of exit in exit pair		
Exit Position	**No Exits**	**One Exit**	**Both Exits**
FWD	0%	28.6%	71.4%
MID - FWD	0%	28.6%	71.4%
MID - AFT	28.6%	57.2%	14.3%
AFT	28.6%	42.9%	28.6%

As can be seen from this analysis, the exit configuration used in certification analysis bears little resemblance to exit combinations experienced in the majority of accidents. Furthermore, the exit configuration actually used in the 90-second certification exercise is not a particularly onerous configuration as an exit is available in each cabin section. For example, a more challenging exit combination for aircraft with three exit pairs – while maintaining the 50% condition – that is also consistent with the observed exit availability, would involve both exits in one of the locations and a single exit available in one other location. For aircraft with four exit pairs, an example of an exit selection that is more consistent with reality (while again maintaining 50% availability) would involve having all the exits available in the front half of the aircraft and none in the rear.

Here it is again important to note that results presented above only refer to a small number of accidents and so cannot be considered conclusive. Furthermore, the analysis only considers the frequency of availability of exits within an exit pair. It does not consider which exit combinations across exit pairs are likely.

5.6.5 Total Exit Availability

Extending the work described in section 5.6.4, total exit availability (where exit availability is defined as in section 5.6.4) was considered. Here we simply consider exit availability as a function of total number of exits on board, irrespective of the exit positions (see Figure 15) or whether exits are lone or paired.

In this analysis we ignore precautionary evacuations and post-incident deplanings. However, aircraft involved with fire, water and cabin ruptures are included. In this analysis, emergency evacuations in which passengers were instructed to use a single exit by CC are considered to be situations in which only a single exit was available, unless passengers disobeyed instructions and made use of other exits. Only aircraft with three and four exit zones, as depicted in Figure 16 and Figure 17, are considered. In AASK V4.0, 15 additional aircraft with three exit zones were found to be suitable for analysis while only one additional aircraft with four exit zones was available [11, 12, 13]. Thus 31 aircraft with three exit zones and 11 aircraft with four exit zones are available for analysis.

Using AASK V4.0, we now find that for aircraft with three exit zones, 11 have less than 50% of the exits available, six had exactly 50% of the exits available and the 14 remaining had more than 50% of the exits available. Of the six aircraft that had exactly 50% exit availability, three had all the exits available on one side and one had only the over-wing exit quad available. For the 11 aircraft with four exit zones, three aircraft had less than 50% of the exits available, one had exactly 50% of the exits available (not down one side), and seven had more than 50% of the exits available.

Combining the results for aircraft with three and four exit zones, of the 42 aircraft suitable for examination, 14 (33.3%) had less than 50% of exits available; 7 (16.6%) had exactly 50% of exits available and 21 (50%) had more than 50% exits available. Furthermore, of the 42 aircraft considered, 23 (55%) had a cabin section in which no exits were available. Only in 3 (7%) cases were all the exits available on one side of the aircraft. Of these, one case involved a planned emergency evacuation of an intact cabin with no fire, while another involved an unplanned emergency during taxi following an engine fire. In the third case passengers commenced unauthorised evacuation via left exits, and were then ordered to deplane via the tailcone exit.

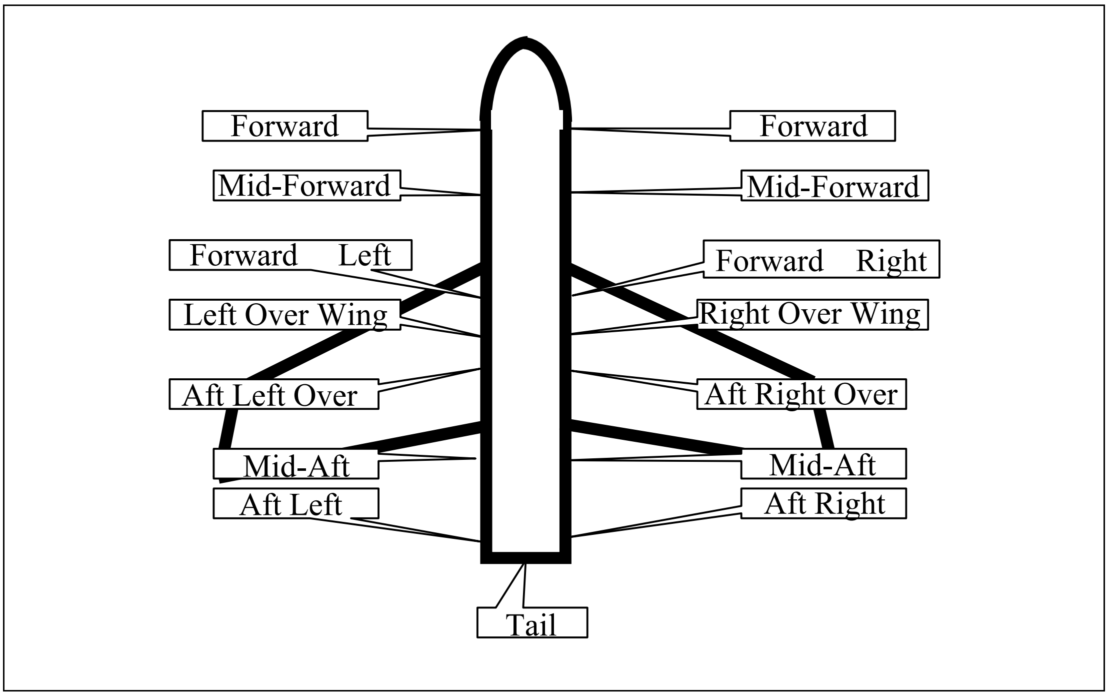

Figure 15 All exits and positions considered in AASK

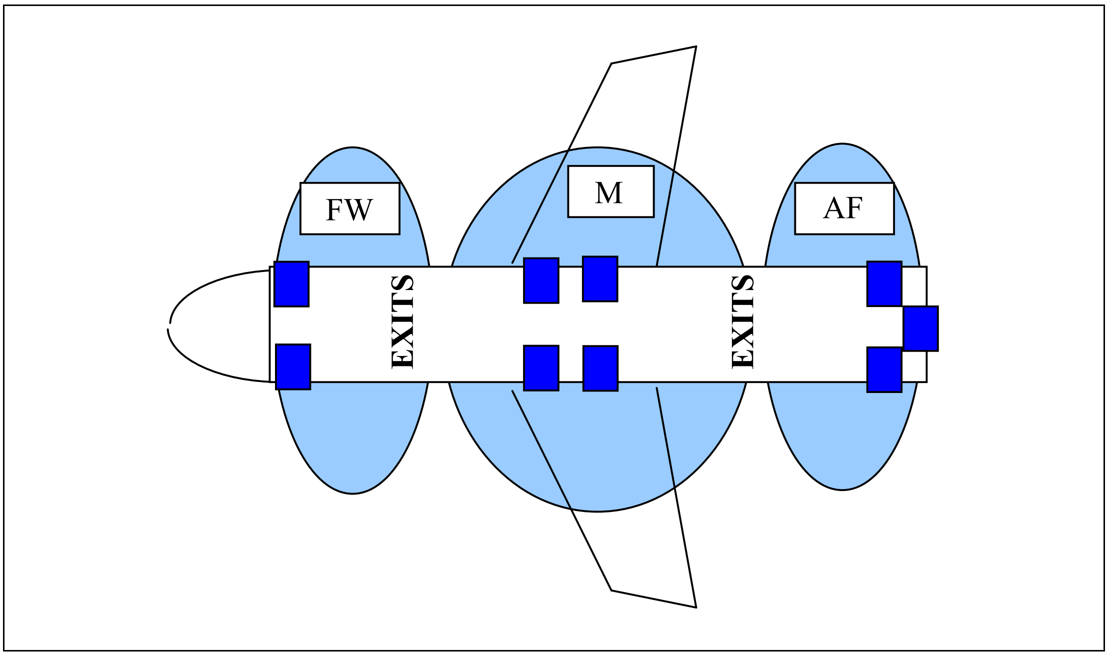

Figure 16 Aircraft showing three exit zones with the maximum possible exit configuration.

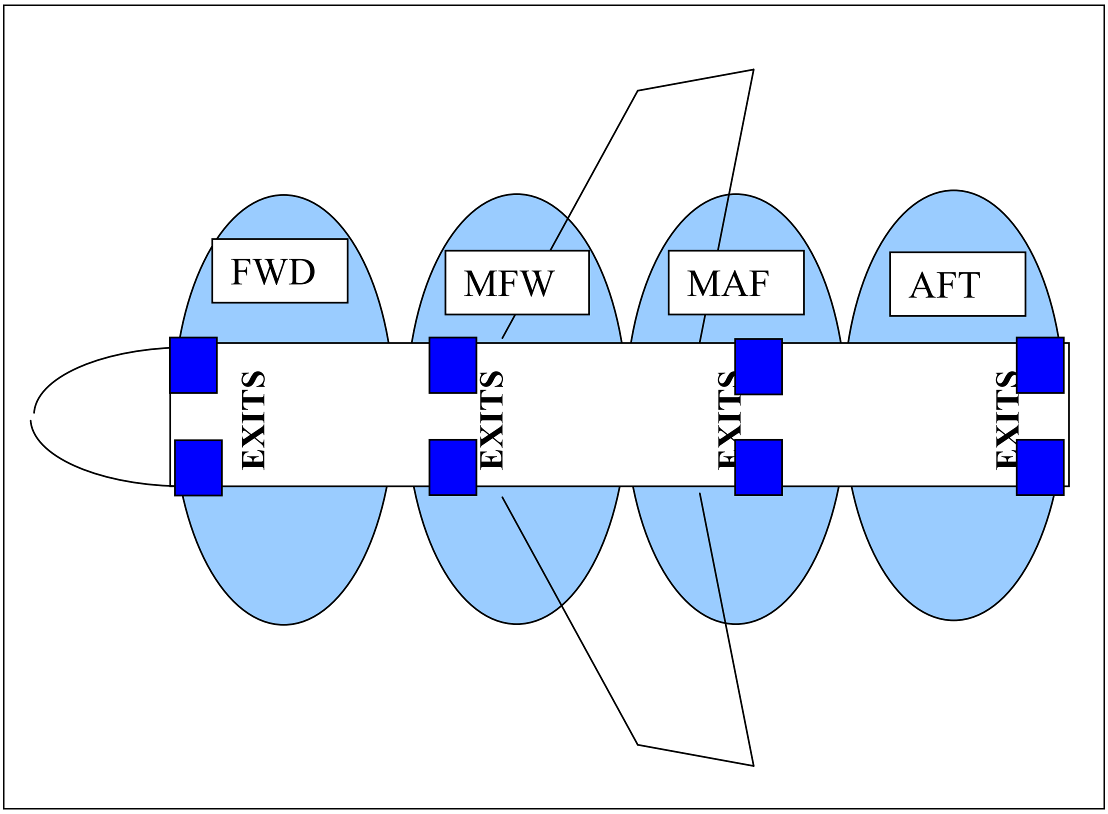

Figure 17 Aircraft showing four exit zones with the usual exit configuration.

In an earlier investigation Fons Schaeffer [17] studied exit availability in 114 accidents. His study was particularly concerned with situations where 'emergency exits were, or could have been, vital for survival'. In this study Schaeffer noted that 48% of accidents had less than 50% of exits available, 19% had exactly 50% of exits available and 33% of accidents had more than 50% of the exits available. The results from AASK V4.0 suggest that fewer aircraft had less than 50% exits available. The Schaeffer study considered accidents from 1960 to 1989, while the AASK V4.0 study investigates accidents from 1977 - 1999, 79% of which are dated 1989 or after. A possible explanation for the lower occurrence of less than 50% exit availability in the AASK study could be the large number of less severe accidents contained in AASK V4.0.

As noted earlier, the 90-second certification trial invariably makes use of a situation in which 50% of the exits are available and that one exit from each exit pair is available. The AASK V4.0 study suggests that 33.3% of accidents involve a more severe situation in which there is less than 50% exit availability and furthermore, only 7% of accidents involve exit availability restricted to all the exits on one side of the aircraft.

5.6.6 **Comparison of AASK and 90 second trial exit usage**

AASK V4.0 was used to analyse evacuation data arising from 90-second certification demonstrations. AASK was used to determine the distance travelled by passengers in the trials to their exit point and to determine whether or not passengers made use of their nearest exit. Trial data involving 5,530 passengers from a total of 18 aircraft was used, 12 of which were wide bodied and six of which were narrow bodied [15].

The AASK analysis of this data suggests that on average 76% of passengers in certification demonstrations make use of their nearest exit. This is compared with 89% of passengers in accidents who made use of their nearest exit or had a good reason for not using their nearest exit (see section 5.6.1). Only in two of the 18 certification demonstrations does the number of passengers using their nearest exit exceed the value achieved in accident situations.

In certification demonstrations, cabin crew may direct passengers away from their nearest exit. This could lead to the reduced number of passengers making use of their nearest exit in certification demonstrations. In contrast, in actual aircraft evacuation emergencies, the 89% figure is made up of passengers who used their nearest exit or had a very good reason not to use their nearest exit e.g. exit blocked. However, in this figure we have included the 6% of passengers who were redirected by cabin crew. In order to be comparable with the certification trial figure, these people should be removed from the total. If this is done the figure is reduced to 83%. Even with these adjusted figures, passengers tend to use their nearest serviceable exits more often in real accident scenarios than we find in certification tests.

5.7 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 than 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 19, the maximum travel distance to an exit for these four aircraft varies from 4 to 7 seat 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 19).

Table 19 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 20). 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 20 is the maximum travel distance actually travelled by a passenger on board the various aircraft.

Table 20 Comparison of theoretical average distance to the nearest viable exit for survivors and fatalities (for which data is avilable 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				

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 which the mean travel distance for each case is weighted by the number of people involved) 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 farthest a passenger actually travelled to a viable exit was 15 seat rows (see Table 20).

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 18. 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 survivors versus 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 as 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.

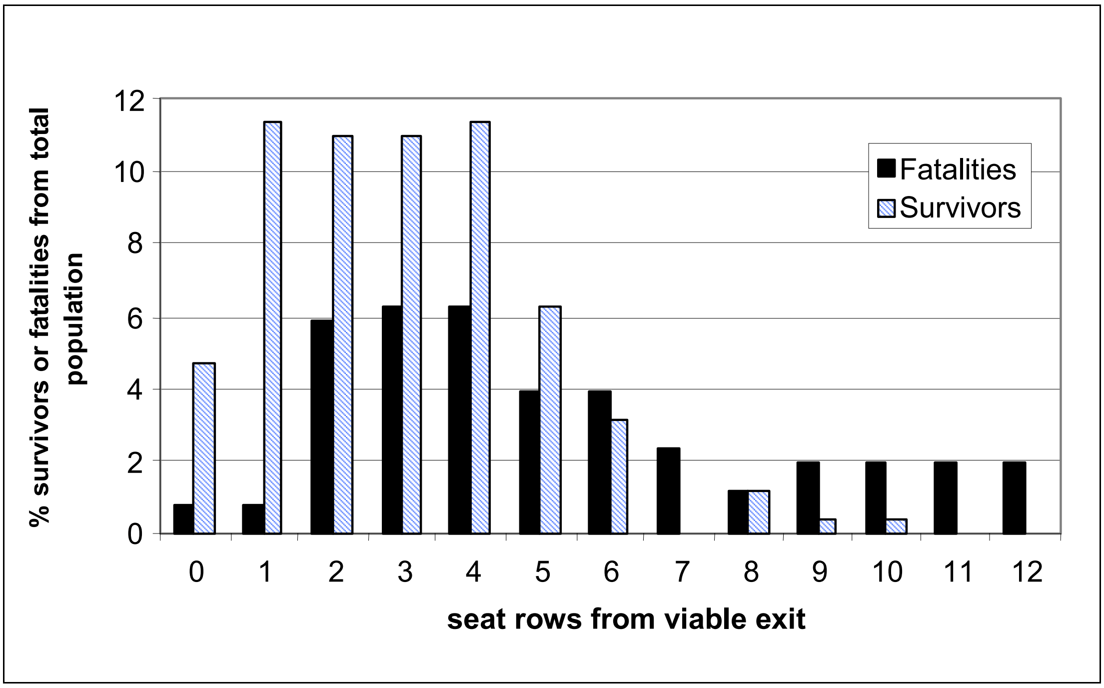

Figure 18 The distribution of rows to nearest viable exits for survivors and fatalities

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 21, 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.

Table 21 Survival rate for aisle seated and non-aisle seated passengers

Aircraft	Survival Rate of Aisle Seated Passengers	Survival Rate of Non-Aisle Seated Passengers
DC-9-32	38%	48%
B737-236	62%	57%
B737-300	86%	61%
DC-9-20	71%	70%
AVERAGE	64%	58%

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 22). 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.

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 22 Survival rate for front and rear seated passengers

Aircraft	Survival Rate of Front Seated Passengers	Survival Rate of Rear Seated Passengers
DC-9-32	33%	100%
B737-236	87%	30%
B737-300	53%	89%
DC-9-20	75%	67%
AVERAGE	65%	53%

One exception is the DC9-32 of which we know the starting and end point of 22 fatalities on this aircraft and the starting point and exit used for 17 survivors. Depicted in Figure 19 is the known information concerning the movements of the deceased passengers overlaid onto the Seat Plan Viewer (SPV) output. This incident was the result of an in-flight fire in which the cabin crew moved the passengers forward during the incident to avoid the developing fire in the rear of the aircraft. Within AASK, data concerning the passengers' original seat assignment and their locations prior to the evacuation are recorded. Exits used in this case were located at seat rows 1, 13 and 14, and the arrows in Figure 19 represent the travel direction of the deceased passengers.

For this accident it is also possible to determine the actual distance travelled by survivors to their exit of choice as well as the theoretical distance that the deceased passengers would have travelled had they reached their target exit. It is assumed here that the two passengers who overshoot the over-wing exits were in fact trying to locate the over-wing exits (however, it is possible that they were attempting to reach the tail cone exit). Passengers who did not leave their seats are not included in this calculation. Thus, for this accident, the 17 survivors travelled an average distance of 2.29 seat rows to reach their exit of choice, while the eight fatalities that attempted to reach an exit would have travelled an average distance of 5.88 seat rows to reach their target exit. For these eight fatalities, the average optimal distance to their nearest viable exit was 4.63 seat rows. Thus, the survivors travelled an estimated 11% further than was actually required while the fatalities would have travelled an estimated 27% further than was required.

start row	body row	comment
3	3	Found in seat
3	3	Found in seat
3	3	Found in seat
4	4	Found in seat
4	4	Found in seat
5	5	Found in seat
5	5	Found in seat
5	5	Found in seat
5	5	Found in seat
5	9	4 rows travelling away from exit
6	6	Found in seat
6	10	4 rows travelling away from exit
6	10	4 rows travelling away from exit
7	6	1 row travelling towards exit
7	7	Found in seat
7	7	Found in seat
8	6	2 rows travelling away from exit
8	8	Found in seat
8	9	1 row travelling towards exit
9	9	Found in seat
9	15	Exits passed by 2 & 1 rows, no further exit
10	17	Exits passed by 4 & 3 rows, no further exit

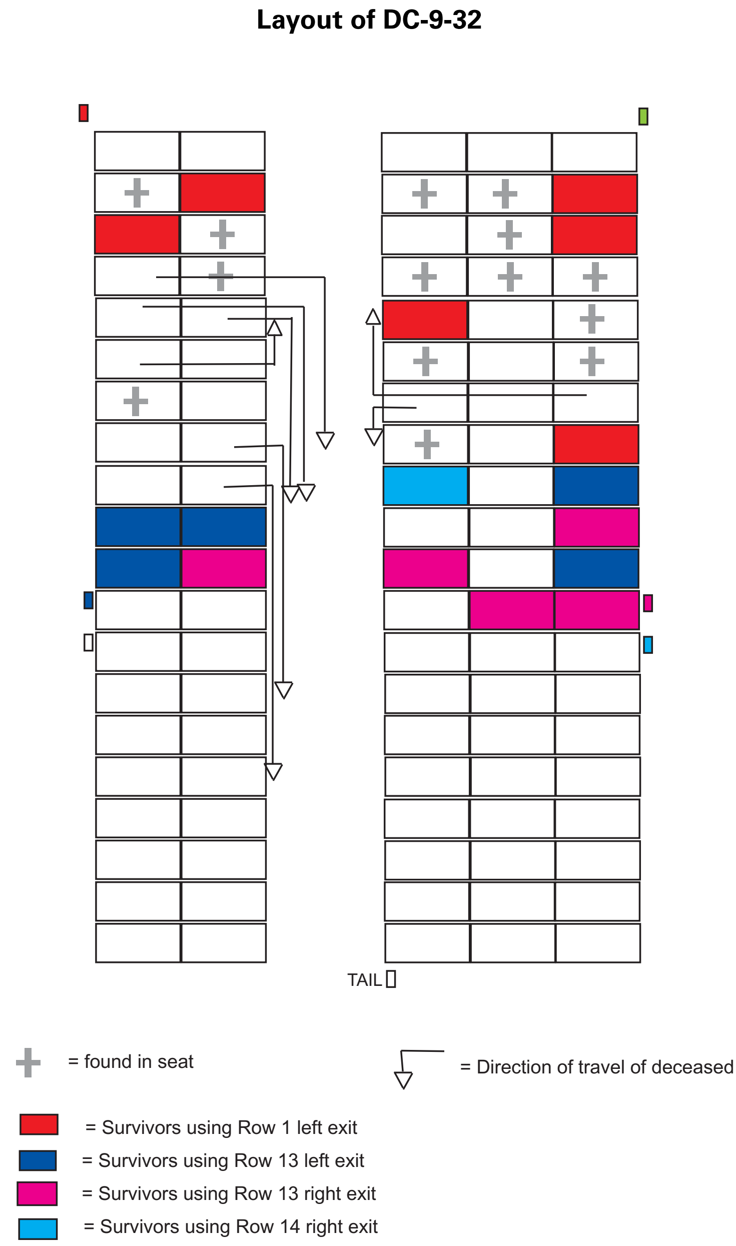

Figure 19 Representation of the information concerning Survivor and Fatality movement for the DC-9-32 accident

These findings are also in support of the earlier findings of Snow and suggest 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.

5.8 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' who 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.

5.8.1 Cabin Crew Staffing Levels

An issue 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 (see Table 23). 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 in relation 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.

Table 23 Passenger loads and crewing levels for accidents under investigation

Aircraft	Accident	Max Pax	Pax on Board	Total CC	Op CC	Theoretical Pax / CC	Actual Pax / CC	Worst Case Pax / CC
						Max Pax / Total CC	Pax on Board / Op CC	Max Pax / Op CC
DC-10-30	1	290	189	10	10	29	19	29
B-727-232	2	148	12	4	4	37	3	37
DC-9-32	3	113	57	3	2	38	29	57
DHC-8-102	4	37	37	1	1	37	37	37
DC-10-10	6	287	286	8	4	36	72	72
B-737-400	7	146	57	4	4	37	14	37
SAAB-340-B	8	34	20	1	1	34	20	34
MD-83	10	148	73	3	3	49	24	49
MD-88	12	142	58	3	3	47	19	47
MD-88	13	142	137	3	3	47	46	47
B-747-136	15	493	451	12	11	41	41	45
MD-82	16	147	110	4	4	37	28	37
B-757-225	17	193	121	5	5	39	24	39
MD-11	18	271	99	8	8	34	12	34
DC-9-32	25	103	102	3	1	34	102	103
B-737-200	29	130	114	3	3	43	38	43
L-1011-385-1	30	275	280	9	9	31	31	31
B-737-275	31	130	76	3	3	43	25	43
B-737-275	32	130	44	3	1	43	44	130
DC-9-32	35	103	57	3	3	34	19	34
B-737-217	37	130	72	4	4	33	18	33
B-727-200	39	146	60	3	3	49	20	49
DC-10-10	40	287	276	8	8	36	35	36
DC-9-31	41	100	81	2	1	50	81	100
DC-8-61	42	241	238	6	6	40	40	40
B-737-222	43	109	102	3	3	36	34	36
DC-10-10	45	268	257	10	10	27	26	27
B-737-204	46	122	128	3	3	41	43	41
L-1011-385-1	47	293	281	8	8	37	35	37
B-737-300	49	128	83	4	4	32	21	32
DC-9-14	51	78	40	2	1	39	40	78
B-727-251	52	146	146	5	5	29	29	29
DC-10-30	53	229	163	11	11	21	15	21
DC-10-30CF	54	354	200	9	7	39	29	51
B-737-222	59	118	114	3	3	39	38	39
CV-580	60	48	30	1	1	48	30	48
DC-9-14	61	83	77	3	2	28	39	42
BAe ATP	64	64	58	2	2	32	29	32
EMB-120RT	65	30	27	1	1	30	27	30
DC-9-32	66	100	41	3	2	33	21	50
DC-9-31	67	103	52	3	2	34	26	52
SAAB SF-340A	69	34	17	1	1	34	17	34
B-737-236	70	130	131	4	2	33	66	65
CRJ	72	50	46	1	1	50	46	50
MD-88	73	142	49	3	3	47	16	47
L-1011-385-1	74	302	152	8	2	38	76	151
DC-9	76	98	101	3	3	33	34	33
SAAB 340	77	34	16	1	1	34	16	34
BAe 31 JETSTREAM	78	30	19	1	1	30	19	30

Table 23 Passenger loads and crewing levels for accidents under investigation (Continued)

Aircraft	Accident	Max Pax	Pax on Board	Total CC	Op CC	Theoretical Pax / CC Max Pax / Total CC	Actual Pax / CC Pax on Board / Op CC	Worst Case Pax / CC Max Pax / Op CC
A-300B4-605R	79	267	243	7	7	38	35	38
B-727-223	80	146	116	3	3	49	39	49
CRJ	82	50	40	1	1	50	40	50
CRJ	83	50	30	1	1	50	30	50
ATR-72	84	64	17	2	2	32	9	32
ATR-42	85	46	22	1	1	46	22	46
SAAB 340	86	34	27	1	1	34	27	34
B-737	87	128	100	3	3	43	33	43
DHC-8	89	36	18	1	1	36	18	36
MD-88	90	142	45	4	4	36	11	36
SAAB 340	91	34	4	1	1	34	4	34
CRJ	92	50	5	1	1	50	5	50
F-100	93	93	70	2	2	47	35	47
ATR-42	94	46	45	1	1	46	45	46
B-737	95	128	109	3	3	43	36	43
B-727	96	146	149	4	4	37	37	37
EMB-145	97	50	48	1	1	50	48	50
A-320	98	150	26	3	3	50	9	50
SAAB-340-B	99	34	27	1	1	34	27	34
MD-82	100	139	139	4	1	35	139	139
B-737	101	128	63	3	3	43	21	43
B-737	102	128	66	3	3	43	22	43
BAe 31 JETSTREAM	103	19	2	1	1	19	2	19
F-100	104	93	99	2	2	47	50	47
MD-80	105	141	69	3	3	47	23	47
B-737	106	128	100	3	3	43	33	43
ATR-42	107	46	36	1	1	46	36	46
ATR-72	108	64	10	2	2	32	5	32
SAAB 340	109	34	3	1	1	34	3	34
DC-9	110	96	27	3	3	32	9	32
BAe 4100 Jetstream	113	30	29	1	1	30	29	30
DHC-8	114	36	19	1	1	36	19	36
BAe 4100 Jetstream	115	30	10	1	1	30	10	30
A-320	116	150	145	4	4	38	36	38
MD-80	117	141	36	5	5	28	7	28
DC-9-32	118	103	82	3	3	34	27	34
B-747-438	119	394	291	16	16	25	18	25
MD-88	120	142	102	4	4	36	26	36

Depicted in Figure 20 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 21 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.

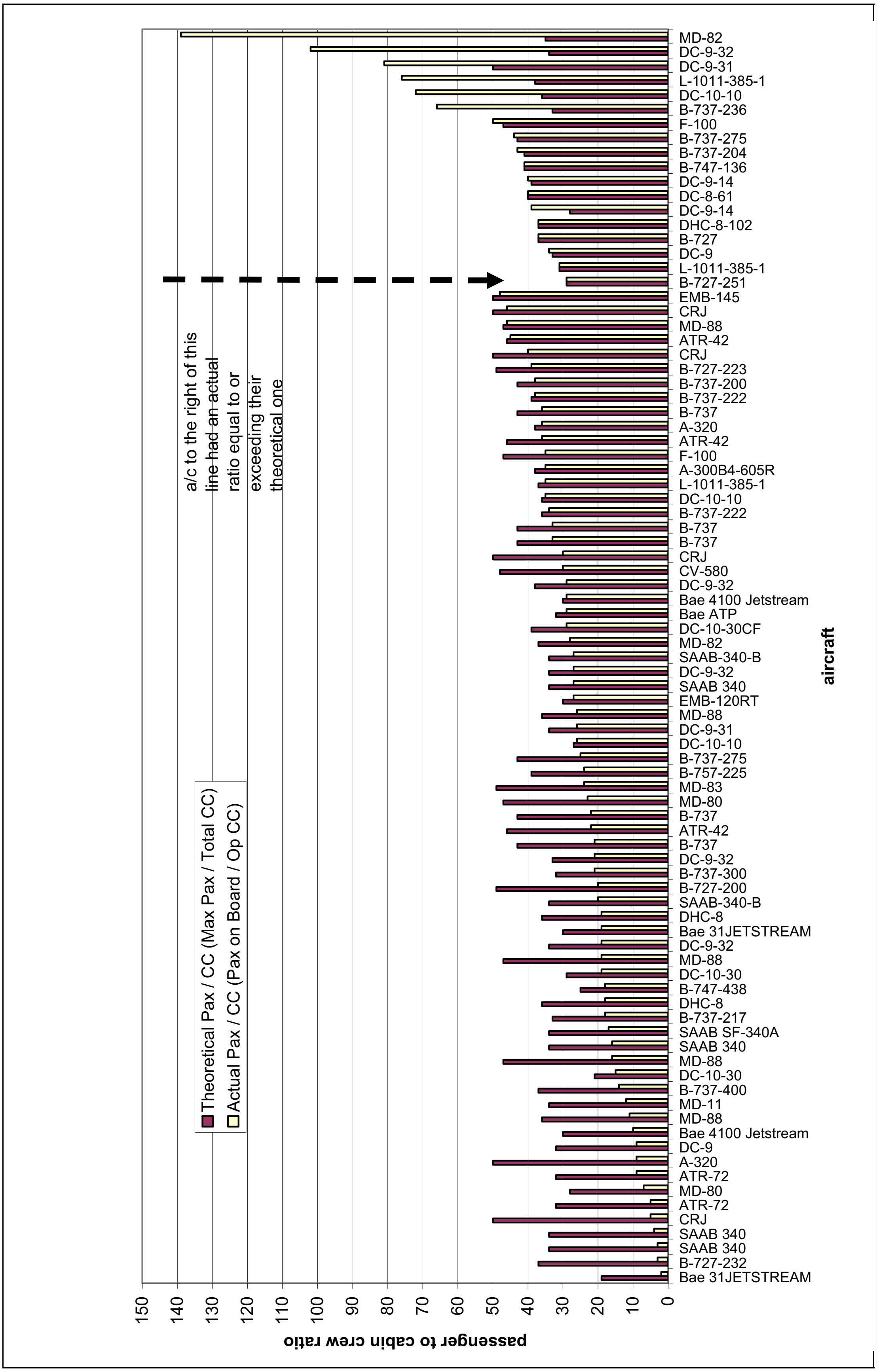

Figure 20 Comparison of theoretical and actual passenger crew ratios in the 87 cited accidents

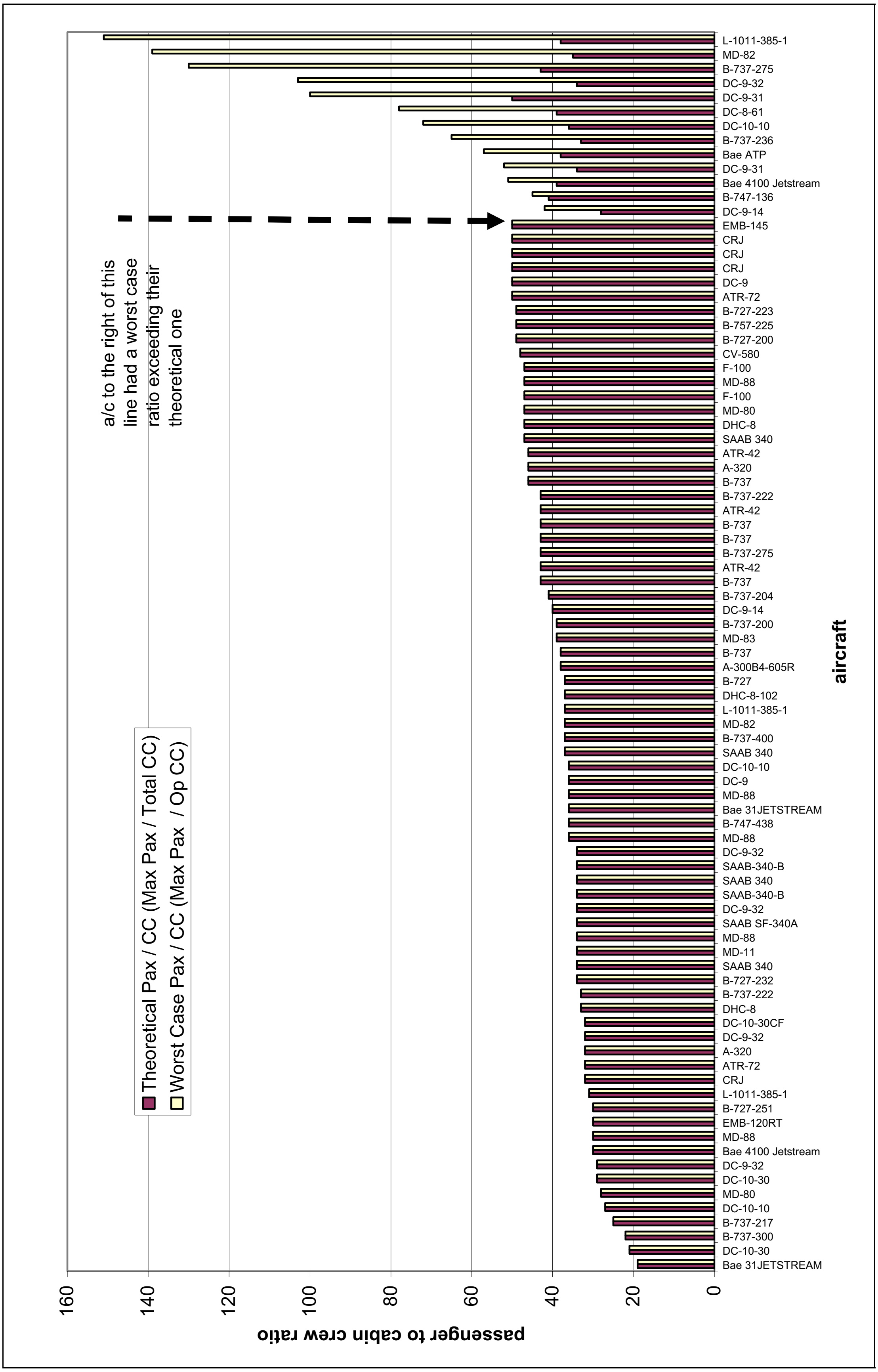

Figure 21 Comparison of theoretical and worst possible passenger crew ratios in the 87 cited accidents.

5.8.2 **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 (see Figure 22).

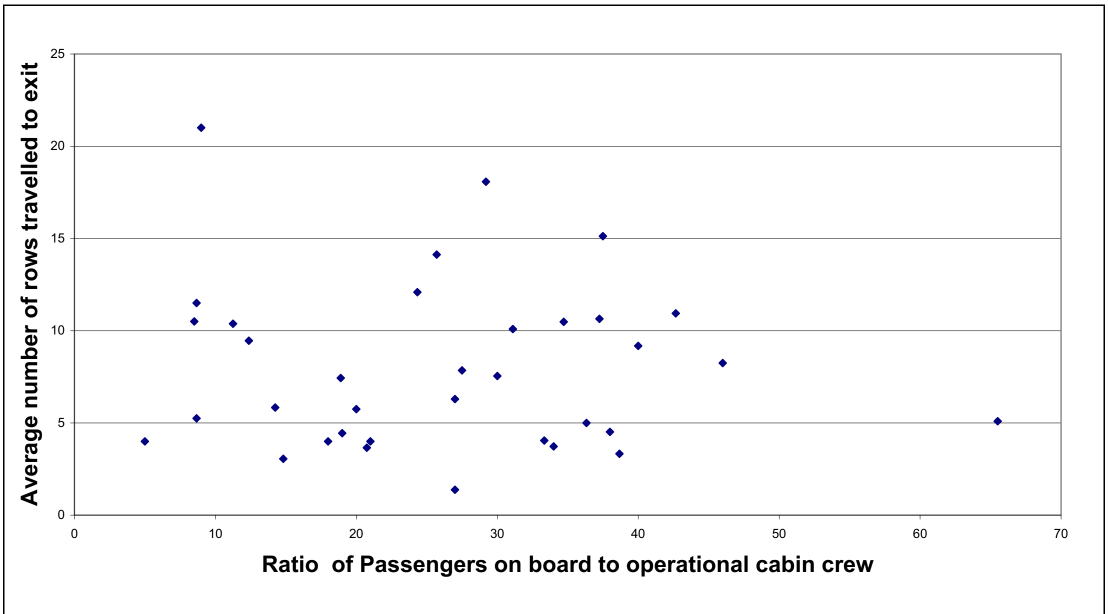

Figure 22 Average distance travelled by passengers and ratio of passengers to operational cabin crew present for 35 accidents within AASK V4.0

Simply using this information (see Figure 22) 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 involving 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.

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;
- Aircraft with fuselage breaks providing alternative means of escape were excluded.

Table 24 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%

Due to these rigorous criteria, only six accidents were found suitable for this analysis (see Table 24). 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.

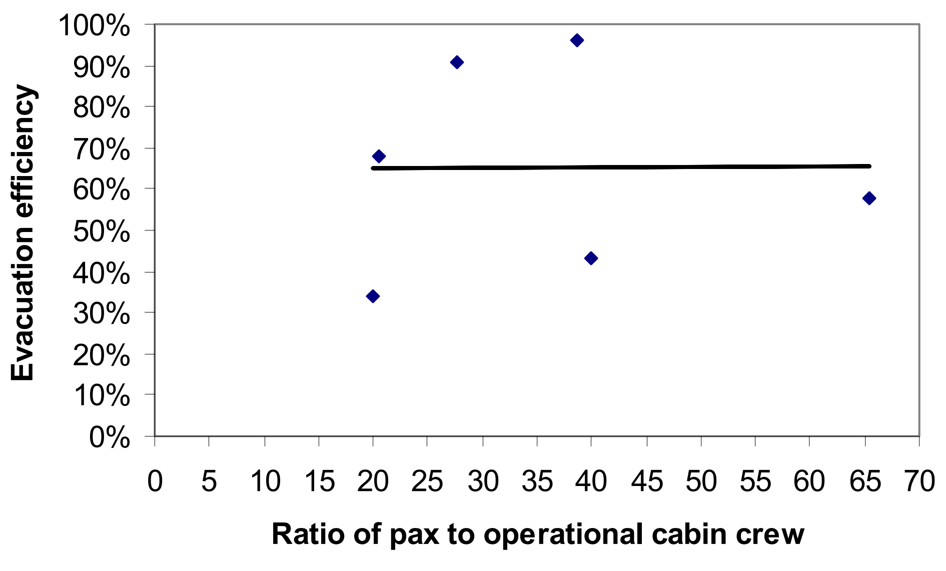

Figure 23 Relationship between Evacuation Efficiency (EE) and the actual passenger to operational cabin crew ratio for the six narrow body accidents

For these six accidents, there appears to be no apparent correlation (see Figure 23) 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 24). 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.

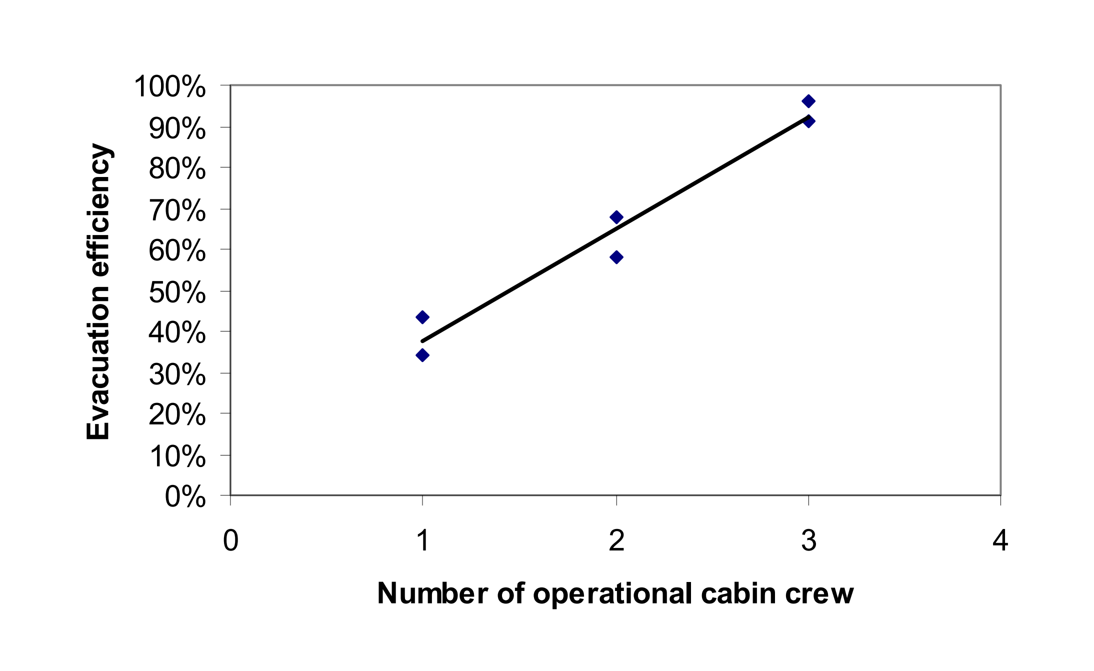

Figure 24 Relationship between Evacuation Efficiency (EE) and the number of operational cabin crew for the five narrow body accidents.

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 24). Furthermore, as can be seen from Figure 24, as the number of available crew increase, the Evacuation Efficiency – as measured by the average distance travelled – increases.

From the results presented in Figure 24 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 24 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.

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 than 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 25). 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 in ref 11 has now been confirmed with these extra aircraft, however these observations are only tentative as they are based on insufficient data.

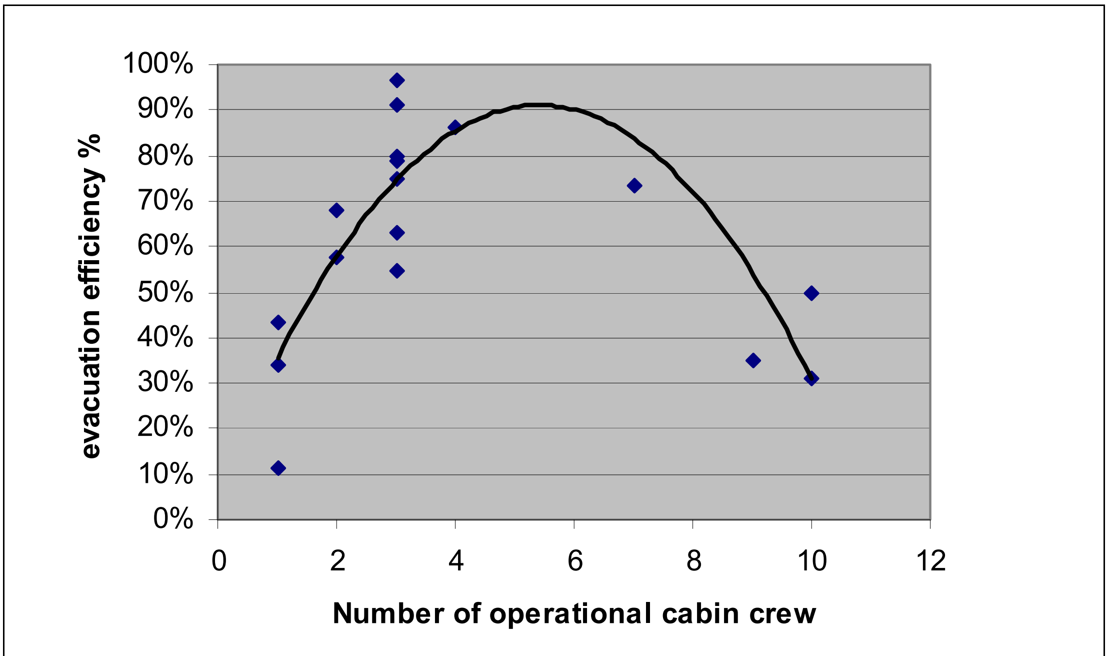

Figure 25 Tentative relationship between Evacuation Efficiency (EE) and the number of operational cabin crew for 17 accidents.

5.8.3 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 26 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 one-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.

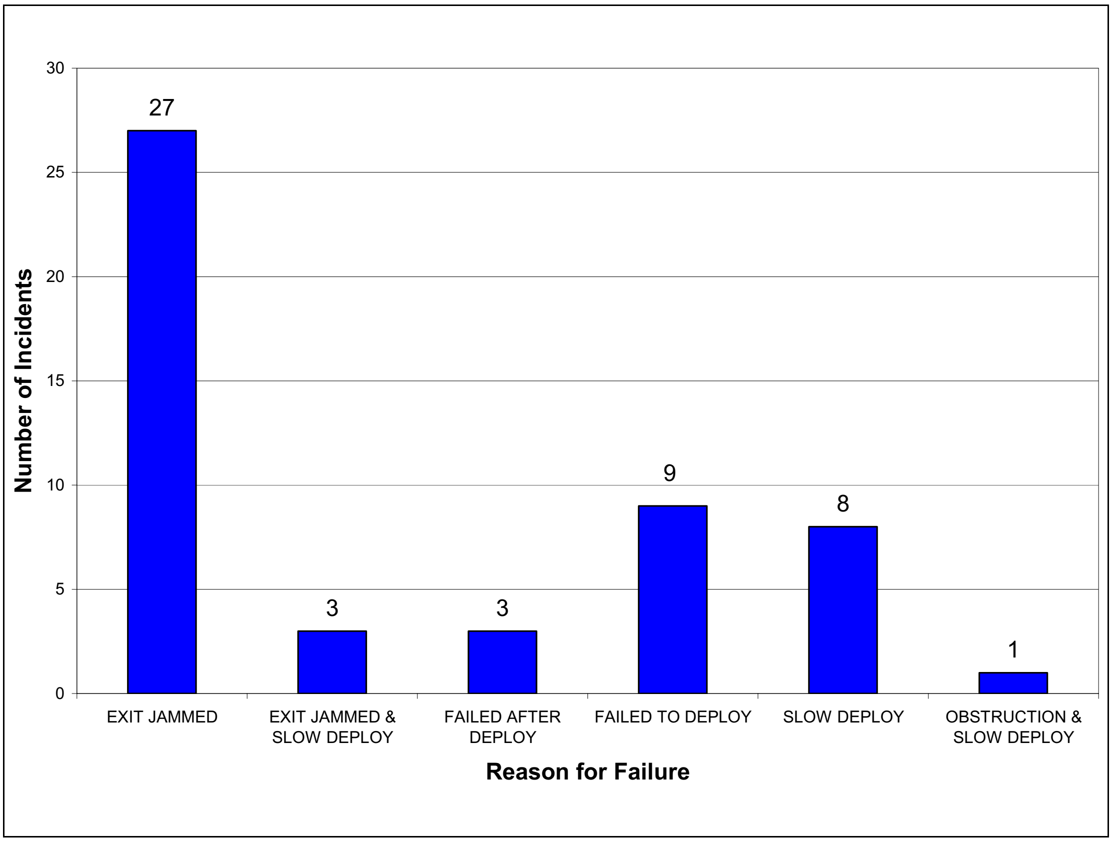

Figure 26 Common exit and slide failures reported by cabin crew members.

6 User Feedback

6.1 Current Users

AASK V4.0 is available over the internet and at the time of writing this report, there were over 30 registered users from nine countries. Some of these have registered as individuals and others have corporate registration. The following organisations are registered users of AASK:

Fire Science and Technology Laboratory, CSIRO	Australia
Victoria University	Australia
Transportation Safety Board of Canada	Canada
F.A.A	France
Chargé d'affaires Facteurs Humains	France
DGAC	France
Sofreavia	France
Europe Amsafe Aviation	France
Institut fuer Psychologie und Arbeitswissenschaft	Germany
Registro Aeronautico Italiano	Italy
CAAS	Singapore
Air Nostrum	Spain
University of Greenwich	UK

Flight Safety Officer – flyastraeus	UK
CAA	UK
RGW Cherry & Associates	UK
ICE Ergonomics	UK
Virgin Atlantic Airways Limited	UK
Cranfield University	UK
Aircraft Design Liaison Surveyor – CAA	UK
Senior Inspector of Air Accidents – AAIB	UK
Safety & Survival Sys	USA
NTSB USA	USA
U.S. General Accounting Office	USA
Association of Flight Attendants	USA

Current users of AASK include regulatory authorities, airlines, research organisations and universities. Other organisations and individuals have had temporary use for the introductory course.

6.2 **The On-line User Questionnaire**

After some initial enquiries concerning difficulties with passwords or technical requirements, there was little feedback from the AASK user-base. As a result, it was decided that an on-line questionnaire would be the most efficient way of eliciting users' views on the content, interface and value of the database.

The questionnaire was designed to make it easy to fill in so that a good response rate might be obtained. The following information was requested :

- Your name
- Your AASK User id
- Your Business/Organisation
- Your email address
- How many times have you used AASK?
- Tick all the parts of the AASK database that you have used
- Please enter the most relevant reason for your use of AASK
- Did you read the instructions before using AASK for the first time?
- Did you refer to the help facility while using AASK for the first time?
- Did you try to run queries?
- Did you obtain useful results?
- If no, why not?
- Did you find any errors in the data?
- If yes, give brief details
- Tick any aspects of the AASK database where you have experienced a technical problem
- Please use this space for any other comments and then press send to submit your answers

The questionnaire went live at the end of July 2002 when all users were sent emails giving details of the new features available online (principally the help, sample queries and Seat Plan Viewer) and requested to give feedback via the online questionnaire. At the time of writing, too few replies have been received to form any conclusions. There are also ongoing opportunities to receive feedback via email and there is an on-line questionnaire as part of the database.

6.3 Workshops

Two workshops were organised in conjunction with the UK CAA in order to present the work of this project to a wider audience. The first was to an audience at the UK CAA in January 2003 and the second was an open workshop in April 2003. Feedback on AASK collected from these workshops has been included below.

6.3.1 CAA Workshop

About 30 people attended an in-house presentation at Aviation House Gatwick. The capabilities of AASK V3.0 were discussed along with some of the results from the analysis using the database. A short demonstration was given showing the Query Builder and the Seat Plan Viewer .

Feedback was very positive including:

"Very interesting presentation. Especially the difference between certification assumptions and operational reality."

"Usefiul source of info"

"Useful presentation. I look forward to using the database"

Suggestions were made as to new features the database might include. Questions were raised that might be answered using AASK V3.0.

6.3.2 Open Workshop

In April 2003 an open AASK workshop was held at the University of Greenwich. This comprised of a morning of presentations and demonstrations and an afternoon of hands-on tutorials. In total some 17 delegates from UK, USA, Norway and France attended. They were drawn from the aircraft manufacturing industry, airlines, safety specialists and the regulatory community and among them represented:

Association of Flight Attendants (US)

British Mediterranean Airways

AMSAFE Aviation

Boeing

DGAC

AAIB

ERA

CAA

Norwegian Cabin Crew Union

Cranfield University

UK Flight Safety Committee

Unfortunately, the numbers attending were affected by the SARS crises which was at its peak and delegates from NTSB, Airbus, and the Flight Attendants Association of Australia who had booked places were unable to attend. Considerable interest was expressed in the origins and capabilities of the database and its link as a source of data for the evacuation model airEXODUS.

Feedback included:

"Great database it will really save me some time";

"Excellent clearly there is some potential for using this tool for data derived safety regulation";

"Useful and to the point";

"Use the animated evacuation model (airEXODUS) to develop limitations for the operation of aircraft with unserviceable exits".

A tutorial booklet was produced for the laboratory sessions which may be revised following some delegate feedback. There was a wide variety of technical competence and industry experience among those attending but all delegates managed to operate AASK. Feedback was mainly verbal although questionnaires were given out at both events and 12 were received completed. Some follow up presentations were requested to other interested groups.

7 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.

Data within AASK V4.0 covers 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).

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, Seat belt 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' who 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].

Further suggested development work on the AASK database includes:

a) Analysis of data.

   i) A considerable amount of data has been entered into AASK V4.0 and to date, analysis of this data has been limited. A detailed analysis of the passenger/crew data is required.

   ii) In addition to the analysis initiated by the research team, it is recommended that the team also canvas specific research questions from the CAA/JAA/EASA and other approved interested parties. For example, some of the questions that came up at the AASK Workshop include:

      - Can we look at size and weight of paxs in exit rows?
      - What evidence is there on the effect of exit storage for Type III exits.
      - Of the slide and door failures, how many of them were due to damage sustained in the accident?
      - Can we have an analysis of the age of the cabin crew? Does this have an impact on evacuation efficiencies?
      - Can you identify accidents that have a significant number of senior citizens (over the age of 55) and do these have different characteristics to flights with a younger age profile?
      - Was exit selection based on briefing by crew, safety card or other?
      - Can we analyse accidents by date so that we can gauge the effects of the introduction of new rules e.g. advice that exit may be behind you?

b) Continued collection and entry of data into AASK,

   A considerable amount of data in the form of interview transcripts remains to be collected from the Canadian and Australian authorities. It is recommended that the UK CAA enter into an agreement with the Canadian and Australian authorities allowing the access and use of this data. In addition, it is suggested that currently used passenger accident questionnaires employed by the various accident investigation authorities be reviewed and suggestions made to modify these so that they can provide more relevant and consistent information for use in AASK. Finally, the fatalities database within AASK should be expanded in line with the recommendation from the US GAO [4] and include more complete fatality and autopsy data. This may require agreement between UK CAA and NTSB in the USA.

c) Maintenance and functional development of the AASK database.

Several developments are recommended:

i) Maintain and improve usability of interface in line with the requirements of item a).

ii) Provide a facility that tracks the use of the database to prevent inactive logins (which needlessly slow down the system).

iii) Extend accident description to include a range of data not currently logged e.g. whether the flight was long or short haul, starting location, destination location, whether the evacuation was a precautionary evacuation, how long the aircraft had been in the air prior to the accident, if the flight was a commuter flight, etc.

iv) Develop an additional library of pre-constructed (both modifiable and non modifiable) queries.

v) Develop a facility to enter SQL statements directly by more advanced users.

vi) Develop a feature to provide a summary statistics table for the accidents.

vii) Contents of the summary statistics table could be defined by the user.

viii) Improve the presentation of the attribute lists.

ix) Facility to save constructed queries and load them into the Query Builder for later use.

x) Develop an email facility so that AASK users can send the UoG team queries which can be added in the list of pre-constructed queries.

xi) Simplify the interface by hiding some unnecessary fields.

xii) Develop a Web based graphical data analysis tool for AASK allowing simple graphical representation of data e.g. pie charts, column graphs, etc.

xiii) Link AASK with other accident databases.

xiv) Extend SPV to display routes taken by passengers to exits and label with a flag those routes that are known to be "indirect".

xv) Display within the SPV the positions of Cabin Crew at the beginning of the evacuation and which exits they used.

xvi) Display in the SPV the location of fuselage ruptures.

xvii) Display in SPV debris and unusable exits.

d) User feedback.

AASK currently has 30 external internet users in nine countries. There have been a number of requests from other potential users including the airline cabin crew training staff. It is essential that the experience of these users in using AASK is monitored and fed back into the development of the AASK database. Issues concerning errors or inconsistency in the data, requests for assistance in either the use of the AASK database or in interpreting the results generated by AASK must be acted on. Issues concerning ease of use and improved functionality should also be monitored.

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Appendix A Project Description

1 Project Workplan

The work plan for the project consisted of the following main tasks:

1.1 **Analysis of collected data**

a) Detailed analysis of data in AASK V3.0. This is to include an analysis of crew data.

b) On completion of a significant proportion of task 1.2, the analysis undertaken in part a) will be extended to include the new data entered.

c) Follow-up on comments and suggestions received from parts a) and b).

1.2 **Continued collection and entry of data into AASK**

A considerable amount of data in the form of interview transcripts remained to be collected from the NTSB, studied, and transformed into a form suitable for inclusion into AASK, in particular the data from the NTSB study covering the period September 1997 to June 1999. This involved 46 evacuations, 2,651 passengers and 18 different types of aircraft. This data will be collected and where possible entered into the AASK database.

1.3 **Maintenance and functional development of the AASK database**

Several developments will be pursued,

a) The AASK database will be transferred to a dedicated PC web server.

b) Maintain and improve usability of interface in line with the requirements of item 1.1).

1.4 **User feedback**

At the start of this project AASK had eight external internet users in UK, France, Italy and Australia. There have been a number of requests from other potential users including the airline cabin crew training staff. Interest has also been shown in AASK from the NTSB. It is essential that the experience of these users in using AASK is monitored and fedback into the development of the AASK database. Issues concerning errors or inconsistency in the data and requests for assistance in either the use of the AASK database or in interpreting the results generated by AASK must be acted on. Issues concerning ease of use and improved functionality should also be monitored.

1.5 **Report preparation**

a) progress report

b) final report.

All parts of the work plan have been completed successfully.

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Appendix B All Accidents Contained in AASK V4.0

Table 25 All accidents contained in AASK V4.0

ID	Date	Aircraft	Location	Pax On Board	Fatal	Serious	Minor	None	Max Pax	Pax Load%	Survivors	Surv ivor%	Transcripts	Reply rate %	Entered (incl inf)	Entered %	Type of accident
62	08/03/1998	DC-10	MANCHESTER A/P ENGLAND	N/D						N/D			120		127		intact, external fire
59	25/10/1986	B-737-222	CHARLOTTE DOUGLAS INT A/P, NC	114	0	3	28	83	118	96.61	114	100.00	3	2.63	114	100.00	intact, no fire
100	01/06/1999	MD-82	LITTLE ROCK, ARKANSAS	139	10	41	64	24	139	100.00	129	92.81	90	69.77	113	87.60	ruptured, external fire
1	14/04/1993	DC-10-30	DALLAS/FORT WORTH INT A/P TEXAS	189	0	2	35	152	290	65.17	189	100.00	71	37.57	112	59.26	intact, external fire
55	31/08/1988	B-727-232	DALLAS/FORT WORTH INT A/P TEXAS	101	12	22	49	18	148	68.24	89	88.12	66	74.16	88	98.88	ruptured, external fire
6	19/07/1989	DC-10-10	SIOUX GATEWAY A/P, IOWA	286	110	42	121	13	287	99.65	176	61.54	66	37.50	85	48.30	ruptured, external fire
96	20/04/1998	B-727	O'HARE INT A/P, CHICAGO, USA	149	0	1	2	146	146	102.05	149	100.00	61	40.94	80	53.69	intact, external fire
70	22/08/1985	B-737-236	MANCHESTER A/P ENGLAND	131	53	15	0	63	130	100.77	78	59.54	74	94.87	78	100.00	intact, external fire
80	09/02/1998	B-727-223	O'HARE INT A/P, CHICAGO, USA	116	0	0	22	94	146	79.45	116	100.00	71	61.21	74	63.79	intact, no fire
79	09/07/1998	A-300B4-605R	LUIS MUNOZ MARIN INT A/P, PUERTO RICO	243	0	0	28	215	267	91.01	243	100.00	51	20.99	67	27.57	intact, external fire
54	23/01/1982	DC-10-30CF	LOGAN INT A/P BOSTON	200	2	2	19	177	354	56.50	198	99.00	55	27.78	59	29.80	ruptured, in water
10	12/11/1995	MD-83	BRADLEY A/P, CONNECTICUIT	73	0	0	1	72	148	49.32	73	100.00	40	54.79	54	73.97	intact, external fire
61	15/11/1987	DC-9-14	STAPLETON INT A/P, COLORADO	77	25	27	24	1	83	92.77	52	67.53	38	73.08	52	100.00	ruptured, no fire
45	27/06/1985	DC-10-10	LUIS MUNOZ MARIN INT A/P, PUERTO RICO	257	0	2	28	227	268	95.90	257	100.00	41	15.95	47	18.29	intact, in water
7	20/09/1989	B-737-400	LaGUARDIA A/P NY	57	2	3	12	40	146	39.04	55	96.49	32	58.18	44	80.00	ruptured, in water
49	01/02/1991	B-737-300	LOS ANGELES INT A/P	83	20	11	15	37	128	64.84	63	75.90	43	68.25	44	69.84	ground collision
30	30/07/1992	L-1011-385-1	JOHN F. KENNEDY INT A/P	280	0	1	9	270	275	101.82	280	100.00	34	12.14	39	13.93	intact, external fire
4	15/04/1988	DHC-8-102	SEATTLE-TACOMA INT A/P	37	0	4	24	9	37	100.00	37	100.00	33	89.19	37	100.00	ruptured, external fire
3	08/06/1995	DC-9-32	HARTSFIELD INT A/P, ATLANTA, GA	57	0	0	7	50	113	50.44	57	100.00	35	61.40	36	63.16	intact, external fire
95	29/07/1998	B-737	NEWARK A/P, NEW JERSEY, USA	109	0	0	11	98	128	85.16	109	100.00	28	25.69	36	33.03	intact, no fire
46	30/12/1989	B-737-204	TUCSON INT A/P	128	0	0	10	118	122	104.92	128	100.00	26	20.31	35	27.34	intact, external fire
87	01/11/1998	B-737	ATLANTA A/P, GEORGIA, USA	100	0	0	11	89	128	78.13	100	100.00	27	27.00	31	31.00	intact, external fire
43	10/08/1988	B-737-222	LITTLE ROCK, ARKANSAS	102	0	5	5	92	109	93.58	102	100.00	23	22.55	26	25.49	intact, external fire
81	27/08/1998	MD-82	PHOENIX A/P, ARIZONA, USA	75	0	0	0	75	142	52.82	75	100.00	24	32.00	26	34.67	intact, no fire
101	22/06/1999	B-737	SCOTSBLUFF, NEBRASKA, USA	63	0	0	0	63	128	49.22	63	100.00	22	34.92	25	39.68	in-flight, internal fire
65	29/04/1993	EMB-120RT	PINE BLUFF A/P, ARKANSAS	27	0	0	12	15	30	90.00	27	100.00	21	77.78	24	88.89	intact, no fire

Table 25 All accidents contained in AASK V4.0

ID	Date	Aircraft	Location	Pax On Board	Fatal	Serious	Minor	None	Max Pax	Pax Load%	Survivors	Surv ivor%	Transcripts	Reply rate %	Entered (incl inf)	Entered %	Type of accident
60	09/01/1983	CV-580	BRAINERD A/P, MINNESOTA	30	1	1	0	28	48	62.50	29	96.67	19	65.52	22	75.86	intact, no fire
41	04/04/1977	DC-9-31	NEW HOPE, GEORGIA	81	60	21	0	0	100	81.00	21	25.93	18	85.71	21	100.00	ruptured, external fire
72	13/08/1998	CRJ	KNOXVILLE, TENNESSEE, USA	46	0	0	0	46	50	92.00	46	100.00	18	39.13	21	45.65	intact, no fire
8	01/02/1994	SAAB-340-B	FALSE RIVER AIR PARK, LOUISIANA	20	0	0	0	20	34	58.82	20	100.00	18	90.00	19	95.00	intact, external fire
53	28/02/1984	DC-10-30	JOHN F. KENNEDY INT A/P	163	0	1	8	154	229	71.18	163	100.00	15	9.20	19	11.66	intact, in water
66	02/06/1983	DC-9-32	GREATER CINCINNATI INT A/P, KENTUCKY	41	23	3	13	2	100	41.00	18	43.90	14	77.78	18	100.00	intact, internal fire
90	26/12/1998	MD-88	DALLAS/FORT WORTH INT A/P TEXAS	45	0	1	0	44	142	31.69	45	100.00	16	35.56	18	40.00	intact, external fire
51	03/12/1990	DC-9-14	DETROIT METRO A/P, MICHIGAN	40	7	4	20	9	78	51.28	33	82.50	17	51.52	17	51.52	ground collision
99	08/05/1999	SAAB-340-B	JOHN F. KENNEDY INT A/P	27	0	1	0	26	34	79.41	27	100.00	12	44.44	17	62.96	intact, no fire
17	29/09/1988	B-757-225	SAN JOSE, COSTA RICA	121	0	0	0	121	193	62.69	121	100.00	14	11.57	14	11.57	intact, no fire
19	30/01/1991	Bae31Jetstream	RALEIGH COUNTY MEMORIAL A/P, WV	17	0	12	3	2	19	89.47	17	100.00	13	76.47	14	82.35	intact, external fire
42	29/12/1980	DC-8-61	SKY HARBOUR INT A/P, PHOENIX, ARIZONA	238	0	2	24	212	241	98.76	238	100.00	13	5.46	14	5.88	intact, external fire
52	03/12/1990	B-727-251	DETROIT METRO A/P, MICHIGAN	146	0	0	0	146	146	100.00	146	100.00	14	9.59	14	9.59	ground collision
67	02/07/1994	DC-9-31	CHARLOTTE, NORTH CAROLINA	52	37	14	1	0	103	50.49	15	28.85	9	60.00	14	93.33	ruptured, external fire
18	02/04/1995	MD-11	JOHN F. KENNEDY INT A/P	37	0	2	35	0	271	13.65	37	100.00	10	27.03	12	32.43	intact, external fire
78	06/06/1998	Bae31Jetstream	EVANSVILLE A/P, INDIANA, USA	19	0	0	1	18	30	63.33	19	100.00	11	57.89	12	63.16	intact, no fire
2	14/10/1989	B-727-232	SALT LAKE CITY INT A/P	12	0	0	1	11	148	8.11	12	100.00	7	58.33	11	91.67	intact, internal fire
98	17/02/1999	A-320	COLUMBUS, OHIO, USA	26	0	0	0	26	150	17.33	26	100.00	8	30.77	8	30.77	intact, no fire
75	25/04/1998	DC-9	DETROIT METRO A/P, MICHIGAN	26	0	0	0	26	0	N/D	26	100.00	7	26.92	7	26.92	intact, external fire
84	19/01/1999	ATR-72	ST LOUIS A/P, MISSOURI, USA	17	0	0	0	17	64	26.56	17	100.00	7	41.18	7	41.18	intact, external fire
92	08/01/1999	CRJ	COVINGTON A/P, KENTUCKY, USA	5	0	0	0	5	50	10.00	5	100.00	4	80.00	4	80.00	intact, no fire
89	12/11/1998	DHC-8	BOSTON A/P, MASSACHUSETTS, USA	18	0	0	0	18	36	50.00	18	100.00	2	11.11	2	11.11	intact, no fire
110	27/03/1998	DC-9	O'HARE INT A/P, CHICAGO, USA	27	0	0	0	27	96	28.13	27	100.00	1	3.70	1	3.70	intact, internal fire
9	20/02/1996	A-300B4	JOHN F. KENNEDY INT A/P	187	0	2	32	153	0	N/D	187	100.00	0	0.00	0	0.00	intact, internal fire
12	19/10/1996	MD-88	LaGUARDIA A/P NY	58	0	0	3	55	0	N/D	58	100.00	0	0.00	0	0.00	intact, no fire
13	06/07/1996	MD-88	PENSACOLA, FLORIDA	137	2	2	3	130	142	96.48	135	98.54	0	0.00	0	0.00	intact, no fire
15	20/12/1995	B-747-136	JOHN F. KENNEDY INT A/P	462	0	0	23	439	493	93.71	462	100.00	0	0.00	0	0.00	intact, no fire
16	02/03/1994	MD-82	LaGUARDIA A/P NY	110	0	0	29	81	147	74.83	110	100.00	0	0.00	0	0.00	intact, no fire

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ID	Date	Aircraft	Location	Pax On Board	Fatal	Serious	Minor	None	Max Pax	Pax Load%	Survivors	Surv ivor%	Transcripts	Reply rate %	Entered (incl inf)	Entered %	Type of accident
25	26/06/1978	DC-9-32	TORONTO INT A/P	102	2	43	57	0	103	99.03	100	98.04	0	0.00	0	0.00	ruptured, no fire
26	11/05/1995	B-727-217	ST JOHN'S A/P, NEWFOUNDLAND	154	0	0	0	154	0	N/D	154	100.00	0	0.00	0	0.00	intact, no fire
*28	01/12/1993	Bae31Jetstream	HIBBING, MINNESOTA	16	16	0	0	0	0	N/D	0	0.00	0	0.00	0	0.00	lack of info for analysis
29	22/03/1984	B-737-200	CALGARY INT A/P, ALBERTA	114	0	4	0	110	130	87.69	114	100.00	0	0.00	0	0.00	intact, external fire
31	14/07/1986	B-737-275	KELOWNA A/P, BRITISH COLUMBIA	76	0	0	0	76	130	58.46	76	100.00	0	0.00	0	0.00	intact, no fire
32	11/02/1978	B-737-275	CRANBROOK A/P, BRITISH COLUMBIA	44	38	5	1	0	130	33.85	6	13.64	0	0.00	0	0.00	ruptured, external fire
33	02/01/1982	B-737	SAULT-STE MARIE A/P, CANADA	117	0	0	0	117	0	N/D	117	100.00	0	0.00	0	0.00	intact, no fire
35	12/05/1983	DC-9-32	REGINA A/P, SASKATCHEWAN	57	0	0	57	0	103	55.34	57	100.00	0	0.00	0	0.00	intact, no fire
37	22/06/1989	B-737-217	SASKATOON A/P, SASKATCHEWAN	72	0	0	1	71	130	55.38	72	100.00	0	0.00	0	0.00	intact, no fire
38	18/05/1991	B-767	EDMONTON INT A/P, ALBERTA	113	0	0	0	113	0	N/D	113	100.00	0	0.00	0	0.00	intact, no fire
39	28/11/1993	B-727-200	DORVAL INT A/P, MONTREAL	60	0	0	7	53	146	41.10	60	100.00	0	0.00	0	0.00	intact, internal fire
40	22/06/1994	DC-10-10	LESTER B. PEARSON INT A/P, ONTARIO	276	0	0	3	273	287	96.17	276	100.00	0	0.00	0	0.00	intact, external fire
47	15/02/1986	L-1011-385-1	JOHN F. KENNEDY INT A/P	281	0	1	14	266	293	95.90	281	100.00	0	0.00	0	0.00	intact, external fire
*50	01/02/1991	SA-227	LOS ANGELES INT A/P	10	10	0	0	0	19	52.63	0	0.00	0	0.00	0	0.00	ground collision
*56	10/07/1991	C99	BIRMINGHAM A/P, ALABAMA	13	12	1	0	0	13	100.00	1	7.69	0	0.00	0	0.00	ruptured, external fire
*57	11/07/1991	DC-8-61	KING ABDULAZIZ INT A/P, SAUDI ARABIA	247	247	0	0	0	0	N/D	0	0.00	0	0.00	0	0.00	ruptured, external fire
64	18/03/1998	Bae ATP	MANCHESTER A/P ENGLAND	58	0	1	0	57	64	90.63	58	100.00	0	0.00	0	0.00	intact, no fire
68	24/04/1994	DC-3	BOTANY BAY, AUSTRALIA	21	0	0	0	21	22	95.45	21	100.00	0	0.00	0	0.00	intact, in water
69	01/07/1992	SAAB SF-340A	DEVONPORT A/P, TASMANIA	17	0	0	0	17	30	56.67	17	100.00	0	0.00	0	0.00	lack of info for analysis
71	09/02/1998	DC-9	HONOLULU INTERNATIONAL A/P, HAWAII	139	0	0	0	139	0	N/D	139	100.00	0	0.00	0	0.00	intact, external fire
73	12/02/1998	MD-88	ARLINGTON, VIRGINIA, USA	49	0	0	0	49	142	34.51	49	100.00	0	0.00	0	0.00	intact, external fire
74	02/08/1985	L-1011-385-1	DALLAS/FORT WORTH INT A/P TEXAS	152	126	14	10	2	302	50.33	26	17.11	0	0.00	0	0.00	ruptured, external fire
76	26/05/1998	DC-9	INDIANAPOLIS A/P, INDIANA, USA	101	0	0	0	101	98	103.06	101	100.00	0	0.00	0	0.00	intact, external fire
77	04/06/1998	SAAB 340	HUNTSVILLE A/P, ALABAMA, USA	16	0	0	0	16	34	47.06	16	100.00	0	0.00	0	0.00	intact, no fire
82	13/09/1998	CRJ	RALEIGH-DURHAM A/P, NORTH CAROLINA, USA	40	0	0	0	40	50	80.00	40	100.00	0	0.00	0	0.00	intact, no fire
83	10/09/1998	CRJ	NEWBURG A/P, NEW YORK, USA	30	0	0	0	30	50	60.00	30	100.00	0	0.00	0	0.00	intact, no fire
85	24/10/1998	ATR-42	SAN JUAN A/P, PUERTO RICO	22	0	0	0	22	46	47.83	22	100.00	0	0.00	0	0.00	intact, external fire
86	30/10/1998	SAAB 340	SHREVEPORT A/P, LOUISIANA, USA	27	0	0	0	27	34	79.41	27	100.00	0	0.00	0	0.00	in-flight, internal fire

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88	03/11/1998	BEECHCRAFT 1900	MIAMI A/P, FLORIDA, USA	19	0	0	0	19	19	100.00	19	100.00	0	0.00	0	0.00	in-flight, internal fire
91	29/12/1998	SAAB 340	WHITE PLAINS A/P, NEW YORK, USA	4	0	0	0	4	34	11.76	4	100.00	0	0.00	0	0.00	intact, no fire
93	24/01/1999	F-100	CHARLOTTE DOUGLAS INT A/P, NC	70	0	0	0	70	93	75.27	70	100.00	0	0.00	0	0.00	intact, no fire
94	28/06/1998	ATR-42	NEWARK A/P, NEW JERSEY, USA	45	0	0	1	44	46	97.83	45	100.00	0	0.00	0	0.00	intact, no fire
97	24/01/1999	EMB-145	NEWARK A/P, NEW JERSEY, USA	48	0	0	0	48	50	96.00	48	100.00	0	0.00	0	0.00	intact, no fire
102	24/09/1997	B-737	SALT LAKE CITY INT A/P	66	0	0	0	66	128	51.56	66	100.00	0	0.00	0	0.00	intact, no fire
103	04/11/1997	Bae31Jetstream	DULLES INTERNATIONAL AIRPORT, WASHINGTON D.C., USA	2	0	0	0	2	19	10.53	2	100.00	0	0.00	0	0.00	intact, no fire
104	07/11/1997	F-100	CHARLOTTE DOUGLAS INT A/P, NC	99	0	0	0	99	93	106.45	99	100.00	0	0.00	0	0.00	intact, external fire
105	19/12/1997	MD-80	SAN FRANCISCO A/P, CALIFORNIA, USA	69	0	0	8	61	141	48.94	69	100.00	0	0.00	0	0.00	intact, no fire
106	25/12/1997	B-737	EUGENE A/P, OREGON, USA	100	0	0	0	100	128	78.13	100	100.00	0	0.00	0	0.00	intact, no fire
107	21/01/1998	ATR-42	BRADLEY A/P, CONNECTICUIT	36	0	0	0	36	46	78.26	36	100.00	0	0.00	0	0.00	intact, external fire
108	22/01/1998	ATR-72	PEORIA, ILLINOIS, USA	10	0	0	0	10	64	15.63	10	100.00	0	0.00	0	0.00	intact, no fire
109	22/02/1998	SAAB 340	LAWTON-FORT SILL, OKLAHOMA, USA	3	0	0	0	3	34	8.82	3	100.00	0	0.00	0	0.00	intact, no fire
111	30/03/1998	B-727	FORT LAUDERDALE A/P, FLORIDA, USA	188	0	3	14	171	0	N/D	188	100.00	0	0.00	0	0.00	intact, external fire
112	15/04/1998	Bae31Jetstream	INDIANAPOLIS A/P, INDIANA, USA	6	0	0	0	6	19	31.58	6	100.00	0	0.00	0	0.00	intact, no fire
113	18/04/1998	Bae 4100 Jetstream	WORCESTER, MASSACHUSETTS, USA	29	0	0	0	29	30	96.67	29	100.00	0	0.00	0	0.00	intact, no fire
114	23/04/1998	DHC-8	ATLANTIC CITY, NEW JERSEY, USA	19	0	0	0	19	36	52.78	19	100.00	0	0.00	0	0.00	intact, no fire
115	08/07/1998	Bae 4100 Jetstream	ROCHESTER, NEW YORK, USA	10	0	0	0	10	30	33.33	10	100.00	0	0.00	0	0.00	intact, external fire
116	22/12/1998	A-320	PHOENIX, ARIZONA, USA	145	0	0	0	145	150	96.67	145	100.00	0	0.00	0	0.00	intact, no fire
117	07/01/1999	MD-80	SAN DIEGO, CALIFORNIA, USA	36	0	0	1	35	141	25.53	36	100.00	0	0.00	0	0.00	intact, no fire
118	19/02/1996	DC-9-32	HOUSTON INTERCONTINENTAL A/P, HOUSTON, TEXAS, USA	82	0	0	12	70	103	79.61	82	100.00	0	0.00	0	0.00	intact, internal fire
119	23/09/1999	B-747-438	BANGKOK INTERNATIONAL AIRPORT, THAILAND	291	0	0	38	253	394	73.86	291	100.00	0	0.00	0	0.00	intact, no fire
120	05/05/1991	MD-88	HARTSFIELD INT A/P, ATLANTA, GA	102	0	1	4	97	142	71.83	102	100.00	0	0.00	0	0.00	lack of info for analysis

*these are non-survivable