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Aircraft Accident Statistics and Knowledge Database: Analyzing Passenger Behavior in Aviation Accidents

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The Aircraft Accident Statistics and Knowledge (AASK) database is a repository of passenger accounts from survivable aviation accidents/incidents compiled from interview data collected by agencies such as the US NTSB. Its main purpose is to store observational and anecdotal data from the actual interviews of the occupants involved in aircraft accidents. The database has wide application to aviation safety analysis, being a source of factual data regarding the evacuation process. It also plays a significant role in the development of the airEXODUS aircraft evacuation model, where insight into how people actually behave during evacuation from survivable aircraft crashes is required. This paper describes the latest version of the database (Version 4.0) and includes some analysis of passenger behavior during actual accidents/incidents.

I. Introduction

THE Aircraft Accident Statistics and Knowledge (AASK) database is a repository of survivor accounts from aviation accidents.[1–5] Its main purpose is to store observational and anecdotal data from interviews of survivors of aircraft accidents conducted by investigative organizations such as the National Transportation Safety Board (NTSB) and the Air Accident Investigation Branch (AAIB). The database has wide application to aviation safety analysis, being a source of factual data regarding the evacuation process. In their recent report to the Committee of Transportation and Infrastructure, U.S. House of Representatives,[6] the U.S. Government Accountability Office, recommended that the Federal Aviation Administration (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 analyze 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,[7–10] where insight into how people actually behave during emergencies is essential.

The development of AASK has been under way since 1997 with initial support from the U.K. Engineering and Physical Sciences Research Council and subsequent support from the U.K. Civil Aviation Authority (CAA). In the course of this development, it was found that, contrary to original expectations, a vast number of observational and anecdotal data concerning human behavior during emergency evacuation situations were available. However, due to their nature, these data are difficult to secure and analyze. To aid in their storage and analysis, the computer-based relational database AASK was developed.[1–5]

This paper describes the capabilities of the AASK V4.0 (Refs. 2, 4) database and presents several analyses of the data. Included in this analysis is a study of the behavior of passenger groups, an important area that up until now has been largely ignored by regulators and researchers.

II. The Aircraft Accident Statistics and Knowledge Database

A. The Data

AASK is a repository for a vast amount of information concerning passenger behavior during survivable accidents and emergencies derived directly from the people involved. AASK V4.0[2,4] has been expanded to include 50 additional accidents/incidents, additional accounts from 622 surviving passengers and 45 surviving crew, and data relating to 11 fatalities (a number of which came from data provided by the NTSB[9]). In addition, the structure of the database and its user interface have been improved, with a number of new and enhanced features. The latest version of the database contains information from 105 accidents and detailed data from 1917 passengers and 155 cabin crew, with information relating to some 338 fatalities. The accidents included in AASK V4.0 cover the period 4 April 1977–23 Sept. 1999. In contract to previous versions of the database, data within AASK V4.0 have been recategorized according to the nature of the evacuation incident. Three types of evacuation are considered-emergency evacuation (which is further categorized into planned and unplanned), precautionary evacuation, and postincident deplaning. These are defined as follows:

1. *Emergency Evacuation*

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:

Planned Emergency: 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. (An exemplary incident is Accident 66, Table 1.)

Unplanned Emergency: In these incidents CC have very little warning before the emergency and 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. (An exemplary incident is accident 70; see Table 1.)

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Table 1 Survivor and reply rate analysis

ID	Date	Aircraft	Location	Pax on Bd	Max Pax	Pax Load %[a]	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	Tuscon 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 A-300	Evansville A/P, Indiana, USA	19	30	63.33	19	100.00	57.89	63.16	intact no fire
79	09/07/98	B4-605R	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, USA	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

[a]Pax loading that exceeds 100% is due to infants not requiring seats.

2. Precautionary Evacuation

Here CC and passengers have preparation time equivalent to that for a planned emergency, but there is no immediate emergency. In precautionary evacuation situations, the passengers, crew, and/or aircraft are not currently 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. Although 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 air stairs. More often than not, precautionary evacuations are planned. (An exemplary incident is accident 78, Table 1.)

3. Postincident Deplaning

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 decision is taken to remove passengers from the aircraft even though there appears to be an immediate threat to passengers resulting in an unscheduled disembarkation onto the tarmac. This may result from, for example, an aborted takeoff causing substantial damage to the aircraft but no postincident 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. (An exemplary incident is accident 15, Table 1.)

B. The Database Structure

AASK V4.0 consists of five main components (see Fig. 1): 1) user interface, 2) data viewer, 3) seat plan viewer, 4) data query interface, and 5) data entry interface.

It should be noted that to preserve the integrity of the data at the heart of AASK, data entry is restricted to the database manager. General users of AASK only have access to view the data and to launch queries.

Details of the AASK database are described in Ref. 10; here only a brief description of the key components of the database is provided.

1. *Data Viewer*

The data viewer allows users to view all of the data records available within AASK. For convenience this is split into four sections, each of which deals with a different aspect of the accident. Depicted in Fig. 2 is a logical representation of the data structures within AASK V4.0. The four main data components relate to accidents, passengers, cabin crew, and fatalities. These are linked to each other and have a large number of tables dealing with subcategories of data. Further details of the data and structure can be found in Ref. 4.

2. *Seat Plan Viewer*

Once the accident details are entered into the database, the layout of the cabin is usually available to view diagrammatically using the seat plan viewer (SPV). The SPV is a graphical tool that allows users to view a plan of the aircraft. Information concerning the seating arrangement, available exits, surviving/fatality passenger seating locations, age and sex of passengers, traveling companions associated with each passenger, and exits used by each passenger is also displayed. All the data required by the SPV are automatically accessed from the database.

Depicted in Fig. 3 is an example output from the SPV depicting 1) title bar with basic accident details; 2) passenger details on each occupied seat (where available); 3) color coding showing passenger exit usage; and 4) label on seat identifying status of passenger (survivor/fatality) and nature of companion relationships that may exist.

3. *AASK V4.0 Query Engine*

AASK V4.0 can be used in three modes; standalone on a single computer, over a local area intranet, and over the Internet. The same user interface is used for all three modes of operation. The user interface developed for AASK has been designed so that users without a detailed understanding of the ACCESS database—on which AASK is based—can easily make use of the data. It should be stressed, however, that to run meaningful queries the user must understand the nature of the data held in the database.

The AASK database query applet enables authorized users to construct queries and to copy and paste query results into other analysis tools such as spreadsheets. The user interface allows operations such as selection of query fields, inclusion of query conditions, and query field sorting. All database management systems use Structured Query Language (SQL) for constructing queries. In other words, to construct and launch a query in any database SQL must be used, and AASK V4.0 is no exception. The AASK database query applet translates user queries based on the selected database fields, conditions, sorting, etc. into SQL. The SQL query is then sent to the AASK database and the results are displayed to the user.

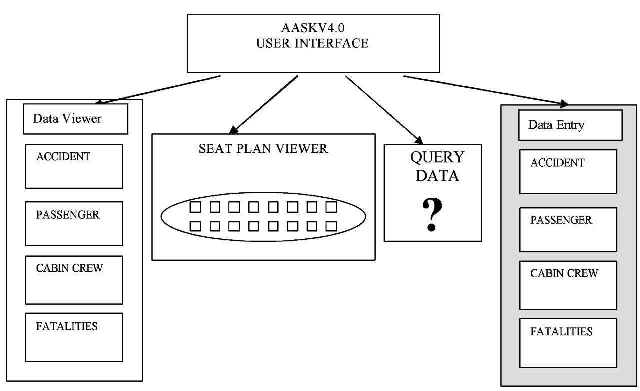

Fig. 1 Overview of AASK V4.0.

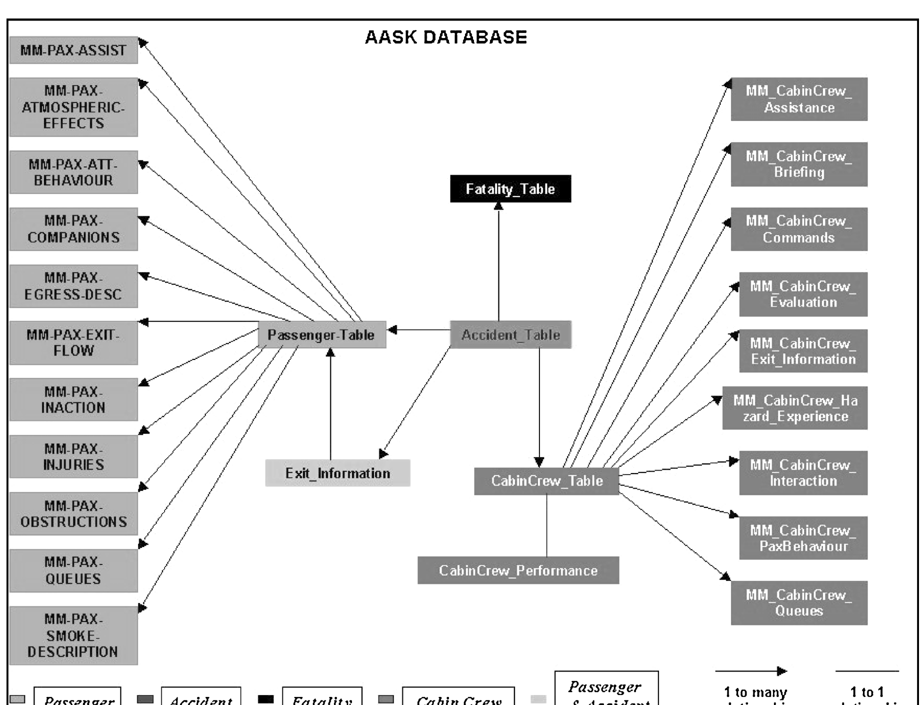

Fig. 2 Data relationships in AASK V4.0.

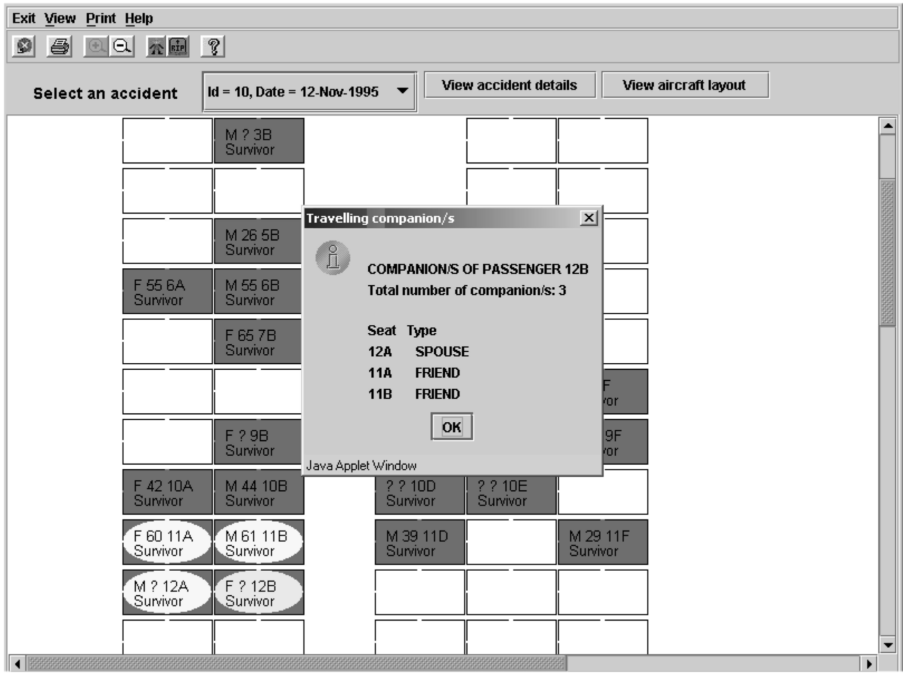

Fig. 3 Seat plan viewer depiction of a single-aisle aircraft showing companion relationships, passenger status, and exit used.

Security of the database is maintained at a number of different levels, with passwords for the software and control of machine access. Currently only users authorized by the UK CAA are given Internet access to AASK V4.0. Those interested in using AASK may register at the site http://fseg.gre.ac.uk/aask/index.html. An online help facility is provided that includes a complete description of the AASK database and its structure. Also included are a number of examples on 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.

III. Analysis of data in AASK V.4.0

The AASK database can be used for a variety of purposes. The type of analyses 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 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 represent a fair cross-section of all the data. For example, a proportion of the survivors who fail to return questionnaires may have exhibited behavior that greatly influenced the outcome of the evacuation.

In publications[3,5] based on earlier AASK versions, several key analyses were conducted. Here we revisit some of these analyses, especially those concerning survivor and reply rate, age and sex distribution, passengers encountering difficulties in releasing their seat belts, and seat-climbing behavior, using the extended database. In addition, the analysis considers some initial precedings analysis, on group behavior exhibited during emergency evacuation.

Of the 105 accidents/incidents entered into AASK V4.0, 49 have detailed passenger and crew accounts and so are suitable for analysis. This compares with 31 accidents/incidents from the previous analysis.[3,5] 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 accident/incidents there are replies from at least 50% of the survivors. Within AASK V4.0, data are available from 42% of the survivors of these accidents.

Table 2 Age and sex distribution in 5-yr age bands

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

A. Survival Rates

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

B. Sex and Age Distribution

Of the 1859 records of passengers in AASK V 4.0 the age is given for 1288 (69%). Of these 721 (56.0%) were male and 558 (43.3%) were female, the remainder being passengers where sex was not recorded. The average age of all survivors where age and sex are known is 40.3 yr, with the average age of females slightly lower at 39.9 yr and the average age of males slightly higher at 40.8 yr. Compared with the data in AASK V3.0,[3,5] we find the average age of the survivors has increased slightly. The oldest surviving female was 86 yr old while the oldest surviving male was 80 yr old.

When the age distribution is broken down by sex there is a large disparity in the numbers in the 35–55 age groups, as can be seen in Table 2 and is graphically illustrated in Fig. 4. As can be seen, there are significantly fewer females than males traveling in this age range. This is thought to be related to sex bias in the professions.

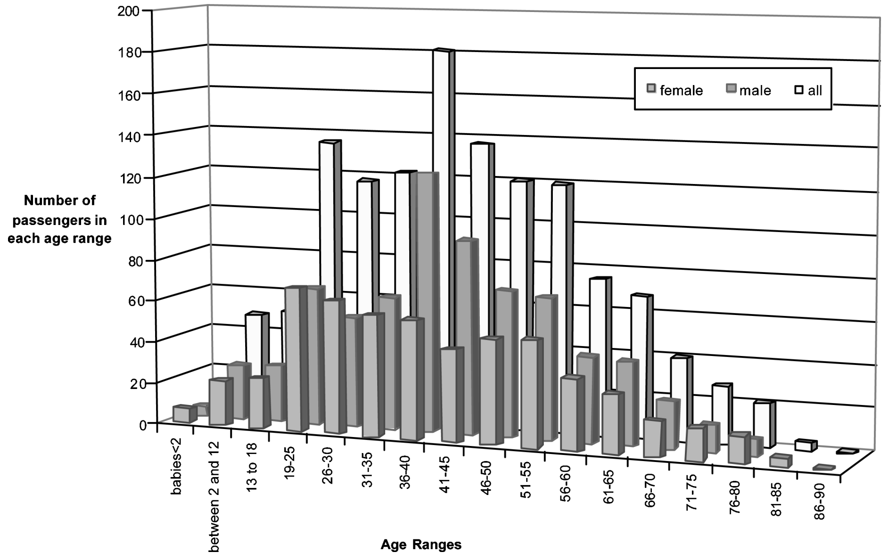

Fig. 4 Age and sex distribution of passengers, where known.

C. Seat Belt Difficulty

This analysis concerns one of the most crucial aspects in an evacuation, the response time of the passengers, that is, 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 difficulty in leaving their seats, either due to the aisle being full of passengers, or simply because they had difficulties releasing their seat belts. In this example analysis, the latter of these cases is investigated.

In AASK three relevant categories of seat belt difficulty have been recorded. These are

1) *Provided help to other pax:* This indicates that the passenger aided at least one other passenger with his or her seat belt (further fields allow a description of who and where).

2) *Difficulty—required no help:* This indicates that the passenger did encounter difficulty releasing his or her seat belt, but was eventually able to undo it without any external assistance.

3) *Difficulty—required help:* This indicates that the passenger experienced some kind of difficulty and required external assistance in order to release his or her seat belt (further fields allow a description of who and how).

In total, 111 passengers experienced a seat belt difficulty falling into one of these three categories. This compares to 81 in AASK V3.0. A simple analysis based on age and sex for each of the three categories is shown in Table 3. It should be noted that this analysis has collected all passengers who experienced some kind of difficulty with releasing their seat belts, 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 where unable to release their belts because of environmental conditions—for example, could not see the seat belt release mechanism, those who could not release their belts because of injury—for example, unconsciousness, fractures, burns, and so on.

Data suggest that there is little difference in ages between the general survivors and those experiencing seat belt difficulty (see Table 3).

1. Gender Analysis Relating to Seatbelt Difficulty

The number of passengers in these three categories is sufficient for some statistical analysis with respect to their sex. 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. This observation is illustrated in Fig. 5.

Table 3 Age and sex breakdown of passengers reporting sea belt difficulties and all AASK passengers

Category	Sex	Number	Mean age (yr)	No age data
Provided help to other pax	Male	18	42.4 * (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

*Indicates children (<18 years) excluded; number in brackets indicates mean age including children.

From this distribution it is clear that males have fewer seat belt-related problems 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 sex proportions. Similarly, the number of females who managed alone or who helped others is significantly less than would be expected from the overall sex mix. Finally, the number of males who received help is significantly less than would be expected from the overall sex mix, whereas the number of females who received help is significantly greater.

Within the category of those experiencing seat belt difficulty, requiring help or not are mutually exclusive cases, so it was possible to estimate the significance of sex in each case. A χ^2 test was conducted on the data to test the hypothesis that sex and need for 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 his or her seat belt, there is a link between the sex of the passenger and whether he or she require help.

The authors suggest that this gender bias could be due to a number of factors, including the following:

1) Males may be physically stronger than females and therefore more able to deal with buckle difficulties.

2) Males may be less prepared to seek assistance than females and so may continue to struggle with the buckle and eventually succeed in releasing the belt.

3) In partners traveling together it may be more likely that the male will assist the female.

2. Age Analysis Relating to Seatbelt 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.

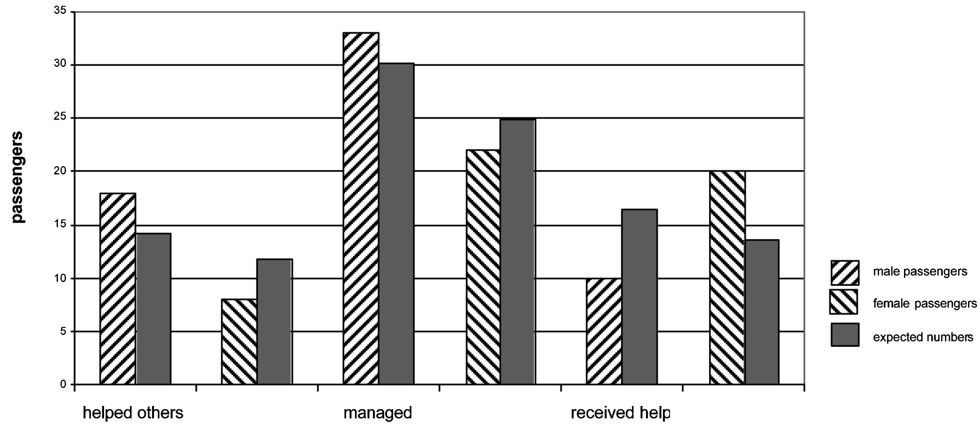

Fig. 5 Comparison of expected and observed values for sex numbers in seatbelt difficulty categories.

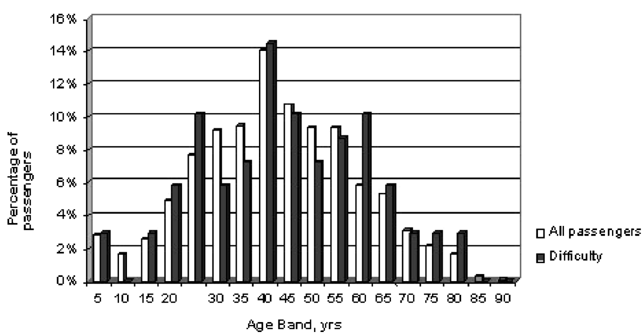

Fig. 6 Age distribution of those with seat belt difficulty.

This analysis requires that the passengers in the first category be 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 as follows:

Unfamiliar with buckle release mechanism:

For example, "It took him 5 to 6 seconds to determine how to undo his seat belt."

Environmental complications excluding immersion in water:

For example, "could not release seat belt due to smoke-reduced visibility problems. Erroneously tugged on the buckle instead of undoing it."

Buckle location:

For example, "Thought seat belt buckle was at side as in a car, not in center."

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 Fig. 6. The age distribution may suggest 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 passengers involved with seatbelt difficulties has higher values to the right (older passengers). However, the mean age of this group experiencing seat belt difficulties is 41.8 yr, while the average age for the entire population is 40.3 yr. Hypothesis testing ($p = 0.22$) suggests that there is not a significant difference between the mean age of the general population and the mean age of the 69 passengers who experienced seat belt difficulties. We therefore conclude from these data that age alone does not appear to be an indicator of the likelihood of experiencing difficulties with seat belts.

D. Seat Climbing

From the data in AASK V3.0, 40 passengers were recorded as climbing seats[5] as part of their exiting behavior, whereas in AASKV4.0 there are 91 passengers exhibiting this behavior. It is important to note here that generally, passenger 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 up to the passenger making the statement. If he or she does not feel that this is relevant information, then no mention is likely to be made of this behavior, even if it did occur. However, for the data entered into AASKV4.0 based on the NTSB evacuation study,[11] 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, B-727-232 at Dallas/Fort Worth, B 737-300 at Los Angeles, and MD-82 at Little Rock) 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 behavior being noted.

Of the 91 passengers who reported climbing over seats, 85 passengers reported both their age and sex 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, among 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 sex information who reported that they were involved in seat climbing activities is 32.9 yr, significantly less than the mean age of the overall population of survivors (mean age 40.3 yr). 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 was 35.5 yr, whereas the mean age of the female passengers was 31.1 yr. The mean age for female seat climbers has increased significantly from that in AASK V3.0 (which was previously 22.7 yr), whereas the mean age for males has remained virtually unchanged. In the female population reporting seat climbing, nine were aged 46 yr and over. For the remaining 41 females (82% of all females both climbing seats and providing age) the average age was 25.4 yr. These results suggest that there are more females of various ages climbing seats 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 4. 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.

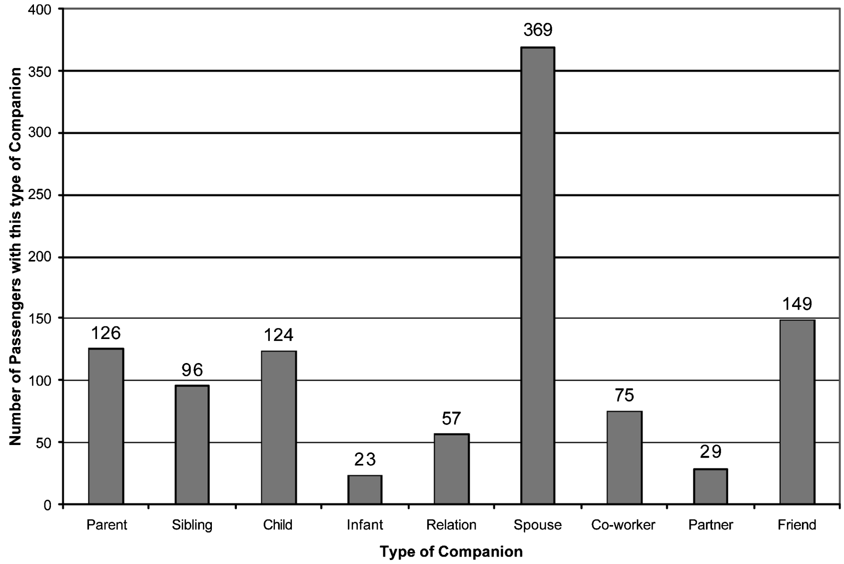

Fig. 7 Types of companion relationships found amongst the 947 passengers in AASK stating that they travelled with a companion.

Table 4 Number of seats involved in seat climbing incidents

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

Table 5 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

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 behavior. 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 who reported climbing seats, 42 passengers provided a reason for jumping the seats, as shown in Table 5. Of those providing reasons for climbing over seats, 41% (17/42) claimed that it was their shortest route to an exit, whereas 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. . . .

E. Group Behavior

An important aspect of behavior that has been practically ignored in aviation safety research is the influence of social bonds on evacuation behavior. The industry standard 90-s 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 behavior during evacuation may be influenced by the presence of traveling companions and the nature of the social bonds that exist between traveling companions. From the 1917 passenger reports in AASK V4.0, 49.5% (947) were entered into the database as traveling with a companion. As with all data reported in AASK and other accident surveys, it should be noted that these data only correspond to those passengers who have agreed to complete a survey. However, because 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. Because 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 behavioral responses of passengers.

1. *Type of Companion*

The term "companion" refers to two or more passengers who are connected through virtue of being family members, friends, work colleagues, or other socially connected traveling associates. Family groups were further broken down into subcategories of spouse, child, infant, parent, sibling, and relation.

The vast majority of the companions were family-related (65% or 616/947), with spouses 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 (Refs. 3, 5). The breakdown of these companions by type is shown in Fig. 7. It should be noted that these categories are not exclusive and that a passenger who was traveling with a spouse and two children would 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, because there is at least one case of a pairing where the term spouse is used by one and partner by the other.

The co-worker (business associate) category within AASK V4.0 has seen a major increase (650%) when compared to AASK V3.0 (Refs. 3, 5). This is possibly due to the type of data added to AASK, which consisted of a large number of smaller commuter flights.

The number of people typically found within a companion grouping varies considerably with groups made up of two or more traveling companions. The largest companion group recorded consisted of 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 companion grouping was 2.4 with the most common group size bons two people. The size of the average companion grouping has decreased slightly from 2.7 in AASK V3.0 (Refs. 3, 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. At first sight, these two numbers appear to be inconsistent. However, it is possible for one person to have several companion relationships; for example, a passenger can be accompanied by several members of his or her family, resulting in the passenger citing several relationships. There were 104 instances reported of rendering assistance to a traveling companion during the course of the evacuation by 87 individual passengers, and all of these were involved in planned or unplanned emergency evacuations.

Care should be taken when interpreting there data, because 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 traveling 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.

The number of individual passengers rendering assistance as a percentage of all passengers traveling 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 that a large number of the companions added to AASK V4.0 were not in family groups but adult business travelers on small commuter aircraft. Furthermore, a significant number of the accidents/incidents added to the database involved precautionary evacuations. Thus whereas the number of passengers traveling with a companion rose from 621 (in V3.0) to 947 (in V4.0), there was less opportunity to render assistance (due to both the nature of the companions and the nature of the incidents).

The type of person who rendered assistance is presented in Table 6. 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 6. Males are disproportionately represented in the role of caregivers to companions, with 65% (68/104) of caregiving 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 Fig. 7). Because 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 caregiver to infants, children, and other family members, females are the dominant sex rendering assistance. In contrast, in cases where a spouse is assisted, the male almost always assists the female. These results appear to support common sex based roles, that is, 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 traveling with a spouse.

From Table 6 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 extrafamilial, from planned and unplanned evacuations. This can be interpreted as meaning that 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 6. The latter interpretation is somewhat unlikely, because for every other type of companionship, including "unknown relationship," assistance was reported.

3. Family Groups

Passengers traveling in family groups make up some 32% (609/1917) of the passengers in AASK. Clearly family units represent a significant proportion of the traveling public and so their likely behavioral response to aviation accidents must be understood. As part of a study of human behavior in severe life-threatening conditions occurring during building evacuation scenarios, Johnson et al.[12] analyzed 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.[12] 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 behavior during evacuation.

Clearly, further data and analysis are needed to fully understand the response of family units and other social groupings. The analysis of family group behavior is difficult because passengers do not always explicitly identify family members within their interview

Table 6 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	Sex of those giving assistance: Female	Sex of those giving assistance: 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 granddaughter, 2 aunts, 3 females, 2 male	6	2
Friend	14	3 females, 11 males	3	11
Unknown relationship	3	1 female, 2 males	1	2
Total	**104**		**36**	**68**

transcripts. It is therefore impossible to determine with certainty that all behavior representative of the various family groupings has been collected and analyzed. However, a family group analysis that was undertaken considered family groups consisting of two adults and two children, 16 of which were found in the AASK database. These family units displayed a variety of evacuation behaviors. In some of these the male adult directs and leads the family; in others it is a joint operation. However, the most common behavior is for each parent to assume responsibility for a child (often with the female adult carrying an infant). The analysis reveals that 10 families stayed together whereas 6 family groups split.

In each of the 16 cases, the family groups had a variety of viable exits available to them. Regarding the 6 family groups who split, in two cases, the male adult and one child went through one exit, whereas 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, whereas 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.[12] 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-yr-old female "unsuccessfully tried to rescue grandmother from seat before exiting."
> An "infant was fatally thrown during impact sequence."
> A 58-yr-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-s certification analysis as a justification. One commonly practiced procedure is that of crew-initiated exit bypass, where crew members direct some passengers away from a functioning exit to another nearby functioning exit. Although 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.

IV. Conclusions

The AASK database is a unique resource currently containing data from over 2000 passenger and crew accounts from 105 survivable accidents. The data in AASK are extracted from accident investigation transcripts supplied by the Air Accident Investigation Branch in the United Kingdom, the National Transportation Safety Board in the United States, and the Australian ATSB.

Data within AASK V4.0 cover the period 4 April 1977–23 September 1999 and consist 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).

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 fatalities component holds data for all fatalities documented in the accident reports, whereas 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.

Although AASK contains much data, the majority of these data are 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 are added to the database, more confidence in performing quantitative analysis is established.

Some of the analysis presented in this paper was intended to reproduce earlier investigations, using the larger data set found in AASK V4.0. It is reassuring to note that much of this analysis has confirmed earlier conclusions based on the smaller data sets. Of particular significance is the analysis relating to the presence and behavior of groups during emergency situations. Groups of passengers displaying strong social bonds have been shown to be involved in a significant number of the accident/incidents within the database. It is reasonable to assume that such groups can be expected to be common among the passenger community. The frequency of passengers traveling within groups, the size and composition of the groups, and the nature of the group dynamic during emergency evacuation situations have significant implications for safety procedures, cabin crew training, and evacuation certification. This important component of evacuation dynamics has until now been virtually ignored by the research and regulatory community but is likely to have as significant an impact on evacuation performance as the type of exits used or the width of the exit bulkhead. Considerably more research and analysis are required to fully assess the impact of socially bonded groups on aircraft evacuation performance.

Although 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, it is hoped that additional data, currently in the possession of national accident investigation authorities such as the Transport Safety Board of Canada and the Australian ATSB, will be made available to the AASK developers for inclusion in AASK and thereby contribute to improving our understanding of human dynamics during aircraft evacuation.

AASK V4.0 is currently available online over the Internet at http://aask.gre.ac.uk. All interested researchers are welcome to make use of this resource.

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