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A Study of the Effects of Engine Configuration, Fuselage Breaks and Ruptures in Aircraft Accidents Involving Ground Pool Fires

June 2009

Final Report

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16. Abstract

This report describes the methodology and results of a study undertaken for the Federal Aviation Administration into the characteristics of *Fuselage Breaks* and their effects on occupant survival in ground pool fire Accidents. For those accidents where the fuselage remains largely intact, a determination has been made of the nature of any *Fuselage Ruptures* resulting from the accident sequence. An assessment has also been made as to whether the probability of occurrence of ground pool fires is different for Aircraft with Wing Mounted Engines than for Aircraft without Wing Mounted Engines. The Cabin Safety Research Technical Group Aircraft Accident Database was used to select Survivable Accidents that occurred during the period 1967 to 2000, to Passenger carrying western world turbojet aircraft. Where appropriate to the study these accidents were analyzed in depth using Accident Reports and other data published by National Airworthiness and Investigating Authorities.

The results of the study suggest that further data would be needed to determine any significant difference that might exist between the probabilities of occurrence of a ground pool fire accident for Aircraft with Wing Mounted Engines and for Aircraft without Wing Mounted Engines. All that can be determined, within the constraints of the size of the existing data set, is that any difference that might exist is unlikely to be large. Whilst it is likely that the majority of ground pool fire accidents in which the aircraft remains largely intact sustain *Fuselage Ruptures*, there are insufficient data available to establish the size of any such ruptures.

For the *Fuselage Break* accidents studied the majority involved at least two breaks. Whilst the number of *Fuselage Breaks* does not appear to be influenced by the intensity of the impact the probability of a *Fuselage Break* tends to increase as the impact becomes more severe. Although no firm conclusions can be made, it is considered likely that approximately half of the Fuselage Breaks occur at a point of structural discontinuity. The occurrence of a *Fuselage Break* in ground pool fire accidents seems to result in a more severe fire threat to the occupants. However, it is evident that for the majority of ground pool fire accidents studied, involving a *Fuselage Break*, the occupants used the breaks as an escape route. In order to ascertain the net effects of Fuselage Breaks on occupant survival a Monte Carlo simulation model was developed. The primary value of the model was an assessment of the effects on occupant survival of changes in the probability of occurrence of *Fuselage Breaks*. Based on the results derived from the model it is considered that *Fuselage Breaks* have a net adverse effect on occupant survival. The change in the number of Fatal Injuries, F, with changes in the probability of a Fuselage Break ΔB for an aircraft with N occupants may be reasonably well represented by the following equation:

$$F = N \times 0.055 \times \Delta B$$

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Whilst it is likely that the majority of ground pool fire accidents in which the aircraft remains largely intact sustain *Fuselage Ruptures*, there are insufficient data available to establish the size of any such ruptures.

For the Fuselage Break accidents studied the majority involved at least two breaks. Whilst the number of *Fuselage Breaks* does not appear to be influenced by the intensity of the impact the probability of a Fuselage Break tends to increase as the impact becomes more severe.

Although no firm conclusions can be made, it is considered likely that approximately half of the *Fuselage Breaks* occur at a point of structural discontinuity.

The occurrence of a Fuselage Break in ground pool fire accidents seems to result in a more severe fire threat to the occupants. However, it is evident that for the majority of ground pool fire accidents studied, involving a Fuselage Break, the occupants used the breaks as an escape route. In order to ascertain the net effects of *Fuselage Breaks* on occupant survival a Monte Carlo simulation model was developed. The primary value of the model was an assessment of the effects on occupant survival of changes in the probability of occurrence of *Fuselage Breaks*.

Based on the results derived from the model it is considered that *Fuselage Breaks* have a net adverse effect on occupant survival. The change in the number of Fatal Injuries, F, with changes in the probability of a Fuselage Break ΔB for an aircraft with N occupants may be reasonably well represented by the following equation:

$$F = N \times 0.055 \times \Delta B$$

1. INTRODUCTION.

This report describes the methodology and results of a study undertaken for the Federal Aviation Administration into the characteristics of *Fuselage Breaks* and their effects on occupant survival in ground pool fire accidents. For those accidents where the fuselage remains largely intact, a determination is made of the nature of any *Fuselage Rupture*s resulting from the accident sequence. An assessment is also made of whether the probability of occurrence of ground pool fires is different for *Aircraft with Wing Mounted Engines* than for *Aircraft without Wing Mounted Engines*.

Terms shown in italics are defined in Section 9 Glossary of Terms.

2. OBJECTIVES.

The prime objectives of the study are as follows:

1. To determine whether the probability of occurrence of ground pool fires differs significantly between *Aircraft with Wing Mounted Engines* and *Aircraft without Wing Mounted Engines*.

2. To determine the characteristics of *Fuselage Breaks*, and the size and location of any *Fuselage Rupture*s where the aircraft remains largely intact, caused by the impact sequence in ground pool fire accidents.

3. To determine the effects on occupant survivability of *Fuselage Breaks* resulting from impact in ground pool fire accidents.

3. SELECTION & CATEGORIZATION OF ACCIDENTS FOR ANALYSIS.

This Section of the report describes the accident selection criteria and their categorization relative to pool fires and *Fuselage Breaks*. To carry out the study, data was required on *Survivable Accidents* involving ground pool fires and *Survivable Accidents* where there was no ground pool fire involvement.

3.1 ACCIDENT SELECTION CRITERIA.

The Cabin Safety Research Technical Group (CSRTG) Aircraft Accident Database, at Issue 24 (see Reference 1), was used for accident selection. Only accidents with Full Screen 3 information[1] were selected based on the following criteria.

[1] "Screen 3" information is textual data contained in the CSRTG Accident Database that is extracted from Accident Reports produced by the Investigating Authority. Further analysis of selected accidents was supported by the library of Accident Reports and Data held by RGW Cherry & Associates Limited.

Aircraft Operation:

- Passenger Carrying or Passenger/Cargo

Accident Characteristics:

- The accident occurred during the period 1967 to 2000
- The accident resulted in *Fatal Injuries* or the aircraft being destroyed
- Accidents involving Illegal Acts (Sabotage, Suicide, or Terrorism) or ground operations were excluded.

Aircraft type:

- Western World Built
- Low Wing Turbo Jet
- MTOW greater than 60,000 pounds

[Note: The aircraft selection criteria are comparable with those used in the Boeing Statistical Summary of Commercial Jet Airplane Accidents (see Reference 2)].

3.2 CATEGORIZATION OF ACCIDENTS.

The Accident Database yielded 147 accidents, meeting the accident selection criteria defined in Section 3.1, as listed in Appendix A. Of these, 101 were considered to be *Survivable Accidents*. The sub-division of these *Survivable Accidents* into categories required to carry out the study is illustrated in Figure 1.

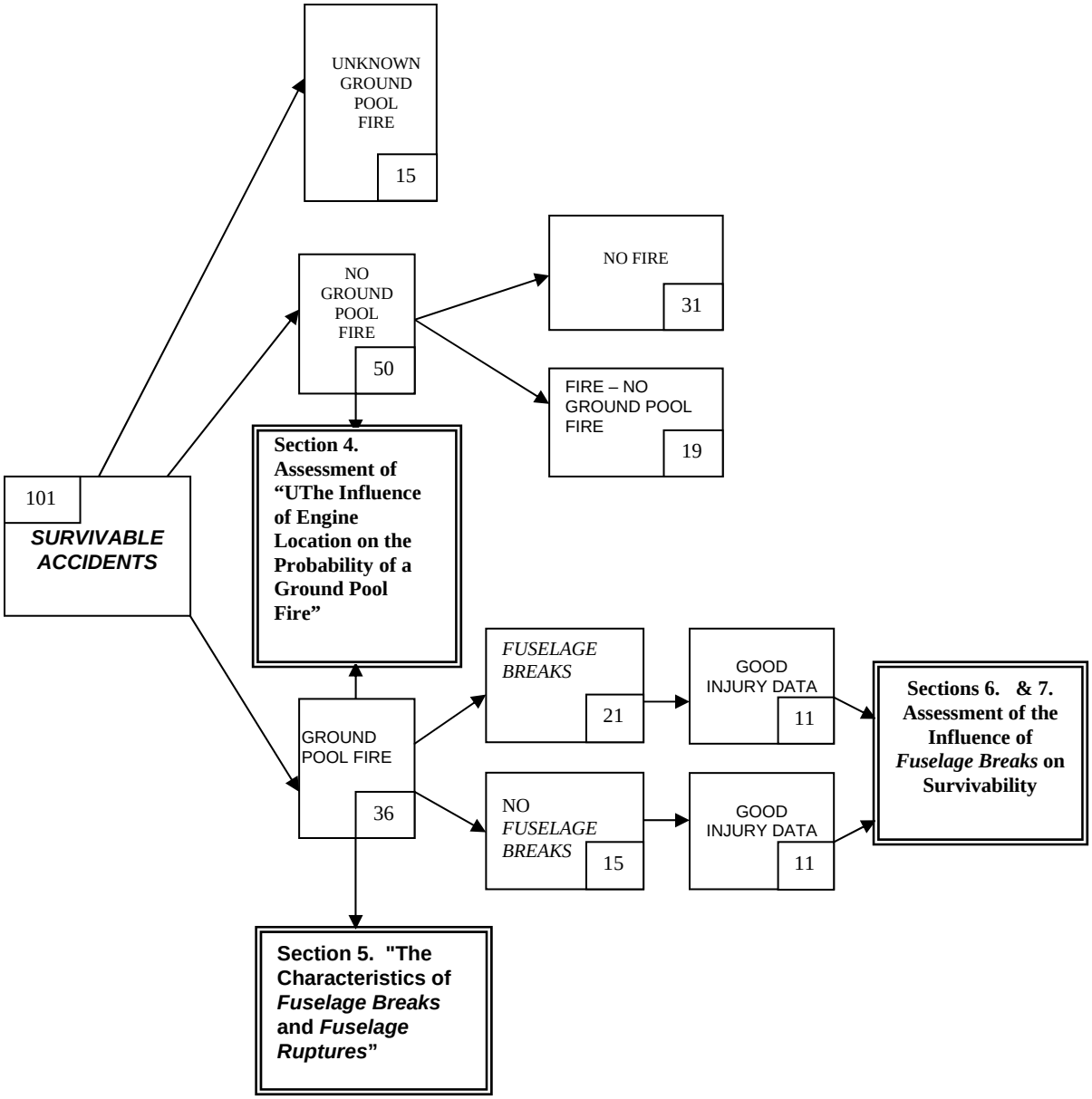


Figure 1. Categorization of Accidents

The *Survivable Accidents* were analyzed and 36 were confirmed as featuring a ground pool fire, while 50 were confirmed as not featuring a ground pool fire. In 15 accidents a determination could not be made. The 36 confirmed ground pool fire accidents are listed in Table 1 and the 50 accidents with no ground pool fire involvement are shown in Table 2.

The 36 confirmed ground pool fire accidents were further categorized into those accidents involving *Fuselage Breaks* (21), and those where the fuselage remained largely intact (15). Both of these accident categories were analyzed in depth, making use of Accident Reports, and Survivor Reports where available, published by the Accident Investigating Authorities, to ascertain the *Serious* and *Fatal Injuries* sustained by the occupants. Eleven of the twenty-one accidents involving *Fuselage Breaks* and eleven of the fifteen accidents where the fuselage

remained largely intact had sufficient data available to make a precise determination of the number and nature of the *Serious* and *Fatal Injuries* sustained by the occupants.

Table 1. List of Accidents Involving a Ground Pool Fire—Confirmed

Date	Aircraft	Location	Break / No Break
05-MAR-1967	DC8-33	NR. MONROVIA, LIBERIA, AFRICA	No Break
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	Break
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	No Break
27-NOV-1970	DC8-63F	ANCHORAGE, ALASKA, U.S.A.	Break
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	Break
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	Break
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	Break
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	No Break
22-JAN-1973	B707-3D3C	KANO AIRPORT, NIGERIA	No Break
26-JAN-1974	F28-1000	COMAOVASI, TURKEY	Break
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	No Break
15-MAR-1974	CARAVELLE 10B3	TEHERAN, IRAN	No Break
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	Break
20-NOV-1974	B747-130	NAIROBI, KENYA	Break
24-JUN-1975	B727-225	KENNEDY AIRPORT, NEW YORK, U.S.A.	Break
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	Break
27-APR-1976	B727-95	ST. THOMAS, VIRGIN ISLAND	Break
27-MAR-1977	B747	TENERIFE AIRPORT, CANARY ISLANDS	Break
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	Break
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	No Break
17-DEC-1978	B737-200	HYDERABAD, INDIA	No Break
07-OCT-1979	DC8-62	ATHENS, GREECE	Break
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	No Break
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	Break
13-SEP-1982	DC10	MALAGA, SPAIN	No Break
07-DEC-1983	B727-200	MADRID, SPAIN	No Break
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	No Break
26-JUN-1988	A320-100	HABSHEIM, FRANCE	No Break
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	Break
14-FEB-1990	A320-231	BANGALORE, INDIA	Break
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	No Break
21-DEC-1992	DC10-30CF	FARO, PORTUGAL	Break
14-SEP-1993	A320-211	WARSAW, POLAND	No Break
26-APR-1994	A300B4-622R	NAGOYA/KOMAKI AIRPORT, NAGOYA, JAPAN	Break
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	Break
31-OCT-2000	B747-412B	CHIANG KAI-SHEK AP, TAIWAN	Break

Table 2. List of Accidents not Involving a Ground Pool Fire—Confirmed

DATE	AC_TYPE	LOCATION
27-DEC-1968	DC9-15	SIOUX CITY AIRPORT, IOWA, U.S.A.
13-JAN-1969	DC8-62	SANTA MONICA BAY, CALIFORNIA, U.S.A.
02-MAY-1970	DC9-33F	ST.CROIX, VIRGIN ISLANDS
15-SEP-1970	DC8-62	J.F.K. AIRPORT, NEW YORK, U.S.A.
06-SEP-1971	BAC1-11-500/515	NR. HASLOH, GERMANY
19-JUL-1972	BAC1-11	CORFU, GREECE
29-DEC-1972	L1011	NR. MIAMI INTERNATIONAL AIRPORT, FLORIDA, U.S.A.
11-JUL-1973	B707-321C	ORLY, NR. PARIS, FRANCE
31-JUL-1973	DC9-31	LOGAN INTERNATIONAL AIRPORT, BOSTON, MASSACHUSETTS, U.S.A.
28-AUG-1973	B707-331B	NR. LOS ANGELES, CALIFORNIA, U.S.A.
03-NOV-1973	DC10-10	NR. SOCORRO & ALBUQUERQUE, NEW MEXICO
27-NOV-1973	DC9-31	AKRON-CANTON AIRPORT, OHIO, U.S.A.
01-JAN-1974	F28-1000	NR. TURIN, ITALY
16-JAN-1974	B707-131B	LOS ANGELES INTL AIRPORT, CALIFORNIA, U.S.A.
23-JUN-1976	DC9-31	PHILADELPHIA INTERNATIONAL AIRPORT, U.S.A.
18-DEC-1977	CARAVELLE 10B1R	NR. FUNCHAL, MADEIRA, PORTUGAL
08-MAY-1978	B727-235	NR. PENSACOLA, FLORIDA, U.S.A.
26-JUN-1978	DC9-32	TORONTO INTERNATIONAL AIRPORT, CANADA
28-DEC-1978	DC8-61	PORTLAND, OREGON, U.S.A.
19-NOV-1980	B747-100	SEOUL, KOREA
22-DEC-1980	L1011	NR. STATE OF QATAR
20-SEP-1981	DC10-30CF	OVER NORTH ATLANTIC OCEAN
13-JAN-1982	B737-222	POTOMAC RIVER, WASHINGTON D.C., U.S.A.
23-JAN-1982	DC10-30CF	LOGAN INT. AIRPORT BOSTON, U.S.A.
09-FEB-1982	DC8-61	HANEDA AIRPORT, TOKYO, JAPAN
02-JUN-1983	DC9-32	CINCINNATI INTERNATIONAL AIRPORT, U.S.A.
12-AUG-1985	B747-SR-100	MOUNT OSUTAKA, GUMMA, JAPAN
25-OCT-1986	B737-222	CHARLOTTE, NORTH CAROLINA, U.S.A.
16-AUG-1987	MD82	DETROIT, U.S.A.
15-NOV-1987	DC9-14	DENVER COLORADO U.S.A.
28-APR-1988	B737-200	NR. MAUI, HAWAII
31-AUG-1988	TRIDENT 2E	HONG KONG
08-JAN-1989	B737-400	KEGWORTH, EAST MIDLANDS AIRPORT, U.K.
24-FEB-1989	B747-122	EN-ROUTE OVER PACIFIC OCEAN
19-JUL-1989	DC10-10	SIOUX CITY, U.S.A.
20-SEP-1989	B737-400	NEW YORK LA GUARDIA, U.S.A.
25-JAN-1990	B707-321B	COVE NECK, LONG ISLAND, NEW YORK, U.S.A.
02-JUN-1990	B737-2X6C	ALASKALEET, ALASKA, U.S.A.
03-DEC-1990	DC9-14	ROMULUS, DETROIT, U.S.A.
22-MAR-1992	F28-4000 a	LA GUARDIA, NEW YORK, U.S.A.
06-APR-1993	MD11	NR. SHEMYA, ALASKA, U.S.A.
14-APR-1993	DC10-30	DALLAS/FORT WORTH AIRPORT, DALLAS, TEXAS, U.S.A.
24-NOV-1993	MD87	COPENHAGEN AIRPORT KASTRUP, DENMARK
08-JUN-1995	DC9-32	WILLIAM B. HARTSFIELD INTL. AIRPORT, ATLANTA, U.S.A.
20-DEC-1995	B757-223	BUGA, NR. CALI, COLOMBIA
06-JUL-1996	MD88	PENSACOLA REGIONAL AIRPORT, FLORIDA, U.S.A.
16-DEC-1997	CL600-2B19	FREDERICTON AP., NEW BRUNSWICK, CANADA
09-FEB-1998	B727-223	O'HARE INTL AIRPORT, CHICAGO, ILLINOIS, U.S.A.
14-SEP-1999	B757-204	GIRONA AIRPORT, SPAIN
05-MAR-2000	B737-300	BURBANK, CA, U.S.A.

4. THE INFLUENCE OF ENGINE LOCATION ON THE PROBABILITY OF A GROUND POOL FIRE.

The objective of this part of the study is to determine whether the probability of ground pool fire occurrence differs significantly between *Aircraft with Wing Mounted Engines* and *Aircraft*

without Wing Mounted Engines. The 86 accidents shown in tables 1 and 2 were further divided into:

> ***Aircraft with Wing Mounted Engines***—Aircraft having wing mounted or wing and tail mounted engines.
>
> ***Aircraft without Wing Mounted Engines***—Aircraft having engines mounted on the tail of the aircraft only; either on the empennage or in the fin and empennage.

A comparison could then be made between the relative number of ground pool fire occurrences in accidents to *Aircraft with Wing Mounted Engines* and *Aircraft without Wing Mounted Engines*. The χ^2 test was applied to determine whether there was any significant statistical difference between the relative numbers of accidents in the two categories of aircraft.

The χ^2 test is used for testing differences between the numbers of occurrences in data sets. The hypothesis used for the χ^2 test is that there is no difference in the rate of occurrence of ground pool fire accidents in the two categories of aircraft. The χ^2 test compares the expected frequency of occurrence to the observed frequency of occurrence. The χ^2 value is calculated by:

$$\chi^2 = \sum \{[(\text{Number Observed} - \text{Number Expected})^2]/\text{Number Expected}\} \qquad \text{Equation 1}$$

The 86 *Survivable Accident*s, for which it could be confirmed whether there was a ground pool fire or not, were then sub-divided into the two categories of aircraft: those *with Wing Mounted Engines* and those *without Wing Mounted Engines*, as shown in Table 3.

Table 3. Pool Fire Accidents by Engine Configuration—Actual

ACTUAL			
AIRCRAFT CATEGORY	**POOL FIRE**	**NO POOL FIRE**	**TOTAL**
AIRCRAFT WITH WING MOUNTED ENGINES	23	28	51
AIRCRAFT WITHOUT WING MOUNTED ENGINES	13	22	35
TOTAL	36	50	86

If it is assumed that there is no difference between the two categories of aircraft then it might be expected that 41.9% (36/86) of accidents would have a ground pool fire involvement.

Using this assumption, since there are a total of 51 accidents to *Aircraft with Wing Mounted Engines*, it might be expected that 41.9%, i.e. 21.3 accidents, would have a ground pool fire involvement.

Therefore, based on the hypothesis that there is no difference between the two aircraft categories, the division of the expected number of accidents would be as shown in Table 4.

Table 4. Pool Fire Accidents by Engine Configuration—Expected

EXPECTED			
AIRCRAFT CATEGORY	**POOL FIRE**	**NO POOL FIRE**	**TOTAL**
AIRCRAFT WITH WING MOUNTED ENGINES	21.3	29.7	51
AIRCRAFT WITHOUT WING MOUNTED ENGINES	14.7	20.3	35
TOTAL	36.0	50.0	86

Using Equation 1 the χ^2 value may be derived as follows:

$$\chi 2 = \{[(23 - 21.3)^2]/21.3\} + \{[(13 - 14.7)^2]/14.7\} + \{[(28 - 29.7)^2]/29.7\} + \{[(22 - 20.3)^2]/20.3\}$$
$$= .128 + .186 + .092 + .134 = .54$$

The data has one degree of freedom, which for a χ^2 value of .54, indicates that no conclusion can be reached as to whether the probability of occurrence of a ground pool fire is significantly different between the two categories of aircraft.

5. THE CHARACTERISTICS OF *FUSELAGE BREAKS* AND *FUSELAGE RUPTURES*.

The 36 confirmed ground pool fire accidents listed in Table 1 were studied and divided into those that involved a *Fuselage Break* and those where the fuselage remained largely intact. As may be seen from Figure 1, 21 of the 36 confirmed ground pool fire accidents involved *Fuselage Breaks*, and the fuselage remained largely intact for the remaining 15 accidents.

5.1 *FUSELAGE BREAKS*.

For the 21 accidents featuring a *Fuselage Break*, 3 involved massive disruption of the fuselage and it was not feasible to determine the characteristics of any breaks. These 3 accidents are shown in Table 5.

Table 5. Accidents Involving Massive Disruption of the Fuselage

Date	Aircraft	Location
24-JUN-1975	B727-225	KENNEDY AIRPORT, NEW YORK, U.S.A.
27-MAR-1977	B747	TENERIFE AIRPORT, CANARY ISLANDS
26-APR-1994	A300B4-622R	NAGOYA/KOMAKI AIRPORT, NAGOYA, JAPAN

The remaining 18 accidents featuring *Fuselage Breaks*, but not massive disruption to the fuselage, were analyzed to assess:

- the degree to which *Fuselage Breaks* were used as an egress route for occupants
- the contribution that *Fuselage Breaks* made to fire entry into the cabin

- the number of *Fuselage Breaks*
- the location of *Fuselage Breaks*

5.1.1 Occupant Egress & Fire Entry.

Fuselage Breaks can be beneficial to mobile occupants in that they provide a possible means of egress; however they are also a potential hazard in that they can provide a route for fire entry. The 18 accidents featuring *Fuselage Breaks* but not massive disruption to the fuselage are shown in Table 6. The assessment of occupant egress and, where possible, fire entry through *Fuselage Breaks*, are summarized in the accident rationales contained in Appendix B to this report.

Table 6. Accidents Featuring *Fuselage Breaks*

Date	Aircraft	Location	Number of *Fuselage Breaks*	*Fuselage Breaks* Used as a Means of Occupant Egress
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	1	N?
27-NOV-1970	DC8-63F	ANCHORAGE, ALASKA, U.S.A.	1	Y
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	2	Y
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	1	N
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	2	Y
26-JAN-1974	F28-1000	COMAOVASI, TURKEY	2	?
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	2	Y
20-NOV-1974	B747-130	NAIROBI, KENYA	2?	Y
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	2	Y
27-APR-1976	B727-95	ST. THOMAS, VIRGIN ISLAND	3	Y
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	2	Y
07-OCT-1979	DC8-62	ATHENS, GREECE	1	N?
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	1	N
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	2	Y
14-FEB-1990	A320-231	BANGALORE, INDIA	2?	Y
21-DEC-1992	DC10-30CF	FARO, PORTUGAL	3	Y
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	2	Y
31-OCT-2000	B747-412B	CHIANG KAI-SHEK AP, TAIWAN	1	Y

Key to Table 6:

Number of *Fuselage Breaks*

? = Estimated Number of *Fuselage Breaks*

***Fuselage Breaks* used as a Means of Occupant Egress**

Y = Yes

N = No

N? = Probably No

? = Unknown

Occupant Egress

It may be seen from Table 6 that of the 18 *Fuselage Break* accidents studied, there were more than 70% in which the accident report stated that the breaks were used by occupants as an exit route.

The following extracts from some of the 18 accident reports studied give an indication of the importance of *Fuselage Breaks* to occupant egress:

VC 10 Addis Ababa, Ethiopia 18th April 1972

> "The evacuation was facilitated considerably by the fortuitous fracture of the left forward fuselage, allowing relatively easy egress. Had it not been for this fracture casualties may well have been greater, as the left emergency exits were jammed by impact damage and the right side exits were blocked by fire."

B737 Chicago, U.S.A. 8th December 1972

> "The fuselage breaks assisted occupants in the evacuation of the aircraft."

DC9 Charlotte, U.S.A. 11th September 1974

> "All survivors in the rear of the aircraft were either thrown out of the wreckage or escaped through holes in the fuselage."

MD 82 Little Rock, Arkansas, U.S.A. 1st June 1999

> "Passengers that were forward of the fuselage separation at row 18 escaped through a large hole on the left side of the first-class section and through a separation in the fuselage at row 12. One passenger reportedly exited the airplane at the fuselage break aft of row 17 on the right side. Two passengers exited the airplane through the fuselage separation directly forward of row 19."

Fire Entry

The extent to which fire entry through *Fuselage Breaks* influenced occupant survival could not be confirmed from the information contained in the Accident and Survivor Reports studied, since:

- There were few accounts of fire entry by eye-witnesses
- The fuselage would often be destroyed by fire and hence accident investigators could not confirm the mechanism for fire entry into the cabin.

Hence, whilst it would seem inevitable that *Fuselage Breaks* would provide a means for fire penetration into the cabin, this cannot be confirmed from the data currently available.

5.1.2 Fuselage Break Location and Number.

For each of the 18 *Fuselage Break* accidents studied, a simple diagram is included in the Accident Rationales (see Appendix B) showing the approximate location and number of *Fuselage Breaks*. As may be seen from Table 6, the majority of the accidents involving *Fuselage Breaks* that did not involve massive disruption featured at least two *Fuselage Breaks*. Attempts were made to correlate the number of *Fuselage Breaks* with *Actual Impact Intensity* since it might be expected that accidents involving severe impact might result in a greater number of *Fuselage Breaks*. However this does not seem to be the case and impact intensity does not appear to influence the number of *Fuselage Breaks* although it appears that the probability of a break occurring increases with *Actual Impact Intensity* (see Section 6.2)

An attempt was also made to determine whether the *Fuselage Breaks* occurred at a point of structural discontinuity (wing front spar, wing rear spar or in close proximity to the rear pressure bulkhead) or at an arbitrary location. Although the information available on *Fuselage Break* locations is not sufficiently precise to make an exact determination, it is considered that approximately half of the *Fuselage Breaks* occurred at a point of structural discontinuity. The following extracts from Accident Reports are examples of when it is considered that the break was in close proximity to a point of structural discontinuity:

CINCINNATI, U.S.A., B707-131, 6 November 1967:

"During the ground slide, the fuselage upper structure broke just forward of the wing root."

ANCHORAGE, ALASKA, U.S.A., DC8-63F, 27 November 1970:

"The fuselage sustained a circumferential fracture near Fuselage Station 1320 [seat row 36]. The tail section came to rest about 30 feet from the main fuselage section and rotated 10 deg anti-clockwise from it."

FORT LAUDERDALE, FLORIDA, U.S.A., DC9-31, 18 May 1972:

"A hard touchdown resulted from the high rate of sink, resulting in the failure of the main landing gear and the separation of the tail section from the aircraft."

COMAOVASI, TURKEY, F28-1000, 26 January 1974:

"The aircraft was separated into three sections: cockpit section, passenger cabin (containing seat rows 1 to 13), and the tail and engine empennage."

KETCHIKAN, ALASKA, U.S.A., B727-81, 5 April 1976:

"The fuselage broke into 3 sections but remained aligned. One break was near the wing's leading edge and the other near the trailing edge. The left wing remained attached to the fuselage but the right wing separated."

ATHENS, GREECE, DC8-62, 7 October 1979:

"The fuselage was broken in front of the vertical stabilizer".

DALLAS FORT WORTH, U.S.A., B727-232, 31 August 1988:

"The fuselage had separated into three major sections: (1) the forward section consisted of the nose forward of fuselage station (FS)-420 [just aft of seat row 1]; (2) the centre fuselage section included the body structure between FS-420 and FS-950c [between seat rows 27 & 28]; and (3) the aft fuselage section extended from FS-950c aft to the end of the No. 2 engine tailpipe."

5.2 *FUSELAGE RUPTURES*.

Table 7 lists the 15 ground pool fire-related accidents where the fuselage remained largely intact after the impact. The table also shows whether there was any occurrence of *Fuselage Rupture*, and where known, the location of any ruptures.

The majority of the accident data does not provide detailed information regarding fuselage condition, other than general statements (e.g. "fuselage was relatively intact", or "fuselage was completely destroyed by fire"). An accident is considered to have a confirmed *Fuselage Rupture* when the Accident Report clearly indicates its presence either based on occupant statements or statements that fuselage panels were found amongst the wreckage. In these instances column 4 of Table 7 is annotated "Y".

Where no evidence of *Fuselage Rupture*s can be found in the accident report, but the accident was impact related, a determination of the likelihood of *Fuselage Rupture*s has been made. If the nature of the impact was such that it was considered very likely to have caused *Fuselage Rupture* (such as a belly or hard landing, or collision with objects on the ground), the accident is classified as an unconfirmed *Fuselage Rupture* (annotated as "Y?" in Table 7). Similarly, accidents featuring less severe impact, where there is less likelihood of *Fuselage Rupture*, are classified as unconfirmed no *Fuselage Rupture*s (annotated as "N?" in Table 7).

Where no determination of the likelihood of a *Fuselage Rupture* could be made, because of insufficient information in the Accident Report regarding fuselage condition, Table 7 is annotated with a "?".

Table 7. *Fuselage Rupture* Occurrence and Location

Key to Table 7:

Fuselage Ruptured

N = No *Fuselage Rupture*

Y= *Fuselage Ruptured*

Y? = Unconfirmed *Fuselage Rupture*

N? = Unconfirmed No *Fuselage Rupture*

? = Undetermined

*The *Fuselage Ruptured* due to collision with another aircraft

Date	Aircraft	Location	Fuselage Ruptured	Rupture Location
05-MAR-1967	DC8-33	NR. MONROVIA, LIBERIA, AFRICA	Y?	?
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	N	-
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	N?	-
22-JAN-1973	B707-3D3C	KANO AIRPORT, NIGERIA	Y?	?
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	Y	Side Wall & Lower Fuselage
15-MAR-1974	CARAVELLE 10B3	TEHERAN, IRAN	N?	-
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	N?	-
17-DEC-1978	B737-200	HYDERABAD, INDIA	Y?	?
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	?	?
13-SEP-1982	DC10	MALAGA, SPAIN	Y	Upper Fuselage
07-DEC-1983	B727-200	MADRID, SPAIN	Y*	Side Wall*
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	N	-
26-JUN-1988	A320-100	HABSHEIM, FRANCE	Y?	?
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	?	?
14-SEP-1993	A320-211	WARSAW, POLAND	Y	Lower Fuselage

As may be seen from Table 7 it can be confirmed that 4 aircraft sustained *Fuselage Rupture*s. It was established that 2 aircraft did not sustain any *Fuselage Rupture*s due to the non-impact nature of the accident.

For only one of the accidents was there sufficient information to make any assessment of the size of the *Fuselage Rupture* –

PAGO PAGO AMERICAN SAMOA, B707, 30 January 1974:

"There was progressive destruction of the aircraft during its travel through the vegetation and as it slid over the ground. The fuselage remained intact except for the forward nose fuselage structure. The Third officer was assisted in his escape by two other cockpit crewmembers and left the aircraft through a hole in the cockpit wall."

6. DATA RELATED TO THE EFFECTS OF *FUSELAGE BREAKS* ON OCCUPANT SURVIVAL.

6.1 *SERIOUS IMPACT* AND *FATAL IMPACT INJURIES*.

6.1.1 Survivability Chains - *Serious Impact and Fatal Impact Injuries*.

For the 36 ground pool fire accidents, data was obtained from Accident Reports and Survivor Reports published by the Accident Investigating Authorities in order to determine the injuries

sustained by the occupants. Of the 36 ground pool fire accidents, 21 involved *Fuselage Breaks*. For the remaining 15 accidents, the fuselage stayed largely intact (see Figure 1).

Of the 21 accidents involving *Fuselage Breaks*, 11 had sufficient data to determine the precise nature of the injuries sustained by the occupants. Of the 15 accidents where the fuselage remained largely intact, precise data on the injuries sustained by the occupants could be determined for 11 of the accidents. Therefore, it was possible to carry out an analysis on the *Serious* and *Fatal Injuries* sustained by the occupants for 22 ground pool fire accidents.

As might be expected, it appeared from the analysis of the data for these accidents that typically the less mobile *Serious Impact Injured* occupants had a higher chance of succumbing to the fire than the more mobile *Impact Survivors*. Whilst the presence of *Fuselage Breaks* provided an escape route for many of the occupants, it is likely that they also enabled fire to enter into the cabin.

Survivability Chains

A mathematical model, known as a Survivability Chain, was used for each of the 22 accidents with sufficient occupant injury data in order to determine the relationship between impact injuries and fire injuries for each of the accidents. An example of a Survivability Chain is shown in Figure 2.

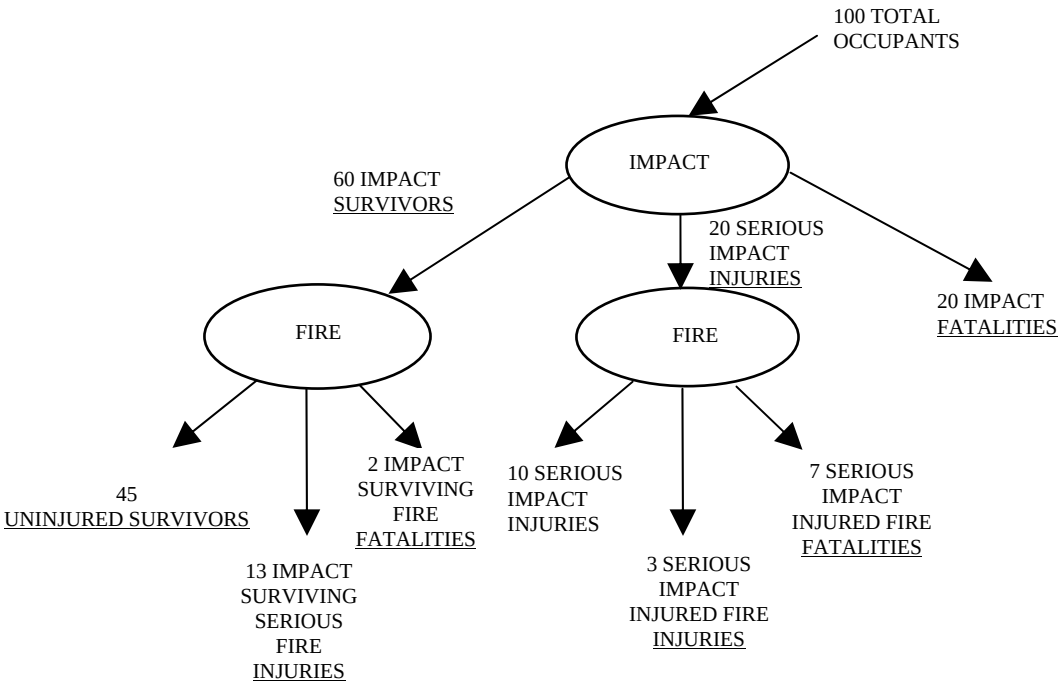


Figure 2. Example of a Survivability Chain

The first step in constructing the Survivability Chain is to identify the *Serious* and *Fatal Injuries* sustained as a result of the impact; in the example shown in Figure 2 this would be 20 *Fatal*

Impact Injuries, 20 *Serious Impact Injuries* and 60 *Impact Survivors*. The next step would be to identify, for the non-fatally injured occupants, the *Serious* and *Fatal Injuries* sustained as a result of the fire. As highlighted in Figure 3, 2 of the 60 *Impact Survivors*, and 7 of the 20 *Serious Impact Injuries*, die as a result of the fire.

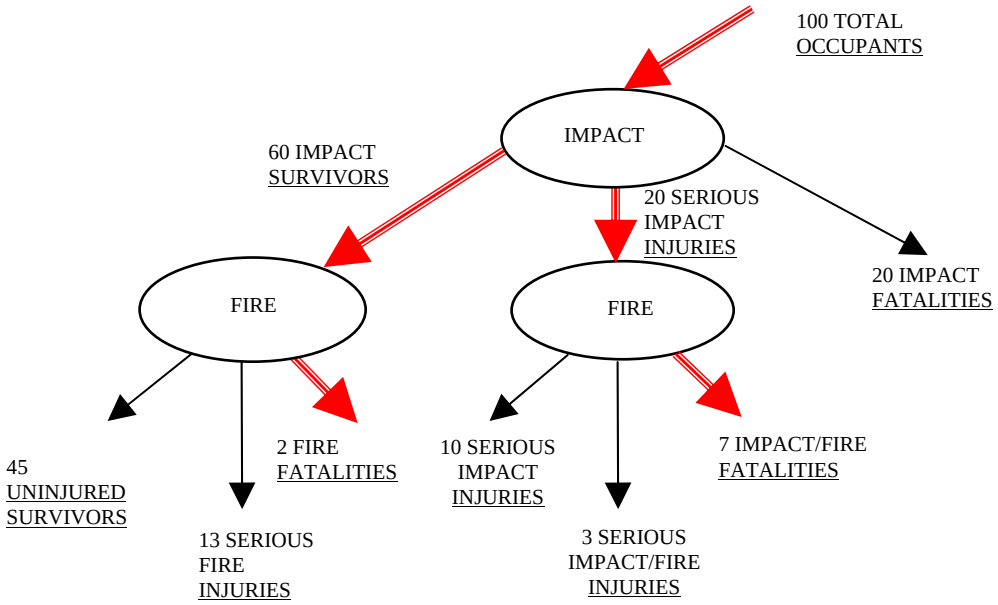


Figure 3. Example of a Survivability Chain

With reference to the example shown in Figure 3 it may be seen that the proportion of occupants sustaining *Fatal Impact Injuries* is given by $20 \div 100 = 0.2$

It may also be seen that the proportion of occupants with *Serious Impact Injuries* sustaining *Fatal Fire Injuries* is $7 \div 20 = 0.35$

These proportions may be derived for each of the accidents having sufficient data to derive a Survivability Chain (see Appendix B – Accident Rationales, for individual Survivability Chains).

Impact Injuries

Of immediate interest is the number of *Serious* and *Fatal Injuries* sustained as a result of the impact. The number of *Fatal Impact Injuries* and *Serious Impact Injuries* sustained in the 22 ground pool fire accidents, having good injury data, are shown in Table 8.

Table 8. *Serious Impact Injuries* and *Fatal Impact Injuries* in Ground Pool Fire Accidents With Sufficient Injury Information

Date	Aircraft	Location	Total Number of Occupants	Total Number of *Fatal Impact Injuries*	Total Number of *Serious Impact Injuries*	Break / No Break
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	36	1	10	Break
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	127	0	0	No Break
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	107	0	0	Break
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	10	0	3	Break
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	63	2	26	Break
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	45	0	0	No Break
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	101	0	1	No Break
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	82	32	14	Break
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	50	1	32	Break
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	49	32	15	Break
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	200	0	32	No Break
17-DEC-1978	B737-200	HYDERABAD, INDIA	132	0	4	No Break
07-OCT-1979	DC8-62	ATHENS, GREECE	154	0	14	Break
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	73	0	1	No Break
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	110	0	4	Break
13-SEP-1982	DC10	MALAGA, SPAIN	394	0	0	No Break
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	137	0	0	No Break
26-JUN-1988	A320-100	HABSHEIM, FRANCE	136	0	1	No Break
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	108	0	14	Break
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	292	0	0	No Break
14-SEP-1993	A320-211	WARSAW, POLAND	70	1	51	No Break
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	145	6	41	Break

6.1.2 *Serious Impact Injuries* and *Fatal Impact Injuries* at *Fuselage Breaks*.

The mechanism that results in *Serious Impact Injuries* or *Fatal Impact Injuries* to occupants at *Fuselage Breaks* is likely to be different to the causes of *Serious Impact Injuries* or *Fatal Impact Injuries* to occupants in parts of the aircraft not directly affected by the breaks. An assessment was therefore required of the number of occupants that were *Seriously* or *Fatally Injured* at the breaks. The data set of ground pool fire Accidents with *Fuselage Breaks* and good injury data (11 accidents) proved to have limited data on the location of occupants since only 4 contained good data regarding the *Serious* and *Fatal Injuries* at breaks.

Since the *Serious* and *Fatal Impact Injuries* at a *Fuselage Break* are unlikely to be influenced by the presence of a ground pool fire, *Serious* and *Fatal Impact Injury* data on 4 other accidents, involving *Fuselage Breaks*, but not ground pool fires, were analyzed in order to obtain a reasonable data set.

The *Serious* and *Fatal Impact Injuries* and the Proportion of *Serious* and *Fatal Impact Injuries* for all eight accidents are shown in Table 9. The 4 non ground pool fire accidents are indicated with an asterisk.

Table 10 shows the *Serious* and *Fatal Impact Injuries* and the Proportion of *Serious* and *Fatal Impact Injuries*, for all eight accidents, for those occupants that **were not** in the vicinity[2] of a *Fuselage Break.*

Table 11 shows the *Serious* and *Fatal Impact Injuries* and the Proportion of *Serious* and *Fatal Impact Injuries*, for all eight accidents, for those occupants that **were** in the vicinity of a *Fuselage Break.*

Table 9. Proportion of *Serious* and *Fatal Impact Injuries* in *Fuselage Break* Accidents

Date	Aircraft	Location	Total Number of Occupants	Number of *Fatal Impact Injuries*	Number of *Serious Impact Injuries*	Proportion of *Serious* and *Fatal Impact Injuries*
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	10	0	3	0.30
07-OCT-1979	DC8-62	ATHENS, GREECE	154	0	14	0.09
15-NOV-1987	DC9-14	DENVER COLORADO U.S.A. *	82	28	26	0.66
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	108	0	17	0.16
08-JAN-1989	B737-400	KEGWORTH, EAST MIDLANDS AIRPORT, U.K. *	126	47	74	0.96
19-JUL-1989	DC10-10	SIOUX CITY, U.S.A. *	295	73	57	0.44
02-JUL-1994	DC9-31	CHARLOTTE, NORTH CAROLINA, U.S.A.*	57	32	15	0.82
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	145	6	41	0.32

* non ground pool fire accidents

[2] For the purpose of this study, the vicinity of a *Fuselage Break* is defined to be the area of the cabin within one seat row either side of the *Fuselage Break*

Table 10. Proportion of *Serious* and *Fatal Impact Injuries* Not in the Vicinity of a *Fuselage Break*

Date	Aircraft	Location	Total Number of Occupants not in the vicinity of a Fuselage Break	Number of *Fatal Impact Injuries* not in the vicinity of a *Fuselage Break*	Number of *Serious Impact Injuries not in the vicinity of a Fuselage Break*	Proportion of *Serious* and *Fatal Impact Injuries not in the vicinity of a Fuselage Break*
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	10	0	3	0.30
07-OCT-1979	DC8-62	ATHENS, GREECE	154	0	14	0.09
15-NOV-1987	DC9-14	DENVER COLORADO U.S.A. *	70	23	22	0.64
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	95	0	14	0.15
08-JAN-1989	B737-400	KEGWORTH, EAST MIDLANDS AIRPORT, U.K. *	107	40	62	0.95
19-JUL-1989	DC10-10	SIOUX CITY, U.S.A. *	247	47	40	0.35
02-JUL-1994	DC9-31	CHARLOTTE, NORTH CAROLINA, U.S.A.*	43	22	13	0.81
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	118	3	32	0.30

* non ground pool fire accidents

Table 11. Proportion of *Serious* and *Fatal Impact Injuries* in the Vicinity of a *Fuselage Break*

Date	Aircraft	Location	Total Number of Occupants in the vicinity of a Fuselage Break	Number of *Fatal Impact Injuries* in the vicinity of a *Fuselage Break*	Number of *Serious Impact Injuries in the vicinity of a Fuselage Break*	Proportion of *Serious* and *Fatal Impact Injuries in the vicinity of a Fuselage Break*
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0	0	0	-
07-OCT-1979	DC8-62	ATHENS, GREECE	0	0	0	-
15-NOV-1987	DC9-14	DENVER COLORADO U.S.A. *	12	5	4	0.75
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	13	0	3	0.23
08-JAN-1989	B737-400	KEGWORTH, EAST MIDLANDS AIRPORT, U.K. *	19	7	12	1.00
19-JUL-1989	DC10-10	SIOUX CITY, U.S.A. *	48	26	17	0.90
02-JUL-1994	DC9-31	CHARLOTTE, NORTH CAROLINA, U.S.A.*	14	10	2	0.86
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	27	3	9	0.44

* non ground pool fire accidents

6.1.3 Injuries as a Measure of Impact Intensity.

It is to be expected that as the intensity of the impact increases, the proportion of *Serious* and *Fatal Impact Injuries* will increase, resulting in a higher number of occupants that succumb to the fire due to their restricted mobility.

It is also to be expected that the probability of the fuselage sustaining breaks will increase as the intensity of the impact increases. The *Fuselage Breaks* will tend to result in *Serious* or *Fatal Impact Injuries* to the occupants in close proximity to the break but will also provide an escape route for the more mobile occupants.

This leads to the conclusion that the intensity of the impact is a major factor in the survivability of occupants in ground pool fire accidents since it will affect both the probability of a *Fuselage Break* and the extent of *Serious* and *Fatal Impact Injuries* to occupants. Therefore in order to understand the overall effects of *Fuselage Breaks* on the probability of occupant survival, there needs to be a determination of the relationship between impact intensity and:

- The probability of *Fuselage Breaks*
- Occupant *Serious* and *Fatal Impact Injuries*

In order to assess the effects on occupant survival due to changes in the probability of *Fuselage Breaks*, a mathematical model was developed. A description of the model can be found in Section 7.

A fundamental issue in developing a model is that there needs to be a measure of impact intensity in order that a mathematical relationship between impact intensity and occupant *Serious* and *Fatal Impact Injuries* and impact intensity and the probability of a *Fuselage Break* may be established.

Quantifying impact intensity in aircraft accidents, in order to assess the likely effects on occupants and the structural integrity of the aircraft, has proven to be difficult. Assessments of "g" levels and degree of disruption are not likely to provide a good measure of impact intensity. An earlier study (see Reference 3) concluded:

> *"Impact Severity may be best assessed in terms of the degree of injury inflicted on occupants"*

If it is assumed that the proportion of occupants sustaining *Serious* or *Fatal Impact Injuries* reflects impact intensity, then it is feasible that the relationship between impact intensity and the probability of a *Fuselage Break* may be simply a relationship between the proportion of *Serious* and *Fatal Impact Injuries* and the probability of a *Fuselage Break*.

It should be noted that this measure of impact intensity cannot be considered as a precise indication of the decelerative forces experienced by the aircraft, nor even by the occupants: the likelihood of an occupant sustaining serious or fatal impact injuries is likely to vary with their physical characteristics (sex, age, state of health, etc.), the nature of the impact, and the protection they are afforded by the aircraft design. For a given impact condition, there will be a resultant affect on the aircraft; however, improvements in occupant protection (e.g., the introduction of 16g seats) will change the magnitude of the derived impact intensity due to a reduction in impact injuries. Any measure of impact intensity, based on occupant injuries, must be considered as simply an indicator of the magnitude of the impact rather than a precise measure.

Therefore, using this definition, it is important that any comparisons of impact intensity between accidents consider the relative build standard of the airplanes involved. For the accidents reviewed in this study, there is no significant difference in this regard. In the absence of a more

precise measure, impact intensity has been based, in this study, on the number of *Fatal* and *Serious Impact Injuries*.

It is considered that the best measure of Impact Intensity, in the accident, would be given by the proportion of occupants not in the vicinity of *Fuselage Breaks* that sustain *Serious* or *Fatal Impact Injuries*, since their injuries are inflicted as a direct result of the decelerative forces. Henceforth this impact intensity will be referred to as the *"Actual Impact Intensity"* and is determined by simply dividing the number of *Seriously* or *Fatally Injured* occupants **not** located at the breaks by the total number of occupants **not** located at the breaks.

The data shown in the column headed "Proportion of *Serious* and *Fatal Impact Injuries* not in the vicinity of a *Fuselage Break"*, contained in Table 10, therefore equates to *Actual Impact Intensity*. Figure 4 shows the Proportion of all occupants sustaining *Serious* or *Fatal Impact Injuries* for the accidents involving *Fuselage Breaks*, as listed in Table 9, plotted against the *Actual Impact Intensity* (Proportion of *Serious* and *Fatal Impact Injuries* not in the vicinity of a *Fuselage Break*) shown in Table 10.

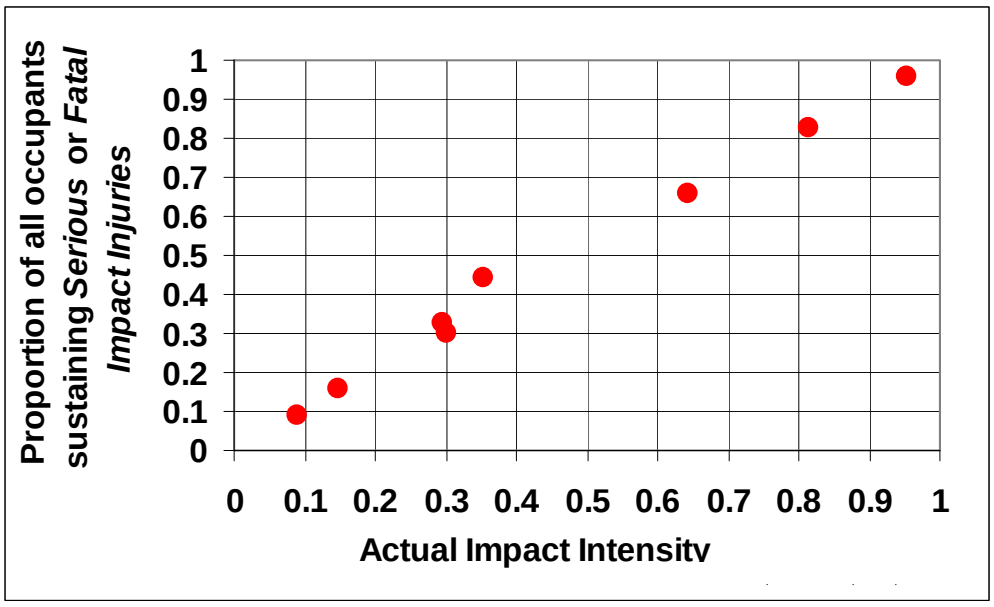


Figure 4. Relationship Between Proportion of all Occupants Sustaining *Serious* or *Fatal Impact Injuries* and *Actual Impact Intensity* for *Fuselage Break* Accidents

It is evident that the curve of "best fit" through these points must pass through the point that corresponds to an *Actual Impact Intensity* of 1 and a Proportion of all occupants sustaining *Serious* or *Fatal Impact Injuries* of 1.

Figure 5 shows the curve of "best fit" which may be represented by the following equation:

$$P = a\,I + c \qquad \text{Equation 2}$$

Where

P is equal to the Proportion of all occupants sustaining *Serious* or *Fatal Impact Injuries*

I is equal to the *Actual Impact Intensity*

a is a constant

c is a constant

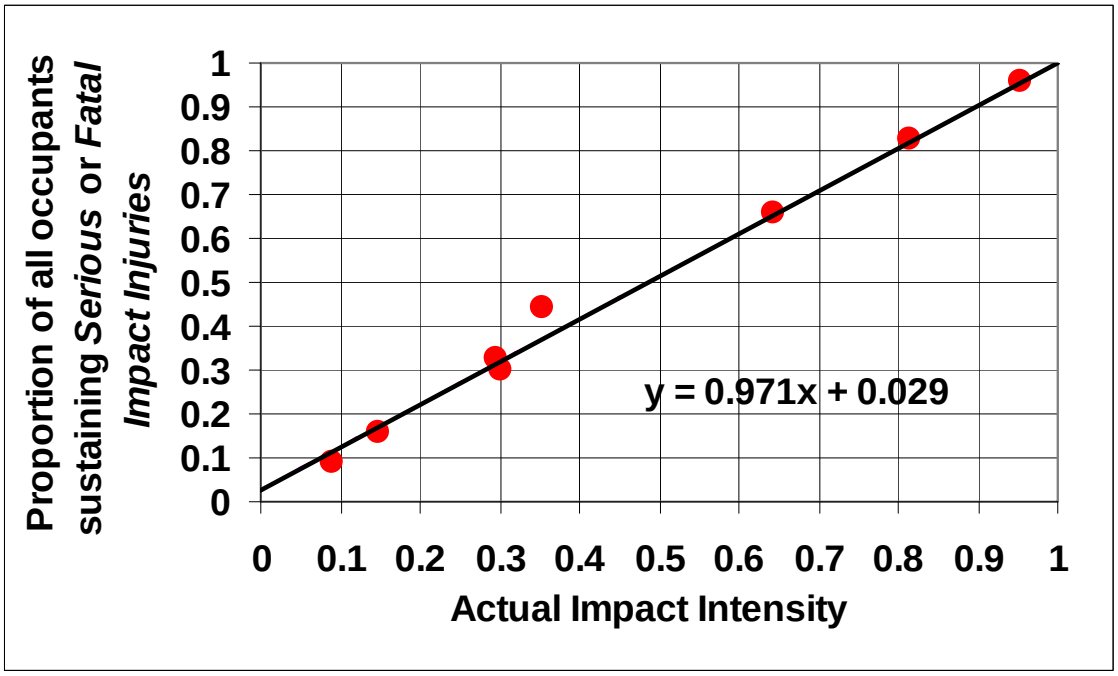


Figure 5. Relationship Between Proportion of all Occupants Sustaining *Serious* or *Fatal Impact Injuries* and *Actual Impact Intensity* for *Fuselage Break* Accidents Showing Curve of "Best Fit"

This curve of "best fit", constrained so that when I = 1 P = 1, yields the following equation:

$$P = 0.971\ I + 0.029 \qquad \text{Equation 3}$$

When considering the 11 ground pool fire accidents having good injury data, which did not involve a *Fuselage Break*, the *Actual Impact Intensity* is derived by simply dividing the total number of *Serious* and *Fatal Impact Injuries* by the total number of occupants. The *Serious Impact Injuries*, *Fatal Impact Injuries* and *Actual Impact Intensities* for these 11 accidents are shown in Table 12.

Table 12. *Actual Impact Intensities* for Ground Pool Fire Accidents not Involving a *Fuselage Break*

Date	Aircraft	Location	Total Number of Occupants	Number of *Fatal Impact Injuries*	Number of *Serious Impact Injuries*	Number of *Fatal* and *Serious Impact Injuries*	*Actual Impact Intensity*
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	127	0	0	0	0.00
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	45	0	0	0	0.00
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	101	0	1	1	0.01
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	200	0	32	32	0.16
17-DEC-1978	B737-200	HYDERABAD, INDIA	132	0	4	4	0.03
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	73	0	1	1	0.01
13-SEP-1982	DC10	MALAGA, SPAIN	394	0	0	0	0.00
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	137	0	0	0	0.00
26-JUN-1988	A320-100	HABSHEIM, FRANCE	136	0	1	1	0.01
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	292	0	1	1	0.00
14-SEP-1993	A320-211	WARSAW, POLAND	70	1	51	52	0.74

Of the 11 ground pool fire accidents having good *Serious* and *Fatal Injury* data, that involved a *Fuselage Break*, four had data relating to the *Serious Impact Injuries* and *Fatal Impact Injuries* sustained in the vicinity of the breaks. For these accidents, the *Actual Impact Intensity* is derived by dividing the total number of *Serious* and *Fatal Impact Injuries* sustained by the occupants, not in the vicinity of the breaks, by the total number of occupants not in the vicinity of the breaks. The injury data and *Actual Impact Intensities* for these four accidents are shown in Table 13.

Table 13. *Actual Impact Intensities* for Ground Pool Fire Accidents Involving a *Fuselage Break* for Accidents With *Serious* and *Fatal Impact Injury* Data at the *Fuselage Breaks*

Date	Aircraft	Location	Total Number of Occupants not in the vicinity of the Break	Number of *Fatal Impact Injuries* not in the vicinity of the Break	Number of *Serious Impact Injuries* not in the vicinity of the Break	Number of *Serious* and *Fatal Impact Injuries* not in the vicinity of the Break	*Actual Impact Intensity*
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	10	0	3	3	0.30
07-OCT-1979	DC8-62	ATHENS, GREECE	154	0	14	14	0.09
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	95	0	14	14	0.15
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	118	3	32	35	0.30

The remaining seven ground pool fire accidents involving a *Fuselage Break* had good *Serious* and *Fatal Injury* data but the precise location of the occupants in relation to the breaks was unknown. One of these accidents involved no *Serious* or *Fatal Impact Injuries*. Hence, the *Actual Impact Intensity* is, by definition, equal to zero. For the remaining six accidents, the proportion of *Serious* and *Fatal Impact Injuries* was entered into Equation 3 to derive the *Actual*

Impact Intensity. The Total Proportion of *Serious* and *Fatal Impact Injuries* and the derived *Actual Impact Intensities* are shown in Table 14.

Table 14. Derived *Actual Impact Intensities* for Ground Pool Fire Accidents Involving a *Fuselage Break* for Accidents With no *Serious Impact Injury* or *Fatal Impact Injury* Data at the *Fuselage Breaks*

Date	Aircraft	Location	Total Number of Occupants	Total Proportion of *Serious* and *Fatal Impact Injuries*	Derived *Actual Impact Intensity*
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	36	0.31	0.28
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	107	0.00	0.00
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	63	0.44	0.43
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	82	0.56	0.55
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	50	0.66	0.65
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	49	0.96	0.96
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	110	0.04	0.01

All 22 accidents shown in Table 12, Table 13 and Table 14 are summarized in Table 15 with the measured, or derived, *Actual Impact Intensities* presented in ascending order.

Table 15. *Actual Impact Intensities* for all 22 Ground Pool Fire Accidents

Date	Aircraft	Location	*Actual Impact Intensity*
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	0.00
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	0.00
13-SEP-1982	DC10	MALAGA, SPAIN	0.00
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	0.00
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	0.00
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	0.00
26-JUN-1988	A320-100	HABSHEIM, FRANCE	0.01
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	0.01
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	0.01
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	0.01
17-DEC-1978	B737-200	HYDERABAD, INDIA	0.03
07-OCT-1979	DC8-62	ATHENS, GREECE	0.09
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	0.15
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	0.16
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	0.28
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	0.30
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0.30
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	0.43
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	0.55
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	0.65
14-SEP-1993	A320-211	WARSAW, POLAND	0.74
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	0.96

From the values shown in Table 15, a cumulative probability distribution may be derived of the *Actual Impact Intensity* for ground pool fire accidents as shown in Figure 6.

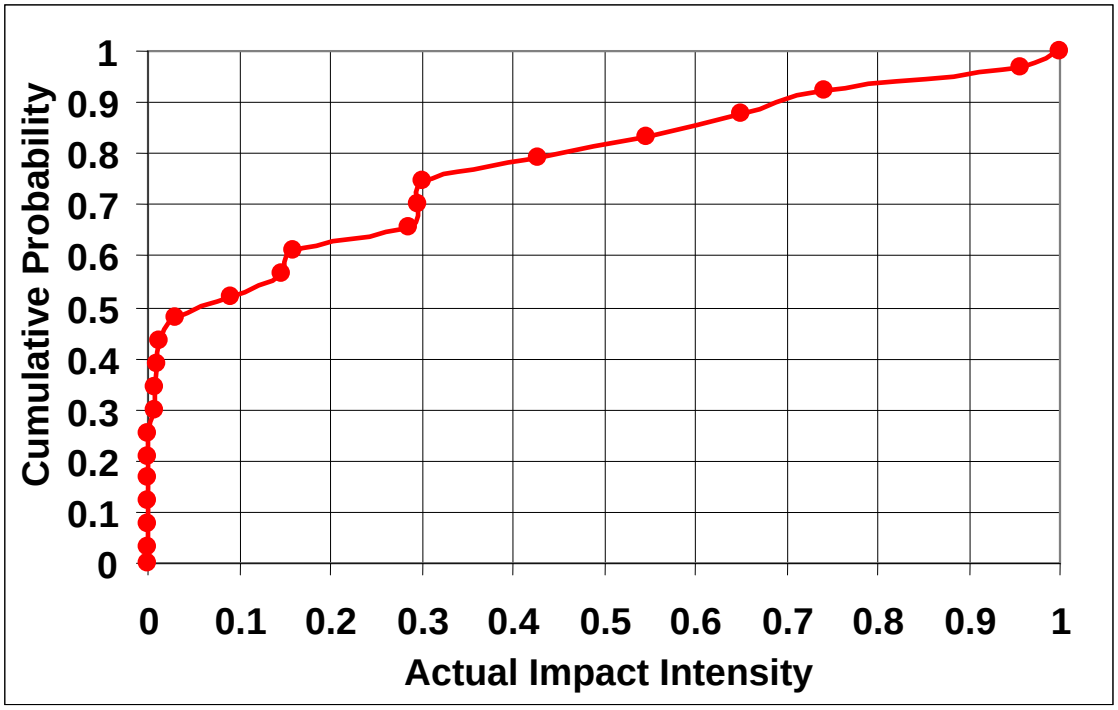


Figure 6. Probability Distribution of *Actual Impact Intensity*

By way of example it may be seen that the data suggests that on 50% of occasions the *Actual Impact Intensity* is less than 0.06 and on 90% of occasions less than 0.7.

6.1.4 Proportion of *Serious* and *Fatal Impact Injuries*.

As explained in Sections 6.1.1 to 6.1.3, for any given *Actual Impact Intensity*, the proportion of *Serious* and *Fatal Impact Injuries* may be derived for accidents involving a *Fuselage Break* and accidents where the fuselage remained largely intact. However, it is also necessary to sub-divide this proportion into the proportion of *Fatal Impact Injuries* and the proportion of *Serious Impact Injuries*. For the 22 accidents having good injury data, these proportions were derived and are shown in Table 16 together with the corresponding *Actual Impact Intensity*.

Table 16. The Proportion of *Fatal Impact Injuries*, *Serious Impact Injuries* and *Impact Survivors*

Date	Aircraft	Location	*Actual Impact Intensity*	Proportion of *Fatal Impact Injuries*	Proportion of *Serious Impact Injuries*	Proportion of *Impact Survivors*
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	0.00	0.00	0.00	1.00
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	0.00	0.00	0.00	1.00
13-SEP-1982	DC10	MALAGA, SPAIN	0.00	0.00	0.00	1.00
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	0.00	0.00	0.00	1.00
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	0.00	0.00	0.00	1.00
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	0.00	0.00	0.00	1.00
26-JUN-1988	A320-100	HABSHEIM, FRANCE	0.01	0.00	0.01	0.99
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	0.01	0.00	0.01	0.99
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	0.01	0.00	0.01	0.99
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	0.01	0.00	0.01	0.99
17-DEC-1978	B737-200	HYDERABAD, INDIA	0.03	0.00	0.03	0.97
07-OCT-1979	DC8-62	ATHENS, GREECE	0.09	0.00	0.09	0.91
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	0.15	0.00	0.15	0.85
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	0.16	0.00	0.16	0.84
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	0.28	0.03	0.26	0.71
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	0.30	0.03	0.27	0.70
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0.30	0.00	0.30	0.70
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	0.43	0.03	0.40	0.57
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	0.55	0.38	0.17	0.45
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	0.65	0.02	0.63	0.35
14-SEP-1993	A320-211	WARSAW, POLAND	0.74	0.01	0.73	0.26
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	0.96	0.65	0.31	0.04

It is considered likely that the proportion of *Fatal Impact Injuries* will increase with *Actual Impact Intensity*. The data in Table 16 supports this hypothesis since there are no *Fatal Impact Injuries* at *Actual Impact Intensities* below 0.28 and the accident with an *Actual Impact Intensity* of 0.96 resulted in 65% of the occupants sustaining *Fatal Impact Injuries*.

The relationship between *Actual Impact Intensity* and the proportion of *Fatal Impact Injuries* will also be dependent on other factors including age and sex of occupants, adoption of the brace position etc. Therefore it is to be expected that the relationship between *Actual Impact Intensity* and the proportion of *Fatal Impact Injuries* will vary markedly amongst accidents. However, it might be expected that the average values of the proportion of *Fatal Impact Injuries* for all accidents of a given *Actual Impact Intensity* would demonstrate a continuous relationship with *Actual Impact Intensity*. The variation in the proportion of *Fatal Impact Injuries* for the 22 accidents having good injury data is shown in Figure 7.

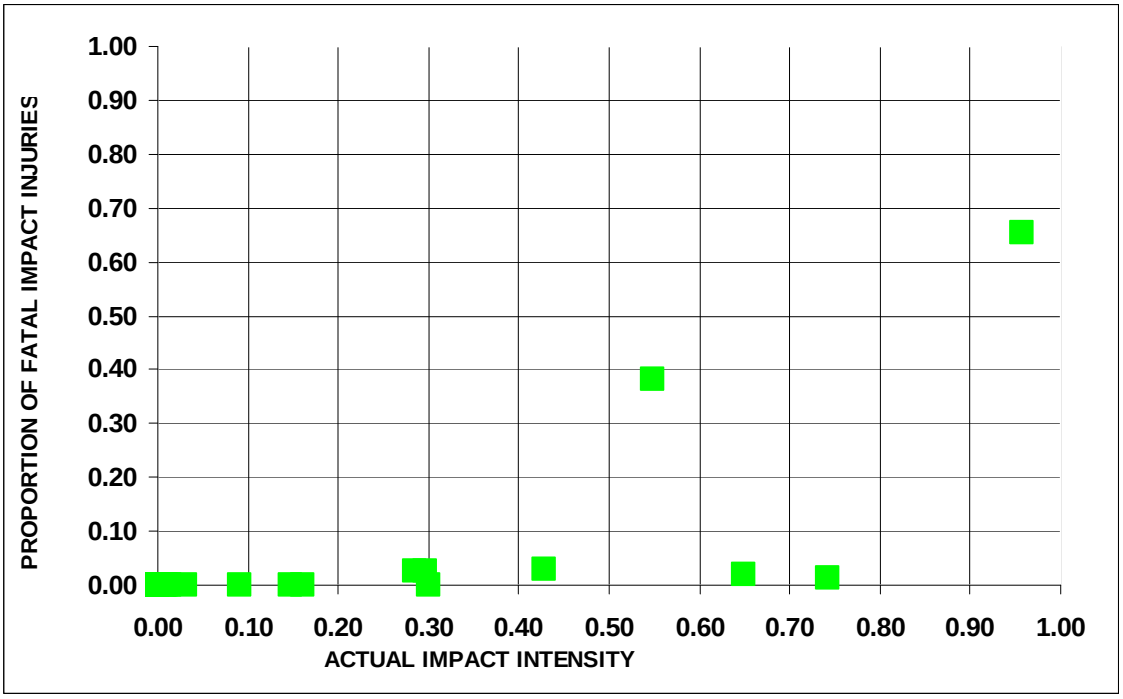


Figure 7. Variation in the Proportion of *Fatal Impact Injuries* With *Actual Impact Intensity* for the 22 Accidents Having Good Injury Data

In order to obtain a mathematical relationship between *Actual Impact Intensity* and the proportion of *Fatal Impact Injuries* a curve of best fit was generated for the data shown in Figure 7. It was considered that since the proportion of *Fatal Impact Injuries* is likely to be 0 at low *Actual Impact Intensities* and limited to a maximum value of 1 the cumulative Weibull distribution

would provide the best relationship between the two variables. The proportion of *Fatal Impact Injuries*, F_I, would then be given by the following expression:

$$F_I = e^{-\left(\frac{I-\gamma}{\eta}\right)^{\beta}} \qquad \text{Equation 4}$$

Where I is the *Actual Impact Intensity*, γ is the "Minimum Life", η is the "Characteristic Life" and β is the "Shape Parameter". The derived variables of the Weibull Distribution for the proportion of *Fatal Impact Injuries* are:

$$\gamma = -1.635, \quad \eta = 2.54, \quad \beta = 16.95$$

The curve of best fit derived from the Weibull distribution is shown in Figure 8.

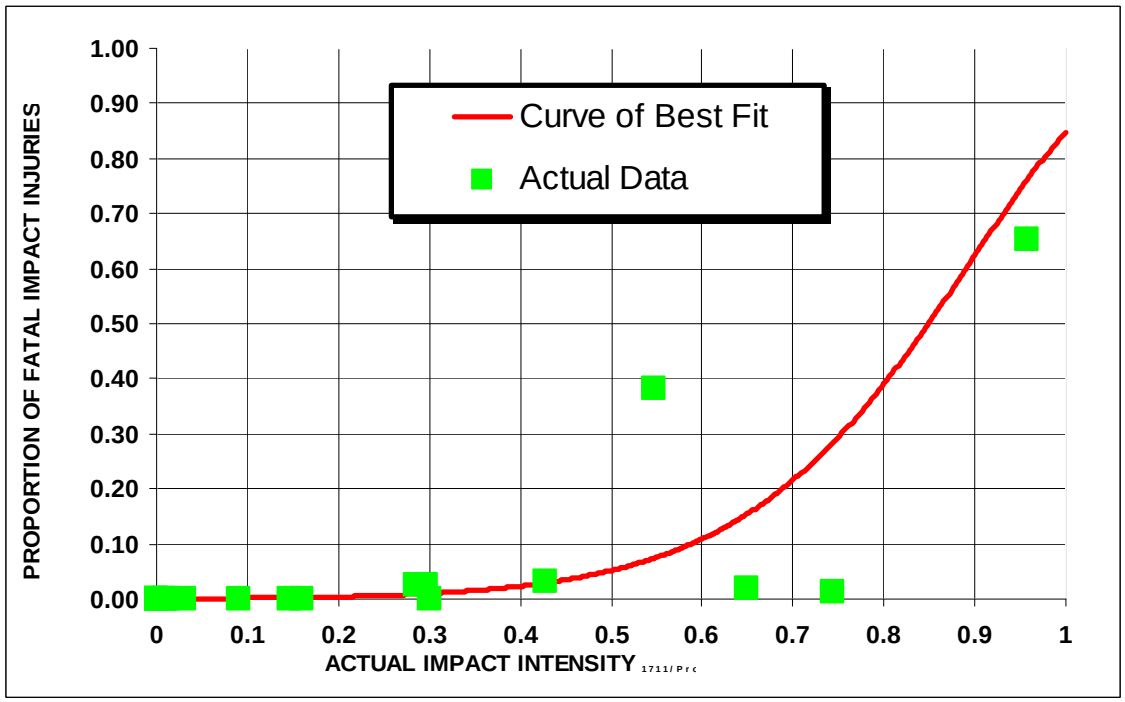


Figure 8. Variation in the Proportion of *Fatal Impact Injuries* With *Actual Impact Intensity* for the 22 Accidents Having Good Injury Data Showing the "Curve of Best Fit"

6.2 THE PROBABILITY OF *FUSELAGE BREAKS*.

As with the proportion of *Fatal Impact Injuries*, it might be expected that the probability of a *Fuselage Break* would increase with increasing impact intensity. Table 17 shows the 22 accidents, ranked in increasing *Actual Impact Intensity*, indicating whether a *Fuselage Break* was involved.

Table 17. *Actual Impact Intensity* for 22 Accidents Having Good Injury Data

Date	Aircraft	Location	*Actual Impact Intensity*	Break / No Break
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	0.00	Break
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	0.00	No Break
13-SEP-1982	DC10	MALAGA, SPAIN	0.00	No Break
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	0.00	No Break
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	0.00	No Break
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	0.00	No Break
26-JUN-1988	A320-100	HABSHEIM, FRANCE	0.01	No Break
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	0.01	Break
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	0.01	No Break
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	0.01	No Break
17-DEC-1978	B737-200	HYDERABAD, INDIA	0.03	No Break
07-OCT-1979	DC8-62	ATHENS, GREECE	0.09	Break
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	0.15	Break
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	0.16	No Break
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	0.28	Break
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	0.30	Break
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0.30	Break
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	0.43	Break
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	0.55	Break
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	0.65	Break
14-SEP-1993	A320-211	WARSAW, POLAND	0.74	No Break
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	0.96	Break

On the assumption that the aircraft involved in the data set of 22 accidents have similar structural characteristics, it is considered that the probability of a *Fuselage Break* at a given *Actual Impact Intensity* may be represented by a Weibull distribution; as with the proportion of *Fatal Impact Injuries*.

The Weibull Distribution may be derived on the basis that the accidents resulting in a *Fuselage Break* are considered to be failures and the accidents where the fuselage remains largely intact are considered to have not failed. The Weibull Distribution, $\mathbf{P_B}$, is given by the following expression:

$$P_B = e^{-\left(\frac{I-\gamma}{\eta}\right)^{\beta}} \qquad \text{Equation 5}$$

Where I is the *Actual Impact Intensity*, γ is the "Minimum Life", η is the "Characteristic Life" and β is the "Shape Parameter". The derived variables of the Weibull Distribution for the Probability of a *Fuselage Break* are:

$$\gamma = -0.054$$
$$\eta = 0.529$$
$$\beta = 1.23$$

The resultant probability distribution is shown in Figure 9. It will be noted that, based on these data, at *Actual Impact Intensities* of 1 it is still feasible that the fuselage will not break.

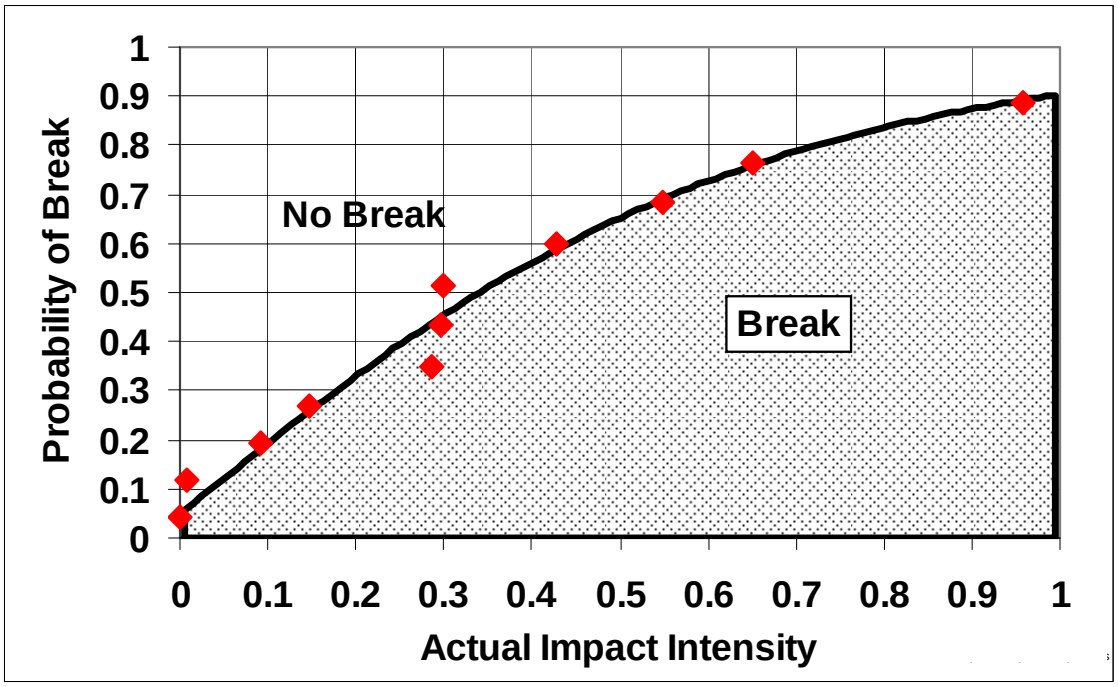


Figure 9. Variation of the Probability of a *Fuselage Break* With *Actual Impact Intensity*

Variations in the probability of a *Fuselage Break* with *Actual Impact Intensity* may be made by simply changing the value of γ, which has the effect of shifting the distribution on the horizontal axis of the cumulative probability distribution.

6.3 *FATAL FIRE INJURIES*.

As described in Section 6.1.1, Survivability Chains were constructed for all 22 ground pool fire accidents having good *Serious* and *Fatal Injury* data. The derived proportions of *Impact Survivors* and *Serious Impact Injuries* sustaining *Fatal Fire Injuries* are shown in Table 18 and Table 19 respectively.

Table 18. Proportion of *Impact Survivors* Sustaining *Fatal Fire Injuries*

Date	Aircraft	Location	Proportion of *Impact Survivors* sustaining *Fatal Fire Injuries*	Break / No Break
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	0.00	Break
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	0.04	No Break
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	0.40	Break
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0.00	Break
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	0.83	Break
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	0.22	No Break
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	0.96	No Break
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	0.97	Break
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	0.00	Break
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	0.00	Break
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	0.01	No Break
17-DEC-1978	B737-200	HYDERABAD, INDIA	0.01	No Break
07-OCT-1979	DC8-62	ATHENS, GREECE	0.00	Break
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	0.00	No Break
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	0.00	Break
13-SEP-1982	DC10	MALAGA, SPAIN	0.13	No Break
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	0.40	No Break
26-JUN-1988	A320-100	HABSHEIM, FRANCE	0.02	No Break
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	0.15	Break
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	0.00	No Break
14-SEP-1993	A320-211	WARSAW, POLAND	0.00	No Break
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	0.03	Break

Table 19. Proportion of *Serious Impact Injuries* Sustaining *Fatal Fire Injuries*

Date	Aircraft	Location	Proportion of *Serious Impact Injuries* sustaining *Fatal Fire Injuries*	Break / No Break
06-NOV-1967	B707-131	CINCINNATI, U.S.A.	0.00	Break
08-APR-1968	B707-465	LONDON (HEATHROW), U.K.	*	No Break
18-APR-1972	VC10	ADDIS ABABA, ETHIOPIA	*	Break
18-MAY-1972	DC9-31	FORT LAUDERDALE, FLORIDA, U.S.A.	0.00	Break
08-DEC-1972	B737-222	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.	0.54	Break
20-DEC-1972	DC9-31	CHICAGO, U.S.A.	*	No Break
30-JAN-1974	B707-321B	PAGO PAGO, AMERICAN SAMOA	1.00	No Break
11-SEP-1974	DC9-31	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.	0.36	Break
05-APR-1976	B727-81	KETCHIKAN, ALASKA, U.S.A.	0.00	Break
11-FEB-1978	B737-275	CRANBROOK B.C., CANADA	0.73	Break
01-MAR-1978	DC10-10	LOS ANGELES, CALIFORNIA, U.S.A.	0.03	No Break
17-DEC-1978	B737-200	HYDERABAD, INDIA	0.00	No Break
07-OCT-1979	DC8-62	ATHENS, GREECE	1.00	Break
21-NOV-1980	B727-92C	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA	0.00	No Break
17-FEB-1981	B737-293	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.	0.00	Break
13-SEP-1982	DC10	MALAGA, SPAIN	*	No Break
22-AUG-1985	B737-236 Sr1	MANCHESTER AP., U.K.	*	No Break
26-JUN-1988	A320-100	HABSHEIM, FRANCE	0.00	No Break
31-AUG-1988	B727-232	DALLAS FORT WORTH, U.S.A.	0.00	Break
30-JUL-1992	L1011-385-1	NEW YORK JFK, U.S.A.	*	No Break
14-SEP-1993	A320-211	WARSAW, POLAND	0.02	No Break
01-JUN-1999	MD82	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	0.05	Break

* There were no *Serious Impact Injuries* in the accidents annotated with an asterisk

Using the data shown in Table 18 and Table 19 Cumulative Probability Distributions of the proportion of occupants sustaining *Fatal Fire Injuri*es were generated for both the *Impact Survivors* and the *Serious Impact Injuries*, as shown in Figure 10 and Figure 11.

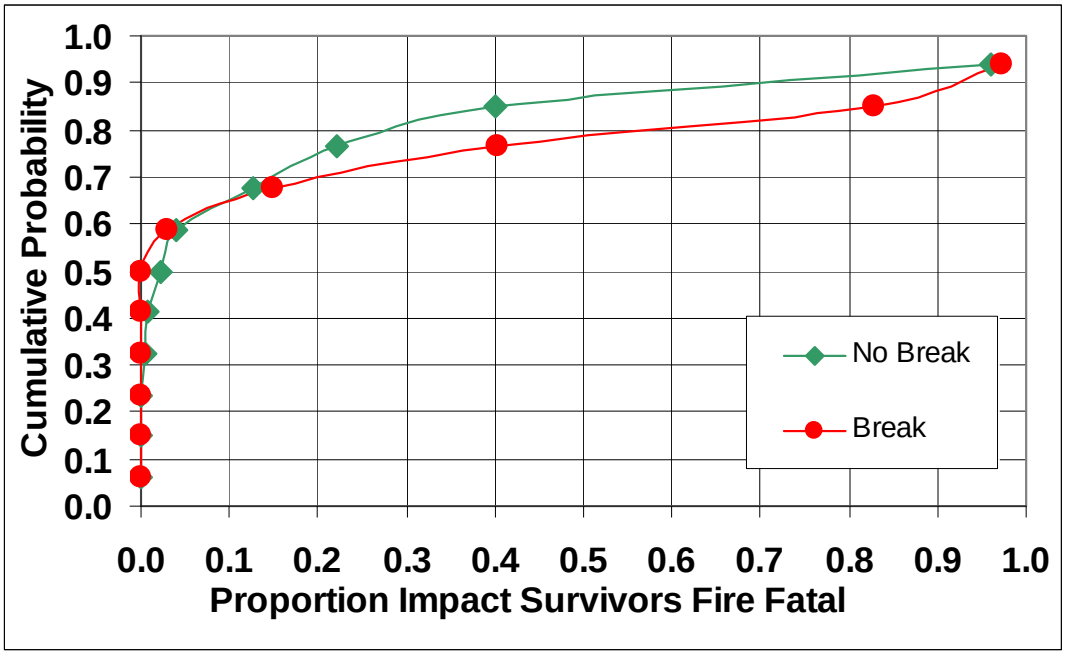


Figure 10. Cumulative Probability Distribution of the Proportion of *Impact Survivors* Sustaining *Fatal Fire Injuries*

It would appear from the distributions illustrated in Figure 10 that the *Impact Survivors* are no more likely to sustain *Fatal Fire Injuries* in an accident where there are *Fuselage Breaks* than they are in accidents where the fuselage remains largely intact. However, this can not be confirmed without further accident and injury data.

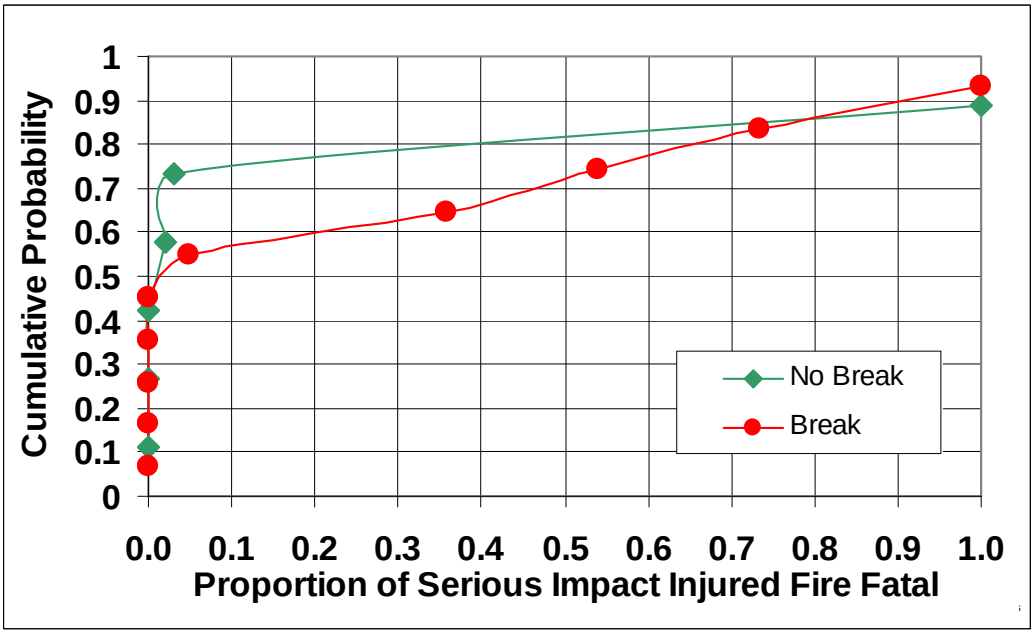


Figure 11. Cumulative Probability Distribution of the Proportion of *Serious Impact Injuries* Sustaining *Fatal Fire Injury*

Figure 11 appears to indicate that the probability distribution for the *Serious Impact Injured* sustaining *Fatal Fire Injuries* is different in accidents involving *Fuselage Breaks* than in accidents where the fuselage remains largely intact. This suggests that the fire has a more severe effect on the *Serious Impact Injuries* when a *Fuselage Break* is present; tending to support the hypothesis that the fire enters through the *Fuselage Breaks* and the more limited mobility of the *Serious Impact Injured* makes them more vulnerable to the fire.

7. A MATHEMATICAL MODEL FOR ASSESSING THE EFFECTS OF *FUSELAGE BREAKS* ON OCCUPANT FATALITIES.

The Mathematical Model, developed to assess the effect of *Fuselage Breaks* on occupant Fatalities, is based on the Monte-Carlo simulation methodology.

Monte-Carlo simulation is a method where variables are randomly chosen based on their probability of occurrence. The variables are then combined to determine the required output, in this case, the Total Proportion of *Fatal Injuries*. By running the Model many times, assessments may be made of the distribution of the Total Proportion of *Fatal Injuries*. The model is constructed so that the effects on the Total Proportion of *Fatal Injuries* may be assessed for varying probabilities of *Fuselage Break*.

The overall structure of the Model, a brief explanation of each step, and the data used in the Model are described in this Section of the report. The structure of the model is shown in Figure 12.

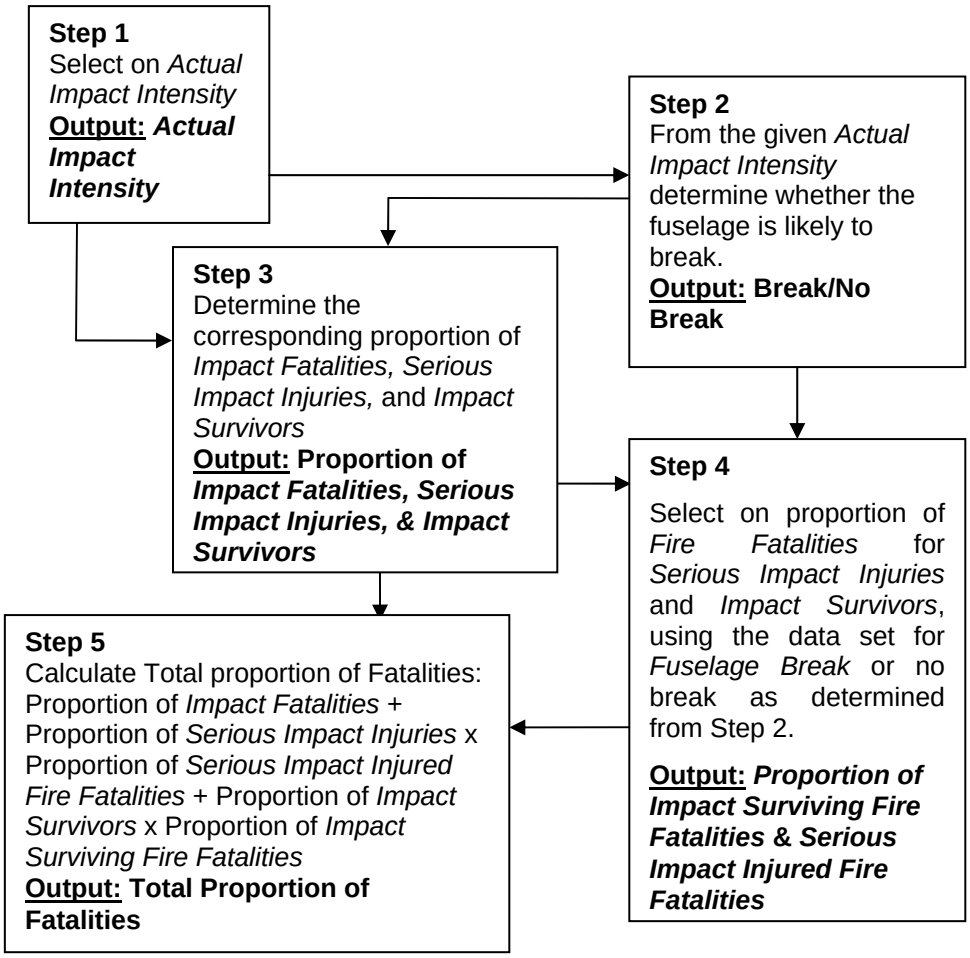


Figure 12. Structure of Mathematical Model

7.1 STEP 1: PROBABILITY OF *ACTUAL IMPACT INTENSITY*.

Step 1 of the model simply derives an *Actual Impact Intensity* based on the distribution shown in Figure 6 of Section 6.1.3. A random number is generated by the model and the associated *Actual Impact Intensity* derived becomes the output from Step 1.

Example iteration of Step 1:

1. The model generates a random number of **0.8**
2. From the data presented in Figure 6 it may be seen that this corresponds to an *Actual Impact Intensity* of approximately **0.44**
3. The output of this step of the model is therefore – *Actual Impact Intensity* = **0.44**

Figure 13 illustrates this example derivation of "*Actual Impact Intensity*".

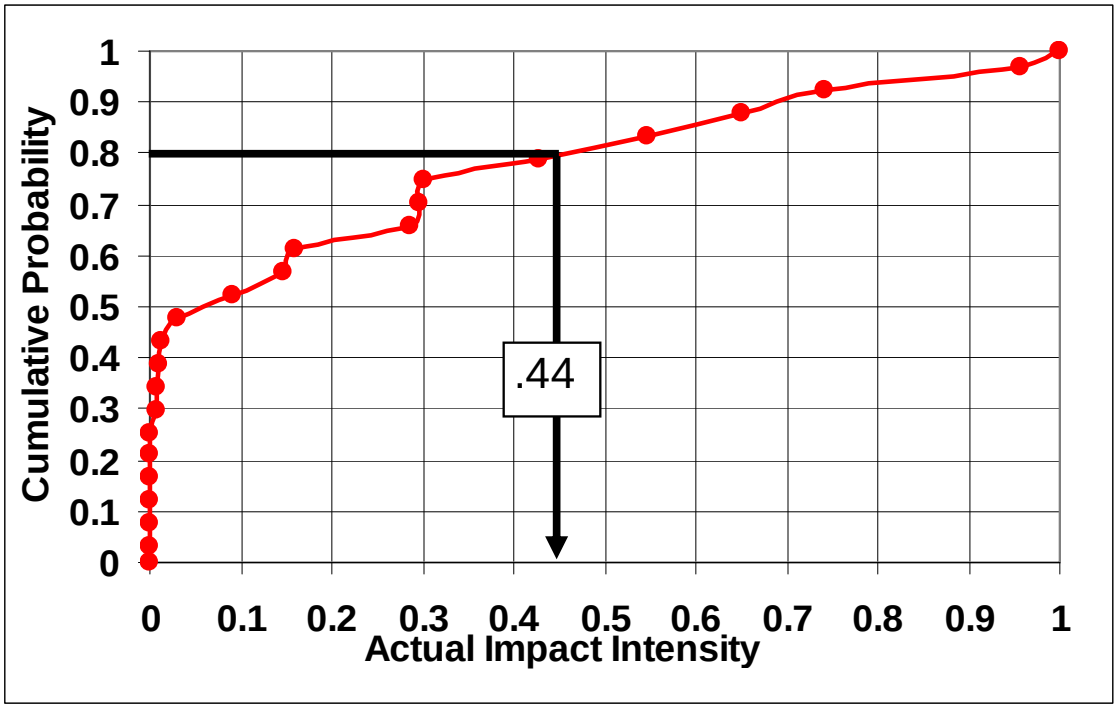


Figure 13. Mathematical Model - Step 1 Derivation of *Actual Impact Intensity*

7.2 STEP 2: PROBABILITY OF A *FUSELAGE BREAK*.

Step 2 of the model uses the *Actual Impact Intensity* derived from Step 1 and derives the probability of occurrence of a break based on the distribution shown in Figure 9. A random number between 0 and 1 is generated within the model and is used to determine whether for this run of the model the fuselage breaks or remains intact.

Example iteration of Step 2:

1. Step 1 generated an *Actual Impact Intensity* of **0.44**
2. From the data presented in Figure 9 this *Actual Impact Intensity* corresponds to a probability of a break of **0.6**
3. At this iteration the model generates a random number of **0.25**
4. Since the random number of **0.25** is less than the probability of a break, **0.6**, then for this iteration the accident is deemed to result in a fuselage break.
5. The output of this step of the model is therefore – **BREAK**

Figure 14 illustrates this example derivation of whether the fuselage breaks or remains intact.

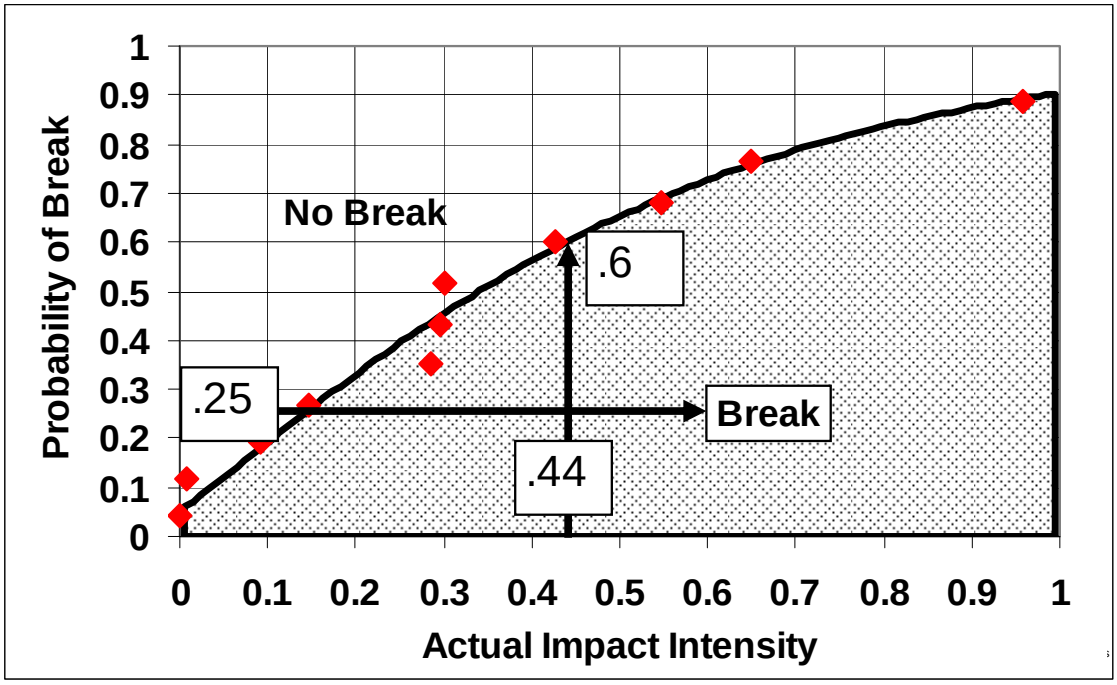


Figure 14. Mathematical Model - Step 2 Determination of Break/No Break

7.3 STEP 3: PROPORTION OF *IMPACT FATALITIES, SERIOUS IMPACT INJURIES,* AND *IMPACT SURVIVORS*.

If Step 2 of the model determines that at this iteration there is no *Fuselage Break* then the model simply takes the *Actual Impact Intensity* generated at Step 1 and determines the proportion of *Fatal Impact Injuries* from Equation 4. The proportion of *Serious Impact Injuries* is simply the *Actual Impact Intensity* minus the proportion of *Fatal Impact Injuries* and the proportion of *Impact Survivors* is 1 minus the *Actual Impact Intensity*.

If Step 2 of the model determines that at this iteration there is a *Fuselage Break* then an intermediate step is required. Allowance has to be made for the occupants that sustain *Serious Impact Injuries* or *Fatal Impact Injuries* at the break. The *Actual Impact Intensity* is modified using the relationship given in Equation 3. The resultant Proportion of *Serious* and *Fatal Impact Injuries* is taken as the *Actual Impact Intensity*. The proportion of *Fatal Impact Injuries*, the Proportion of *Serious Impact Injuries*, and the proportion of *Impact Survivors* are derived in the same manner as the no *Fuselage Break* case.

Example iteration of Step 3:

1. Step 1 generated an *Actual Impact Intensity* of **0.44**
2. Step 2 determined that there is a fuselage **BREAK**
3. From Equation 3 it may be seen that the Proportion of Impact Injuries, for an accident involving a fuselage break with an *Actual Impact Intensity* of **0.44,** is given by **0.971** x **0.44** + **0.029** which is approximately equal to **0.46**
4. Using this "modified" *Actual Impact Intensity* and substituting in Equation 4 the following are obtained:

Proportion of Fatal Impact Injuries = 0.02

Proportion of Serious Impact Injuries = 0.44

Proportion of Impact Survivors = 0.54

7.4 STEP 4: PROPORTION OF *FIRE FATALITIES*.

From the *Impact Survivors* and *Serious Impact Injuries* generated from Step 3, the proportions of each that sustain *Fatal Fire Injuries* are derived. The model generates a random number and selects the appropriate Probability of *Impact Survivors* sustaining *Fatal Fire Injury* from the data shown in Figure 10 and the appropriate Probability of the *Serious Impact Injured* sustaining *Fatal Fire Injury* from the data shown in Figure 11. The model will use the probability curve appropriate to *Fuselage Break* accidents or accidents in which the fuselage remained largely intact dependent on the determination made at Step 2.

Example iteration of Step 4:

1. The model generates a random number of **0.71**

2. Based on the distribution appropriate to a *Fuselage Break* accident shown in Figure 10

Proportion of Impact Surviving Fire Fatalities = 0.26

3. Based on the distribution appropriate to a *Fuselage Break* accident shown in Figure 11

Proportion of Serious Impact Injured Fire Fatalities = 0.46

Figure 15 illustrates this example derivation of the proportion of *Fatal Fire Injuries* based on the data contained in Figure 10 and Figure 11.

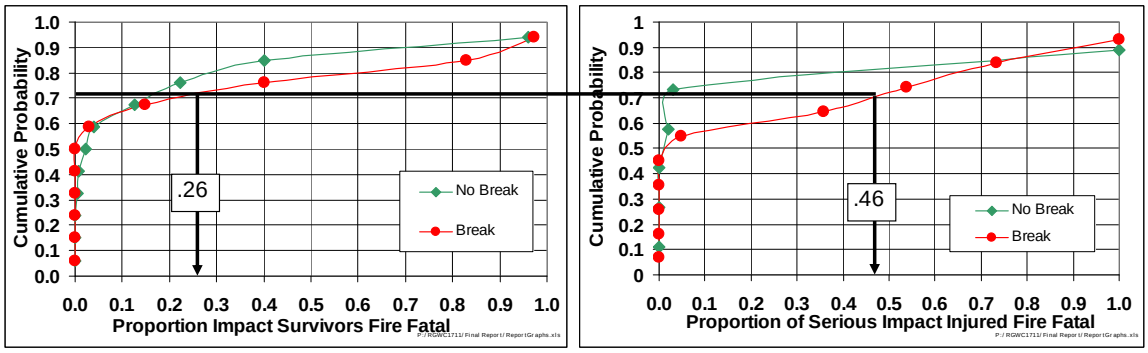


Figure 15. Mathematical Model - Step 4 Derivation of the Proportion of *Fatal Fire Injuries*

7.5 STEP 5: PROPORTION OF TOTAL *FATAL INJURIES*.

Step 5 simply derives the Proportion of Total *Fatal Injuries* from all causes for this iteration of the model. The Proportion of Total *Fatal Injuries* is comprised as follows

- The Proportion of *Fatal Impact Injuries* as determined directly from Step 3
- The Proportion of *Serious Impact Injured Fire Fatalities* is determined by taking the Proportion of *Serious Impact Injuries* derived from Step 3 and multiplying it by the Proportion of *Serious Impact Injured Fire Fatalities* derived from Step 4.
- The Proportion of Impact Surviving *Fire Fatalities* is determined by taking the Proportion of *Impact Survivors* derived from Step 3 and multiplying it by the Proportion of Impact Surviving *Fire Fatalities* derived from Step 4.

The model then adds all of the proportions of *Fire Fatalities* to determine the Proportion of Total *Fatal Injuries* at this iteration of the model.

Example iteration of Step 5:

1. From Step 3
   Proportion of *Fatal Impact Injuries* = 0.02

2. From Step 3 the proportion of Impact Survivors = **0.54** and from Step 4 the proportion of Impact Surviving *Fire Fatalities* is **0.26**. Therefore multiplying **0.54** by **0.26** gives
   Proportion of Impact Surviving *Fire Fatalities* = 0.141

3. From Step 3 the Proportion of Serious Impact Injuries = **0.44** and from Step 4 the Proportion of Serious Impact Injured Fire fatalities is **0.46**. Therefore multiplying **0.44** by **0.46** gives
   Proportion of *Serious Impact Injured Fire Fatalities* = 0.202

Therefore at this iteration of the model the

Total Proportion of Fatalities = 0.02 + 0.141+ 0.202 = 0.363

7.6 MODEL OUTPUT.

7.6.1 Proportion of Occupant *Fatal Injuries*.

By running the model many thousands of times a distribution and an average may be obtained of the Proportion of Occupant *Fatal Injuries*.

The Distribution of the Proportion of Occupant *Fatal Injuries* predicted by the model in ground pool fire accidents is shown in Figure 16 and the average is 0.229.

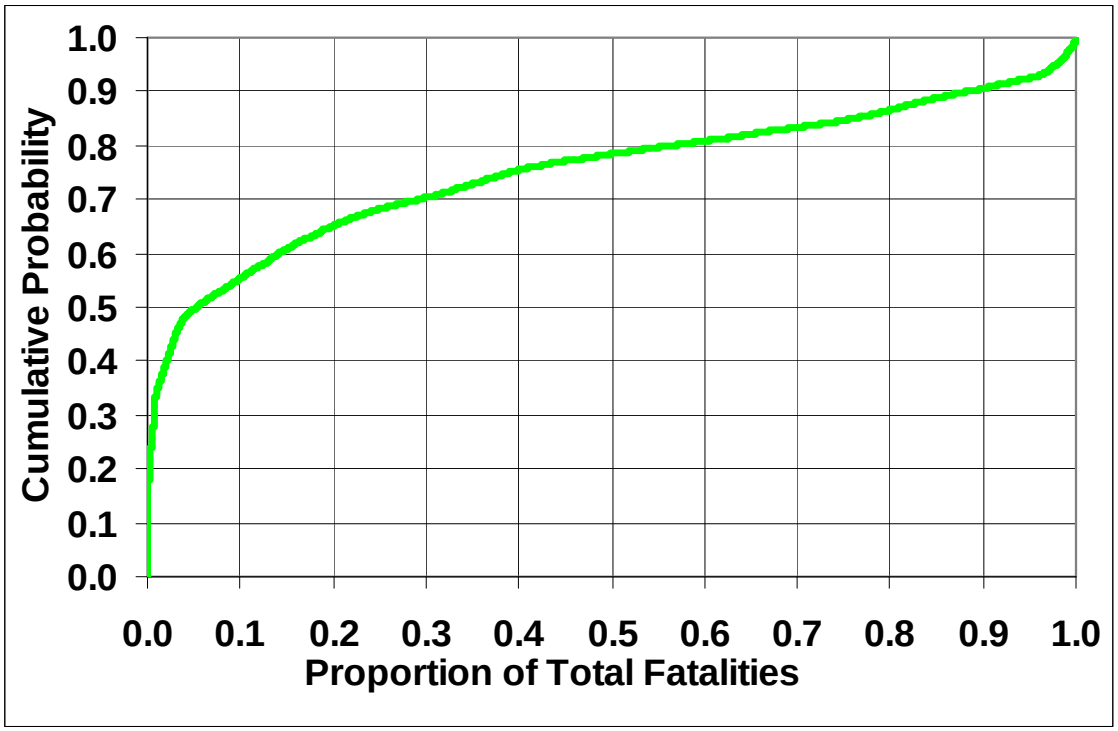


Figure 16. Mathematical Model - Distribution of Proportion of Occupant *Fatalities* in Ground Pool Fire Accidents

By way of example it may be seen that the model output suggests that, on 70% of occasions, ground pool fire accidents will result in 29% or less of the occupants sustaining *Fatal Injuries* as a result of the impact, or of the fire, or of a combination of the impact and the fire.

7.6.2 Effects of *Fuselage Breaks*.

One of the prime objectives of the study is to determine the effects, on occupant survivability, of *Fuselage Breaks*, resulting from impact, in ground pool fire accidents. This may be done by assessing the change in the Average Proportion of Occupant *Fatal Injuries* with changes in the probability of the *Fuselage Breaking* for a given *Actual Impact Intensity*.

The model is capable of making this prediction simply by changing Step 2 to vary the probability of a *Fuselage Break* as described in Section 6.2. In this way an assessment may be made of the average Proportion of Occupant *Fatal Injuries* resulting from *Fuselage Break* probabilities ranging from 0 to 1. (Where a probability of 0 indicates that the fuselage will never break, at any impact intensity, in a ground pool fire accident and a probability of 1 indicates that the fuselage will always break in a ground pool fire accident.) The model may be changed incrementally over this range and the associated Average Proportion of Occupant *Fatal Injuries* assessed.

The output of the model is shown in Figure 17.

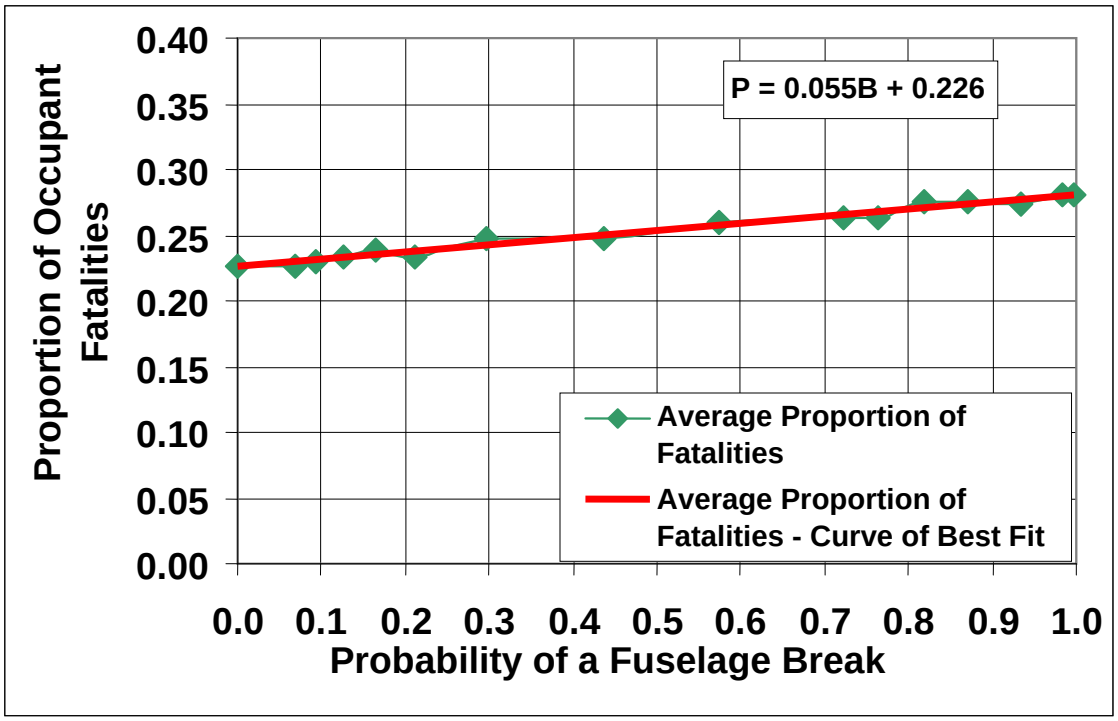


Figure 17. Variation in the Proportion of Occupant *Fatal Injuries* With the Probability of a *Fuselage Break*

It may be seen that the Average Proportion of Occupant *Fatal Injuries* varies from approximately 0.23 to 0.28 as the probability of a *Fuselage Break* varies from 0 to 1. The relationship between Average Proportion of Occupant *Fatal Injuries* and the probability of a *Fuselage Break* may be expressed by the following equation:

Average Proportion of *Fatal Injuries* = 0.055 x (Probability of a *Fuselage Break*) + 0.226 Equation 6

The change in the Average Proportion of *Fatal Injuries* with changes in the Probability of a *Fuselage Break* is therefore given by:

$$\Delta P = 0.055 \times \Delta B \qquad \text{Equation 7}$$

Where ΔP = the change in the Average Proportion of *Fatal Injuries*
and ΔB = the change in the Probability of a *Fuselage Break*

For an aircraft with N occupants the change in the average number of occupant *Fatal Injuries*, F, may be expressed as:

$$F = N \times 0.055 \times \Delta B \qquad \text{Equation 8}$$

For the 36 ground pool fire accidents, 21 resulted in a *Fuselage Break*, hence the assessed Probability of a *Fuselage Break* will approximate to 21/36 = 0.583. Based on this probability and Equation 7, the change in the average number of occupant *Fatal Injuries*, for an aircraft with 200 occupants is as shown in Figure 18.

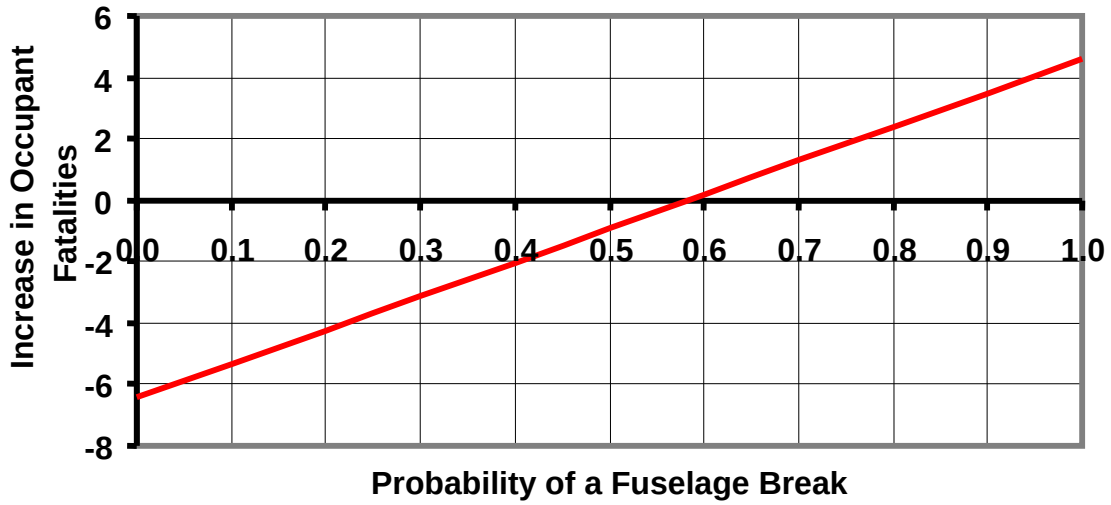


Figure 18. Derived Increase in Average Number of Occupant *Fatal Injuries* With Change in the Probability of a *Fuselage Break* for an Aircraft With 200 Occupants

8. DISCUSSION AND CONCLUSIONS.

8.1 THE INFLUENCE OF ENGINE LOCATION ON THE PROBABILITY OF A GROUND POOL FIRE.

Further data would be needed to determine, to a high level of confidence, any significant difference that might exist between the probabilities of occurrence of a ground pool fire accident for *Aircraft with Wing Mounted Engines* and for *Aircraft without Wing Mounted Engines.* All that can be determined, within the constraints of the size of the existing data set, is that any difference that might exist is unlikely to be large.

Conclusion:

More accident data is required to determine if there is any significant difference between the probability of occurrence of a ground pool fire accident involving *Aircraft with Wing Mounted Engines* (aircraft having wing mounted or wing and tail mounted engines) and *Aircraft without Wing Mounted Engines* (aircraft having engines mounted on the tail of the aircraft only).

8.2 *FUSELAGE BREAK* - LOCATION AND NUMBER.

The majority of the accidents featuring *Fuselage Breaks*, that did not involve massive disruption, featured at least two *Fuselage Breaks*. Attempts were made to correlate the number of *Fuselage Breaks* with *Actual Impact Intensity* since it might be expected that accidents involving severe

impact might result in a greater number of *Fuselage Breaks*. However this does not seem to be the case and *Actual Impact Intensity* does not appear to relate directly to the number of *Fuselage Breaks*.

The probability of *Fuselage Breaks* occurring seems to increase with increasing *Actual Impact Intensity* and the relationship between the two variables seems to be represented well by the Weibull Distribution. Although the information available on *Fuselage Break* locations is not sufficiently precise in many of the accidents studied to make an exact determination, it is considered that approximately half of the *Fuselage Breaks* occurred at a point of structural discontinuity.

Conclusion:

For the majority of accidents studied featuring a *Fuselage Break*, there were at least two *Fuselage Breaks*. The probability of a *Fuselage Break* occurring appears to increase with increasing *Actual Impact Intensity*, however the number of *Fuselage Breaks* does not appear to be related to *Actual Impact Intensity*. Although no firm conclusions can be made, it is considered likely that approximately half of the *Fuselage Breaks* occur at a point of structural discontinuity.

8.3 *FUSELAGE BREAK* - OCCUPANT EGRESS AND FIRE ENTRY.

For the ground pool fire accidents studied it would seem inevitable that the *Fuselage Breaks* provide a means for fire entry into the cabin. However, this could not be confirmed from the information contained in the Accident Reports. The occupant injury information suggests that the proportion of *Serious Impact Injured* occupants that succumb to the fire is greater for ground pool fire accidents involving a *Fuselage Break* than in accidents where the fuselage remains largely intact, suggesting that *Fuselage Breaks* are a significant issue in occupants surviving the fire.

It is evident that *Fuselage Breaks* provide an egress route for occupants in ground pool fire accidents. In more than 70% of the accidents studied that involved *Fuselage Breaks* occupants used them as an escape means. An earlier study carried out for Transport Canada suggested that in high fire intensity accidents approximately 8% of evacuees used *Fuselage Breaks* as an escape route.

Conclusion:

Based on the analysis of the occupant injury data the occurrence of a *Fuselage Break* in ground pool fire accidents would seem to result in a more severe fire threat to the occupants. However, this cannot be confirmed from statements made in the Accident Reports. *Fuselage Breaks* provided a significant means of escape for occupants in more than 70% of ground pool fire accidents studied.

8.4 *FUSELAGE RUPTURES*.

For the fifteen ground pool fire accidents, in which the aircraft remained largely intact:

- It would appear that the majority resulted in *Fuselage Ruptures*, however in only four could this be confirmed.

- The dimensions of *Fuselage Ruptures* could not be established for any of the fifteen accidents. The only accident for which an approximation could be made of rupture size was the accident to the Boeing 707 in Pago Pago, American Samoa, in 1974, which had a *Fuselage Rupture* of sufficient size to allow the Third Officer to escape.

Conclusion:

It is likely that the majority of ground pool fire accidents in which the aircraft remains largely intact sustain *Fuselage Ruptures*. However, there are insufficient data contained in the accident reports studied to establish their size.

8.5 THE EFFECTS OF *FUSELAGE BREAKS* ON SURVIVABILITY.

The effects of *Fuselage Breaks* on occupant survivability were evaluated using a Monte Carlo simulation model that evaluated the change in the Proportion of Occupant *Fatal Injuries* with changes in the probability of a *Fuselage Break*.

Whilst the model has been constructed to reflect aircraft currently in service, no account has been taken of the influence of later requirements that might improve occupant survival. It is likely that if this could be taken into account, the model output for the distribution and average Proportion of Occupant *Fatal Injuries* would change. It might be expected that later requirements related to fire and evacuation would be more effective when the fuselage remains largely intact and there are no *Fuselage Breaks*. If this is the case, taking into account later requirements would tend to increase the difference in the proportion of occupant *Fatal Injuries* for accidents involving a *Fuselage Break* and accidents where the fuselage remains largely intact.

8.5.1 Average Proportion of Occupant *Fatal Injuries*.

Based on the data from the 22 ground pool fire accidents with good *Serious* and *Fatal Injury* data, the Average Proportion of Occupant *Fatal Injuries* predicted by the model was 0.229 for the current fleet of aircraft.

Conclusion:

The average proportion of occupant *Fatal Injuries* in ground pool fire Accidents predicted by the model was .229. Further accident and injury information is required to establish the confidence that may be assigned to this prediction.

8.5.2 Cumulative Probability Distribution of the Proportion of Occupant *Fatal Injuries*.

The Cumulative Probability Distribution of the proportion of occupant *Fatal Injuries*, as predicted by the model using the data from the 22 ground pool fire accidents with good *Serious* and *Fatal Injury* data is shown in Figure 16. This distribution is of particular interest since it may be compared with the Actual Distribution of the Proportion of Occupant *Fatal Injuries* for the 22 ground pool fire accidents with good *Serious* and *Fatal Injury* data. This comparison is shown in Figure 19.

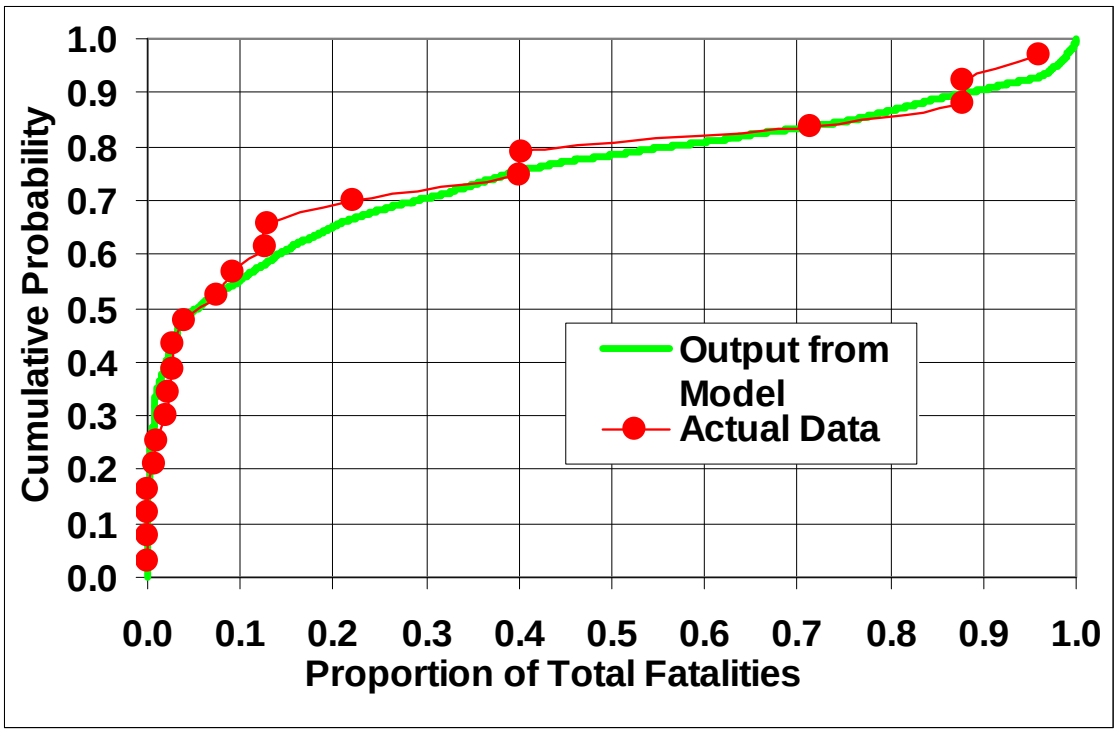


Figure 19. Mathematical Model – Comparison of Actual and Model Prediction of the Distribution of the Proportion of Occupant *Fatal Injuries* in Ground Pool Fire Accidents

It may be seen that there is good correlation between the distribution predicted by the model and the actual distribution for the 22 ground pool fire accidents giving some confidence in the validity of the model. However, as discussed In Section 8.5.1 further accident and injury information is required to establish the confidence that may be assigned to the model predictions.

Conclusion:

The Monte Carlo simulation model appears to reflect the proportion of occupant fatalities for the 22 ground pool fire accidents with good *Serious* and *Fatal Injury* data reasonably well. However further accident and injury information is required to establish the confidence that may be assigned to the model predictions.

8.5.3 The Change in the Average Proportion of Occupant *Fatal Injuries* With the Probability of a *Fuselage Break*.

It was shown in Section 7.6.2 that the change in the Average Proportion of Occupant *Fatal Injuries* with the Probability of a *Fuselage Break* may be derived from the equation:

Average Proportion of *Fatal Injuries* =
0.055 x (Probability of a *Fuselage Break*) + 0.226

and that for an aircraft with **N** occupants the change in the number of *Fatal Injuries*, F, may be expressed as:

$$F = N \times 0.055 \times \Delta B$$

Where ΔB = the change in the Probability of a *Fuselage Break*

In order to gain a better understanding of the influence of the limited data set on the model outputs, estimates were made of the likely *Serious* and *Fatal Injuries* that were sustained by the occupants in the complete data set of thirty-six ground pool fire accidents. The model output using the data from these accidents yielded a relationship between the Average Proportion of Occupant *Fatal Injuries* and the Probability of a *Fuselage Break* of:

Average Proportion of *Fatal Injuries* =
0.058 x (Probability of a *Fuselage Break*) + 0.29

Therefore, for an aircraft with **N** occupants the change in the number of *Fatal Injuries*, **F**, would be:

$$F = N \times 0.058 \times \Delta B$$

It may be seen that the prediction of the change in the number of *Fatal Injuries*, F, is very similar for the two accident data sets giving confidence that the model is able to predict this value with some accuracy.

Conclusion:

The change in the number of *Fatal Injuries*, F, with changes in the probability of a *Fuselage Break* ΔB for an aircraft with N occupants may be reasonably well represented by the equation.

$$F = N \times 0.055 \times \Delta B$$

9. GLOSSARY OF TERMS.

Fatal Injury (Source: NTSB, ICAO)
"An injury resulting in death within thirty days of the date of the accident."

Serious Injury (Source: NTSB, ICAO)
"An injury, which is sustained by a person in an accident and which:

(a) Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; or

(b) Results in a fracture of any bone (except simple fractures of fingers, toes, or nose); or

(c) Involves lacerations which cause severe hemorrhage, nerve, muscle or tendon damage; or

(d) Involves injury to any internal organ; or

(e) Involves second or third degree burns, or any burns affecting more than 5 per cent of the body surface; or

(f) Involves verified exposure to infectious substances or injurious radiation."

For the purposes of this analysis the following definitions have been used:

Actual Impact Intensity is the proportion of aircraft occupants, not in the vicinity of *Fuselage Breaks*, that sustain *Serious Impact Injuries* or *Fatal Impact Injuries*.

Fatality Rate is the total number of *Fatalities* divided by the total number of occupants aboard.

Fatal Impact Injury is a *Fatal Injury* sustained by an occupant as a direct result of the impact sequence in the accident.

Fatal Fire Injury is a *Fatal Injury* sustained by an occupant as a result of the fire.

Fuselage Break is a major disruption of the fuselage that provides a potential escape route for occupants or a means of fire entry.

Fuselage Rupture is a hole in an otherwise intact area of the fuselage.

Serious Impact Injury is a *Serious Injury* sustained by an occupant as a direct result of the impact sequence in the accident.

Serious Fire Injury is a *Serious Injury* sustained by an occupant as a result of the fire.

Impact Survivor is an occupant that sustains only Minor or no injuries as a result of the impact sequence in the accident.

Survivable Accident is an accident where there were one or more survivors or there was potential for survival.

Aircraft with Wing Mounted Engines - Aircraft having wing mounted or wing and tail mounted engines.

Aircraft without Wing Mounted Engines - Aircraft having engines mounted on the tail of the aircraft only; either on the empennage or on the fin and empennage

10. REFERENCES.

1. Cabin Safety Research Technical Group (CSRTG) Aircraft Accident Database at Issue 24

2. Boeing Statistical Summary of Commercial Jet Airplane Accidents www.boeing.com/news/techissues May 2004

3. Analysis of Structural Factors Influencing the Survivability of Occupants in Aeroplane Accidents 1996 R.G.W. Cherry & Associates Ltd. CAA Paper 96011

APPENDIX A—ACCIDENTS RESULTING IN *FATAL INJURIES* OR THE AIRCRAFT BEING DESTROYED FOR WHICH THERE ARE FULL SCREEN 3[3] DATA

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
05-MAR-1967	DC8-33	PP-PEA	NR. MONROVIA, LIBERIA, AFRICA
09-MAR-1967	DC9-15	N1063T	NR. URBANA, OHIO, U.S.A.
23-JUN-1967	BAC1-11-204AF	N1116J	NR. BLOSSBURG, PENNSYLVANIA, U.S.A.
19-JUL-1967	B727-22	N68650	HENDERSONVILLE, NORTH CAROLINA, U.S.A.
04-NOV-1967	CARAVELLE 10BIR	EC-BDD	BLACK DOWN HILL, SUSSEX, U.K.
06-NOV-1967	B707-131	N742TW	CINCINNATI, U.S.A.
20-NOV-1967	CV880	N821TW	CONSTANCE, KENTUCKY, U.S.A.
06-MAR-1968	B707-328C	F-BLCJ	POINTE A PITRE, GUADELOUPE
08-APR-1968	B707-465	G-ARWE	LONDON (HEATHROW), U.K.
27-DEC-1968	DC9-15	N974Z	SIOUX CITY AIRPORT, IOWA, U.S.A.
13-JAN-1969	DC8-62	LN-MOO	SANTA MONICA BAY, CALIFORNIA, U.S.A.
18-JAN-1969	B727-22C	N7434U	SANTA MONICA BAY, LOS ANGELES, CALIFORNIA, U.S.A.
09-SEP-1969	DC9-30	N988VJ	NR. FAIRLAND, INDIANA, U.S.A.
20-NOV-1969	VC10-1101	5N-ABD	LAGOS, NIGERIA
02-MAY-1970	DC9-33F	N935F	ST.CROIX, VIRGIN ISLANDS
03-JUL-1970	COMET 4	G-APDN	SIERRA DEL MONTENSY, GERONA, SPAIN
05-JUL-1970	DC8-63	C-FTIW	TORONTO, CANADA
15-SEP-1970	DC8-62	I-DIWZ	J.F.K. AIRPORT, NEW YORK, U.S.A.
14-NOV-1970	DC9-31	N97S	TRI-STATE AP., HUNTINGTON, WEST VIRGINIA, U.S.A.
27-NOV-1970	DC8-63F	N4909C	ANCHORAGE, ALASKA, U.S.A.

[3] "Screen 3" information is textual data contained in the CSRTG Accident Database that is extracted from Accident Reports produced by the Investigating Authority. Further analysis of selected accidents was supported by the library of Accident Reports and Data held by RGW Cherry & Associates Limited.

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
28-DEC-1970	B727-200	N8790R	ST.THOMAS, VIRGIN ISLANDS
02-JAN-1971	COMET 4C	SU-ALC	TRIPOLI AP., LIBYA
06-JUN-1971	DC9-31	N9345	NEAR DUARTE, CALIFORNIA, U.S.A.
04-SEP-1971	B727-193	N2969G	NEAR JUNEAU, ALASKA, U.S.A.
06-SEP-1971	BAC1-11-500/515	D-ALAR	NR. HASLOH, GERMANY
18-APR-1972	VC10	5X-UVA	ADDIS ABABA, ETHIOPIA
18-MAY-1972	DC9-31	N8961E	FORT LAUDERDALE, FLORIDA, U.S.A.
18-JUN-1972	TRIDENT 1C	G-ARPI	STAINES, HEATHROW, U.K.
19-JUL-1972	BAC1-11	G-AWYS	CORFU, GREECE
08-DEC-1972	B737-222	N9031U	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.
20-DEC-1972	DC9-31	N954N	CHICAGO, U.S.A.
29-DEC-1972	L1011	N310EA	NR. MIAMI INTERNATIONAL AIRPORT, FLORIDA, U.S.A.
22-JAN-1973	B707-3D3C	JY-ADO	KANO AIRPORT, NIGERIA
11-JUL-1973	B707-321C	PP-VJZ	ORLY, NR. PARIS, FRANCE
31-JUL-1973	DC9-31	N975NE	LOGAN INTERNATIONAL AIRPORT, BOSTON, MASSACHUSETTS
28-AUG-1973	B707-331B	N8705T	NR. LOS ANGELES, CALIFORNIA, U.S.A.
03-NOV-1973	DC10-10	N60NA	NR. SOCORRO & ALBUQUERQUE, NEW MEXICO
27-NOV-1973	DC9-32	N3323L	CHATTANOOGA MUNICIPAL AIRPORT, TENNESSEE, U.S.A.
27-NOV-1973	DC9-31	N8967E	AKRON-CANTON AIRPORT, OHIO, U.S.A.
01-JAN-1974	F28-1000	I-TIDE	NR. TURIN, ITALY
16-JAN-1974	B707-131B	N757TW	LOS ANGELES INTL AIRPORT, CALIFORNIA, U.S.A.
26-JAN-1974	F28-1000	TC-JAO	COMAOVASI, TURKEY
30-JAN-1974	B707-321B	N454PA	PAGO PAGO, AMERICAN SAMOA
03-MAR-1974	DC10-10	TC-JAV	ERMENONVILLE FOREST, NR. PARIS, FRANCE

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
15-MAR-1974	CARAVELLE 10B3	OY-STK	TEHERAN, IRAN
22-APR-1974	B707-321C	N446PA	DENPASAR, BALI, INDONESIA
11-SEP-1974	DC9-31	N8984E	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.
20-NOV-1974	B747-130	D-ABYB	NAIROBI, KENYA
01-DEC-1974	B727-231	N54328	BERRYVILLE, VIRGINIA, U.S.A.
04-DEC-1974	DC8-55F	PH-MBH	ANJIMALAI MOUNTAIN, SRI LANKA
24-JUN-1975	B727-225	N8845E	KENNEDY AIRPORT, NEW YORK, U.S.A.
05-APR-1976	B727-81	N124AS	KETCHIKAN, ALASKA, U.S.A.
27-APR-1976	B727-95	N1963	ST. THOMAS, VIRGIN ISLAND
23-JUN-1976	DC9-31	N994VJ	PHILADELPHIA INTERNATIONAL AIRPORT
10-SEP-1976	TRIDENT 3B	G-AWZT	VROBEC, YUGOSLAVIA
10-SEP-1976	DC9-32	YU-AJR	VROBEC, YUGOSLAVIA
27-MAR-1977	B747	N736PA	TENERIFE AIRPORT, CANARY ISLANDS
27-MAR-1977	B747-206B	PH-BUF	TENERIFE AIRPORT, CANARY ISLANDS
04-APR-1977	DC9-31	N1335U	NEW HOPE GEORGIA, U.S.A.
18-DEC-1977	CARAVELLE 10B1R	HB-ICK	NR. FUNCHAL, MADEIRA, PORTUGAL
11-FEB-1978	B737-275	C-FPWC	CRANBROOK B.C., CANADA
01-MAR-1978	DC10-10	N68045	LOS ANGELES, CALIFORNIA, U.S.A.
08-MAY-1978	B727-235	N4744NA	NR. PENSACOLA, FLORIDA, U.S.A.
26-JUN-1978	DC9-32	C-FTLV	TORONTO INTERNATIONAL AIRPORT, CANADA
25-SEP-1978	B727-214	N533PS	SAN DIEGO, CALIFORNIA, U.S.A.
17-DEC-1978	B737-200	VT-EAL	HYDERABAD, INDIA
28-DEC-1978	DC8-61	N8082U	PORTLAND, OREGON, U.S.A.
25-MAY-1979	DC10-10	N110AA	CHICAGO-O'HARE AP., ILLINOIS, U.S.A.

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
07-OCT-1979	DC8-62	HB-IDE	ATHENS, GREECE
31-OCT-1979	DC10-10	N903WA	MEXICO CITY, MEXICO
28-NOV-1979	DC10-30	ZK-NZP	MT. EREBUS, ANTARCTICA
25-APR-1980	B727-64	G-BDAN	NR. TENERIFE NORTE AP., CANARY ISLANDS
19-AUG-1980	L1011	HZ-AHK	NR. RIYADH, SAUDI ARABIA
19-NOV-1980	B747-100	HL-7445	SEOUL, KOREA
21-NOV-1980	B727-92C	N18479	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA
22-DEC-1980	L1011	HZ-AHJ	NR. STATE OF QATAR
17-FEB-1981	B737-293	N468AC	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.
20-SEP-1981	DC10-30CF	N112WA	OVER NORTH ATLANTIC OCEAN
13-JAN-1982	B737-222	N62AF	POTOMAC RIVER, WASHINGTON D.C., U.S.A.
23-JAN-1982	DC10-30CF	N113WA	LOGAN INT. AIRPORT BOSTON, U.S.A.
09-FEB-1982	DC8-61	JA-8061	HANEDA AIRPORT, TOKYO, JAPAN
09-JUL-1982	B727-235	N4737	KENNER, LOUISIANA, U.S.A.
13-SEP-1982	DC10	EC-DEG	MALAGA, SPAIN
02-JUN-1983	DC9-32	C-FTLU	CINCINNATI INTERNATIONAL AIRPORT, U.S.A.
07-DEC-1983	B727-200	EC-CFJ	MADRID, SPAIN
07-DEC-1983	DC9-32	EC-CGS	MADRID, SPAIN
18-DEC-1983	A300B4-120	OY-KAA	KUALA LUMPUR, MALAYSIA
02-AUG-1985	L1011-385-1	N726DA	DALLAS FORT WORTH, U.S.A.
12-AUG-1985	B747-SR-100	JA-8119	MOUNT OSUTAKA, GUMMA, JAPAN
22-AUG-1985	B737-236 Sr1	G-BGJL	MANCHESTER AP., U.K.
06-SEP-1985	DC9-14	N100ME	MILWAUKEE, WISCONSIN, U.S.A.
12-DEC-1985	DC8-63	N950JW	GANDER, NEWFOUNDLAND, CANADA

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
31-AUG-1986	DC9-32	XA-JED	CERRITOS, CALIFORNIA, U.S.A.
25-OCT-1986	B737-222	N752N	CHARLOTTE, NORTH CAROLINA, U.S.A.
16-AUG-1987	MD82	N312RC	DETROIT, U.S.A.
31-AUG-1987	B737-200	HS-TBC	NR. PHUKET AP., THAILAND
15-NOV-1987	DC9-14	N626TX	DENVER COLORADO U.S.A.
28-APR-1988	B737-200	N73711	NR. MAUI, HAWAII
26-JUN-1988	A320-100	F-GKFC	HABSHEIM, FRANCE
31-AUG-1988	TRIDENT 2E	B-2218	HONG KONG
31-AUG-1988	B727-232	N473DA	DALLAS FORT WORTH, U.S.A.
08-JAN-1989	B737-400	G-OBME	KEGWORTH, EAST MIDLANDS AIRPORT, U.K.
24-FEB-1989	B747-122	N4713U	EN-ROUTE OVER PACIFIC OCEAN
10-MAR-1989	F28-1000	C-FONF	DRYDEN, ONTARIO, CANADA
19-JUL-1989	DC10-10	N1819U	SIOUX CITY, U.S.A.
20-SEP-1989	B737-400	N416US	NEW YORK LA GUARDIA, U.S.A.
25-JAN-1990	B707-321B	HK-2016	COVE NECK, LONG ISLAND, NEW YORK, U.S.A.
14-FEB-1990	A320-231	VT-EPN	BANGALORE, INDIA
02-JUN-1990	B737-2X6C	N670MA	ALASKALEET, ALASKA, U.S.A.
03-DEC-1990	DC9-14	N3313L	ROMULUS, DETROIT, U.S.A.
01-FEB-1991	B737-300	N388US	LOS ANGELES, CALIFORNIA, U.S.A.
03-MAR-1991	B737-291	N999UA	COLORADO SPRINGS, COLORADO, U.S.A.
26-MAY-1991	B767-3Z9ER	OE-LAV	PHU TOEY VILLAGE , THAILAND
11-JUL-1991	DC8-61	C-GMXQ	KING ABDULAZIZ INT. AP., JEDDAH, SAUDI ARABIA
20-JAN-1992	A320-100	F-GGED	NR STRASBOURG, FRANCE
22-MAR-1992	F28-4000 a	N485US	LA GUARDIA, NEW YORK, U.S.A.

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
30-JUL-1992	L1011-385-1	N11002	NEW YORK JFK, U.S.A.
21-DEC-1992	DC10-30CF	PH-MBN	FARO, PORTUGAL
06-APR-1993	MD11	B-2171	NR. SHEMYA, ALASKA, U.S.A.
14-APR-1993	DC10-30	N139AA	DALLAS/FORT WORTH AIRPORT, DALLAS, TEXAS, U.S.A.
14-SEP-1993	A320-211	D-AIPN	WARSAW, POLAND
24-NOV-1993	MD87	SE-DIB	COPENHAGEN AIRPORT KASTRUP, DENMARK
26-APR-1994	A300B4-622R	B-1816	NAGOYA/KOMAKI AIRPORT, NAGOYA, JAPAN
02-JUL-1994	DC9-31	N954VJ	CHARLOTTE AIRPORT, CHARLOTTE, NORTH CAROLINA
10-AUG-1994	A300B4-622R	HL-7296	CHEJU ISLAND AIRPORT, KOREA
08-SEP-1994	B737-300	N513AU	NR. ALIQUIPPA, PENNSYLVANIA, U.S.A.
08-JUN-1995	DC9-32	N908VJ	WILLIAM B. HARTSFIELD INTL. AIRPORT, ATLANTA
20-DEC-1995	B757-223	N651AA	BUGA, NR. CALI, COLOMBIA
06-FEB-1996	B757-225	TC-GEN	PUERTO PLATA, DOMINICAN REPUBLIC
11-MAY-1996	DC9-32	N904VJ	EVERGLADES, FLORIDA, U.S.A.
13-JUN-1996	DC10-30	PK-GIE	FUKUOKA AIRPORT, JAPAN
06-JUL-1996	MD88	N927DA	PENSACOLA REGIONAL AIRPORT, FLORIDA, U.S.A.
17-JUL-1996	B747-131	N93119	OFF LONG ISLAND, U.S.A.
06-AUG-1997	B747-3B5B	HL-7468	NIMITZ HILL, NR AGANA, GUAM
16-DEC-1997	CL600-2B19	C-FSKI	FREDERICTON AP., NEW BRUNSWICK, CANADA
19-DEC-1997	B737-300	9V-TRF	PALEMBANG, INDONESIA
09-FEB-1998	B727-223	N845AA	O'HARE INTL AIRPORT, CHICAGO, ILLINOIS, U.S.A.
02-SEP-1998	MD11	HB-IFW	IN SEA, NR. PEGGY'S COVE, NOVA SCOTIA, CANADA
01-JUN-1999	MD82	N215AA	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.
14-SEP-1999	B757-204	G-BYAG	GIRONA AIRPORT, SPAIN

DATE	AIRCRAFT TYPE	REGISTRATION	LOCATION
31-OCT-1999	B767-366ER	SU-GAP	NANTUCKET ISLAND, MA, U.S.A.
31-JAN-2000	MD83	N963AS	ANACAPA ISLAND, CA, U.S.A.
05-MAR-2000	B737-300	N668SW	BURBANK, CA, U.S.A.
17-JUL-2000	B737-200	VT-EGD	NEAR PATNA AP, INDIA
25-JUL-2000	CONCORDE	F-BTSC	GONESSE, FRANCE
23-AUG-2000	A320	A40-EK	NEAR BAHRAIN AP, BAHRAIN
31-OCT-2000	B747-412B	9V-SPK	CHIANG KAI-SHEK AP, TAIWAN

APPENDIX B—ACCIDENT RATIONALES

Explanation of Rationales

The header of each Rationale contains information regarding the following:

- *Accident Database Reference* – the reference number allocated to the accident in the CSRTG Accident Database
- *Location* – the geographical location of the accidents
- *Aircraft* – the aircraft type and series (where known)
- *Date* - the date of the accident
- *Operator* – the aircarft operator
- *Registration* – the aircraft registration
- *Engine Location* – the location of the engines:
  - Wing - Aircraft having wing mounted or wing and tail mounted engines.
  - Tail - Aircraft having engines mounted on the tail of the aircraft only; either on the empennage or in the fin and empennage
- Fuselage Break – indicates YES there was a Fuselage Break or No there were no *Fuselage Breaks*. [Where a *Fuselage Break* is defined as "a major disruption of the fuselage that provides a potential escape route for occupants or a means of fire entry."]
- Number of Breaks - indicates the number of *Fuselage Breaks*
- Fuselage Break Category – indicates
  - INTACT there were no *Fuselage Breaks*
  - MAJOR BREAKS there were *Fuselage Breaks*
  - MASSIVE DISRUPTION – indicates an accident featuring *Fuselage Breaks*, however the extent of the disruption was such that it was not feasible to determine the characteristics of any breaks

The remainder of the rationale is divided into four major sections:

Résumé of Accident: This section gives a brief summary of the accident

Occupant *Injuries* & Survivability Chain: This section gives a summary of the resultant *Injuries* sustained by the occupants of the accident aircraft. The Survivability Chain (See Section 6.1.1 of this Report) illustrates the number and type of *Injuries* sustained in the accident.

Impact Injuries that were not sustained during the crash sequence (e.g. those incurred during or after the evacuation) are not considered as *Impact Injuries* in the survivability chain.

Where the accident report does not mention how the *Impact Injuries* were sustained, it was assumed that they were sustained during the crash sequence.

***Fuselage Breaks* & *Ruptures*:** This section gives a more detailed description of the aircraft impact damage. In those instances where the impact resulted in *Fuselage Breaks* their approximate location and number are illustrated in a diagram of the aircraft.

For those accidents where the aircraft fuselage remained largely intact information is provided regarding the likelihood of *Fuselage Ruptures* and whenever possible their size and location (For the accidents contained in this Appendix the data on *Fuselage Ruptures* is extremely limited).

Occupant Egress & Fire Entry This section gives a description of the evacuation. Special attention has been paid to the use of breaks or *Ruptures* as an occupant egress means and whether there is evidence that they acted as a route for fire entry.

Accident Database Reference	Location		Aircraft
19670305A	NR. MONROVIA, LIBERIA, AFRICA		DC8-33
Date	**Operator**		**Registration**
05-MAR-1967	VARIG AIRLINES		PP-PEA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

On 05-Mar-1967 a Varig Airlines DC8-33 registered as PP-PEA was approaching Roberts International Airport, Monrovia, Liberia after a non-stop flight from Rome, Italy.

The flight was conducting a VOR/locator instrument let down and landing approach when it touched the ground in the middle of a small village slightly to the right of the extended centreline of the runway, approximately 6000 feet short of the runway threshold.

The aircraft lost its undercarriage, engines, and other components during a ground slide of approximately 850 feet and burned.

The aircraft caught fire externally during its ground slide with the fire entering the fuselage through an overwing emergency exit, which came open, almost completely dividing the cabin at row 15 and progressing more rapidly toward the rear of the aircraft than the front.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	90	51	23	16

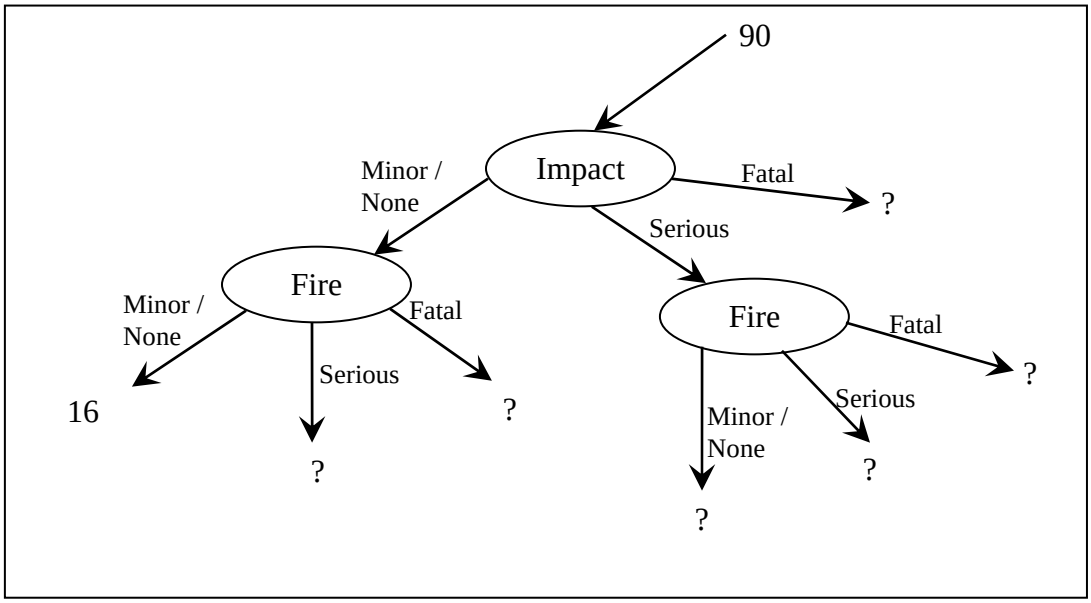
Of the 19 crew and 71 passengers aboard, the flight engineer and 50 passengers suffered *Fatal Injuries*. 16 crew and 7 passengers suffered *Serious Injuries*. 2 crew and 14 passengers suffered minor or no injuries.

Among the 39 survivors, 21 needed medical attention for fractures, second-degree burns, contusions, lacerations and lung congestion from fumes. Nine crewmembers and four passengers were hospitalised.

Most of the bodies were found severely burned in the aft section of the economy class cabin lying in the debris with their heads in the direction of the rear of the aircraft pyramided between the last three rows of seats.

Post-mortem examination of the bodies revealed a few cases of additional fractures that appeared to be ante-mortem and the bodies showed evidence of carbon monoxide poisoning.

Based on the data available a complete survivability chain cannot be generated. The only confirmed injury data is that of the 90 occupants 16 survived with minor or no injuries.



Fuselage Breaks & Ruptures

The aircraft, with the exception of the tail assembly, which was substantially damaged, was destroyed by ground impact and fire. Based on the data currently available it is believed that there were no *Fuselage Breaks*, however, due to the nature of the impact, it is probable that there were *Fuselage Ruptures* although there is insufficient information to make a determination of their location or number.

Occupant Egress & Fire Entry

The aft left hand passenger door could not be opened on the first attempt. The crew and passengers reported that they tried to open the aft right hand passenger door by the galley, but this door could not be opened either and, in fact, was never opened. The left hand aft passenger door was successfully opened on the second attempt and all survivors aft of coach seat row 15 escaped through this exit. One passenger and probably more who did not survive headed toward the front of the cabin after unsuccessfully attempting to escape through the rear of the aircraft.
A number of the passengers who survived from the front section of the aircraft from seat row 13 forward were assisted through the first class section by the cabin staff and evacuated through the forward left hand passenger door. Cabin crewmembers from the front section were unable to gain further access through the cabin to the rear due to fire, which divided the cabin at row 15 rendering movement through it impossible.

The accident report gives no indication of any survivor using any exit route other than the emergency exits.

There is no indication from the accident report that fire entered through any *Fuselage Breaks* or *Ruptures*.

Accident Database Reference	Location		Aircraft
19671106A	CINCINNATI, U.S.A.		B707-131
Date	**Operator**		**Registration**
06-NOV-1967	TRANS WORLD AIRLINES (TWA)		N742TW
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	1	Major Breaks

Résumé of Accident

On 06-Nov-1967 a TWA B707-131 registered as N742TW was taking off from Cincinnati. During the take-off roll at approximately V1 the aircraft passed an aircraft stuck close to the runway. The crew experienced a loud bang, and, believing a collision had occurred they aborted the take-off but overran the runway.

The aircraft ran off the end of the runway, rolled across the terrain for approximately 225 ft, to the brow of a hill, and became airborne momentarily. It next contacted the ground approximately 67 ft further down the embankment, the main landing gear was torn off, and the

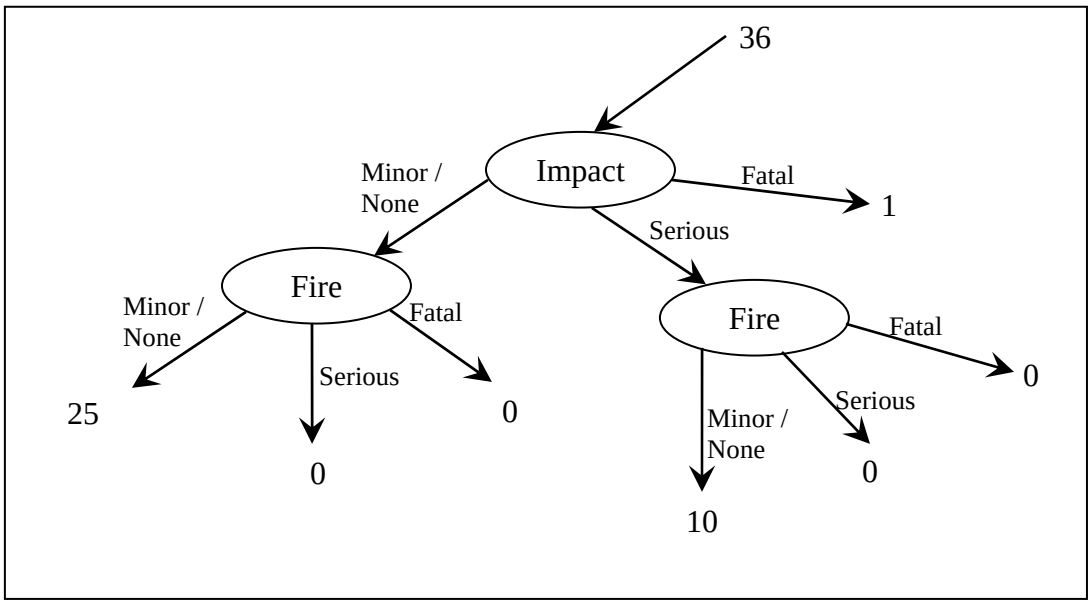
nosewheel was displaced rearward, forcing the cabin floor upward by approximately 15 in. The aircraft slid down the embankment and came to rest on a road approximately 421 ft from the end of the runway.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	36	1	10	25

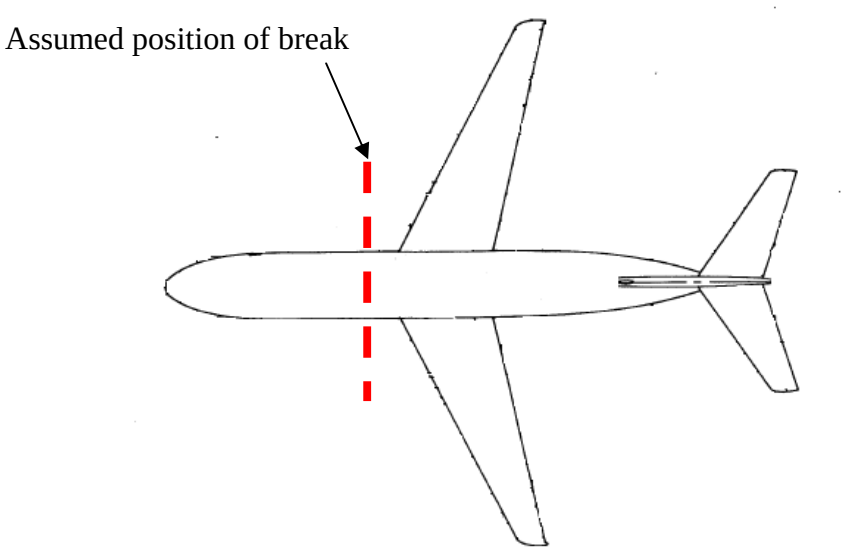
Of the 7 crew and 29 passengers aboard, 11 occupants were *Seriously Injured*. One of the injured died 4 days after the accident.

It is understood that the 1 *Fatal*ity and the 10 *Injuries* were caused as a result of impact.



Fuselage Breaks & Ruptures

During the ground slide, the fuselage upper structure broke just forward of the wing root.



Occupant Egress & Fire Entry

The forward galley door and aft main door were both opened by the assigned hostesses; the hostess assigned to the main passenger loading door was unable to open it due to buckling of the cabin floor. The aft galley door was opened by the assigned hostess, but she closed it because of the fire on the right side of the aircraft. She then assisted people to the aft main loading door and exited when no one else was in sight. The left aft overwing exit was opened and utilised by two passengers.

There is no indication from the accident report as to the extent of the break or its influence on occupant survival. However photographic evidence suggests that:

- Although it may have had the potential to allow fire entry it was unlikely that fire entry actually occurred.
- It was unlikely to have provided a viable escape route for occupants.

Accident Database Reference	Location		Aircraft
19680408A	LONDON (HEATHROW), U.K.		B707-465
Date	**Operator**		**Registration**
08-APR-1968	BOAC		G-ARWE
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

On 08-Apr-1968 BOAC B707 registered as G-ARWE was taking off from London (Heathrow) airport.

Approximately one minute after take-off the No. 2 engine failed and a few seconds later caught fire. The fire did not go out and the aircraft was manoeuvred for the quickest possible return. During the approach, the No. 2 engine fell away from the aircraft. The aircraft made a successful landing but fuel released on the port side caught fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	127	5	38	84

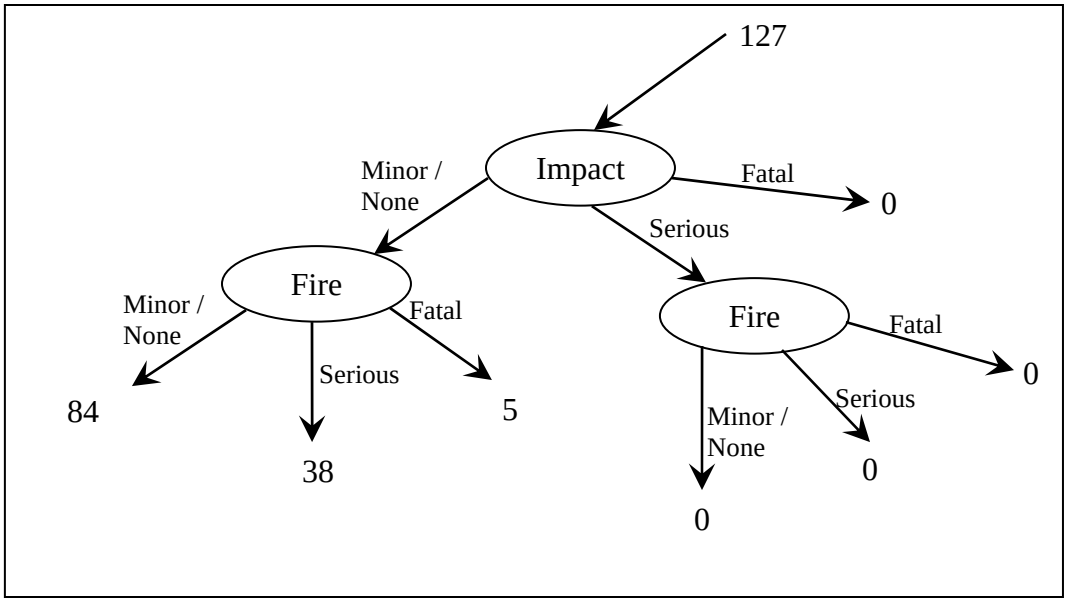
The aircraft made a smooth touchdown and the Captain brought the aircraft to halt normally. There was no impact.

Of the 11 crew and 116 passengers aboard, 1 crewmember and 4 passengers suffered *Fatal Injuries*. 38 passengers suffered *Serious Injuries*. 10 crew and 74 passengers escaped with minor or no injuries.

Four of the passengers and one stewardess were overcome by heat and smoke in the rear of the aircraft and did not escape.

Thirty-eight passengers sustained injuries during the evacuation.

Since there was no impact, it was assumed that the 38 *Serious Injuries* were due to the effects of fire.



Fuselage Breaks & Ruptures

The aircraft made a smooth touchdown and the Captain brought the aircraft to halt normally. There was no impact and hence no *Fuselage Breaks* or *Ruptures*.

Occupant Egress & Fire Entry

An emergency evacuation was initiated using exits on the starboard side as the fire and smoke spread from the rear forwards.

The passengers commenced evacuation from the two starboard overwing exits, and shortly afterwards, when the escape chutes had been inflated, from the rear starboard galley door and then the forward starboard galley door.

Because of the spread of the fire under the rear of the fuselage, the escape chute at the rear galley door soon burst and following the first explosion, the overwing escape route, also became unusable.

Conditions in the cabin were quite good in the early stages but they deteriorated rapidly when the explosion occurred. As the evacuation progressed, dense black smoke advanced forward up the cabin from the rear as the fire took deeper and deeper hold. There was some difficulty in helping passengers at the rear of the aircraft, which was the first part of the fuselage to be overwhelmed by the fire.

Accident Database Reference	Location		Aircraft
19701127A	ANCHORAGE, ALASKA, U.S.A.		DC8-63F
Date	**Operator**		**Registration**
27-NOV-1970	CAPITOL		N4909C
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	1	Major Breaks

Résumé of Accident

On 27-Nov-1970 a Capitol International Airways DC8-63F registered as N4909C was taking off from Anchorage, Alaska.

As a result of a high frictional drag which was caused by a failure of all main landing gear wheels to rotate, the aircraft failed to become airborne during the takeoff run and overran the end of the runway. It continued along the ground and struck a low wooden barrier, the ILS structure, and a 12-foot deep drainage ditch before coming to a stop approximately 3400 feet beyond the end of the runway.

Major structural damage occurred on the second impact, at which time the aft section of the cabin broke open and the right wing tore loose spilling the fuel contained therein.
The aircraft was destroyed in the intense ground fire, which developed subsequent to the crash.

Occupant *Injuries* & Survivability Chain

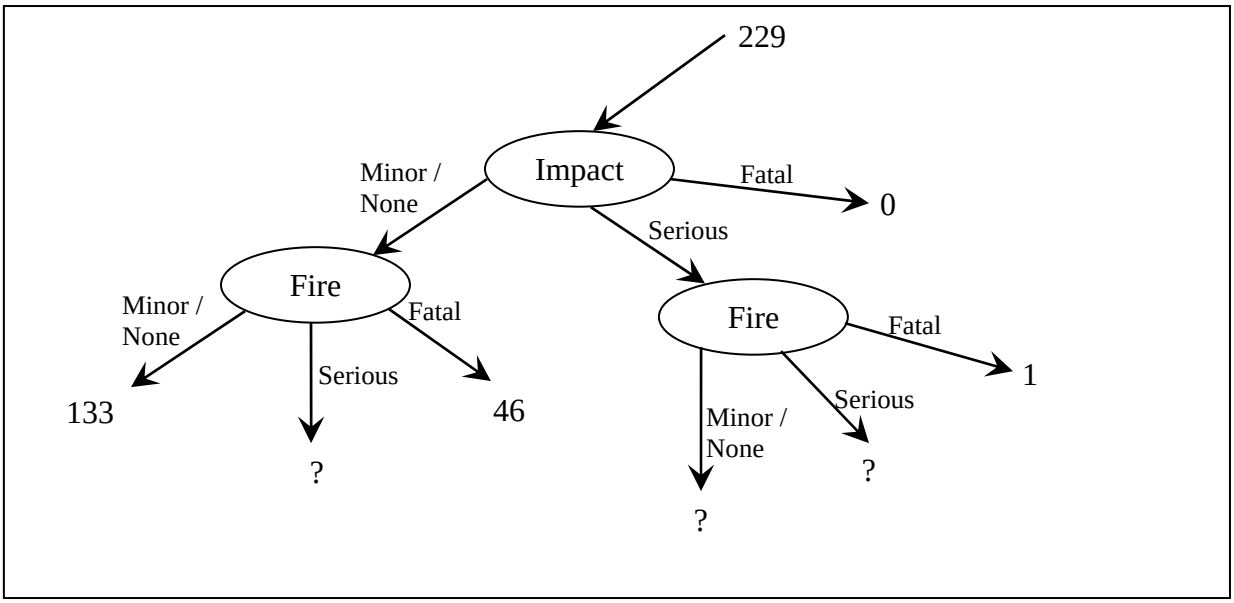
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	229	47	49	133

Of the 10 crew and 219 passengers aboard, 1 crewmember and 46 passengers suffered *Fatal Injuries*. 6 crew and 43 passengers suffered *Serious Injuries*. 3 crew and 130 passengers escaped with minor or no injuries.

The majority of the occupants were soaked in fuel when gross amounts entered the cabin.

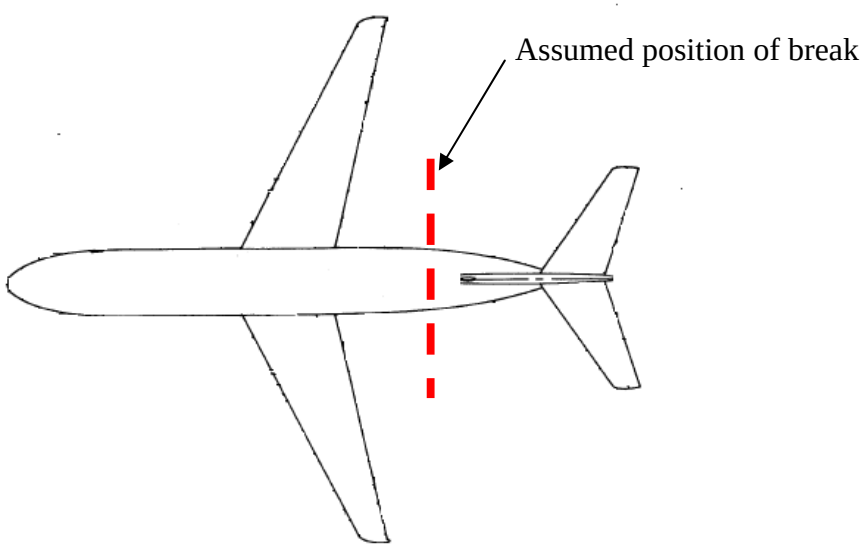
Pathological examination of the deceased disclosed that the primary cause of death was fire with evidence of the inhalation of the products of combustion. There were no traumatic *Injuries* found that would have caused death. In only one *Fatality* was there any finding that would indicate a possible degree of incapacitation due to decelerative forces.

Based on the data available a complete survivability chain cannot be generated.



Fuselage Breaks & Ruptures

The fuselage sustained a circumferential fracture near Fuselage Station 1320 [seat row 36]. The tail section came to rest about 30 feet from the main fuselage section and rotated 10 deg anti-clockwise from it.



Occupant Egress & Fire Entry

During the impact sequence numerous interior fixtures including galley equipment, overhead racks, and liferafts tore loose from their attachments and obstructed aisles and exits in the passenger cabin. The forward galley exit was completely blocked by loose galley equipment, and the ceiling panel, which prevented the use of this exit in the evacuation.

Impact conditions were survivable, as the occupied area of the aircraft remained relatively intact and decelerated forces were not of a magnitude to cause incapacitation trauma that would have prevented escape. However, post-crash fire and explosions caused intolerable conditions, which prevented the escape of some of the non-incapacitated occupants.

The majority of the *Fatalities* had been occupying seats located in an area aft of the wing and forward of the main break in the rear passenger cabin. This area predominantly encompassed seating rows 26 through 35. There were 2 jet escape doors located in this area (row 33); however according to a survivor seated next to the door on the right side, he was unable to open either of them. He exited through the break in the fuselage near row 36. The other survivors from this area, as well as all of the survivors in the forward cabin areas, used the overwing exit, forward jet escape doors and forward entry door.

The remaining survivors in the aft cabin area either, found themselves outside of the aircraft after it stopped, or exited through the break in the fuselage. A few survivors used the aft galley exit, which could only be partially opened as it was lodged next to a small embankment. The aft entry door was jammed and could not be opened by the flight attendant assigned to that station.
The *Fuselage Break* assisted occupants in the evacuation of the aircraft.

There is no indication from the accident report that fire entered through the *Fuselage Break*s. However, the aircraft was destroyed by the post impact fire, and hence it is possible that fire had entered through the *Fuselage Break*s.

Accident Database Reference	Location		Aircraft
19720418A	ADDIS ABABA, ETHIOPIA		VC10
Date	**Operator**		**Registration**
18-APR-1972	EAST AFRICAN AIRWAYS		5X-UVA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	Yes	2	Major Breaks

Résumé of Accident

A Super VC10 was taking off from Addis Ababa on 18-Apr-1972. Just prior to decision speed the nosewheel tyre hit a jacking pad that had fallen from a Cessna 185 a few hours earlier. The tyre burst and the crew initiated an aborted take-off but were unable to stop the aircraft before the end of the runway.

The aircraft slid down an embankment at the end of the runway and struck a steel lattice tower, which ruptured the fuel tank. The spilling fuel ignited and the aircraft broke into three sections as it came to rest.

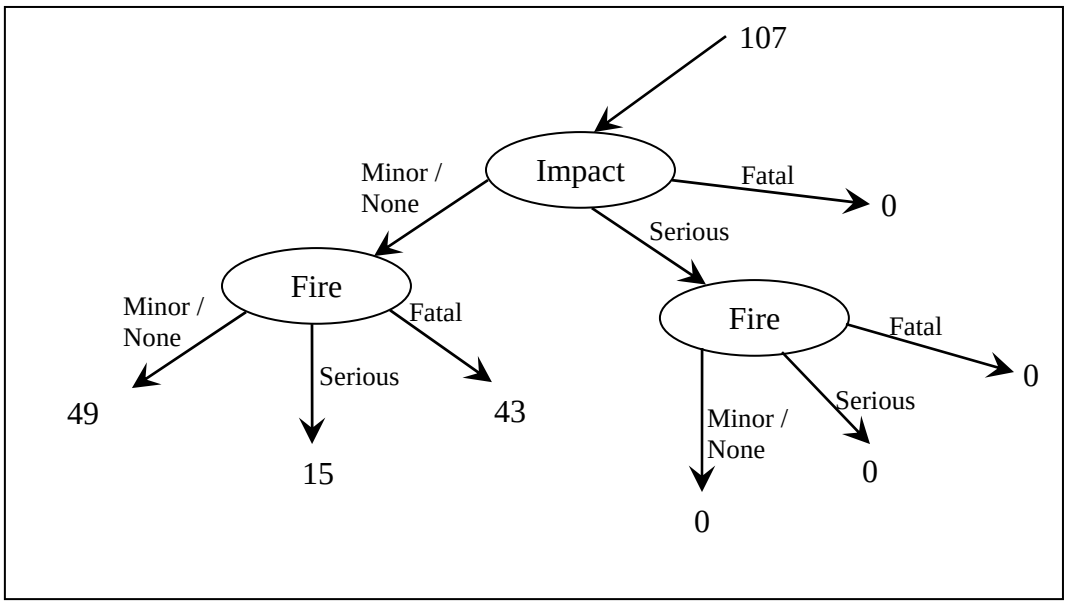
Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	107	43	15	49

Of the 11 crew and 96 passengers aboard, 8 crew and 35 passengers suffered *Fatal Injuries*.

It appears that all those on board survived the impact, but some subsequently succumbed to the effects of the fire.

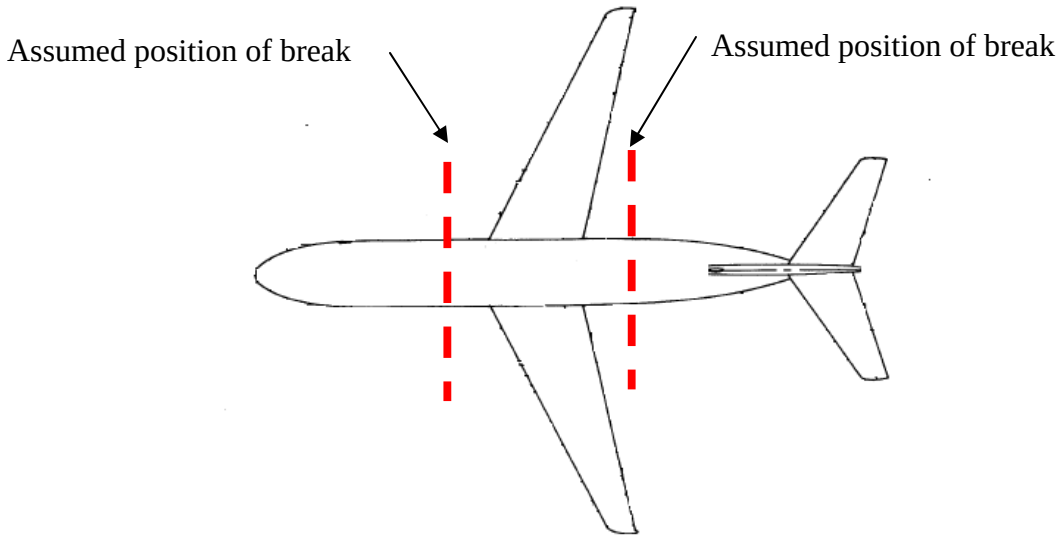
Thirty-three occupants were *Fatally Injured* by fire before evacuating. Ten cabin occupants succumbed to fire following evacuation.



Fuselage Breaks & Ruptures

The aircraft fell heavily on to the ground below the runway level and broke up immediately on impact into three major portions, namely the tail empennage with the engines attached; the centre section and wings; and the forward part of the fuselage.

The evacuation was facilitated considerably by the fortuitous fracture of the left forward fuselage, allowing relatively easy egress. Had it not been for this fracture casualties may well have been greater, as the left emergency exits were jammed by impact damage and the right side exits were blocked by fire.



Occupant Egress & Fire Entry

Survivors evacuated the aircraft through the *Fuselage Break*s as the left emergency exits were jammed by impact damage and the right side exits were blocked by fire. Ten people had to walk away from the aircraft between streams of fuel, which subsequently caught fire and trapped them.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

There is no indication from the accident report that fire entered through the *Fuselage Break*s. However, as the aircraft was destroyed by the post impact fire, it is possible that fire had entered through the *Fuselage Break*s.

Accident Database Reference	Location		Aircraft
19720518A	FORT LAUDERDALE, FLORIDA, U.S.A.		DC9-31
Date	**Operator**		**Registration**
18-MAY-1972	EASTERN AIR LINES, INC.		N8961E
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	Yes	1	Major Breaks

Résumé of Accident

On 18-May-1972 an Eastern Air Lines DC9-31 registered as N8961E was executing a straight-in localiser approach to the Fort Lauderdale-Hollywood International Airport, Fort Lauderdale, Florida.

At the time of the accident, heavy rain showers, associated with thunderstorm activity, were occurring at the airport.

The aircraft touched down hard on the runway, resulting in the failure of the main landing gear and the separation of the tail section from the aircraft.

The aircraft was destroyed by subsequent ground fire.

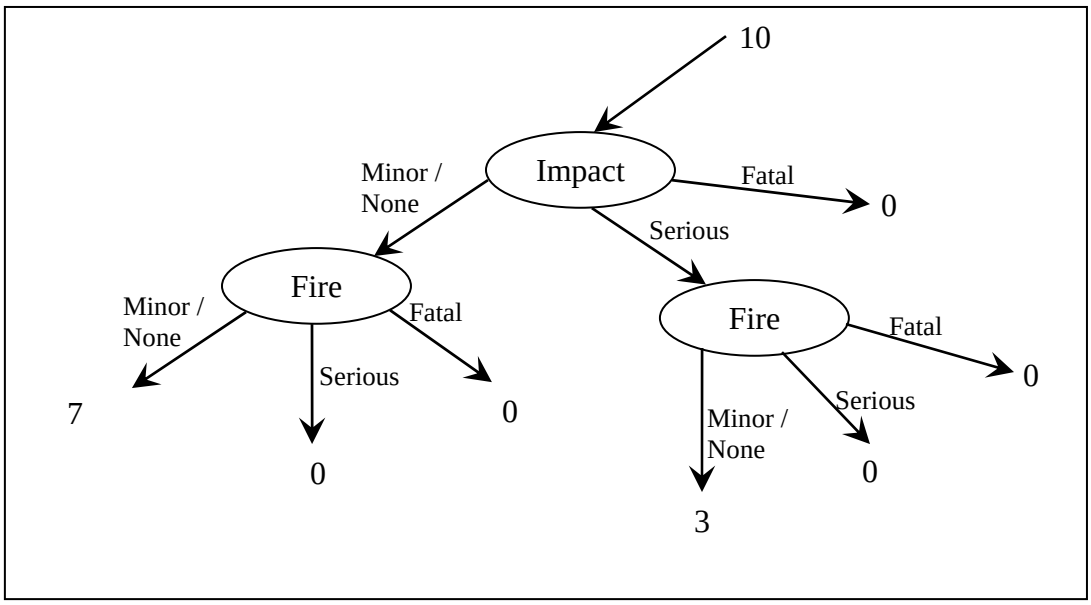
Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	10	0	3	7

There were 4 crew and 6 passengers on board.

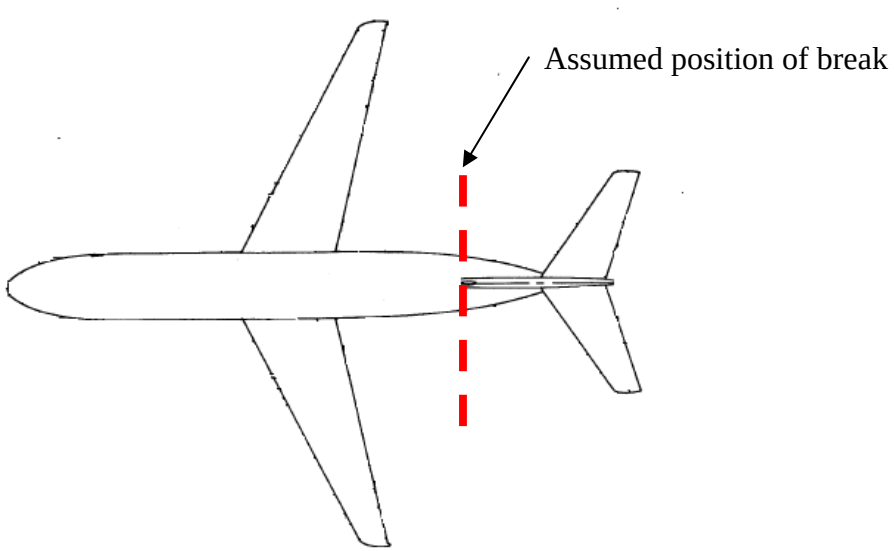
The captain, 1 stewardess and 1 passenger suffered non-*Fatal Injuries*.

All *Injuries* were sustained as a result of the forces of the initial impact.



Fuselage Breaks & Ruptures

A hard touchdown resulted from the high rate of sink, resulting in the failure of the main landing gear and the separation of the tail section from the aircraft.



Occupant Egress & Fire Entry

All crewmembers and passengers exited the aircraft through the forward main entry door. The aircraft had come to rest on its belly and the height from the floor level to the ground was approximately 3 feet.

The stewardess experienced difficulty in opening the forward entry door and was subsequently assisted by the first officer and the passengers. The opening difficulty occurred when the fibreglass slide cover became caught in the doorway. Three of the passengers jumped from the doorway prior to escape chute deployment, while the remaining three passengers and the crew deplaned via the escape chute.

The accident report gives no indication of any survivor using the *Fuselage Break* as an escape route.

There is no indication from the accident report that fire entered through the *Fuselage Break*. However, as the aircraft was destroyed by the post impact fire, it is possible that fire had entered through the *Fuselage Break*.

Accident Database Reference	**Location**		**Aircraft**
19721208A	NR. MIDWAY AIRPORT, CHICAGO, U.S.A.		B737-222
Date	**Operator**		**Registration**
08-DEC-1972	UNITED AIRLINES		N9031U
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	2	Major Breaks

Résumé of Accident

On 08-Dec-1972 a United Airlines B737-222 registered as N9031U was approaching Midway Airport, Chicago.

While making a non-precision instrument approach, in overcast conditions, airspeed was allowed to decay and the aircraft entered a stall. The aircraft crashed about 1.5 nautical miles southeast of the runway into a residential area. The tail section came into contact with electrical wires just before the crash. Several houses were destroyed. The fuselage stopped in the debris of a destroyed house.

The aircraft was destroyed by the impact and a subsequent fire.

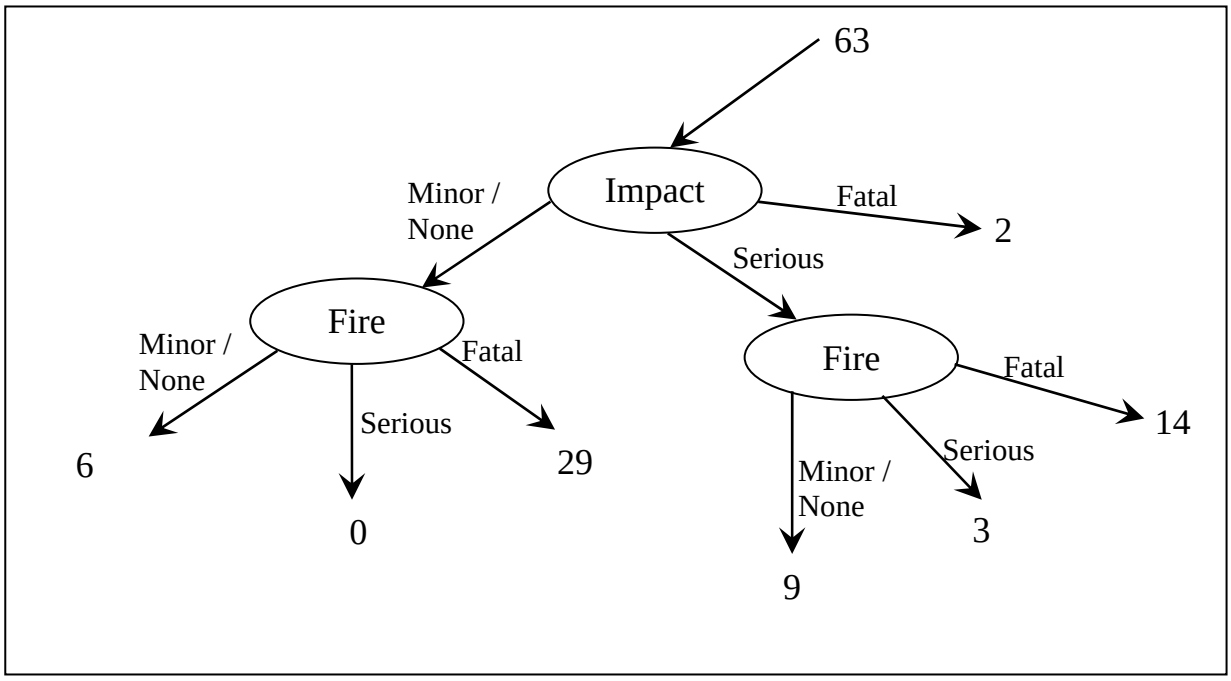
Occupant *Injuries* & Survivability Chain

	Total Occupants	**Occupant *Fatal*ities**	**Occupant *Serious Injuries***	**Minor / No Injures**
Number	63	45	12	6

There were 6 crew and 57 passengers on board. 3 crew and 42 passengers suffered *Fatal Injuries*. 1 crew member and 11 passengers suffered *Serious Injuries*. 2 crew and 4 passengers suffered minor or no injuries.

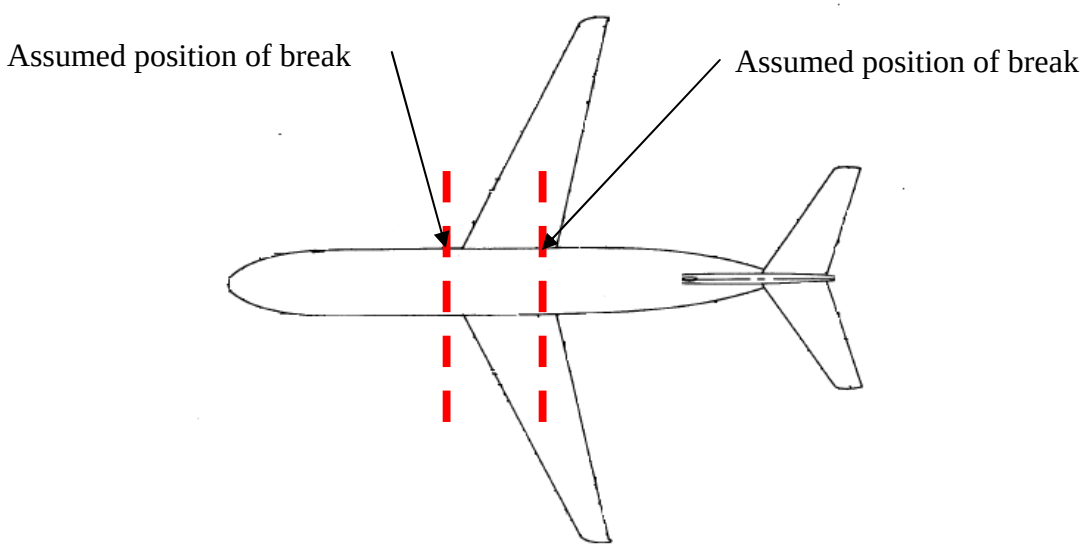
The survivability chain can be determined using Attachment III of NTSB's Human Factors Group Chairman's Factual Report.

There is a discrepancy between the number of occupants stated in the NTSB Report (AAR-73-16) and the NTSB Human Factors Group Chairman's Factual Report (Docket No. SA-435, Exhibit No. 6A). The NTSB Report stated 43 aircraft occupant *Fatal*ities and 18 aircraft occupant survivors; however, the NTSB Human Factors Group Chairman's Factual Report's occupant injury table provided a total of 63 occupants, including 45 *Fatal*ities and 18 survivors. Since there is detailed information from the Human Factors Group Report, it is considered that it should take precedence over the NTSB Report.



Fuselage Breaks & Ruptures

Survivors reported two sizeable breaks in the right side of the fuselage at the cabin partition (forward of row 6) and between seat rows 9 and 10. The breaks in the right side of the fuselage were not noticed until they were illuminated by the fire from outside the aircraft.



Occupant Egress & Fire Entry

Only seconds after the aircraft came to rest, one flight attendant from the coach section opened the aft entry door and closed it because smoke and flames were coming in. She had difficulty closing it due to blockage by the partially deployed door slide. The galley service door was opened soon thereafter into a scene of much burning debris and wood, a 3-4 foot drop was bridged with the inflated evacuation slide.

The flight attendant in the jump seat in the forward cabin blacked out at impact. She found herself trapped in her seat, pinned at her right arm and both legs. Debris around her was at least waist deep. She felt fire around her on the back and right arm before being rescued by firemen. Six survivors exited via the break in the fuselage, nine passengers, and two uninjured flight attendants exited via the rear exit door.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

There is no indication from the accident report that fire entered through the *Fuselage Break*s. However, as the aircraft was destroyed by the post impact fire, it is possible that fire had entered through the *Fuselage Break*s.

Accident Database Reference	Location		Aircraft
19721220A	CHICAGO, U.S.A.		DC9-31
Date	**Operator**		**Registration**
20-DEC-1972	NORTH CENTRAL		N954N
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	No	0	Intact

Résumé of Accident

A North Central Airlines DC9-31 was taking off under poor visibility in fog. A Delta Airlines Convair CV-880 was taxiing across the runway at the same time due to poor air traffic control. The DC-9 collided with the tail of the CV-880 and as a result was unable to climb and landed back on the runway. The undercarriage collapsed and the aircraft caught fire.

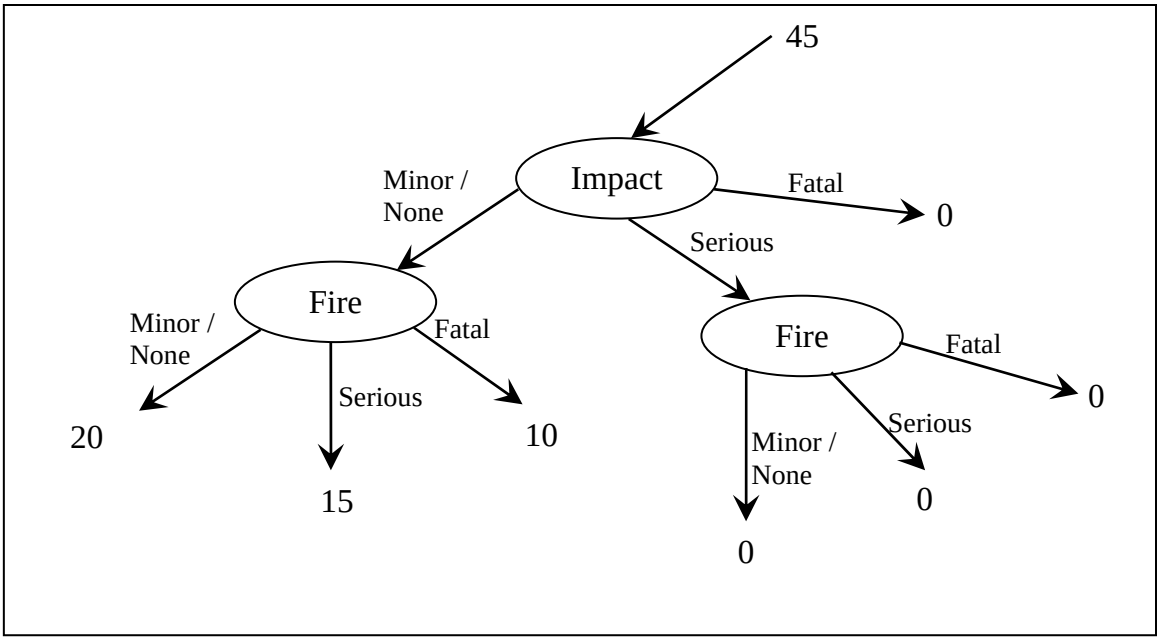
Passengers described the collision as being a slight bump. The subsequent touch down of the aircraft and the crash slide were described as being comparable to normal landing. Deceleration forces were described as being very slight with some side-to-side motion. None of the passengers reported being propelled into the seat in front of them.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	45	10	15	20

Nine of the ten *Fatally Injured* passengers failed to escape from the aircraft. They received no traumatic *Injuries* but succumbed instead to the effects of smoke inhalation or burns or both. Of the passengers who had left their seats, two were found in the cockpit area and two were found in the aft section. They apparently attempted to find an exit but were unable to do so in dense smoke and poor lighting conditions. Five others remained in their seats.

The 10th *Fatally Injured* passenger succumbed 5 days later.



Fuselage Breaks & Ruptures

After the collision with the CV880, the captain decided that his aircraft could not maintain flight, at which time he took control, and flew the aircraft back onto the runway. Gouge marks on the runways and adjacent sodden areas indicated that the DC9 had left Runway 27L and had scribed a curved path to the point where it stopped on Runway 32L.

The DC9 was found upright with the fuselage resting on the runway surface. The nose gear and left main landing gear had failed rearward. The fuselage from FS 160 to FS 900 was gutted by fire.

There is no indication from the report as to whether the fuselage had been ruptured and due to the modest nature of the impact it is considered probable that no rupture occurred.

Occupant Egress & Fire Entry

After the aircraft came to a stop smoke began to enter the cabin almost immediately.

There were 4 crew and 41 passengers aboard. Nine passengers failed to escape the cabin fire because they could not locate the exits in dense smoke and poor lighting conditions.

There is no indication from the accident report that fire entered through *Ruptures* or even that *Ruptures* occurred. However, since it was reported that smoke began to enter the cabin almost immediately after the aircraft stopped, it is possible that there may have been *Ruptures*.

Accident Database Reference	Location		Aircraft
19730122A	KANO AIRPORT, NIGERIA		B707-3D3C
Date	**Operator**		**Registration**
22-JAN-1973	ALIA ROYAL JORDANIAN AIRLINES		JY-ADO
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

On 22-Jan-1973 an Aila Royal Jordanian Airlines B707 registered as JY-ADO was landing in poor visibility at Kano airport, Nigeria.

The aircraft touched nosewheel first steady and heavy with main wheels barely in contact with the runway. The nosewheel entrenched itself then collapsed. The main gear contacted later in rapid deceleration, pierced the main wings and the aircraft collapsed along the runway centreline.

A fire broke out and after a prolonged pause the passengers and crew evacuated.

Of the 202 occupants aboard, 176 suffered *Fatal Injuries* as a result of the fire.

Occupant *Injuries* & Survivability Chain

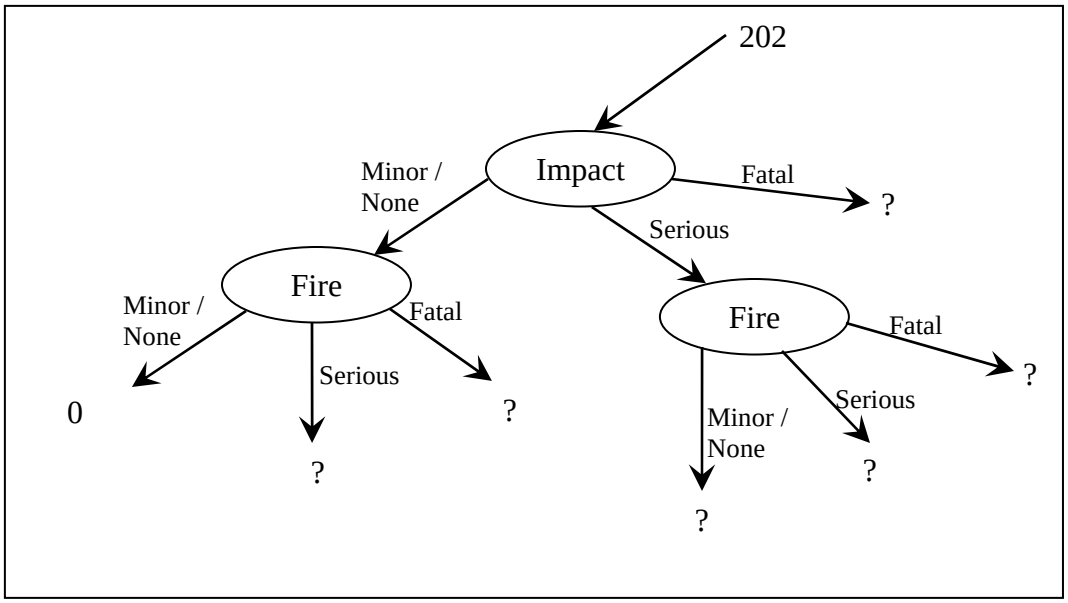
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	202	176	26	0

There has been no report available to the accident investigators to indicate that autopsies were performed. Therefore, the official cause for passenger deaths is not known. It appears that fire was the major cause of *Fatalities*.

One crewmember and 175 passengers suffered *Fatal Injuries*.

Ten crewmembers and 16 passengers suffered *Serious Injuries*.

Since this is an impact related accident, there is insufficient information to determine if fire is the sole cause of *Injuries*. Therefore, the survivability chain cannot be accurately determined.



Fuselage Breaks & Ruptures

The airplane proceeded down the runway in a shallow swerve to the right crossing the runway right hand edge approximately 2300 feet from runway threshold. The airplane continued on across a grassy strip coming to rest across a drainage ditch opposite the 3500 foot mark and 500 feet to the right of the runway centreline. The fuselage forward of the aft pressure bulkhead and the wings were almost completely destroyed by fire.

Due to the nature of the impact, it is probable that there may be *Fuselage Ruptures*. However, there is insufficient information to make a determination of the location or number of any Ruptures.

Occupant Egress & Fire Entry

Once the aircraft came to a stop, the cockpit windows were opened and the crew exited to assist passengers out of the cabin.

There was a prolonged pause when nothing seemed to be happening to evacuate passengers, then an overwing exit was activated and a mass of passengers came through, in doing so they crushed a steward to death. This movement of a bulk of passengers from post-impact lethargy to safety coincided with the spread of fire.

Interviews with the surviving flight stewards indicated that a mass of people in the galley area prevented opening of the galley door. The steward who was stationed in the aft cabin section stated that he was unable to open the aft left hand entry door and escaped from the right hand aft galley exit. The stewards at the forward end of the cabin indicated that fire entered the cabin as the left hand forward entry door was opened and they escaped through the fire.

There is no indication from the accident report that fire entered through any Ruptures. However, as the aircraft was destroyed by the post impact fire, if any *Fuselage Ruptures* had occurred, it is possible that fire could have entered through them.

Accident Database Reference	Location		Aircraft
19740126A	COMAOVASI, TURKEY		F28-1000
Date	**Operator**		**Registration**
26-JAN-1974	THY		TC-JAO
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	Yes	2	Major Breaks

Résumé of Accident

On 26-Jan-1974 a Turkish Airlines F28 registered as TC-JAO was taking off from Izmir/ Comaovasi Airport after an overnight stay outside in freezing conditions. It is believed that frost accretion on the wings was not noticed during the walk-around inspection that would cause the aircraft to stall if it was over-rotated at take-off.

According to witnesses the aircraft had run approximately 3200 feet before becoming airborne. When about 8 to 10 m above the ground it yawed to the left and pitched nose down. Contact with the ground was made in a nearly level attitude, first by the outboard fairing doors of the left wing flap, then by the left side of the fuselage belly, hitting the bank of a drainage ditch, which parallels the left side of the runway.

The aircraft then disintegrated and caught fire within 100 m of travel.

The tail and engine empennage separated from the fuselage, overtaking it and striking the forward fuselage between the cabin and cockpit sections. This resulted in separating the cockpit from the passenger cabin. The main fuselage turned upside down. The nose section, passenger door and a part of the service door scattered ahead of the fuselage's final travel and came to rest in a stack of empty drums.

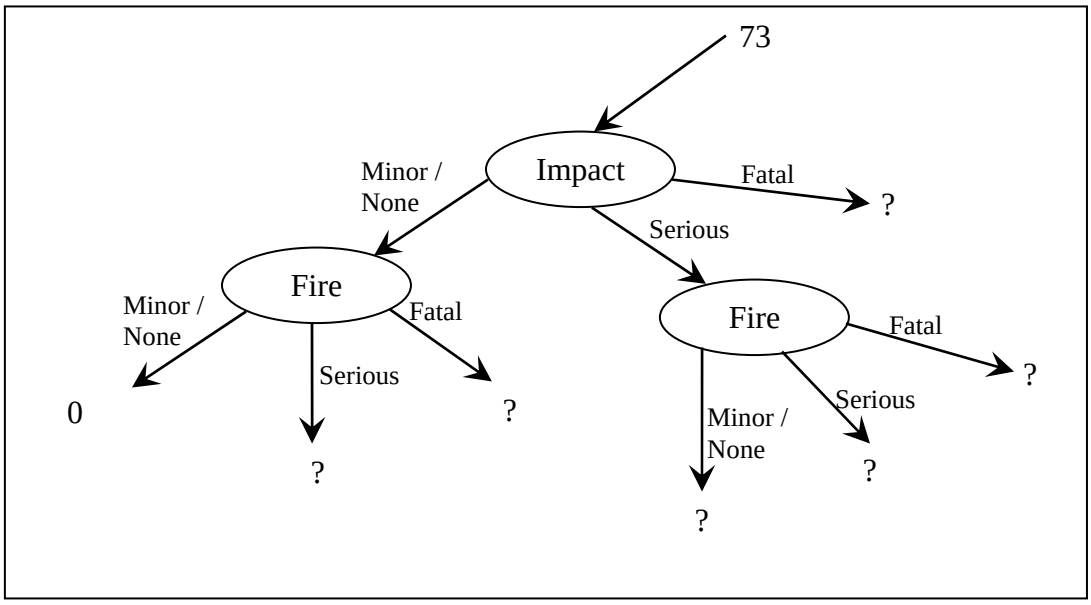
Airport personnel and others who witnessed the accident ran towards the site and tried to assist in personnel evacuation. The fire fighters required outside assistance before they were able to control the fire and then extinguish it.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	73	66	7	0

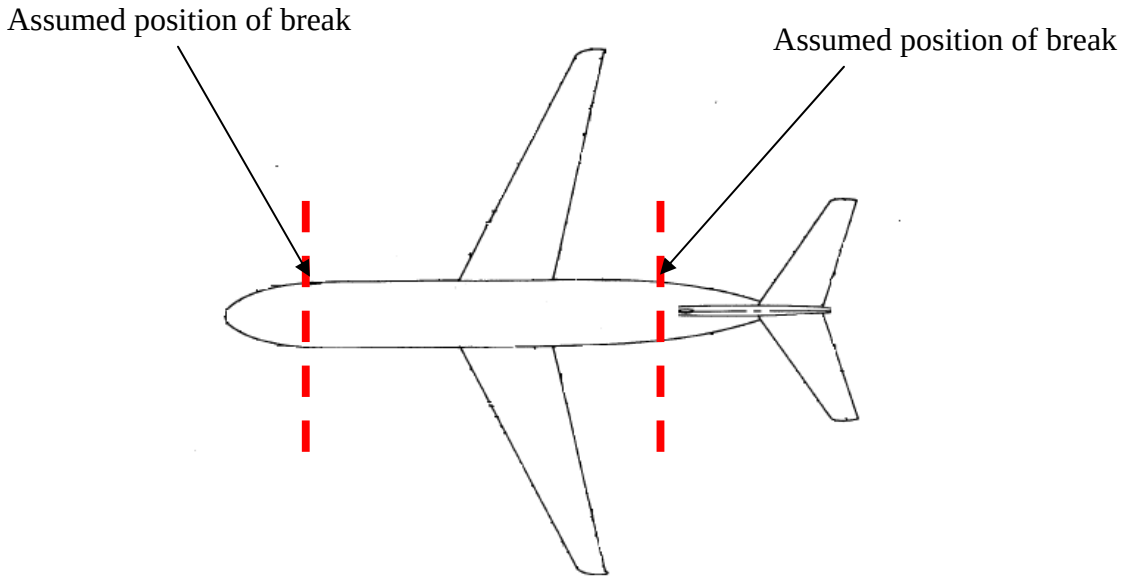
Of the five crew and 68 passengers aboard, 4 crew and 62 passengers suffered *Fatal Injuries*, one crew and six passengers suffered *Serious Injuries*.

There is insufficient information to determine the survivability chain for this accident.



Fuselage Breaks & Ruptures

The aircraft was separated into three sections: cockpit section, passenger cabin (containing seat rows 1 to 13), and the tail and engine empennage.



Occupant Egress & Fire Entry

Due to the speed with which the fire started and spread over the accident site, it was not possible to save all passengers and crew with the attendant fire fighting and rescue facilities.

The accident report gives no indication of any survivor using *Fuselage Break*s as an escape route.

There is no indication from the accident report that fire entered through the *Fuselage Break*s. However, the aircraft was destroyed by the post impact fire, and it is likely that the fire entry to the cabin had been facilitated by the *Fuselage Break*s.

Accident Database Reference	Location		Aircraft
19740130A	PAGO PAGO, AMERICAN SAMOA		B707-321B
Date	**Operator**		**Registration**
30-JAN-1974	PAN AMERICAN WORLD AIRWAYS (PAWA)		N454PA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

On 30-Jan-1974, B707-321B was making an ILS approach at night to Pago Pago International Airport in American Samoa. The aircraft encountered destabilising wind changes, which resulted in an excessive descent rate, and as a result the aircraft crashed short of the runway. The landing gear was extended at the time of impact.

There was progressive destruction of the aircraft during its travel through the vegetation and as it slid over the ground. The fuselage remained intact except for the forward nose fuselage structure.

Passengers who survived the accident said that the impact forces were slightly more severe than a normal landing. No damage to the cabin interior was reported. A fire broke out and the occupants could not open all the emergency exits. Of the 101 occupants, 97 suffered *Fatal Injuries*.

The aircraft was destroyed by the impact and subsequent fire.

Occupant *Injuries* & Survivability Chain

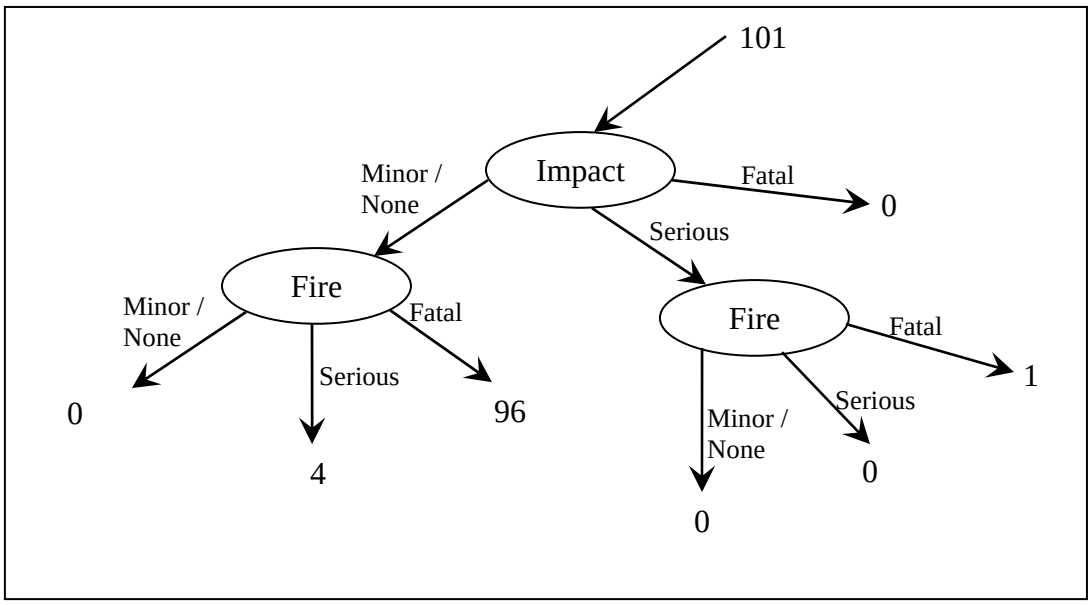
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	101	97	4	0

Of the 101 occupants, 97 suffered *Fatal Injuries*.

Nine passengers and one crewmember initially survived the crash and fire. However, one passenger died the next day, the crewmember and three passengers died 3 days after the accident. One passenger died 9 days after the accident but at that time '*Fatal*ities' were defined as deaths occurring within 7 days of the accident and so the passenger was considered a survivor. However for consistency, the current definition of a *Fatal*ity has been used and hence this passenger has been determined to have sustained *Fatal Injuries*.

Except for the Third Officer, all *Fatally Injured* persons died of smoke inhalation, massive 1st, 2nd and 3rd degree burns and complications from those massive burns. The Third Officer survived the crash but died later of traumatic leg and arm *Injuries* and severe burns.

Toxicological examinations of the casualties revealed significant levels of carbon monoxide and hydrogen cyanide.



Fuselage Breaks & Ruptures

The aircraft cut a swath through the trees, jungle vegetation, and a 3-foot-high lava rock wall before stopping.

The fuselage of the aircraft was totally intact except for the right forward section of the cockpit. The third officer exited through this hole and crawled into the undergrowth.

There was evidence of extensive damage to the cargo section of the aircraft during the crash sequence. The lower fuselage structure from the nose to just forward of the rear pressure bulkhead was severely damaged.

Occupant Egress & Fire Entry

Large fires were seen outside the right side of the aircraft. One person opened an overwing exit on the right side of the aircraft; flames came in through the exit, and he closed it.

Other survivors opened the left overwing exits, and all the survivors except the first officer escaped through those exits. The wing was described as very hot and several survivors fell into flaming fuel at the trailing edge.

The third officer was assisted in his escape by two other cockpit crewmembers and left the aircraft through a hole in the cockpit wall.

Post accident investigation revealed that the forward and the rear entry doors were not opened or used for escape. The forward door was opened about 2 to 3 inches, but the aft door was closed.

The *Fuselage Rupture* assisted one occupant in the evacuation of the aircraft.

There is no indication from the accident report that fire entered through the *Fuselage Rupture*.

Accident Database Reference	Location		Aircraft
19740315A	TEHERAN, IRAN		CARAVELLE 10B3
Date	**Operator**		**Registration**
15-MAR-1974	STERLING AIRWAYS		OY-STK
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	No	0	Intact

Résumé of Accident

On 15-Mar-1974, a Stirling Airways Caravelle registered as OY-STK was taxiing at Teheran/Mehrabad International Airport, Teheran, Iran.

Shortly before the aircraft was going to initiate a left turn towards the run-up area two loud noises were heard in the aircraft and the right wing dropped to the ground and struck the runway. The aircraft came to a stop 90 metres further on and a heavy fire developed.

Evacuation of the aircraft was carried out through exits on the left side of the aircraft.

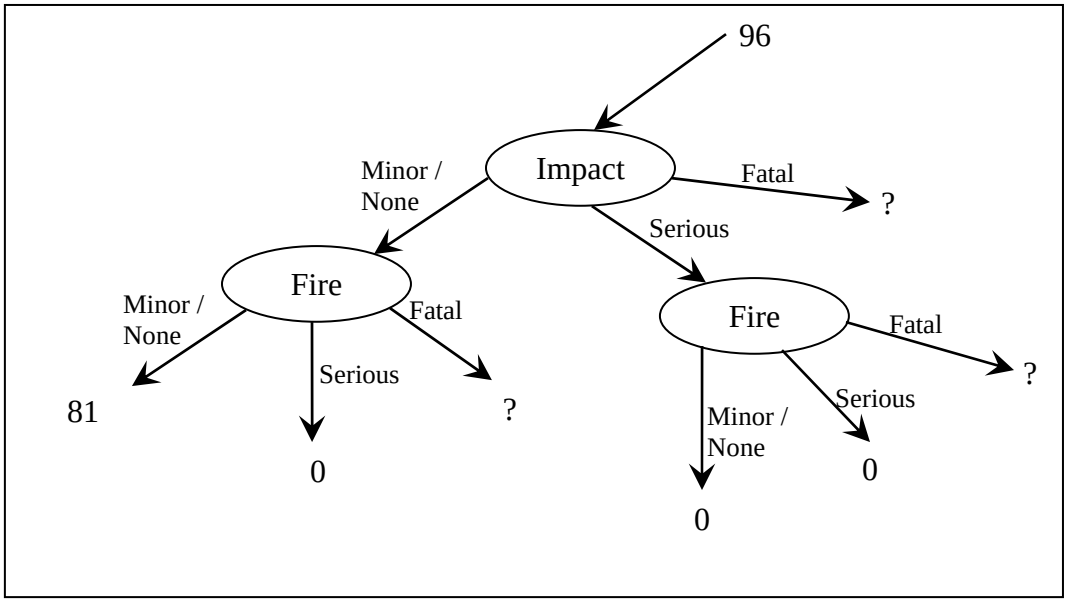
Preliminary investigation revealed that the right landing gear collapsed due to structural failure of a fitting (lower 'candelabra'). A rupture of the fuel tank resulted and the fuel escaping from the tank ignited before the aircraft came to a stop. The source of the ignition was not determined.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	96	15	0	81

There were 4 crew and 92 passengers aboard. Fifteen passengers suffered *Fatal Injuries*.

Although it is likely that all 15 passengers suffered *Fatal Fire Injuries*, there is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

It is inferred from the phase of flight of the aircraft (taxiing) that there was no impact to cause damage to the fuselage. Therefore, as no information could be found to indicate *Fuselage Rupture*, it is considered probable that no *rupture* occurred

Occupant Egress & Fire Entry

Evacuation of the aircraft was carried out through exits on the left side of the aircraft.

Evacuation time was thought to be approximately 2 minutes. The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

There is no indication from the accident report that there were any *Ruptures* that may have provided an entry path for the fire into the cabin.

Accident Database Reference	**Location**		**Aircraft**
19740911A	DOUGLAS AIRPORT, CHARLOTTE, N.CAROLINA, U.S.A.		DC9-31
Date	**Operator**		**Registration**
11-SEP-1974	EASTERN AIR LINES		N8984E
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	Yes	2	Major Breaks

Résumé of Accident

On 11-Sep-1974 an Eastern Airlines DC9-31 registered as N8984E was approaching Douglas Municipal Airport, Charlotte, North Carolina.

The aircraft was conducting a VOR DME non-precision approach with visibility restricted by patchy dense ground fog. The aircraft descended too low, struck some small trees, struck larger trees, and then impacted a cornfield 3.3 miles short of the runway.

On impact the aircraft burst into flames, and was destroyed by the impact and ensuing fire.

Occupant *Injuries* & Survivability Chain

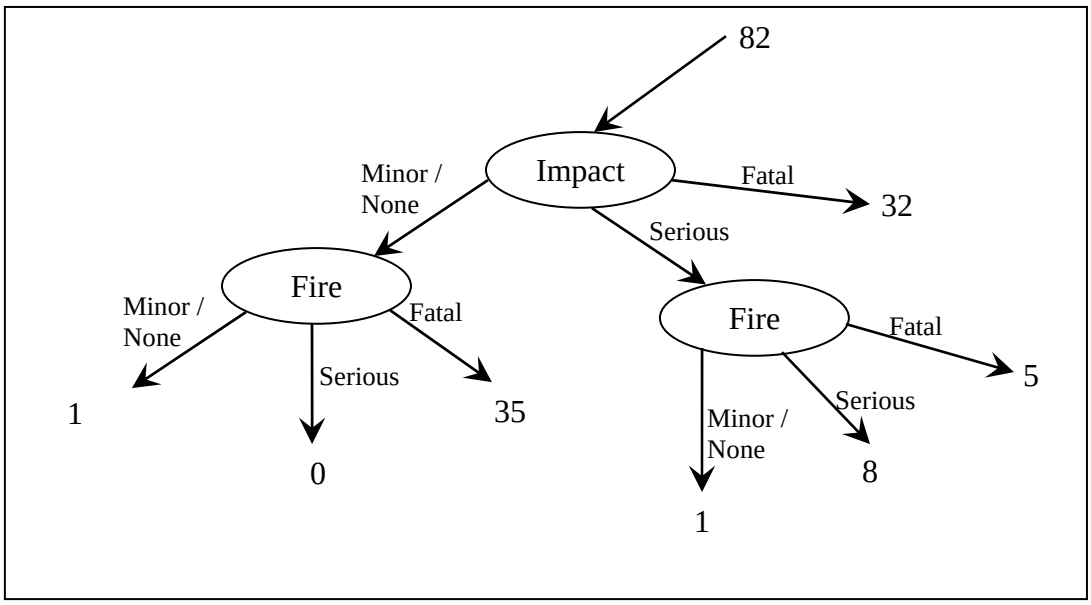
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	82	72	9	1

There were 4 crew and 78 passengers on board. Two crew and 70 passengers suffered *Fatal Injuries*. 1 crew member and 8 passengers suffered *Serious Injuries*. One crewmember escaped with minor or no injuries.

Of the 72 persons who died as a result of the accident, 31 passengers and one crewmember died of *Impact Injuries*. Twenty-three passengers died of burns and smoke inhalation; seven passengers died of burns only; three passengers died of combined thermal injury and CO poisoning, one passenger and one crewmember died of smoke inhalation. The remaining five passengers died because of combined traumatic and thermal *Injuries*.

The survivability chain was determined from information available in the NTSB Human Factors Group Factual Report.

There is a discrepancy between the NTSB Aircraft Accident Report and the NTSB Human Factors Group Factual Report in terms of the injury numbers. The Human Factors Group Factual Report figures were used because detailed information was provided of the occupant *Injuries*.



Fuselage Breaks & Ruptures

After the aircraft had travelled 550 feet beyond the initial impact point, the left wing contacted other trees and the wing broke in sections; at this point, ground fire began and spread in the direction of travel of the aircraft until the aircraft came to rest. The right wing and right stabiliser were sheared off.

The remainder of the aircraft - the fuselage and part of the empennage section - continued through a wooded area. The Fuselage Break-up was more severe in this area.

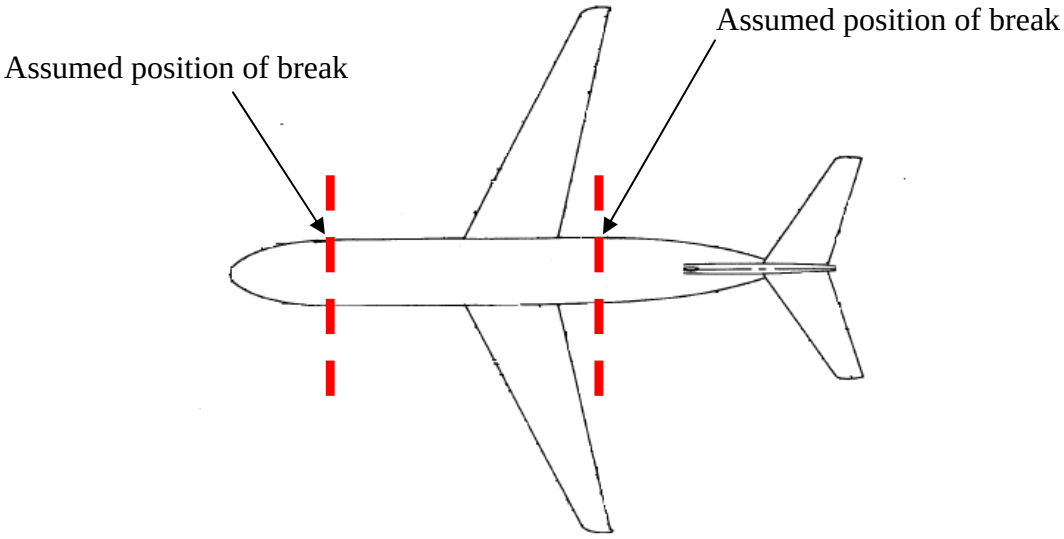
The aircraft wreckage came to rest in a ravine 995 feet from the initial impact point. The cockpit section came to rest on a magnetic heading of 310°; the aft fuselage section came to rest on a magnetic heading of 290°. The wreckage area was 995 feet long and 110 feet wide. No parts of the aircraft were found outside the main wreckage area.

From the NTSB Human Factors Group Chairman's Factual Report, it could be determined that the fuselage structure was broken into three major portions: cockpit, center section, and tail.

The cockpit section came to rest on a magnetic heading of 310°; the aft fuselage section came to rest on a magnetic heading of 290°.

The fuselage broke into three major sections, at the following fuselage stations:

- Forward section (cockpit) FS-7 to FS-256,
- Centre section FS-256 to FA-800
- Aft Fuselage (tail) FS-800 to FS1168



Occupant Egress & Fire Entry

All survivors in the rear of the aircraft were either thrown out of the wreckage or escaped through holes in the fuselage.

A passenger and the flight attendant in the forward cabin assisted the first officer in making his escape. All three escaped from the aircraft through the left cockpit sliding window. The right cockpit window was useable but was not used in the evacuation.

The forward cabin entry door was found partially open but was blocked by a fallen tree. Because of the position of the wreckage, the ground blocked the forward galley door. The centre fuselage overwing escape windows were destroyed by fire.

The auxiliary exit in the tail of the aircraft was usable; however, it was not used for escape.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	**Location**		**Aircraft**
19741120A	NAIROBI, KENYA		B747-130
Date	**Operator**		**Registration**
20-NOV-1974	LUFTHANSA		D-ABYB
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	2?	Major Breaks

Résumé of Accident

On 20-Nov-1974 a Lufthansa B747-130 registered as D-ABYB was taking off from Nairobi Airport, Kenya.

The pneumatic system, which operates the leading edge flaps, had not been switched on and as a result the leading edge flaps remained retracted and the aircraft became airborne in a partially stalled condition.

During the take-off the crew felt vibration after lift off and suspected engine trouble, subsequently the captain, suspecting wheel imbalance, raised the landing gear. The first officer, who was handling the aircraft, noticed a complete lack of acceleration and had to lower the nose in an attempt to maintain airspeed.

The aircraft lost altitude and the rear fuselage made contact with the ground approximately 1120 metres beyond the departure end of the runway. Parts of the aircraft struck an elevated road 114 metres further on and it started to break up. The main portion skidded an additional 340 metres during which time it turned to the left through 180 deg.

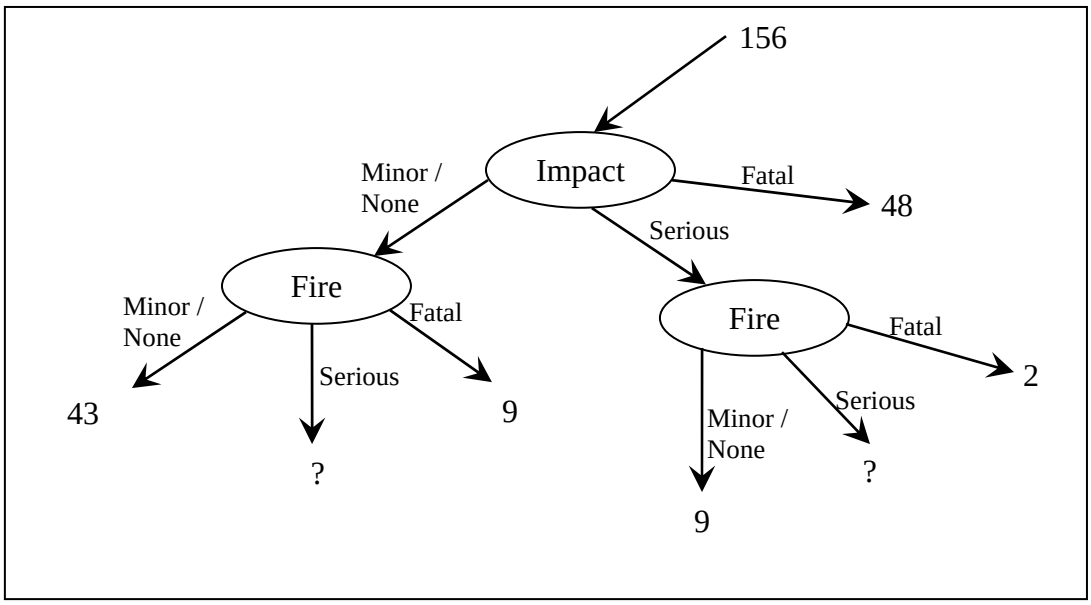
The aircraft was destroyed by the impact and subsequent fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	156	59	54	43

Of the 17 crew and 139 passengers aboard, 4 crew and 55 passengers suffered *Fatal Injuries*, 9 crew and 45 passengers suffered *Serious Injuries* and 4 crew and 39 passengers escaped with minor or no injuries.

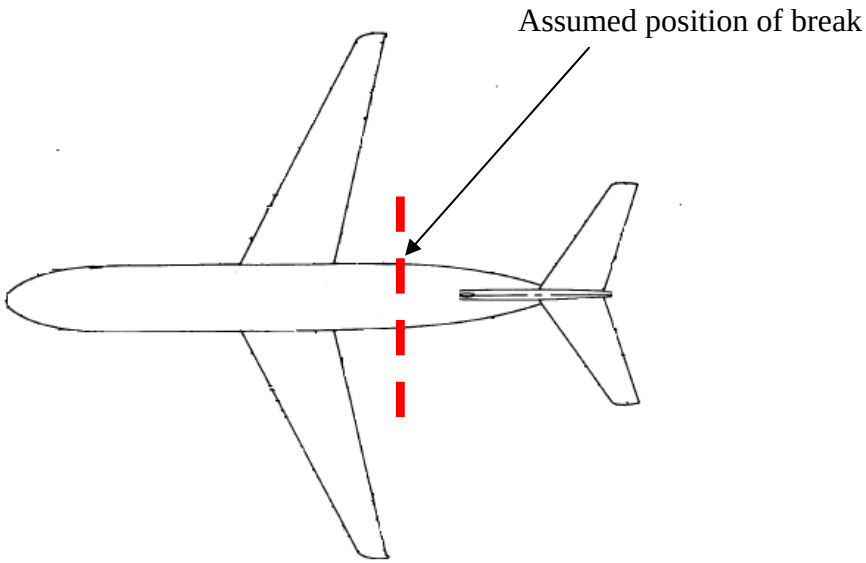
Although the accident report supplied detailed descriptions of the *Fatal Injuries*, there was insufficient information to develop fully the survivability chain.



Fuselage Breaks & Ruptures

On impact the tail structure began to disintegrate, but the major part of the aircraft skidded a further 340 metres, during the course of which it turned to the left and came to rest facing in the opposite direction.

It is suggested in the accident report that there were further Fuselage Break-ups during the skid; however, there was insufficient information to determine the exact number and location.



Occupant Egress & Fire Entry

Escape from the left hand side of the cabin was impossible because of the fierce fire that had developed, but evacuation through doors numbered 2 and 3 on the right hand side was accomplished.

A number of passengers and some cabin crew were thrown out of the cabin as it disintegrated, and some left through fractured openings after the aircraft came to rest. It was reported that determined efforts to open doors Nos. 1 and 4 on the right hand side of the cabin were unsuccessful.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19750624A	KENNEDY AIRPORT, NEW YORK, U.S.A.		B727-225
Date	**Operator**		**Registration**
24-JUN-1975	EASTERN AIRLINES		N8845E
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	Yes	Many	Massive Disruption

Résumé of Accident

On 24-Jun-1975 an Eastern Airlines B727-225 registered as N8845E was landing at the John F Kennedy International Airport, New York.

There was a very strong thunderstorm that was located astride the ILS localizer course. The aircraft encountered adverse winds and the resultant high descent rate caused the aircraft to crash into the approach lights to the runway.

Eastern 66 first contacted the top of the No. 7 approach light tower 2400 feet from the threshold of the runway. Near the No. 13 tower, the aircraft's direction of travel changed from a magnetic heading of 220° to 205°; the fuselage struck towers 13, 14, 15, 16 and 17. The aircraft then continued to Rockaway Boulevard, where it came to rest.

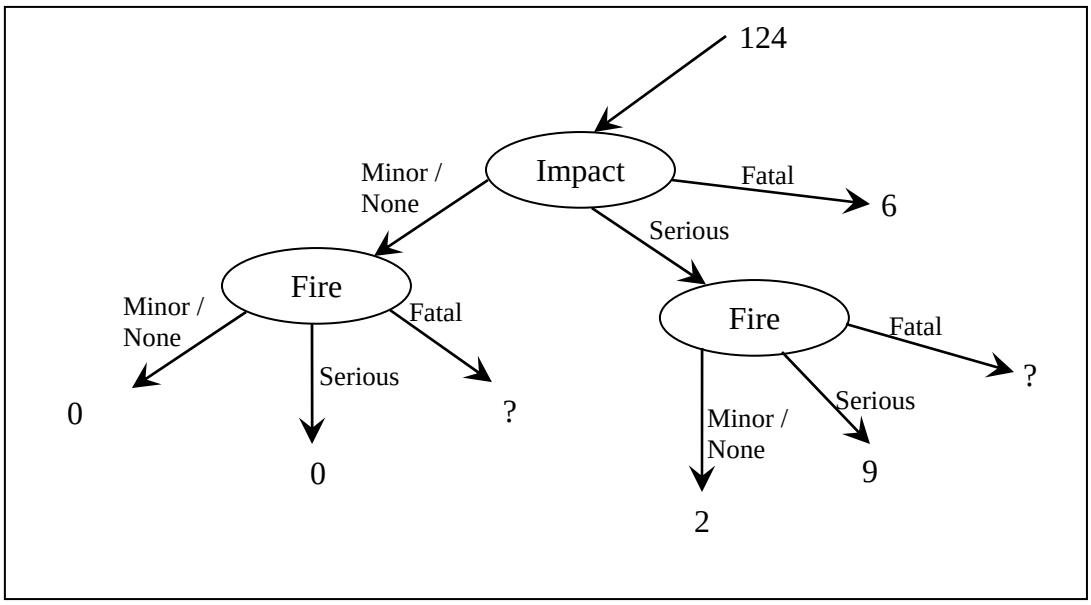
The aircraft was destroyed by the impact and a fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	124	113	11	0

Of the 8 crew and 116 passengers aboard, 6 crew and 107 passengers suffered *Fatal Injuries*, two crew and nine passengers suffered *Serious Injuries*.

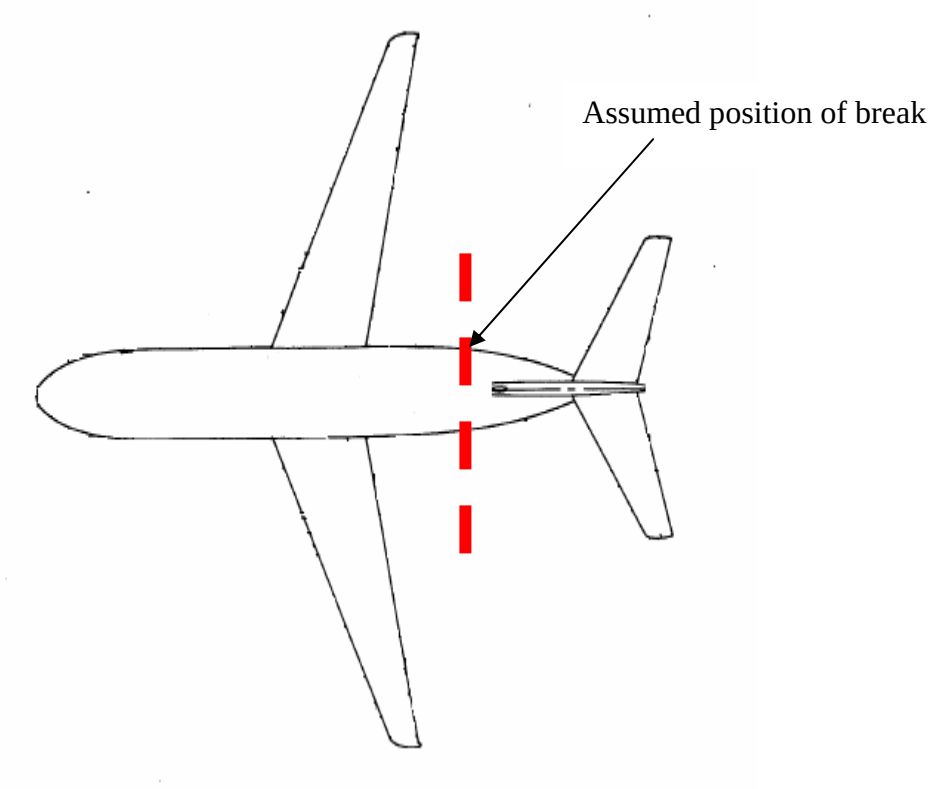
Although the accident report supplied detailed descriptions of the *Fatal Injuries*, there is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

There was near complete destruction of the aircraft's fuselage. The cockpit seats, the forward flight attendants' seats, and the passengers' seats were torn from their supporting structures. The seats were mangled and twisted and were scattered throughout the area along the last 500 to 600 feet that the aircraft travelled. Only the aft flight attendants' seats remained attached to their supporting structure. Almost all passenger seatbelts remained attached to their seat structures and remained fastened.

The 14 survivors were seated in the inverted rear portion of the passenger cabin. Although their seat support structures (except the aft flight attendants') also failed, they were less severely injured because the rear portion of the passenger cabin and the empennage section remained relatively intact. The aft flight attendants were able to escape unaided because their restraint systems did not fail, and they were protected from flying debris.



Occupant Egress & Fire Entry

The 14 survivors were seated in the inverted rear portion of the passenger cabin. Although their seat support structures (except the aft flight attendants') also failed, they were less severely injured because the rear portion of the passenger cabin and the empennage section remained relatively intact. The aft flight attendants were able to escape unaided because their restraint systems did not fail, and they were protected from flying debris. However, the accident report does not confirm that the *Fuselage Break*s were used as an escape route nor that fire entry into the cabin was via *Fuselage Break*s.

Accident Database Reference	Location		Aircraft
19760405A	KETCHIKAN, ALASKA, U.S.A.		B727-81
Date	**Operator**		**Registration**
05-APR-1976	ALASKA AIRLINES		N124AS
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	Yes	2	Major Breaks

Résumé of Accident

On 05-Apr-1976 an Alaska Airways B727-81 registered as N124AS was landing at the Ketchikan International Airport, Ketchikan, Alaska in conditions of low ceilings and low visibility onto a wet runway.

From an unstabilized approach there followed an excessively long and fast touchdown. The captain initiated a go-around after he was committed to a full stop landing. As a result, the aircraft overran the departure end of the runway and crashed into a ravine about 700 feet past the runway threshold.

None of the flight attendants felt the aircraft decelerate or heard normal reverse thrust. Many passengers anticipated the accident because of the high speed of the aircraft after touchdown and the lack of deceleration. As the aircraft left the runway overrun, it cleared a gully and a service road. The left wing hit a localizer antenna array support structure, which was located on the runway centreline. The aircraft then struck large rocks and tree stumps and came to rest.
The aircraft was destroyed by the impact and a post crash fire.

Occupant *Injuries* & Survivability Chain

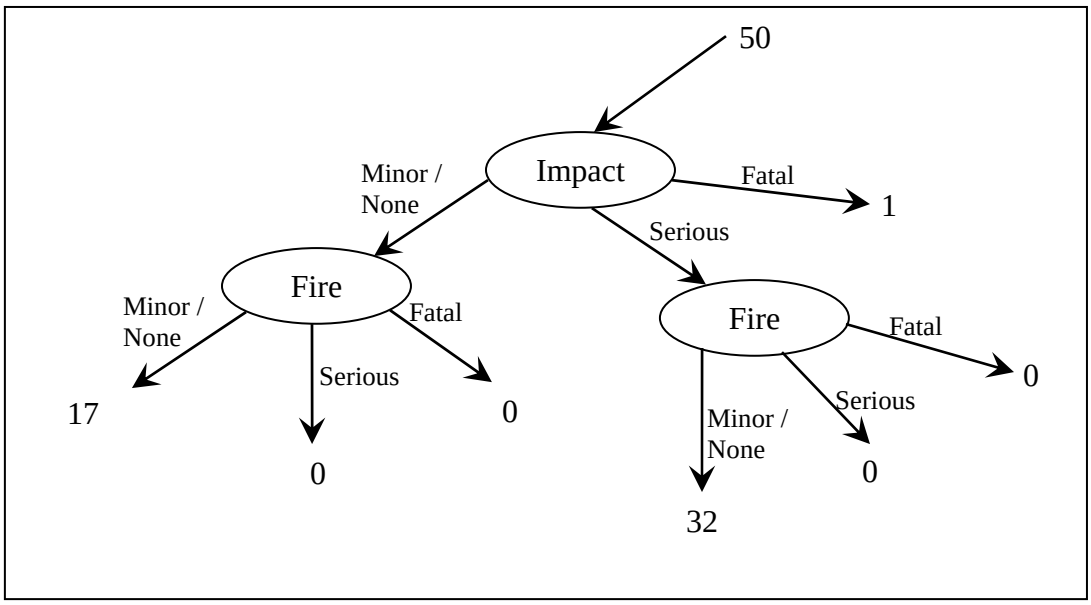
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	50	1	32	17

Of the 7 crew and 43 passengers aboard, one passenger died, 5 crew and 27 passengers suffered *Serious Injuries* and 2 crew and 15 passengers escaped with minor or no injuries.

The captain sustained multiple fractures to his legs and ribs as well as contusions and abrasions. The first officer sustained skull, leg, rib and spinal fractures and contusions and lacerations. The second officer sustained multiple spinal fractures and a fractured rib.

One flight attendant, who was seated in 6C, sustained lacerations to both legs and abdominal bruises. The flight attendant in 8C sustained an acute cervical strain and rib fractures on the right side. The flight attendant in 22C sustained contusions to the left arm, left knee and head and fuel burns to his skin. The flight attendant in 22D sustained multiple contusions, fuel irritation to her right eye and singed hair on the back of her head.

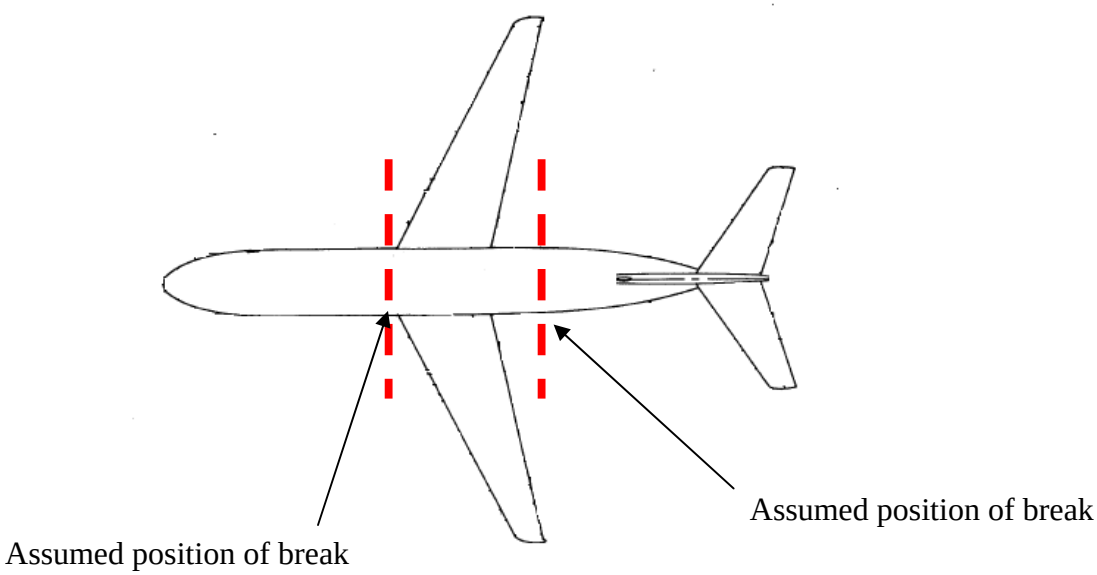
Passenger *Injuries* included spinal, leg and rib fractures, lacerations, contusions and abrasions
The *Fatally Injured* passenger died of impact trauma.



Fuselage Breaks & Ruptures

The fuselage broke into 3 sections but remained aligned. One break was near the wing's leading edge and the other near the trailing edge. The left wing remained attached to the fuselage but the right wing separated.

The accident report also states that two flight attendants evacuated through a break near the ventral stairs. However it is considered that this break is the one that occurred near the wing trailing edge (the empennage on this aircraft is relatively close to the wing trailing edge)



Occupant Egress & Fire Entry

2 flight attendants and about 10 passengers evacuated from the main cabin door. The door sprung open about 18 inches and jammed at impact. One passenger crawled through a hole in the ceiling above his seat and at least 3 passengers crawled through a hole in the cabin wall behind the left wing. The remaining passengers evacuated from the two overwing exits on the left side. Two flight attendants evacuated through a break near the ventral stairs.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19760427A	ST. THOMAS, VIRGIN ISLAND		B727-95
Date	**Operator**		**Registration**
27-APR-1976	AMERICAN AIRLINES		N1963
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	Yes	3	Major Breaks

Résumé of Accident

On 27-Apr-1976 an American Airlines B727-95 registered as N1963 was landing at the Harry S Truman Airport, Charlotte Amalie, St Thomas, Virgin Islands.

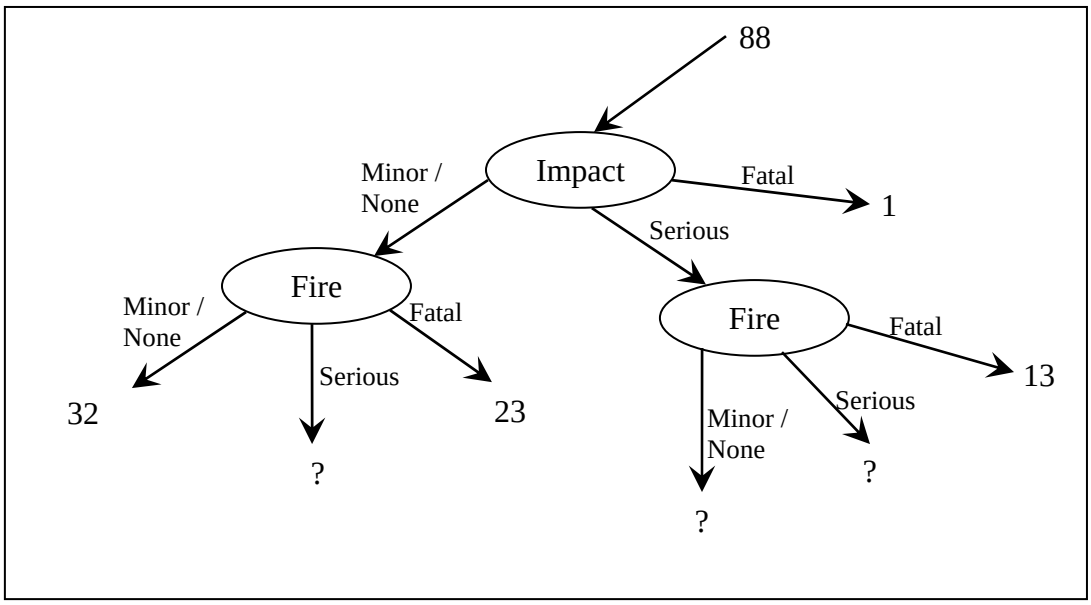
After a long touchdown, the captain initiated a go-around with insufficient runway remaining. As a result the aircraft overran the departure end of the runway, struck an ILS antenna, crashed through a chain link fence and came to rest against a building breaking into four main sections. The aircraft was destroyed by the impact and a post crash fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	88	37	19	32

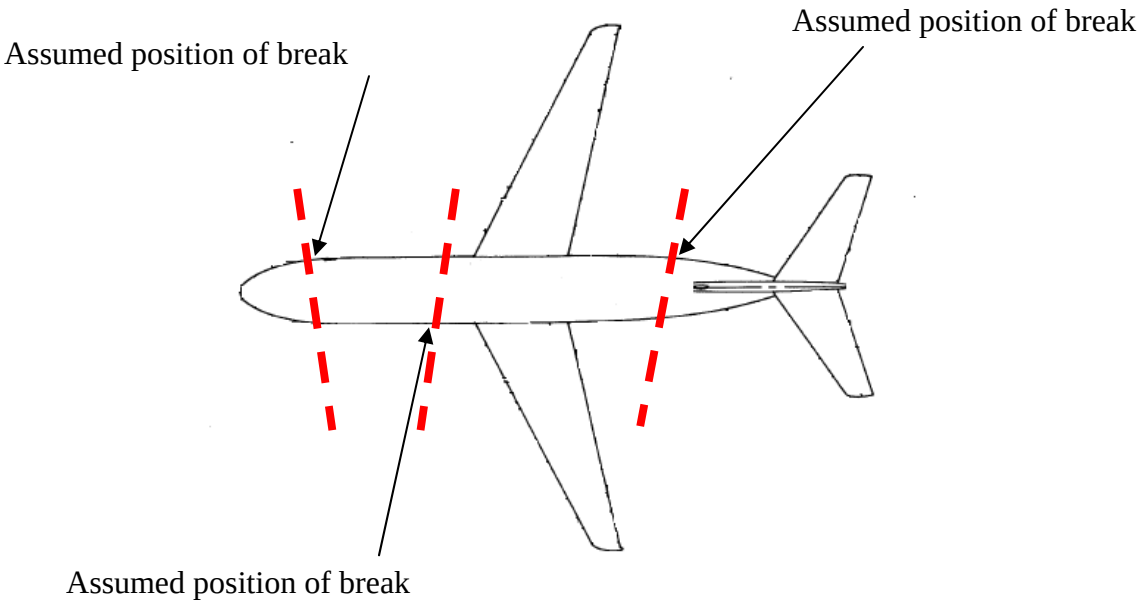
Of the 7 crew and 81 passengers aboard 2 crew and 35 passengers suffered *Fatal Injuries*. 2 crew and 17 passengers suffered *Serious Injuries*. 3 crew and 29 passengers escaped with minor or no injuries.

Although the accident report supplied detailed descriptions of the *Fatal Injuries*, there is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

The fuselage broke into 4 sections; the flight deck, the first class cabin from seat rows 2 to 7, the coach cabin from seat rows 9 to 18 and the tail section with seat rows 19, 20 and the rear exit/airstair.



Occupant Egress & Fire Entry

The passengers and flight attendants who survived the accident escaped through breaks in the fuselage or through the overwing emergency exits on the left side of the fuselage within an estimated 1 to 1.5 minutes after the aircraft came to a stop. Two of the passengers, seated by the left overwing exits opened them quickly and easily. The mass attempt to exit from the crashed aircraft was hampered by a funnel effect on approach to the emergency exit windows.

The three flight crew escaped through the first officer's sliding window because the cockpit-cabin internal door was jammed.

The forward entry door was unopened. The aft door was damaged and in no way could be opened as a means of escape since the exit and stairway rested on the ground.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19770327A	TENERIFE AIRPORT, CANARY ISLANDS		B747
Date	**Operator**		**Registration**
27-MAR-1977	PAA		N736PA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	Many	Massive Disruption

Résumé of Accident

On 27-Mar-1977 a PAA B747 registered as N736PA attempted to taxi onto a taxiway at Tenerife Airport in fog conditions and was forced to stop across the runway. A KLM B747 was taking off from the same runway and due to the fog did not observe the stationary PAA aircraft. The KLM aircraft started its take-off roll and was just airborne when it collided with the PAA aircraft.

The KLM aircraft started its take-off roll and was just airborne when it collided with the PAA aircraft, which was about 45 deg relative to the centre of the runway. It is possible that the PAA aircraft continued to move after the impact.

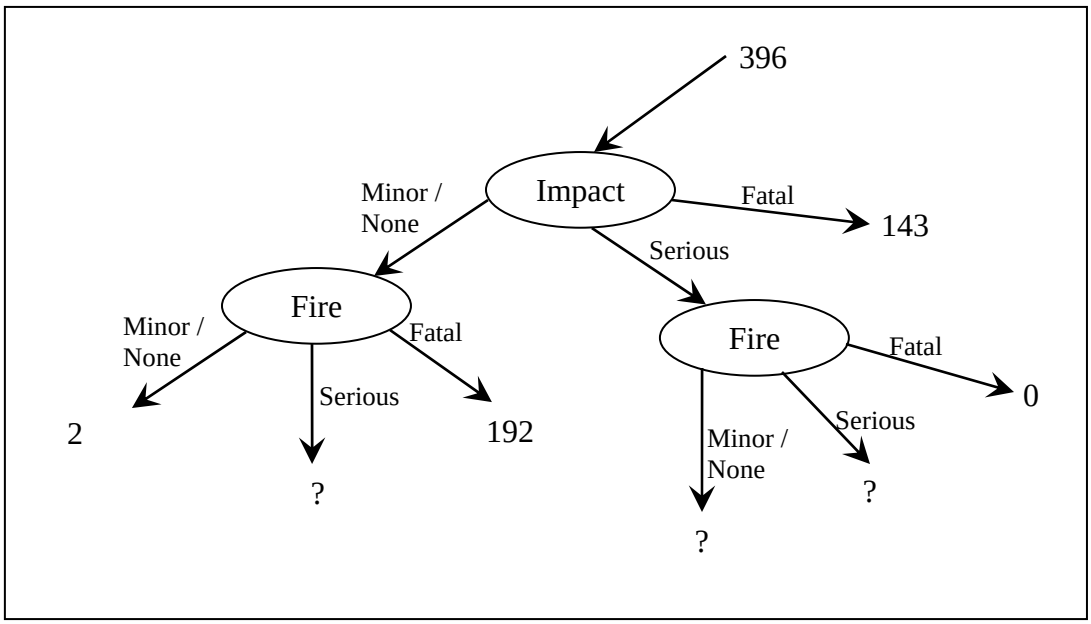
Apparently the KLM No. 1 engine only grazed the tip of the PAA aircraft's right side; the nose and front landing gear overshot and the main landing gear smashed against it in the area of its No. 3 engine. The KLM fuselage skidded over the PAA fuselage, destroying it and shearing off the empennage. The KLM aircraft came down beyond the runway. Some sections of the right side of the PAA aircraft were found near the KLM one.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	396	335	59	2

Of the 16 crew and 380 passengers aboard 9 crew and 326 passengers suffered *Fatal Injuries*. Seven crew and 52 passengers suffered *Serious Injuries*. Two passengers escaped with minor or no injuries.

There is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

The first class lounge disappeared as a result of the impact, as well as nearly the whole of the top of the fuselage. The KLM fuselage skidded over the PAA fuselage, destroying it and shearing off the empennage. There is also evidence, from the description of occupant evacuation, that there was a sizable Fuselage Rupture on the left hand side. However, the number and location of *Fuselage Breaks* cannot be determined precisely.

Occupant Egress & Fire Entry

According to the survivors, the shock of impact was not excessively violent, leading them to believe that the cause was an explosion. They jumped to the ground through openings in the left side or through door L2. A large number of passengers escaped off this wing, jumping from it to the grass. The crew had to jump to the first class section and get out through a hole in the left wall behind the L1 exit. This hole was the main escape route for the passengers located in the

forward part of the aircraft. The *Fuselage Breaks* assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Breaks* provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19780211A	CRANBROOK B.C., CANADA		B737-275
Date	**Operator**		**Registration**
11-FEB-1978	PACIFIC WESTERN AIRLINES		C-FPWC
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	2-3	Major Breaks

Résumé of Accident

On 11-Feb-1978 a Pacific Western B737 registered as C-FPWC was landing at Cranbrook, BC. Cranbrook is an 'uncontrolled' airport without a control tower, but within controlled airspace, with an 'Aeradio' station providing communications, weather, and advisory service. At Cranbrook it was snowing with the visibility reported as 3/4 of a mile, and a radio equipped snow removal vehicle was sweeping the runway. The Aeradio operator at Cranbrook alerted the vehicle operator about the incoming aircraft and gave him the ETA; they both expected the flight would report by the 'Skookum Beacon' on a straight-in approach to the runway, thus giving the vehicle operator about seven minutes to get off the runway.

Cranbrook Aeradio advised the flight that snow removal was in progress and gave the latest visibility. The aircraft acknowledged. No further transmissions were received from the flight by Aeradio or ATC.

Evidence indicates the aircraft passed the Skookum beacon inbound on a straight-in instrument approach, and flew the ILS to touchdown. According to witnesses and estimates partially derived from flight data recorder information, the aircraft touched down approximately 800 feet from the threshold and reverse thrust was selected.

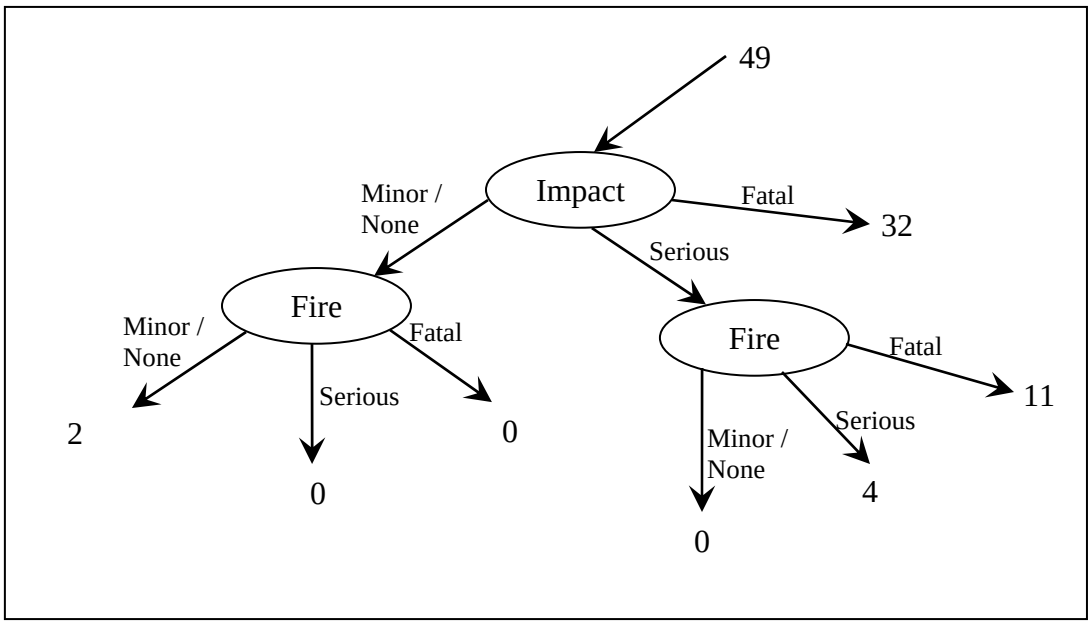
A snow removal vehicle was spotted still on the runway so reverse thrust was cancelled immediately and a go-around was initiated. The aircraft became airborne prior to the 2000-foot mark, and flew down the runway at a height of 50 to 70 feet, flying over the snow removal vehicle. About this time the left engine thrust reverser doors deployed. A few seconds later, the flap was selected up from 40 deg to 15 deg. The landing gear remained down and locked. Six seconds before impact and just over 4000 feet from the runway threshold, the flight recorder data indicates that a large amount of left rudder was momentarily applied. The aircraft climbed to 300 or 400 feet above the airfield, banked steeply to the left, lost height and side-slipped into the ground to the left of the runway. Fire broke out on impact.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	49	43	4	2

Of the 5 crew and 44 passengers aboard 4 crew and 39 passengers suffered *Fatal Injuries*. Four passengers suffered *Serious Injuries*. One crewmember and one passenger escaped with minor or no injuries.

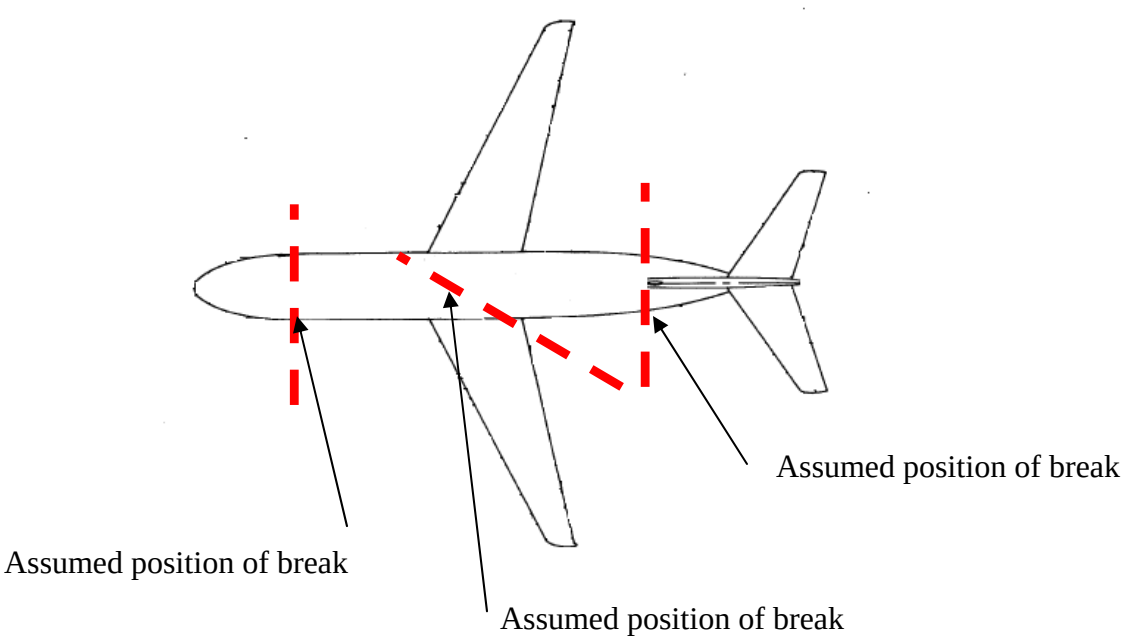
The survivability chain was determined from information in the accident report.



Fuselage Breaks & Ruptures

The fuselage centre section was broken up and the wing centre section broke diagonally across from the left rear spar to the right wing front spar as the fuselage crashed into the ground.

It is unclear from the accident report whether the diagonal break at the wing box section resulted in an additional break in the fuselage centre section, or if it separated the centre section from the rear section.



Occupant Egress & Fire Entry

Two survivors escaped through the right rear emergency door. Some difficulty was encountered opening the door because of refuse blocking access to the exit. Because of the catastrophic break-up, the other exits were not required; survivors were able to evacuate through breaks in the fuselage; one passenger was thrown clear still in a seat.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19780301A	LOS ANGELES, CALIFORNIA, U.S.A.		DC10-10
Date	**Operator**		**Registration**
01-MAR-1978	CONTINENTAL AIRLINES		N68045
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING/FIN	No	0	Intact

Résumé of Accident

On 01-Mar-1978 a Continental Airlines DC10-10 registered as N68045 was taking off from Los Angeles International Airport with wet runway conditions.

Multiple tire failure occurred on the left main gear and the take-off was aborted. The aircraft overran the end of the runway and as it left the load-bearing surface of the runway, the left main landing gear collapsed and ruptured the left wing fuel tank. Fire erupted from the left wing area.

The aircraft slid to a stop about 664 feet from the departure end of the runway.

The fuselage, though burned extensively on the left side, remained intact.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	200	2	31	167

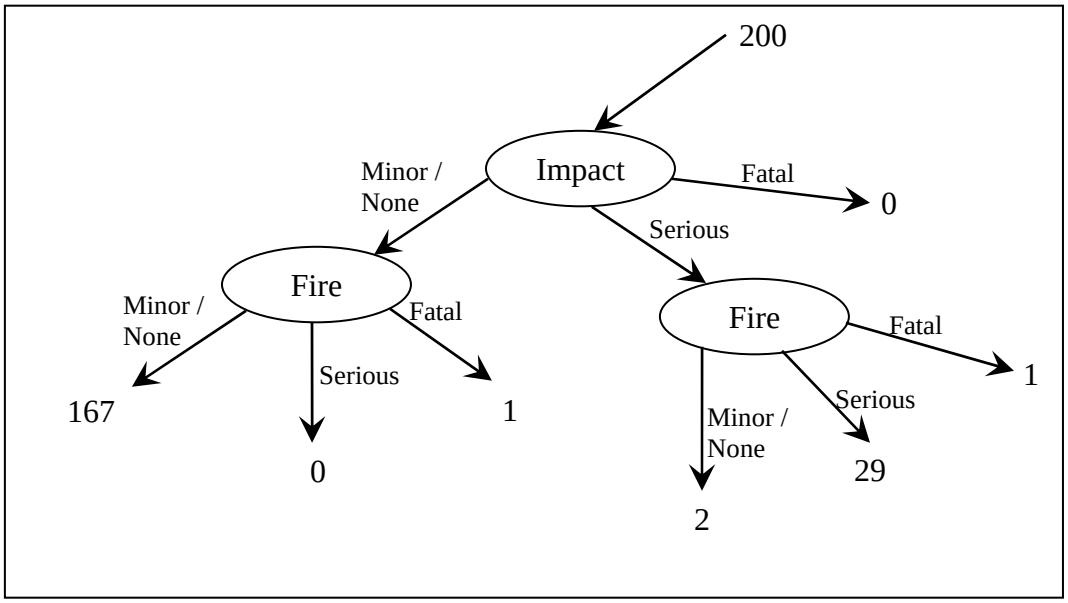
Of the 14 crew and 186 passengers aboard 2 passengers (husband and wife) perished in the fire while on the ground outside the aircraft. They died of burns and smoke inhalation – the female is believed to have become incapacitated from *Injuries* sustained in a fall.

Of the 71 passengers examined, 28 required hospitalisation. Their *Injuries* included various fractures, abrasions, burns, contusions, and rope burns.

The injuries of 43 passengers who were treated and released included various arm, elbow, leg and ankle contusions and sprains and rope burns.

The flight attendant's injuries included burns, back and neck injuries, knee and elbow injuries, a fractured heel, smoke inhalation and rope burns.

The flight crew injuries included bruises, rope burns, and leg injuries.



Fuselage Breaks & Ruptures

There is indication from the accident report that the structural integrity of the cockpit and cabin area was not compromised, since the entire fuselage remained intact and the fire remained outside the fuselage. There is also a lack of evidence of fuselage fragments. Therefore, there is insufficient information to make a determination as to whether there were any Ruptures.

Occupant Egress & Fire Entry

All exits were opened but some slide/rafts did not operate correctly. All slide/rafts failed before the evacuation was complete. The emergency evacuation was a success due to the efforts of the entire flight crew and cabin crew in seeking alternate escape routes when normal routes were rendered useless.

From the data available there is no indication of egress of occupants other than via the emergency exits. There is also no indication that fire entry occurred via any *Ruptures*.

Accident Database Reference	Location		Aircraft
19781217A	HYDERABAD, INDIA		B737-200
Date	**Operator**		**Registration**
17-DEC-1978	INDIAN AIRLINES		VT-EAL
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

Indian Airlines B737 registered as VT-EAL was taking off from Hyderabad Airport on 17-Dec-1978. The leading edge devices did not deploy and as a result the aircraft became aerodynamically unstable. The take-off was aborted and the aircraft was flared for a belly landing with undercarriage retracted. The aircraft belly-landed in nose up, left wing low attitude, on the centre line of the runway. It slid for 3080 feet, hit a boundary fence, crossed a drain, ploughed in rough terrain negotiating with small boulders, and came to rest. Fire broke out on impact.

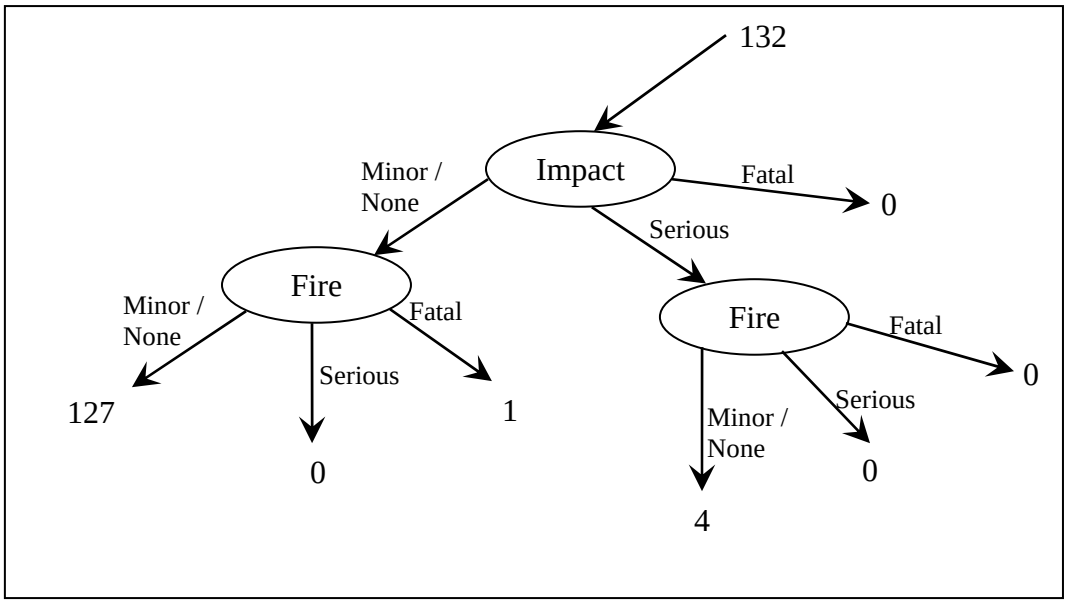
As the aircraft slid into rough terrain it began breaking up, shed the port engine, starboard engine and engine accessories. The rest of the aircraft remained intact.

The aircraft was destroyed by fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	132	1	4	127

There were 6 crew and 126 passengers aboard, of which one passenger suffered *Fatal* burn *Injuries* (he was admitted to hospital but died three days later), 1 cabin attendant and 3 passengers were *Seriously Injured* attributable to the impact.



Fuselage Breaks & Ruptures

Due to the nature of the accident, it is probable that Fuselage Rupture occurred; however, there was insufficient information to determine the location and number of any Ruptures.
Occupant Egress & Fire Entry

The Captain said he was unable, due to preoccupancy, to announce emergency and order passenger evacuation. The emergency drill was not adopted and the control tower was not alerted. The fire crew, however, observed the crash landing and proceeded at once to the site.
The accident report did not state which doors were used in the evacuation.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route and whilst it is probable that Fuselage Rupture occurred the entry of fire into the cabin via *Ruptures* cannot be confirmed.

Accident Database Reference	**Location**		**Aircraft**
19791007A	ATHENS, GREECE		DC8-62
Date	**Operator**		**Registration**
07-OCT-1979	SWISSAIR		HB-IDE
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	1	Major Breaks

Résumé of Accident

On 7-Oct-1979, a DC8-62 was landing at night on a wet runway at Athens Airport, Greece.

After a late and fast touchdown and after ineffective breaking, the aircraft overshot the runway end and the overrun area, fell down a slope of 4m, and caught fire.

Touch down was at approximately 500m from the displaced runway threshold. There was a very short flare phase and the nose wheel touched down almost simultaneously with the main landing gear. Immediately after touch down the captain selected idle reverse on all 4 engines and took control of the aircraft from the co-pilot. The co-pilot set normal reverse. A few seconds later brake application was initiated which gave an impression of almost normal braking conditions.

After rolling over the asphalt overrun area of approximately 65m length, the aircraft fell approximately 4m onto a bitumen road, which crossed the runway axis almost rectangularly.

The aircraft was destroyed by the hard impact in the vicinity of the road and by the ensuing fire.

Occupant *Injuries* & Survivability Chain

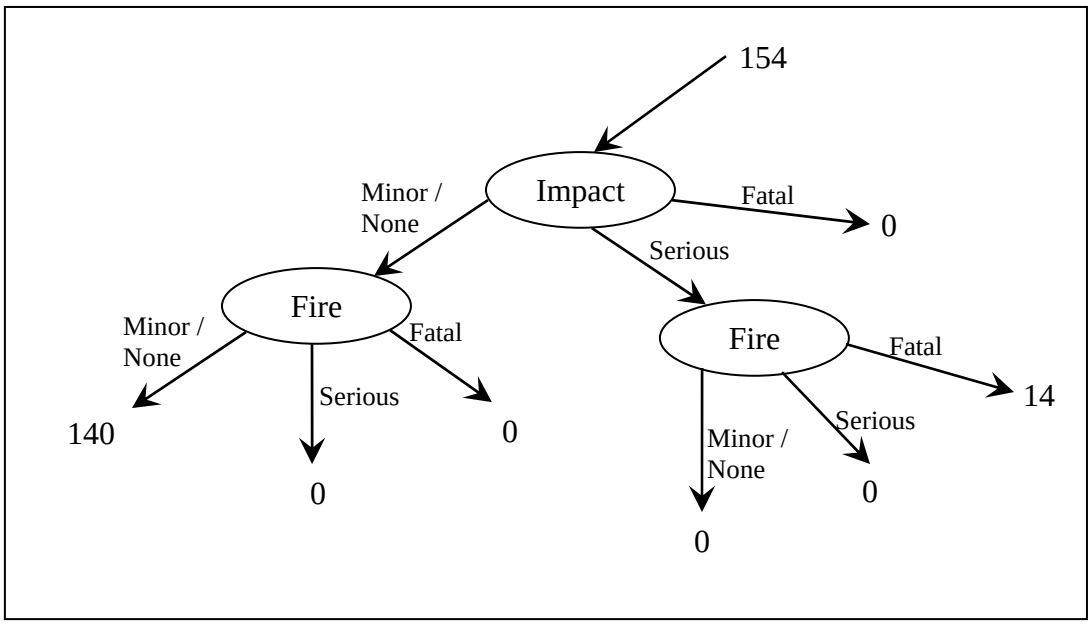
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	154	14	0	140

Of the 10 crew and 144 passengers aboard, 14 passengers suffered *Fatal Injuries*.

Fourteen *Fatal*ities were found sitting in rows 21-26. The forensic medical post-mortem reports testify that the death of 14 passengers was caused by burns of third degree on the whole body.

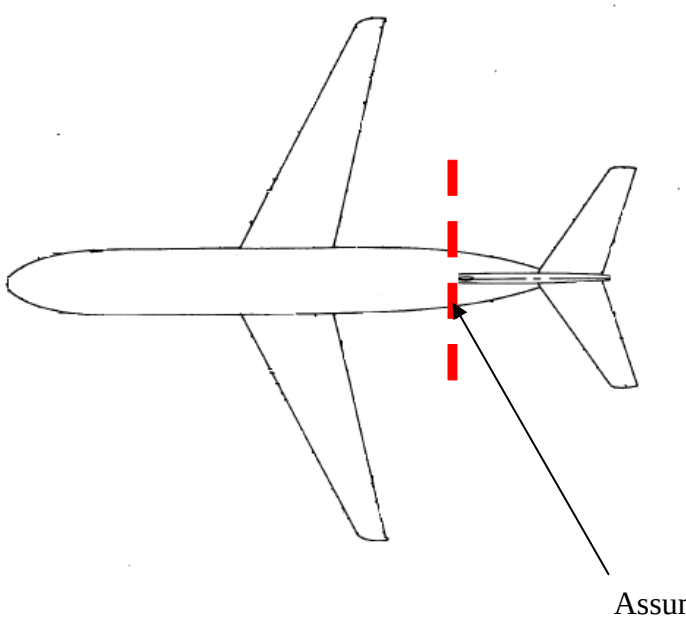
Eleven passengers suffered minor injuries during the evacuation.

According to witness statement the 14 dead persons were seated at the rear part of the aircraft between the 21st and 26th row. It seems that these passengers had not tried to leave the aircraft, considering the evacuation had been completed from the rear door, as stated by the flight attendant. Five of the dead were seated in row 25. Many passengers walked through that area and no one had reported any difficulties in passing through. It was inferred from this that the 14 *Fatal* passengers must had been incapacitated during the impact, which led to their *Fatal Fire Injuries*.



Fuselage Breaks & Ruptures

The fuselage was broken in front of the vertical stabiliser.



Occupant Egress & Fire Entry

According to crew and passenger statements, approximately 120-130 passengers left the aircraft through the left front exit. The exit doors and emergency exits at the right side of the aircraft were not used. Overwing exits at the left side were not used either because, according to the

flight attendants' statements, there was external fire in that area. The delay in opening the rear door resulted in passengers moving back and forth.

The accident report gives no indication of any survivor using the *Fuselage Break* as an escape route.

There is no indication from the accident report that fire entered through the *Fuselage Break*. The aircraft was destroyed by fire and it is likely that the *Fuselage Break* provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19801121A	YAP ISLAND, WESTERN CAROLINE ISLANDS, MICRONESIA		B727-92C
Date	**Operator**		**Registration**
21-NOV-1980	CONTINENTAL AIR LINES		N18479
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	No	0	Intact

Résumé of Accident

On 21-Nov-1980, at 0952 local time, a Continental Airlines/Air Micronesia Boeing B727-92C, Flight 614, registered as N18479, crashed while attempting to land on runway 7 at Yap Airport, Yap, Western Caroline Islands.

The aircraft touched down 13 feet short of the runway and the right main landing gear immediately separated from the aircraft. The aircraft gradually veered off the runway and came to rest in the jungle about 1,700 feet beyond the initial touchdown. A severe ground fire erupted immediately along the right side of the aircraft as it came to rest.

The entire fuselage was mostly consumed by fire from the aft pressure bulkhead forward. Only portions of the left side below the window line and belly area escaped severe melting and fire damage. The right side of the fuselage and the right wing structure were burned away or melted. The left wing was burned only on the top surface adjacent to the fuselage. It had sustained severe buckling and crushing. The cockpit interiors, including the instrument panel, overhead, and pedestal, were consumed by fire.

The empennage escaped major fire damage. The aft pressure bulkhead door and airstair assemblies remained intact although damaged by fire.

Occupant *Injuries* & Survivability Chain

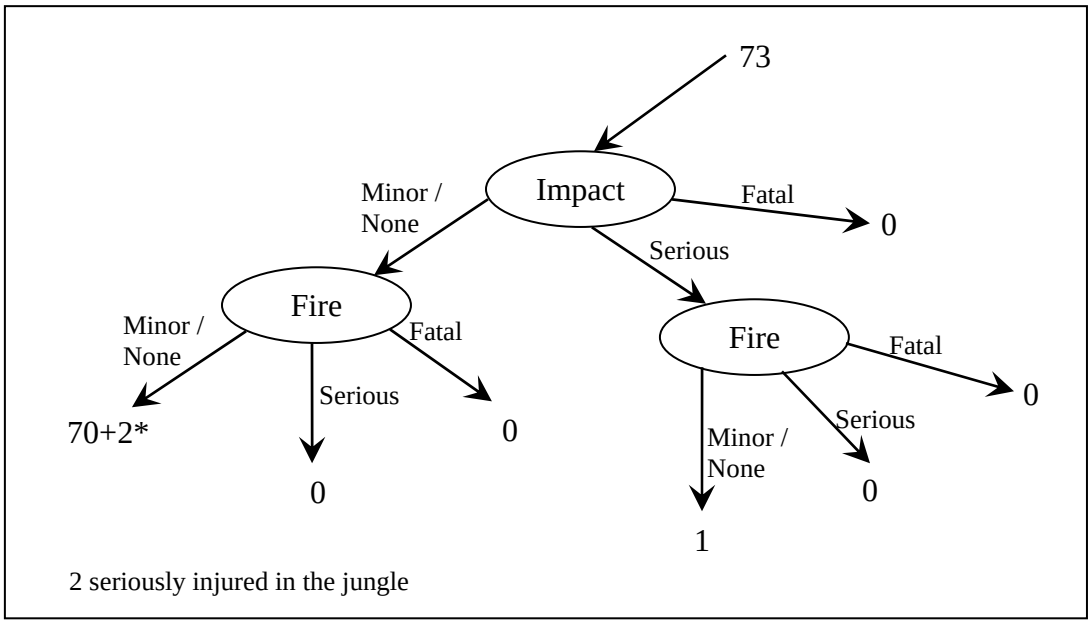
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	73	0	3	70

There were 6 crewmembers and 67 passengers on board the aircraft. All 73 occupants escaped before fire destroyed the aircraft. Three persons received *Serious Injuries*; the remainder received minor or no injuries.

The captain sustained fractures of the left collarbone and a bone in the top portion of his right foot. Both injuries resulted from the crash deceleration.

One passenger sustained a fractured ankle and another passenger sustained a fractured wrist. Both fractures occurred in the jungle as the passengers ran from the aircraft. The remainder of the injuries were minor bumps, bruises, and abrasions, most of which also occurred in the jungle. None of the occupants was burned.

Since the fracture injuries sustained by the two passengers were not results of the impact, they were not considered to be *Injuries* in the survivability chain.



Fuselage Breaks & Ruptures

The entire fuselage was mostly consumed by fire from the aft pressure bulkhead forward.

There was insufficient information in the accident report to determine the location and number of any *Ruptures* prior to the fire.

Occupant Egress & Fire Entry

The first and second officers and the mechanic reported that all passengers had departed from the cabin by the time they reached it. The cockpit occupants reported that the cargo remained in its restraining nets but shifted and appeared "flattened out," blocking the aisleway along the left side of the cargo area.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

There is no indication from the accident report that fire entered through any *Ruptures*. However, as the aircraft was destroyed by the post impact fire, if any *Fuselage Ruptures* occurred, it is possible that fire could have entered through them.

Accident Database Reference	Location		Aircraft
19810217A	JOHN WAYNE AIRPORT, SANTA ANA, CALIFORNIA, U.S.A.		B737-293
Date	**Operator**		**Registration**
17-FEB-1981	AIR CALIFORNIA		N468AC
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	1	Major Break

Résumé of Accident

On 17-Feb-1981, at 1644 pacific standard times (pst), an Air California Boeing B737-293, Flight 336 (ACL336), registered as N468AC, a scheduled passenger service flight from San Jose to Santa Ana departed San Jose, California. The en route portion of the flight was normal. About 1732 pst, the aircraft was handed off to the John Wayne Orange County Airport control tower for a visual approach to runway 19R. The flight was initially sequenced for landing behind a Beech Bonanza and a Boeing 737, Western Flight 383. The Bonanza was turned out of traffic and subsequently sequenced to land behind Air California 336.

Western 383 landed and Air California Flight 931, Santa Ana to San Jose, was cleared onto the runway and then cleared for takeoff. Recognising that the separation criteria between Air California 336 and Air California 931 had been jeopardised, the air traffic controller instructed Air California 336 to go-around and Air California 931 to abort the takeoff. Air California 931 aborted and Air California 336 subsequently touched down on the runway and came to rest about 2,070 feet down the runway, with the landing gear retracted.

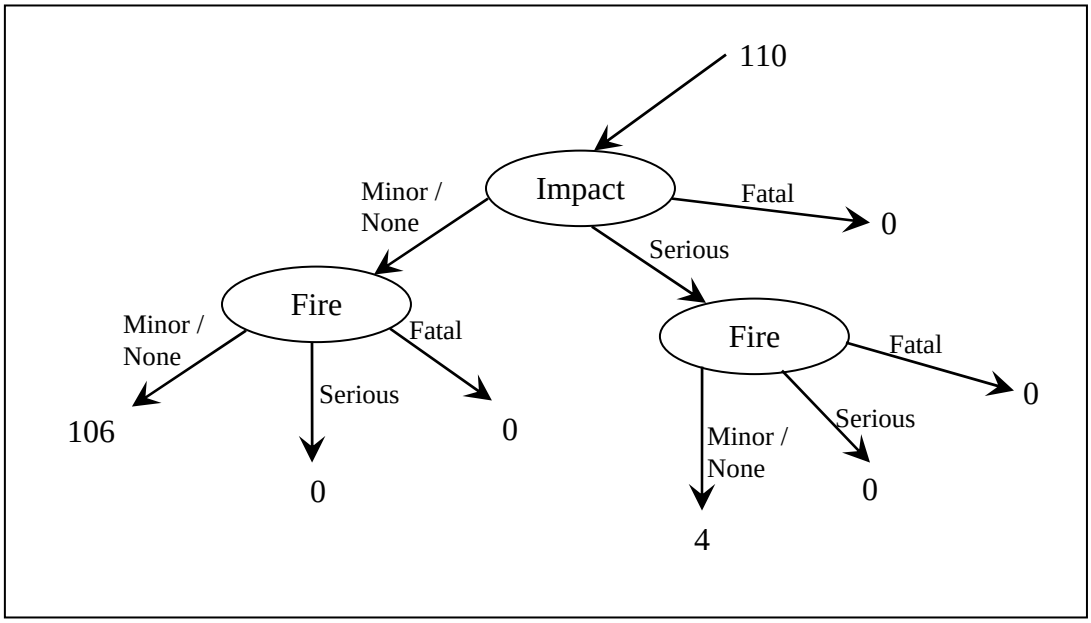
The aircraft impacted the airport runway at approximately 1734 during daylight hours. The aircraft was destroyed by impact and post impact fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatalities*	Occupant *Serious Injuries*	Minor / No Injures
Number	110	0	4	106

There were 5 crewmembers and 105 passengers onboard the aircraft; four passengers sustained *Serious Injuries* and 29 passengers incurred minor injuries during the accident.

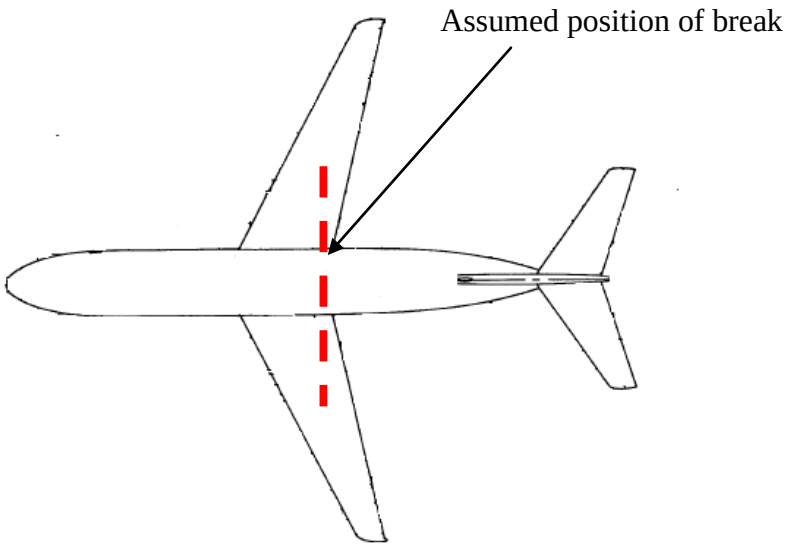
Four passenger injuries were classified as *Serious* and 3 of these passengers were hospitalised for over 24 hours. One of these 3 passengers, an elderly man, remained in the coronary care unit for observation for 3 days and then released. Another male passenger in his early 30's complained of severe internal pain; he was kept in observation for 4 days and released. The third male passenger, age 31, sustained a fractured clavicle; he was kept in the hospital for 24 hours and released. A fourth male passenger had a chip fracture of the knee. The 29 passengers who suffered minor sprains, contusions, and abrasions were treated and released from 4 local hospitals on the evening of the accident.



Fuselage Breaks & Ruptures

Engine components, lower fuselage panels, and flap fairing sections were scattered along the wreckage distribution pattern.

When the aircraft came to rest in a level attitude, a fuselage vertical separation occurred at fuselage station 727, or seat row 14, aft of the overwing exit.



Occupant Egress & Fire Entry

The accident was survivable since the decelerative forces during the accident were low and the cabin area remained mostly intact.

The passenger cabin had four doors and two overwing exits that could be used to evacuate the aircraft. Although two of the passengers exited through the left overwing exit, most of the passengers exited from the front and rear left exits.

The accident report gives no indication of any survivor using the *Fuselage Break* as an escape route. Photographic evidence suggests that there was no fire entry through the *Fuselage Break*.

Accident Database Reference	Location		Aircraft
19820913A	MALAGA, SPAIN		DC10
Date	**Operator**		**Registration**
13-SEP-1982	SPANTAX		EC-DEG
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING/FIN	No	0	Intact

Résumé of Accident

On 13-Sep-1982 a Spantax DC10-30F registered as EC-DEG was taking off from Malaga Airport in Spain.

The pilot aborted the takeoff because of 'vibrations' of unknown origin. The aircraft proceeded off the end of the runway and struck a number of objects, creating sufficient damage to cause fuel spillage, but no fire, as it decelerated.

Approximately 700 feet from the end of the runway, the aircraft crossed a road and struck a house. This impact was quite severe, ripping off the right wing and creating a fireball. The fireball 'followed' the aircraft until it came to rest approximately 1000-1200 feet beyond the runway.

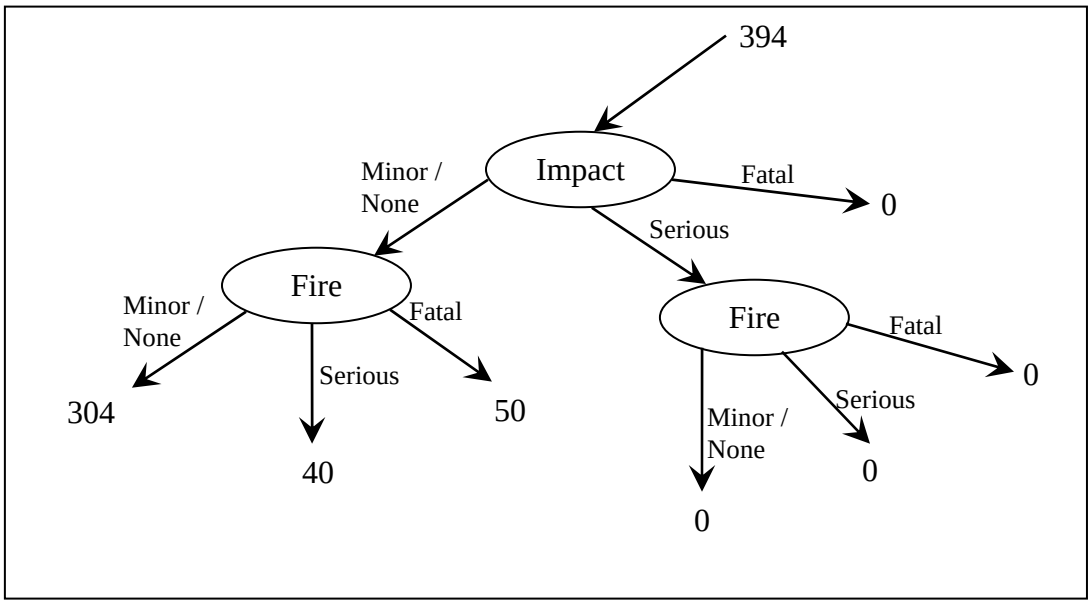
The fuselage is believed to be entirely intact at this point, resting on its belly.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	394	50	40	304

Of the 13 crew and 381 passengers aboard, 3 crew and 47 passengers suffered *Fatal Fire Injuries*. Forty passengers were *Seriously Injured*.

It was inferred from the accident report that all *Serious Injuries* were due to the effects of fire.



Fuselage Breaks & Ruptures

There are witness accounts that fire broke in through the tail and dense smoke seeped in probably through a tear in the upper part of the passenger cabin at the height of door 4R.

It is also probable that the fuselage had suffered damage, as the fuselage passed over the remnants of the agricultural concrete structure the aircraft had hit on its right-hand side, finally coming to a stop some 450 meters away from the end of Runway 14 and approximately 40 meters to the left of the axis.

There is insufficient information to determine the location and number of any *Ruptures*.

Occupant Egress & Fire Entry

The evacuation took place slowly because the passengers picked up their carried luggage before evacuating. In the third cabin, besides the problems brought about by hand-carried luggage, a bottleneck resulted due to the number of passengers, most of them on the left aisle, which were trying to reach door L3. On top of that, evacuation was carried on with difficulty due to the fire having destroyed the L3 slide.

The lack of visibility, due to the fire and smoke, and the cabin dividers made it impossible to have a view of the plane as a whole, and consequently, three different evacuations were carried out, one from each cabin.

The 91 passengers in the first cabin left the plane through doors L1, R1 and L2. The 122 in the second cabin left through doors L2, L3 and some through R2. The third cabin was occupied by 167 passengers. On these, the 117 that evacuated the plane did so by using door L3 that was affected by the fire through most of the process. The L3 slide was rendered useless. The 47 passengers and three crew members that died occupied the third cabin.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

The accident report states the following with regard to fire entry through rupture:

'There are witness accounts that fire broke in through the tail and dense smoke seeped in probably through a tear in the upper part of the passenger cabin at the height of door 4R.'

Although the accident report is not definitive, it is assumed that fire did penetrate through the tear. Of the *Fatal*ities, it is understood that eight victims died of the direct consequence of the fire that penetrated the plane, probably through the crack in the upper part of the passenger cabin at the height of door 4R.

Accident Database Reference	Location		Aircraft
19831207A	MADRID, SPAIN		B727-200
Date	**Operator**		**Registration**
07-DEC-1983	IBERIA		EC-CFJ
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	No	0	Intact

Résumé of Accident

On 07-Dec-1983 an Iberia B727-200 registered as EC-CFJ was taking off from Madrid-Barajas Airport, Spain in fog conditions.

As the aircraft reached V1 speed, it collided with a DC-9, which had taxied onto the runway in error due to the poor visibility.

The aircraft spun round, caught fire, and was destroyed.

At the moment of impact the B727 had just reached V1 and was travelling substantially on the runway axis.

The port side of the aircraft's fuselage on a level with the partitioning bulkhead between the crew and passenger cabins collided with the port wingtip of the DC-9, which had invaded the flight runway.

The effect of this initial impact was to instantly cause the other aircraft to swing round, leaving it practically parallel with, but in the opposite direction to, the B727, which lost its port wing and landing gear. The B727 continued along the runway, swinging round and moving over until it came to a halt at 460 m from the point of impact on the left hand edge of the runway, facing the opposite way to the direction of take-off.

Occupant *Injuries* & Survivability Chain

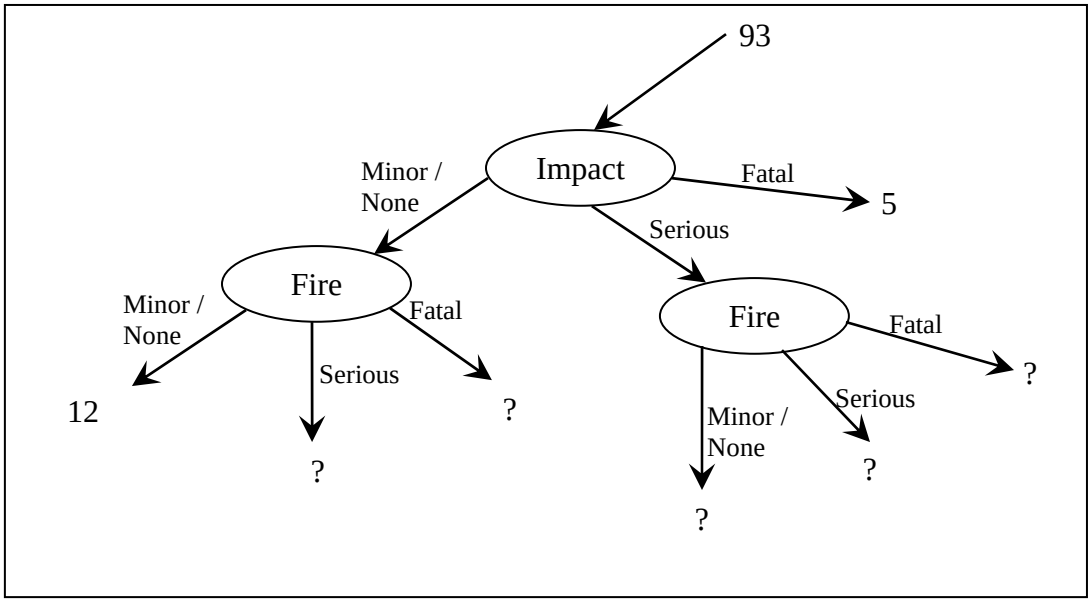
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	93	51	30	12

Of the 9 crew and 84 passengers aboard, 1 crewmember and 50 passengers suffered *Fatal Injuries*. Four crew and 26 passengers suffered *Serious Injuries*. Four crew and eight passengers escaped with minor or no injuries.

Five people died instantly as a result of the impact of the DC-9's port wing with the B727's fuselage.

The effects of the smoke and fire, which broke out on collision, plus the traumatic injuries, incapacitated a large number of victims, preventing them from evacuating the aircraft.

There is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

The port side of the aircraft's fuselage (B727) on a level with the partitioning bulkhead between the crew and passenger cabins collided with the port wingtip of the aircraft, which had invaded the flight runway (DC9).

The initial impact of the port wingtip of the DC-9 was with the part of the B727's fuselage level with the bulkhead separating the crew compartment from the passenger cabin.

The rupture in the fuselage was caused by aircraft collision.

Occupant Egress & Fire Entry

The instantaneous fire, which broke out on the port side of the aircraft and the aircraft's subsequent violent swing round, incapacitated the victims who were unable to reach the exits.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

There is no indication from the accident report that fire entered through *Ruptures*.

Accident Database Reference	Location		Aircraft
19850822A	MANCHESTER AP., U.K.		B737-236 Sr1
Date	**Operator**		**Registration**
22-AUG-1985	BRITISH AIRTOURS		G-BGJL
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

At 0612 hrs G-BGJL, carrying 131 passengers and 6 crew on a charter flight to Corfu, took off from Manchester with the co-pilot handling. About 36 seconds later, as the airspeed passed 125 knots, the left engine suffered an uncontained failure, which punctured a wing fuel tank access panel. Fuel leaking from the wing ignited and burnt as a large plume trailing directly behind the engine. The crew heard a 'thud', and believing that they had suffered a tyre-burst or bird-strike, abandoned the take-off immediately, intending to clear the runway to the right. They had no indication of fire until 9 seconds later, when the left engine fire warning occurred. After an exchange with ATC, during which the fire was confirmed, the commander warned his crew of an evacuation from the right side of the aircraft, by making a broadcast over the cabin PA system, and brought the aircraft to a halt in the entrance to link Delta.

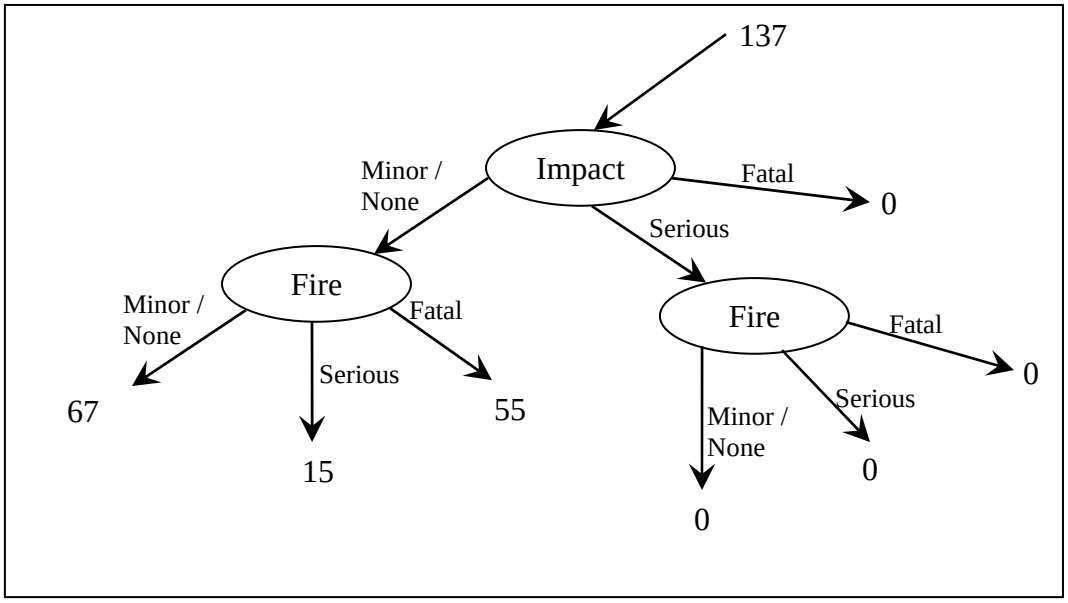
As the aircraft turned off, a wind of 7 knots from 250° carried the fire onto and around the rear fuselage. After the aircraft stopped the hull was penetrated rapidly and smoke, possibly with some flame transients, entered the cabin through the aft right door, which was opened shortly before the aircraft came to a halt. Subsequently fire developed within the cabin. Despite the prompt attendance of the airport fire service, the aircraft was destroyed and 55 persons on board lost their lives.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	137	55	15	67

There were 6 crew and 131 passengers on board the aircraft. 2 crew and 54 passengers were *Fatally Injured*, 15 passengers were *Seriously Injured*.

The major cause of the *Fatal*ities was rapid incapacitation due to the inhalation of the dense toxic/irritant smoke atmosphere within the cabin. All *Injuries* were the result of fire.



Fuselage Breaks & Ruptures

There were no impact related *Fuselage Breaks* or *Ruptures*.

Occupant Egress & Fire Entry

With regard to the exits used during the evacuation, some 15-17 used the left forward exit; 34-36 used the right forward exit. Some 27 passengers (including two infants) used the right overwing exit. Survivors indicated hesitation by some to exit the left front on the side of the fire, which slowed evacuation out of the doors.

There was no fire entry through impact related *Fuselage Breaks* or *Ruptures*.

Accident Database Reference	Location		Aircraft
19880626B	HABSHEIM, FRANCE		A320-100
Date	**Operator**		**Registration**
26-JUN-1988	AIR FRANCE		F-GKFC
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

During an air show on 26-Jun-1988, A320 F-GKFC made a level pass at about 30 ft, gear and flaps out, engines almost at idle and 130 passengers on board. After the go-around, the aircraft hit trees at the end of the runway. The right wing broke up and a fire erupted.

All passengers evacuated the aircraft except three who suffered *Fatal Injuries* as a result of the fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	136	3	1	132

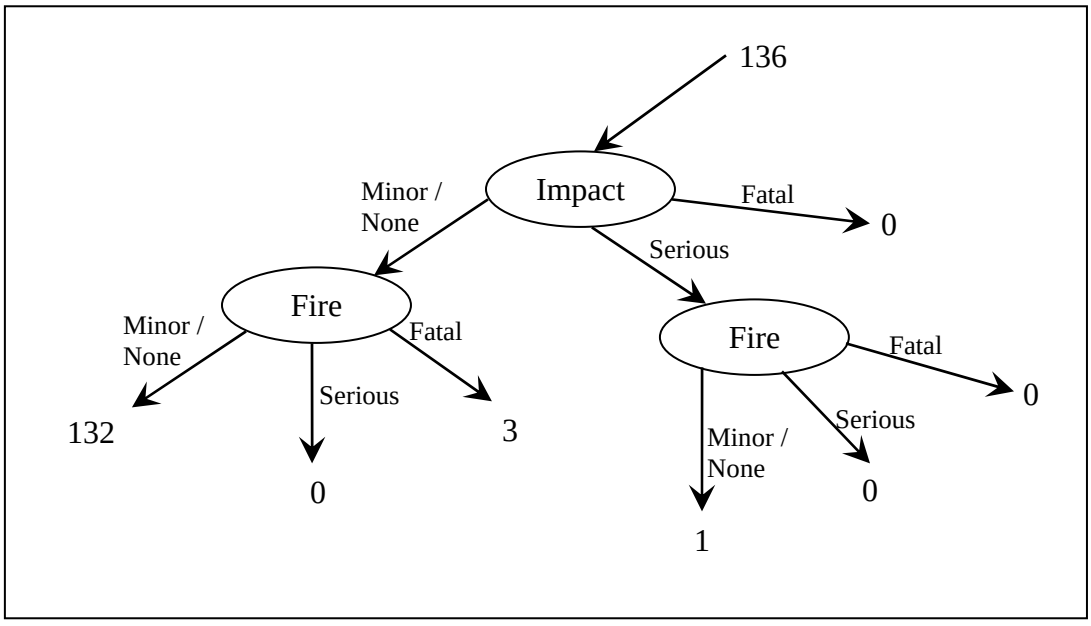
All passengers were able to leave the aircraft, except three who succumbed to the fire:

A young handicapped boy in seat 4F who seems to have remained in his seat.

A little girl located at 5C who, according to her young brother (who was carried away by the flow of the other passengers), had not been able to open her seat belt and was blocked by the back of her seat, which was tilted over onto her.

A woman travelling in seat 10B who, according to her husband, had reached the left forward door, as her body was found near that of the little girl, we can reasonably assume that she went back into the cabin to help the little girl and was overcome by the fumes.

All of the 127 surviving passengers suffered minor or no injuries. It is believed that the first officer sustained *Serious Injuries* as a result of the impact.



Fuselage Breaks & Ruptures

The aircraft was largely destroyed by fire that followed the accident; the fuselage was completely burnt out, except for the empennage and the zone located aft of the pressure bulkhead.

Several pieces of flight control surfaces (slats and flaps, ailerons), and of empennage, cowlings and engine accessories were found together with small pieces of skin, it is therefore likely that *Fuselage Ruptures* were present. However the size and location of ant such *Ruptures* cannot be determined.

Occupant Egress & Fire Entry

As soon as the aircraft came to rest, the stewards stationed at the forward and aft doors, seeing the fire on the right of the aircraft, opened the left doors.

The left forward door was blocked by branches after it had started to open correctly. The left aft door was opened without any problems and the escape slide was correctly deployed.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

If there were any *Ruptures* in the fuselage it is likely they would have provided an entry route for the fire.

Accident Database Reference	Location		Aircraft
19880831B	DALLAS FORT WORTH, U.S.A.		B727-232
Date	**Operator**		**Registration**
31-AUG-1988	DELTA AIRLINES		N473DA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL/FIN	Yes	2	Major Breaks

Résumé of Accident

On 31-Aug-1988, B727-232 registered as N473DA was taking off from Dallas-Fort Worth International Airport, Texas. The slats and flaps were not properly configured and as a result the aircraft did not gain altitude after rotation.

The aeroplane struck an instrument landing system (ILS) localiser antenna array approximately 1000 feet beyond the end of the runway and came to rest about 3200 feet beyond the departure end of the runway. The flight was airborne approximately 22 seconds from lift-off to the first ground impact near the ILS localiser antenna. The aeroplane was destroyed by impact forces and the postcrash fire.

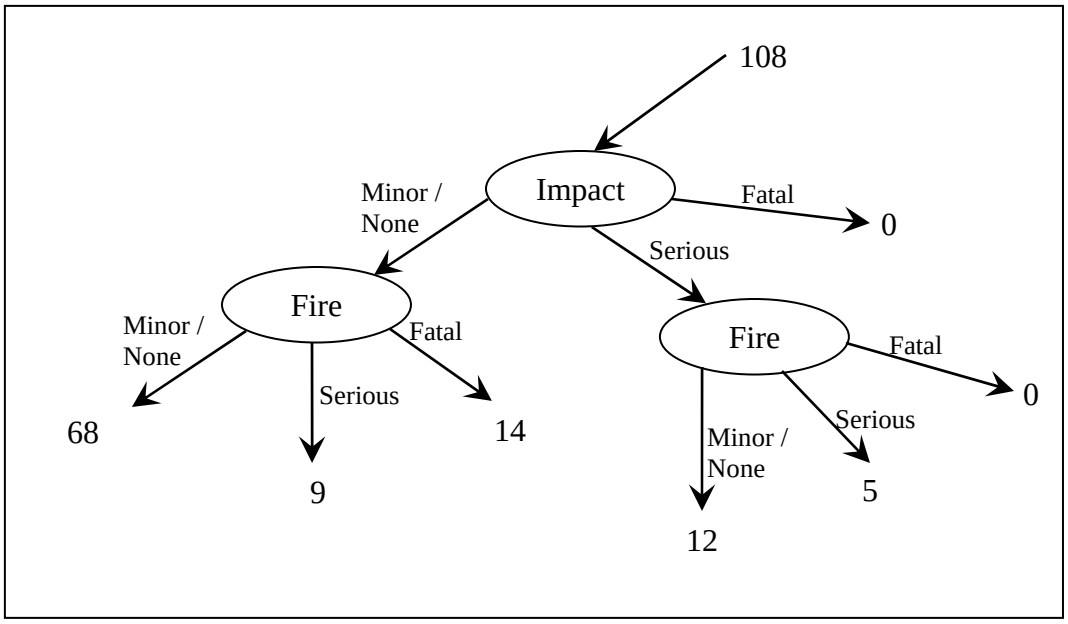
Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	108	14	26	68

Of the 108 persons on board, 12 passengers and 2 crewmembers were killed, 22 passengers and four crewmembers were *Seriously Injured*, and 67 passengers and 1 crewmember sustained minor or no injuries. The combination of jammed left aft service door and the intense impenetrable fire trapped 12 occupants.

The cause of death of 11 passengers and the two flight attendants was determined to be smoke inhalation. A 14th *Fatal*ity was a passenger who had successfully evacuated but later attempted to re-enter the burning aeroplane. This passenger died of severe burns, 11 days after the accident.

The survivability chain was determined by using information from the NTSB Human Factors Group Chairman's Factual Report.



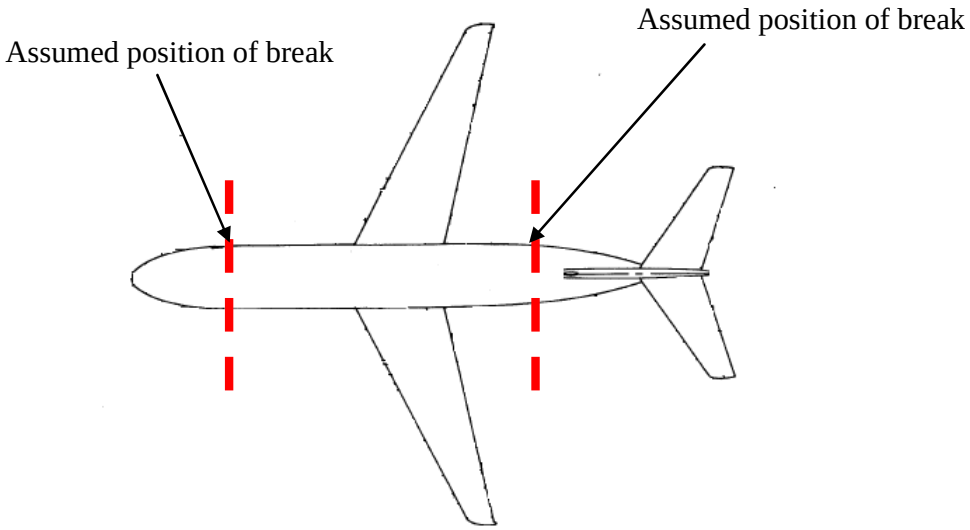
Fuselage Breaks & Ruptures

The fuselage had separated into three major sections:

(1) The forward section consisted of the nose forward of fuselage station (FS)-420 [just aft of seat row 1];

(2) The centre fuselage section included the body structure between FS-420 and FS-950c [between seat rows 27 & 28]; and

(3) The aft fuselage section extended from FS-950c aft to the end of the No. 2 engine tailpipe.



Occupant Egress & Fire Entry

The investigation found that although the fuselage had separated in several places, the occupiable volume of the cabin was not substantially compromised.

Exit from the aft cabin was hampered by the fire that impinged on the right side of the aeroplane. Exit from the mid and forward cabin was through breaks in the fuselage and through the left side exits, except for the left aft service door, which was not opened.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

There is no confirmation from the accident report that fire entered through the *Fuselage Break*s. However, the aircraft was destroyed by the post impact fire, and fire entry through the *Fuselage Break*s is considered likely.

Accident Database Reference	Location		Aircraft
19900214A	BANGALORE, INDIA		A320-231
Date	**Operator**		**Registration**
14-FEB-1990	INDIAN AIRLINES		VT-EPN
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	2?	Major Breaks

Résumé of Accident

On 14-Feb-1990 an Indian Airlines A320-231 registered as VT-EPN was approaching Bangalore Airport, India.

During the final approach, the aircraft descended below the normal approach path and its wheels contacted ground in a golf course area about 2300 feet short of the runway and impacted an embankment at the boundary of the golf course. The aircraft thereafter hopped over a ditch and a road adjacent to it and landed on an area outside the boundary wall of the airport.

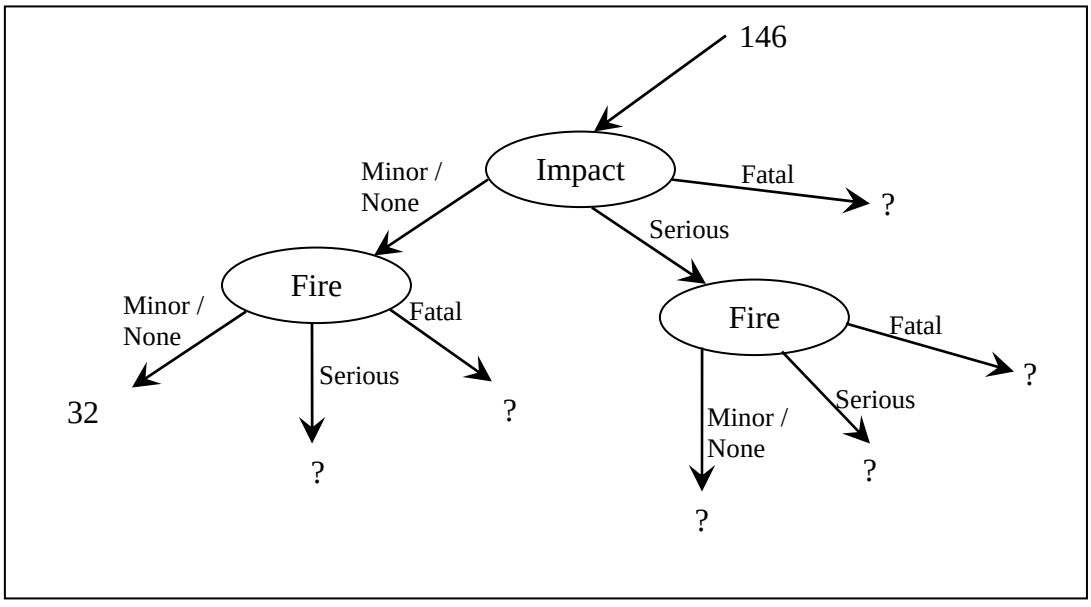
The aircraft was destroyed as a result of impact with ground and subsequent fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	146	92	22	32

Of the 7 crew and 139 passengers aboard, four crew and 86 passengers died in the cabin fire. Two passengers later succumbed to their *Injuries* in hospital. 1 flight attendant and 21 passengers suffered *Serious Injuries*. 2 flight attendants and 30 passengers escaped with minor or no injuries.

Although the accident report supplied detailed descriptions of the *Fatal Injuries*, there is insufficient information available to develop completely the survivability chain.

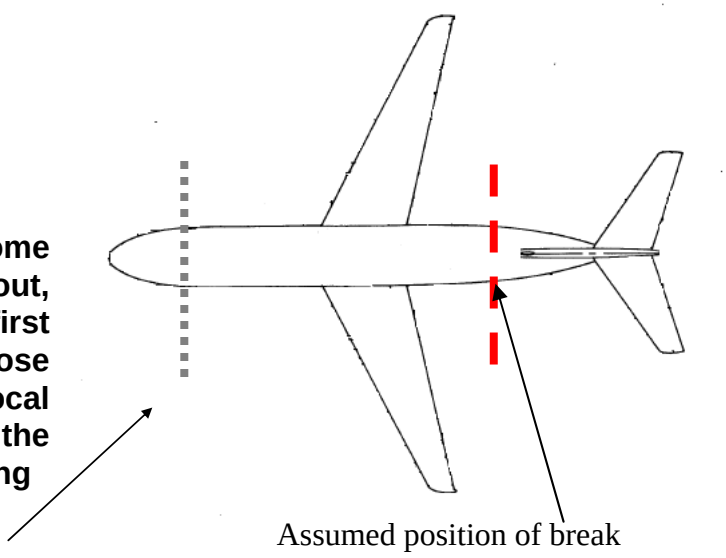


Fuselage Breaks & Ruptures

Severe longitudinal/circumferential crumpling was observed aft of the centre wing box. About 11 feet aft of the wing rear spar there was a fuselage fracture about 9 inches wide extending from just above the window line to the lower belly on the left hand side. On the right hand side this was not observed.

It is unclear in the report as to the actual number of *Fuselage Breaks*; however, inferences from occupant evacuation suggested more than one break.

[From Accident Report: "Some passengers were seen coming out, in inverted position with head first from underneath the damaged nose portion. They were helped by local people who pulled them out of the wreckage. One person while trying to come out from there was caught up by the fire and was seen dying there."]



Occupant Egress & Fire Entry

Upon impact, many people had impacted the seats in front of them causing various injuries, dizziness and shock. Some seats in the middle to forward section of the cabin had also broken. Breaks in the fuselage were large enough to facilitate escape for a few passengers.

According to two airhostesses the passengers were slow in reacting to their announcement, probably due to shock or injuries. They had to help some passengers to exit out of the aircraft. Some passengers also helped other passengers to come out of the aircraft.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19920730A	NEW YORK JFK, U.S.A.		L1011-385-1
Date	**Operator**		**Registration**
30-JUL-1992	TRANS WORLD AIRLINES (TWA)		N11002
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING/FIN	No	0	Intact

Résumé of Accident

On 30-Jul-1992 a Trans World Airlines Lockheed L1011 registered as N11002 was taking off from John F. Kennedy International Airport, Jamaica, New York.

The aircraft experienced an aborted takeoff and came to rest upright and on fire on grass-covered soil about 290 feet to the left of the departure end of the runway.

The aircraft was destroyed by fire.

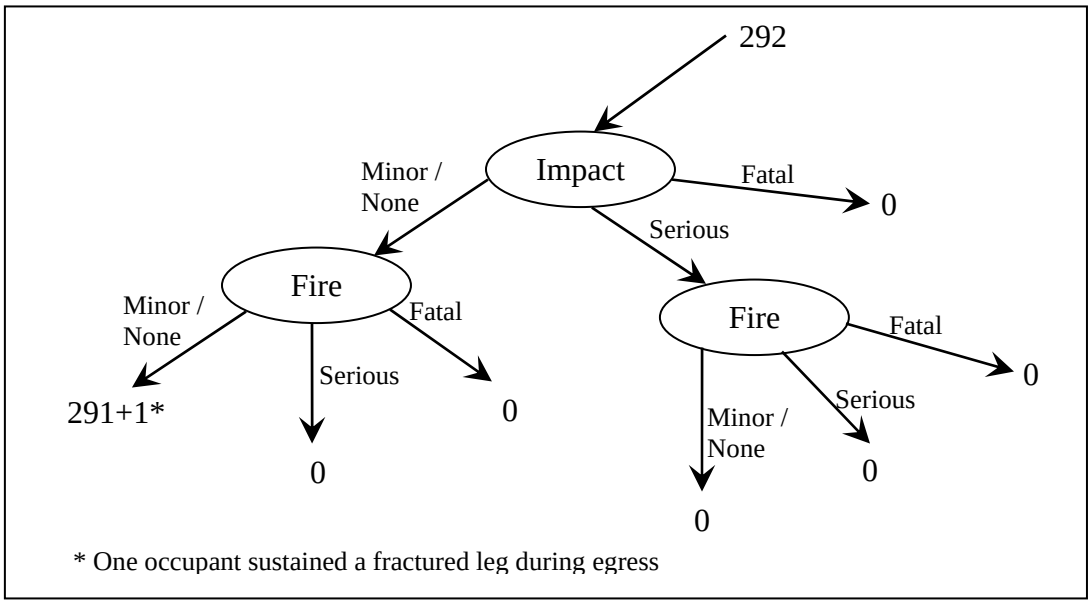
Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	292	0	1	291

Of the 12 crew and 280 passengers aboard, one passenger suffered *Serious Injuries* during the evacuation.

There were 10 reported injuries that occurred during egress. Of the injuries most were minor. There was one occupant with a fractured leg.

Since all occupant injuries were during egress, and the only *Serious* injury was a fractured leg, there was no *Serious* impact injury sustained during the crash. Therefore, the one occupant with a fractured leg is not included as an impact injury in the survivability chain.



Fuselage Breaks & Ruptures

There is insufficient information in the accident report to determine the location and number of any *Fuselage Ruptures* prior to the fire.

Occupant Egress & Fire Entry

The crew quickly evacuated all of the passengers through the most forward right and the two forward left cabin exits. The second cabin exit hatch on the right side was opened during the evacuation, but because smoke and fire were immediately outside the exit, it was quickly closed.

The captain examined the cabin for any remaining passengers and was the last person to exit the aircraft.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

There is no indication from the accident report that fire entered through any *Ruptures*. The aircraft was destroyed by the post impact fire hence if any *Fuselage Ruptures* had occurred it is possible that fire could have entered through them.

Accident Database Reference	**Location**		**Aircraft**
19921221A	FARO, PORTUGAL		DC10-30CF
Date	**Operator**		**Registration**
21-DEC-1992	MARTINAIR, HOLLAND		PH-MBN
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING/FIN	Yes	3	Major Breaks

Résumé of Accident

On 21-Dec-1992 a Martinair DC-10-30CF registered as PH-MBN was approaching Faro Airport, Portugal.

After a flight of 2 hrs and 17 minutes the flight was cleared to descend to Faro.

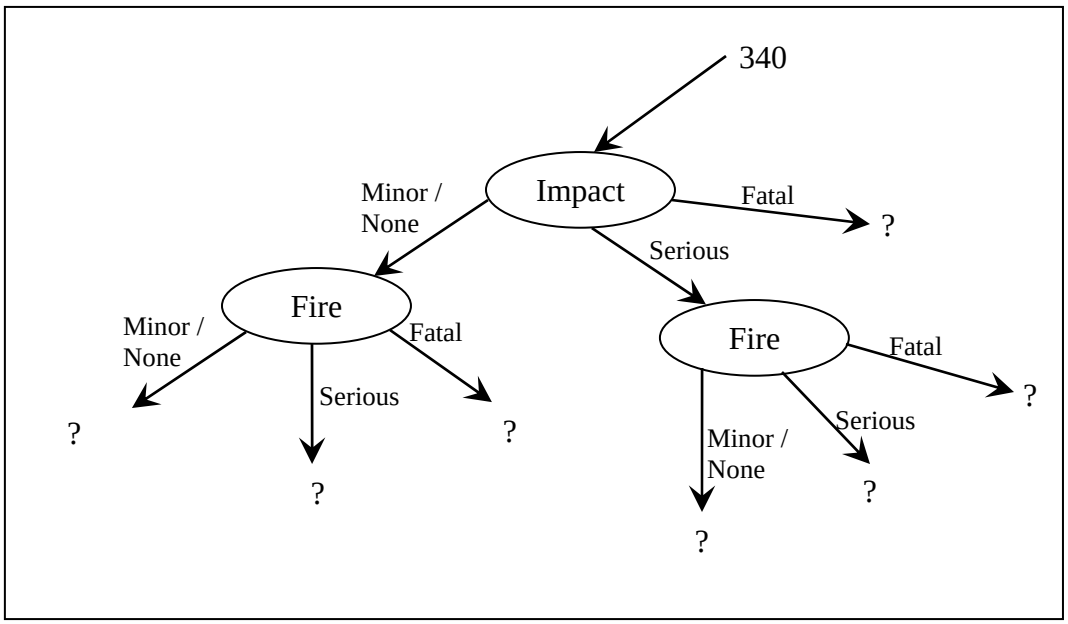
At an altitude of 303m and 140kts speed the approach became unstable and at 177m the first officer switched the autopilot from CMD (command mode) to CWS (control-wheel steering). One minute later it was switched from CWS to manual and the airspeed began falling below approach reference speed. About 3-4 seconds short of touchdown the elevator was pulled to pitch up and engine power was increased. When the no.3 and 5 spoilers extended, the aircraft had a 25deg. bank, left wing up. The right main gear contacted the runway with a 900ft/min descent rate at 126kts, +8.79deg, pitch up, +5.62deg roll and 1.9533G. The right wing separated while the aircraft slid down the runway. The aircraft came to rest 1100m from the Runway threshold and 100m to the right of the centreline and caught fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	340	56	?	?

There were 13 crew and 327 passengers on board. 2 crew and 54 passengers suffered *Fatal Injuries*.

There is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

The fuselage broke into four main sections.

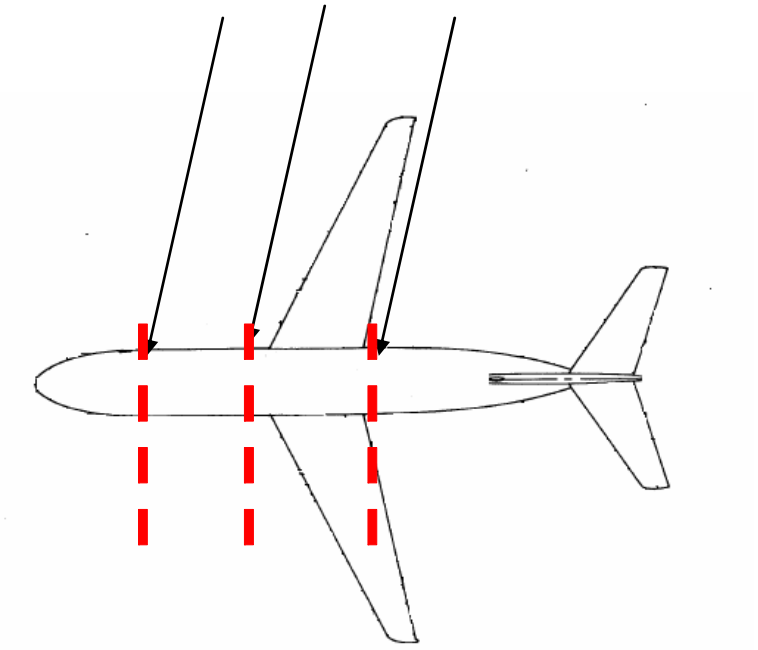
1 - Seat rows 1 to 10: This section came to rest on its left side at 70 deg. There was no fire.

2 - Seat rows 11 to 19: This section corresponds to the transverse rupture of the cabin due to the longitudinal twisting moment of the fuselage.

3 - Seat rows 20 to 27: This section corresponds to where, upon first strike, fire propagated in from the right wing.

4 - Seat rows 28 to 41: This section contains the cabin which structurally resisted the crash most and where evacuation was possible.

Assumed position of breaks



Occupant Egress & Fire Entry

In the forward section (1) passengers and crewmembers exited through holes in the cabin walls, since none of the four exits was operational. L1 and L2 were half buried in the ground and R1 and R2 were unused since they were almost vertical.

In the mid-forward section (2) the passengers and crewmembers exited exclusively through a *Fuselage Break*, mainly through the left side. Most of the passengers who were aware of having been ejected (94%) were sitting in this section, which records also the greatest number of ejected passengers for the total survivals (37%).

In the mid-rearward section (3) an explosion occurred soon after the aircraft came to a halt. Sixty one percent of the people seated in this section died. Of the survivors, 52% claim not being aware of how they managed to get out of the aircraft. The remaining survivors claim to have exited through *Ruptures*, either in the fuselage walls or in the cabin floor. Only 2 passengers state having used the emergency exit on the left wing (L3) which was burst open by the explosion. The R3 exit was not used.

In the rear section (4) evacuation was carried out, in less than 4 minutes, through the 2 rear exits (R4 & L4) before an explosion re-lit the fire in the mid section which spread to the rear section. From the total number of occupants in this section, 97.6% survived. Most of them recall having come out through rear exits, though they cannot state which side it was. The L4 exit opened spontaneously before the aircraft came to a halt. The escape slide was partially deployed. Most of the passengers used this exit, being immediately covered by the firemen's foam. The R4 exit was opened by the R4 stewardess and the escape slide partially deployed.

The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

There is no indication from the accident report that fire entered through *Fuselage Break*s, however, it is likely that the spread of fire in the mid section to the rear section was due to fire entering through a break.

Accident Database Reference	Location		Aircraft
19930914A	WARSAW, POLAND		A320-211
Date	**Operator**		**Registration**
14-SEP-1993	LUFTHANSA		D-AIPN
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	No	0	Intact

Résumé of Accident

On 14-Sep-1993 a Lufthansa A320 registered as D-AIPN was landing at Okecie in Warsaw, Poland.

The pilot in the left seat was subject to check but was the pilot flying at the time of the accident. The pilot in the right seat was the instructor who was in overall command of the aircraft.

Okecie tower warned the crew of windshear and so the flight crew increased the approach speed by 20 knots, in accordance with the Flight Manual. A storm front passed through the aerodrome area at that time which produced a tail wind and as a result the aircraft touched down too fast. The very light touch of the runway surface with the landing gear and lack of compression of the left landing gear leg (to the extent understood by the aircraft computer as the actual landing) resulted in delayed deployment of spoilers and thrust reversers. Delay was about 9 seconds. Thus the braking commenced with delay and in a condition of heavy rain the aircraft did not stop on the runway.

The aircraft ran off the end of the runway, collided with an embankment, and stopped the other side of it. The aircraft caught fire as a result of the impact.

Occupant *Injuries* & Survivability Chain

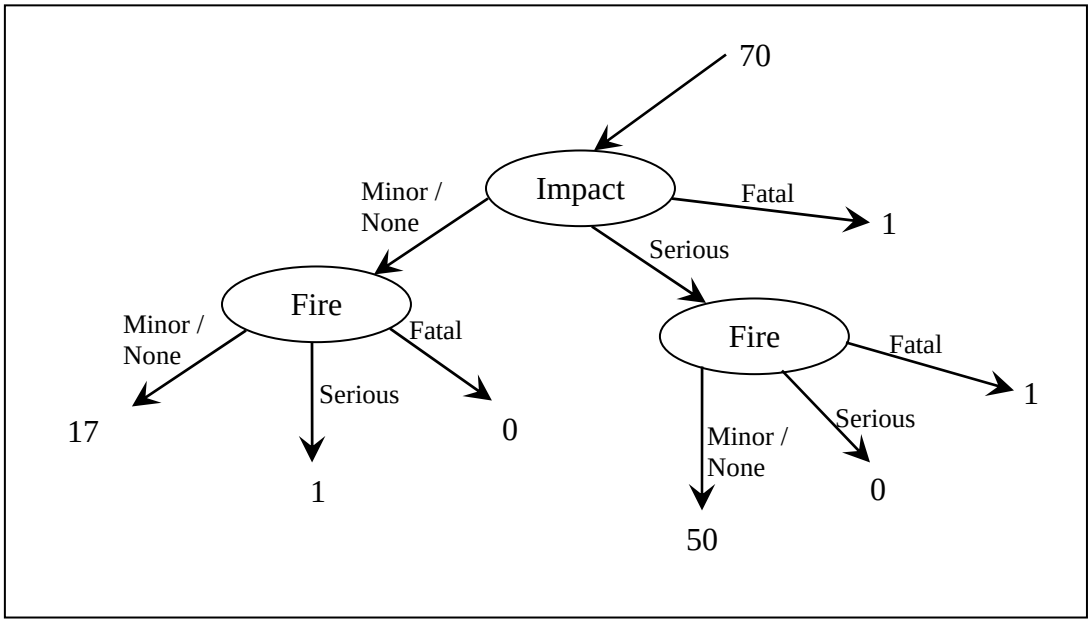
	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	70	2	51	17

There were 6 crew and 64 passengers aboard. 1 crew member and 1 passenger suffered *Fatal Injuries*. 2 crew and 49 passengers suffered *Serious Injuries*. 3 crew and 14 passengers escaped with minor or no injuries.

The passenger seated in the utmost left seat in "business class" sustained a fracture of the first lumbar vertebra and of both hands. This probably made him unable to leave his seat unaided. In

addition, his temporary loss of consciousness during the impact did not allow him to draw the attention of other passengers and cabin attendants.

The survivability chain was determined using information from the accident report.



Fuselage Breaks & Ruptures

The bottom part of the fuselage up to the wing area was found significantly deformed and broken in the wing area.
The aft part of the fuselage, from aft doors, was found complete, with minor deformation.

Occupant Egress & Fire Entry

The front and aft passenger doors were found open with escape slides deployed.

During the landing the cabin crew were seated in two pairs, one near to the front entrance and the other near to aft entrance. Only two were available to act immediately. A stewardess from the aft pair, due to breathing difficulties, fainted after opening the door and initialisation of the escape slide and was unable to take part in the further activities, and chief steward (with injured head), who was in the front part of cabin, remained unconscious all the time during passenger evacuation. After regaining consciousness he managed to release the injured pilot blocked in the cockpit, enabling him to leave the aircraft through the open front door. However, he was not able to lift the body of the instructor remaining in the cockpit.

The accident report gives no indication of any survivor using *Fuselage Ruptures* as an escape route.

The aircraft was destroyed by fire and it is likely that any *Fuselage Ruptures* may provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
19940426A	NAGOYA/KOMAKI AIRPORT, NAGOYA, JAPAN		A300B4-622R
Date	**Operator**		**Registration**
26-APR-1994	CHINA AIRLINES		B-1816
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	Many	Massive Disruption

Résumé of Accident

On 26-Apr-1994 Airbus A300-600R registered as B-1816 and operated by China Airlines was approaching the Nagoya/Komaki Airport, Nagoya, Japan.

The first officer was manually flying the aircraft with the autopilot off. The Safety Board believes that the first officer inadvertently selected the auto-throttle system to the go-around mode. The CVR transcript indicates that the flight crew did not understand why the aircraft was not responding to the control inputs when the autopilot was engaged and apparently did not realise that the autopilot was trimming the aircraft nose up.

As a result, the aircraft entered an aerodynamic stall at approximately 1800 feet above ground level and the pilots were unable to regain control prior to striking the ground short of the runway.

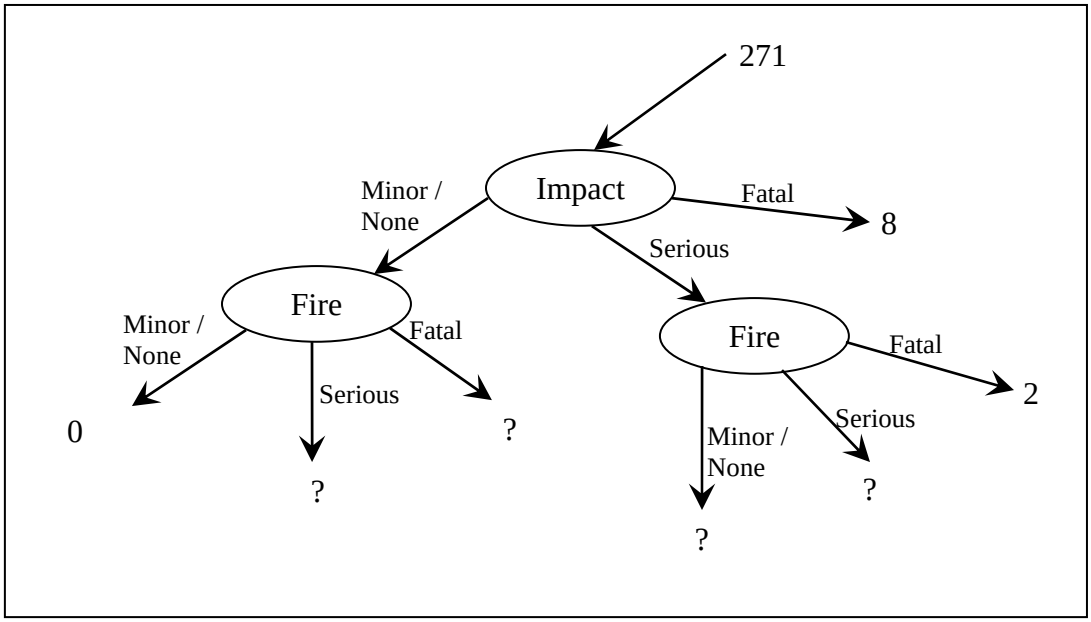
The aircraft ignited and was destroyed.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	271	264	7	0

There were 15 crew and 256 passengers aboard. 15 crew and 249 passengers suffered *Fatal Injuries*. Seven passengers suffered *Serious Injuries*.

Although the accident report supplied detailed descriptions of the *Fatal Injuries*, there is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

Due to the impact of the crash, the wreckage of the aircraft except the RH and LH wings, the vertical and horizontal tail planes, the tail section of the fuselage, and the engines, was scattered over an approximately 140 metres long and 60 metres wide area to the east-northeast of the LH main landing gear's ground scar. Fragments of the destroyed skin of the nose and forward fuselage sections were strewn over an approximately 40 metres long and 30 metres wide area, some 120 metres away from the LH main landing gear's ground scar to the east-northeast direction.

Occupant Egress & Fire Entry

There were 2 flight crew, 13 cabin crew and 256 passengers (including 2 infants) aboard.
Due to the severe nature of the impact and destruction of the fuselage volume, an evacuation was not carried out.

Accident Database Reference	**Location**		**Aircraft**
19990601A	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.		MD82
Date	**Operator**		**Registration**
01-JUN-1999	AMERICAN AIRLINES		N215AA
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
TAIL	Yes	2	Major Breaks

Résumé of Accident

On June 1, 1999, at 2350:44 central daylight time, American Airlines flight 1420, a McDonnell Douglas DC9-82 (MD-82), N215AA, crashed after it overran the end of runway 4R during landing at Little Rock National Airport in Little Rock, Arkansas. Flight 1420 departed from Dallas/Fort Worth International Airport, Texas, about 2240 with 2 flight crewmembers, 4 flight attendants, and 139 passengers aboard and touched down in Little Rock at 2350:20.

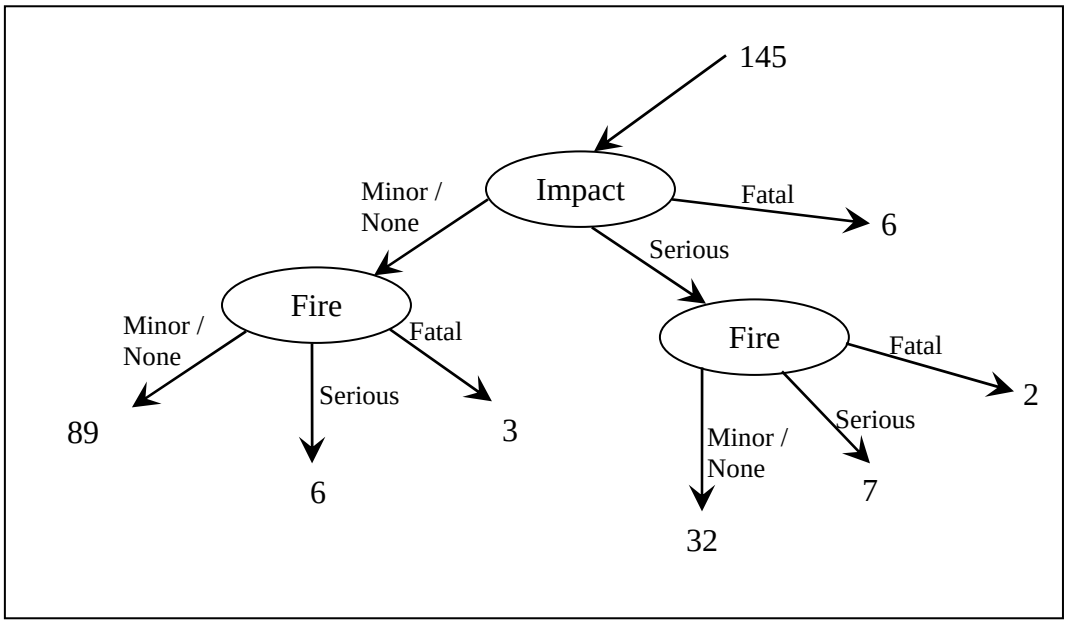
After departing the end of the runway, the airplane struck several tubes extending outward from the left edge of the instrument landing system localizer array, located 411 feet beyond the end of the runway; passed through a chain link security fence and over a rock embankment to a flood plain, located approximately 15 feet below the runway elevation; and collided with the structure supporting the runway 22L approach lighting system.

Occupant Injuries & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	145	11	45	89

1 of the flight-crew and 10 passengers were *Fatally Injured*. 1 flight-crew, 3 cabin-crew and 41 passengers were *Seriously Injured*. 1 cabin-crew and 64 passengers suffered minor injuries. Twenty-four passengers received no injury.

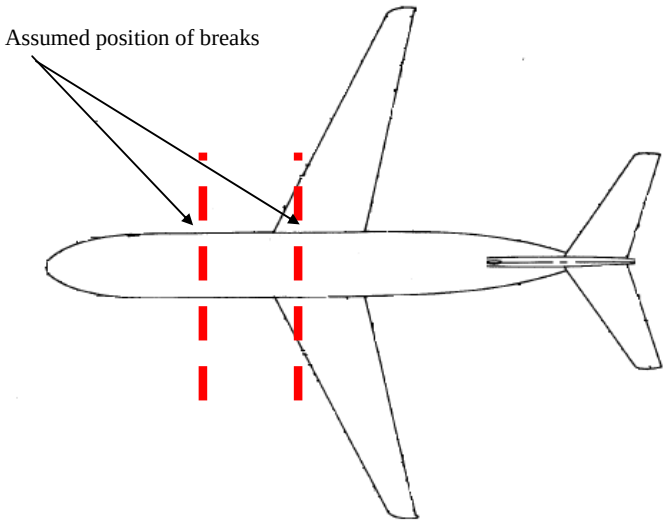
The survivability chain was determined using information from the NTSB Occupant *Injuries* Data.



Fuselage Breaks & Ruptures

The fuselage had separated into three main sections (forward, center, and aft).

It could be inferred from the information on passenger evacuations that the two fuselage separations occurred at row 12 and forward of row 19.



Occupant Egress & Fire Entry

The forward entrance (1L) and forward galley (1R) doors could not be used because of structural deformation of the fuselage. All four overwing emergency exits were opened by passengers from inside the cabin. The (2L) door could not be used because of impact damage. The flight attendant and passengers jumped on the tail cone and created a gap between the fuselage and the tail cone that 12 people used to escape.

Passengers that were forward of the fuselage separation at row 18 escaped through a large hole on the left side of the first- class section and through a separation in the fuselage at row 12. One passenger reportedly exited the airplane at the *Fuselage Break* aft of row 17 on the right side. Two passengers exited the airplane through the fuselage separation directly forward of row 19. The *Fuselage Break*s assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.

Accident Database Reference	Location		Aircraft
20001031B	CHIANG KAI-SHEK AP, TAIWAN		B747-412B
Date	**Operator**		**Registration**
31-OCT-2000	SINGAPORE AIRLINES		9V-SPK
Engine Location	***Fuselage Break***	**Number of Breaks**	***Fuselage Break* Category**
WING	Yes	1	Major Breaks

Résumé of Accident

On the night of 31 October 2000, Singapore Airlines Flight SQ 006, Boeing 747-412, 9V-SPK, was on a scheduled passenger flight, from Taipei to Los Angeles with 3 pilots, 17 cabin-crew and 159 passengers. In inclement weather, believing that they were on the correct runway, the crew of SQ 006 mistakenly taxied into and commenced their take-off on a runway (Runway 05R) at Chiang Kai-shek (CKS) Airport, which was adjacent and parallel to the runway on which they intended to take off (Runway 05L). Just over one kilometre along Runway 05R, and out of sight of the crew at the position from which they commenced their take-off, a portion had been closed due to works in progress. During its take-off run, SQ 006 collided with heavy construction equipment on the closed Runway 05R. The aircraft broke into two sections and was subsequently destroyed by the post crash fire.

Occupant *Injuries* & Survivability Chain

	Total Occupants	Occupant *Fatal*ities	Occupant *Serious Injuries*	Minor / No Injures
Number	179	83	39	57

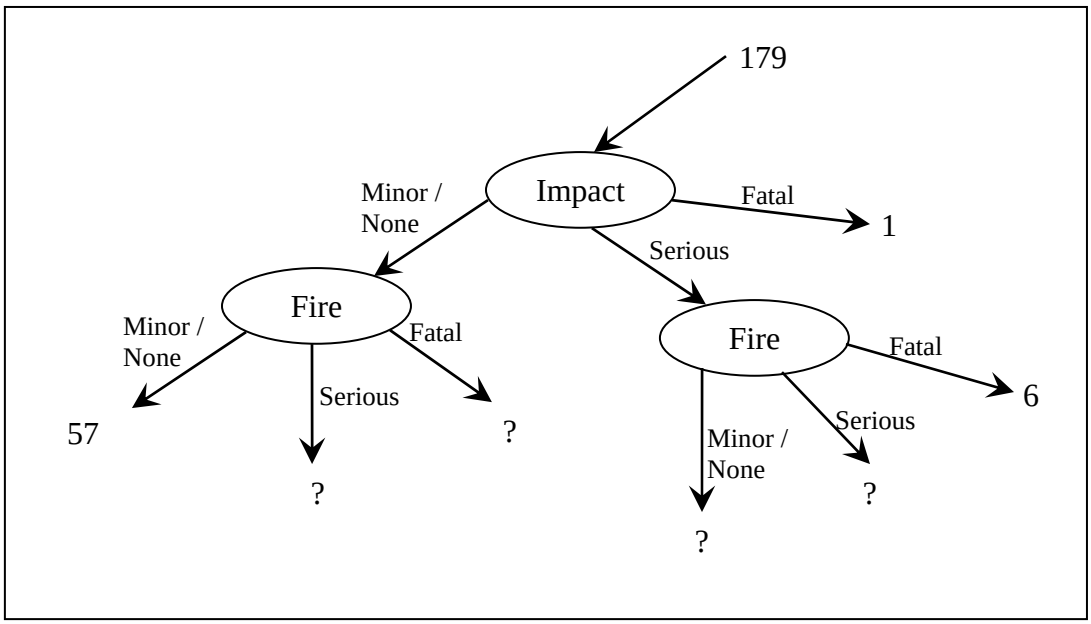
Of the three flight crewmembers, 17 cabin crewmembers and 159 passengers aboard SQ 006, 4 cabin crewmembers and 79 passengers were *Fatally Injured*.

4 cabin crewmembers and 35 passengers were *Seriously Injured*.

1 flight crewmember, 9 cabin crewmembers, and 22 passengers received minor injuries.

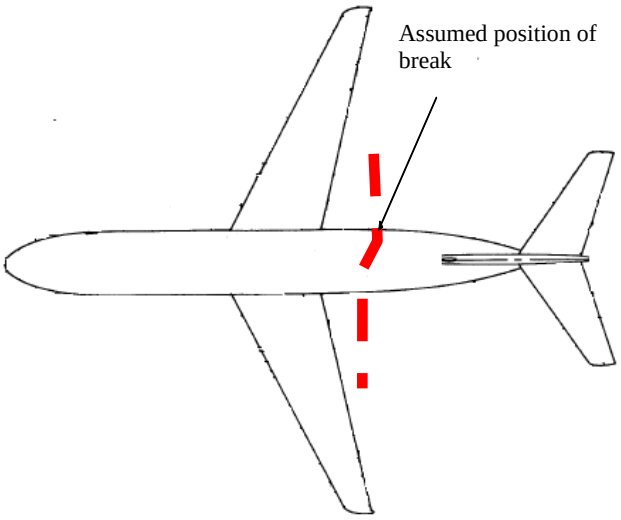
Only seven post-mortem autopsies were conducted, all of which were on passengers. There were no records of the locations of the bodies.

There is insufficient information available to develop completely the survivability chain.



Fuselage Breaks & Ruptures

The aircraft broke into two main sections about fuselage body Station 1560. The aft fuselage containing passenger seat Rows 49 through 64 had separated from the remainder of the fuselage and was generally intact.]



Occupant Egress & Fire Entry

The flight crew and cabin crew directed passengers out of the aircraft through the useable exits and the severed sections of the fuselage.

The evacuation was difficult for the following reasons: intense fire, billowing smoke, heat, fumes, difficulty in breathing, limited visibility, disorientation of survivors, strong winds, obstructions from displaced cabin/galley fittings and equipment, dislodged cabin baggage, aft fuselage section on its side, and some emergency exits could not be used.

Post accident inspection of slides at door 1 Left and door 2 Left indicated that, before these two slides could inflate fully, they were damaged by fire. As a result the slides did not function correctly, and some survivors were injured when they evacuated. Other survivors had to jump from the exits because the slides were unusable.

The *Fuselage Break* assisted occupants in the evacuation of the aircraft.

The aircraft was destroyed by fire and it is likely that the *Fuselage Break*s provided an entry route into the cabin for the fire. However, this cannot be confirmed from the information contained in the accident report.