

ACCIDENT REF: 19890108A

Date:	08-Jan-1989	Flight Phase:	Climb
Aircraft:	B737	Location:	Kegworth

DESCRIPTION OF ACCIDENT

RESUME

G-OBME left Heathrow Airport for Belfast at 1952 hrs with 8 crew and 118 passengers (including 1 infant) on board. As the aircraft was climbing through 28,300 feet, the outer panel of one blade in the fan of the No. 1 (left) engine detached. This gave rise to a series of compressor stalls in the No. 1 engine, which resulted in airframe shuddering, ingress of smoke and fumes to the flight deck, and fluctuations of the No. 1 engine parameters. Believing that the No. 2 engine had suffered damage, the crew throttled that engine back and subsequently shut it down. The shuddering caused by the surging of the No. 1 engine ceased as soon as the No. 2 engine was throttled back, which persuaded the crew that they had dealt correctly with the emergency. They then shut down the No. 2 engine. The No. 1 engine operated apparently normally after the initial period of severe vibration and during the subsequent descent.

The crew initiated a diversion to East Midlands Airport and received radar direction from air traffic control to position the aircraft for an instrument approach to land on runway 27. The approach continued normally, although with a high level of vibration from the No. 1 engine until an abrupt reduction of power followed by a fire warning occurred on this engine at a point 2.4 nm from the runway. Efforts to restart the No. 2 engine were not successful.

The aircraft initially struck a field adjacent to the eastern embankment of the M1 motorway and then suffered a second severe impact on the sloping western embankment of the motorway.

Thirty-nine passengers died in the accident and a further eight passengers died later from their injuries. Of the other 79 occupants, 74 suffered serious injury.

IMPACT

During the descent, the cabin crew carried out their emergency drills, checking that all passengers had their lap belts fastened and stowing all loose carry-on luggage in the overhead bins. Approximately 10 seconds prior to the first impact the commander warned the passengers to prepare for a crash landing. Some, but not all, of the passengers adopted a crash position prior to the aircraft striking the ground.

The aircraft suffered two distinct impacts with the ground, the first just before the eastern embankment of the M1 motorway and the second on the western edge of the northbound M1 carriageway at the base of the western embankment. The first impact was at an airspeed of 113 knots CAS, with a rate of descent of between 8.5 feet/sec and 16 feet/sec. The pitch attitude was

13° nose up. The second and major impact occurred at a speed of between 80 and 100 knots, at an angle of approximately 16° below the horizontal, and with the aircraft at a pitch attitude of between 9° and 14° nose down. The associated peak deceleration was of the order of 22 to 28 g, predominantly longitudinal.

In the second impact, the forward fuselage separated from the overwing section of fuselage and the tail section buckled over and to the right of that section of fuselage just aft of the wing.

Two major structural failures of the fuselage occurred in the impact, one slightly forward of the wing leading edge (approximately stations 500B to 500D) and one aft of the trailing edge (approximately stations 727G to 827). These failures left the structure in three principal sections. In addition, all three landing gear legs and both engine supports failed without rupturing the fuel tanks.

A total of 21 of the 52 triple seats remained fully attached to the cabin floor: 14 of these were in the overwing area and 7 in the aft fuselage.

During the impact the fuselage broke into three main sections with four distinct areas of damage: the area forward of the wing (rows 1-9) where the floor structure was completely disrupted and all the seats became detached; the centre section (rows 10-17) where the majority of the seats remained attached to the floor; and the area behind the wing (rows 18-23L/24R) where the floor failed and the fuselage was disrupted, both circumferentially and from above, by the overturning tail section in which seat rows 24L/25R-27 remained attached.

All five attendant seats had been occupied at ground impact. The aft attendant seats (one double seat, one single) remained intact, with some downwards distortion of the seat pan of the aft double seat. However, the aft/left toilet module, to which this double seat was attached, had partially separated from the airframe. This had allowed the toilet aft bulkhead, with this double seat, to rotate through approximately 90° into the centre aisle.

All the overhead stowage bins were recovered from the wreckage and their respective cabin positions determined. Photographs taken during the rescue operation on the night of the accident did not show any of the bins in the forward and centre sections still to be attached at their fuselage attachments apart from the forward bin on the right-hand side (1R), which was partially detached. Interview evidence with rescuers indicated that this had been caused by the aircraft impact and not by rescue personnel. The bins in the remaining sections (areas III and IV) were also found detached and although there was no photographic evidence to show when this had occurred, the evidence from the rescuers again indicated that these detachments had been caused by the impact.

Some of the doors on the overhead stowage bins opened during the last seconds of flight. There was no evidence to show whether or not either the bins or their contents had been in forcible contact with any of the aircraft occupants.

The initial injuries that occurred were caused by the impact of a seat occupant into the back of the seat in front. In those areas where the floor structure, and hence the seat attachment, failed, the initial injury mechanism was compounded by secondary impacts of the seat occupant with loose seats and passengers and other parts of damaged aircraft structure.

Virtually all the passengers sitting in seat rows 10-17 and 25-27 suffered from severe bruising under the lap belt and five passengers sustained iliac fractures as a direct result of lap belt loading.

In addition to the results of direct loading of the pelvis by the lap belt the following generalised injury mechanism occurred. As the seat occupant moved forward, the knees contacted the back of the seat in front, loading the knee and the upper leg. This transmitted load back into the pelvis causing a variety of injuries including dislocation of the hip, fracture of the hip joint, and fracture of the pelvis. Fractures of the femur occurred as a result of the combination of axial and bending loads induced by the front cross bar of the seat as well as contact with the back of the seat in front. Depending upon the position of the lower leg, damage was caused to the knee as the upper leg moved forwards in relation to the lower leg. In a similar manner, where the foot was fixed by contact with aircraft or seat structure, the foot and ankle also sustained injury as the lower leg moved forward in relation to the foot and ankle, causing a combination of torsional and posterior dislocation injuries.

Gross lower leg fractures occurred where the seats failed and the lower legs were trapped and subjected to secondary impacts.

Head and chest injury occurred even where passengers had adopted the crash position and some passengers who rested their heads on their forearms prior to the impact fractured their forearms as a consequence. Some other passengers braced themselves by placing their extended arms onto the back of the seat in front, and some of them suffered fractured upper arms and shoulder joints in consequence.

The child seated on his mother's lap in seat 3F sustained major head and limb injuries as a result of the accident and the mother sustained major injuries, some of which were suggestive of having been caused by forcible flexion of the mother over the child during the impact.

FIRE

There were two separate areas on the No. 1 engine which had been affected by fire and these were the only areas where there was evidence of fire on the aircraft. The most seriously affected zone was on the fan case within the forward engine cowling, and the less serious zone was on the rear edge of the reverser duct, on the outboard side.

Ground witness reports indicated that immediately after the ground impact of the aircraft the only fire visible was relatively localised and centred around the forward end of the No 1 engine, but that after a short time the fire suddenly grew in intensity. Upon the arrival of the airport fire

service, the fire was quickly extinguished using a combination of aqueous film forming foam (AFFF) and fluoroprotein foams.

EVACUATION

Due to the extent of the injuries to occupants, an evacuation under the direction of the cabin crew was not carried out. Only 14 of the passengers were able to make a significant contribution to effecting their own escape.

AIRCRAFT FACTORS

The aircraft was a Boeing 737 Series 400 with four floor level exits and four overwing exits. It was configured with 156 passenger seats in a single class cabin with a total of 26 rows of pairs of triple seats. The seats were of a type designated as the Model 4001 tourist seat by the manufacturer, Weber Aircraft, Inc. The seat rows were numbered conventionally from 1 to 27 (no row 13) from the front to the back of the aircraft. The seat pitch ranged from a maximum of 38 inches, for the two-seat rows (12 and 14) next to the overwing emergency exits to a minimum of 30 inches for row 27L. The remaining seat pitches were either 31 or 32 inches.

The upholstered seat backs are pivoted at the lower end to breakover forward to ease emergency evacuation and to recline for passenger comfort. The exceptions in the G-OBME configuration were the seats adjacent to the overwing exits, rows 11, 12, and 14, where the seat backs were fixed. The detachable flotation cushions are supported on an alloy sheet suspended between the front and rear horizontal spars: these spars are mounted on a welded lower structure of hollow steel members of square section. Longitudinal locking to the seat tracks is at the rear attachments only and both the front and rear leg attachments are designed to allow for some angular deformation of the seat tracks in an impact. At the rear leg this flexibility is achieved by incorporating a pivot and at the forward leg a U-strap at the track attachment. The intent of the U-strap is principally to make the seat structure compliant with floor deformations and also to provide some load attenuation through the buckling mechanism.

The Model 4001 seats were approved by the FAA in December 1985 as meeting the performance standards of TSO-C39a and were approved by the CAA in February 1986 as meeting the more stringent requirements of BCAR Sections D3-8 and D4-4.

In addition to meeting the static loading criteria required by the above performance standards, the Model 4001 seat was tested at the FAA's Civil Aeromedical Institute (CAMI) in 1987 to the standards of FAR Part 25 Amendment 25-64, (paragraph 1.17.11). Although these Amendment 25-64 (dynamic loading criteria) tests were for development rather than certification, the results indicated that the seat would probably meet the certification criteria; although the testing was done prior to the issue of the requirements for seat deformation. Longitudinal impact tests on the front legs had shown buckling loads of around 4800 lb. for the U-strap at the base of the front leg; load cell measurements on the test leg showed, for the 16-g/44-feet-per-second (fps) decelerations, vertical loads in excess of this (4800 lb.) load.

ENVIRONMENTAL CONDITIONS

The actual weather at East Midlands Airport, reported to the pilot by ATC at 2011 hrs was wind velocity 250°/10 kts; visibility 10 km; cloud 7 oktas, base 1,700 feet; temperature +9°C; QNH 1018.

INJURIES TO OCCUPANTS

There were 8 crew and 118 passengers (including one infant) on board. Thirty-nine passengers died at the scene of the accident, 8 more died in hospital at times up to 22 days later. Of the other 79 occupants, 74 suffered serious injury.

The most severe injuries occurred in rows 6-8 in the region of the forward fuselage break, with serious injuries occurring in the whole of the area forward of the wing where the floor structure failed. Further serious and fatal injuries occurred in the region of the failure of the rear fuselage and floor and in the area where the tail structure had swung over, and into, the rear fuselage. The least injuries occurred in the rear of the aircraft.

All but 1 of the 39 fatalities at the scene of the accident sustained head injuries of varying severity. Forty-three nonsurvivors had facial injuries. Seventy-four of the 83 patients removed to the hospital had suffered head or facial injury. Thirty-one cases of facial injury required treatment. Seventeen patients showed clinical evidence of a strike to the head from behind. Forty-three of the patients at the hospital had suffered an episode of impairment of consciousness. Five of the 83 patients removed to the hospital had suffered severe head injuries.

Twenty-one nonsurvivors and 6 survivors sustained injuries to neck structure.

Nineteen fatalities and 28 survivors sustained fractures and dislocations of the upper limbs and shoulders.

Some degree of generally major chest injury was found in all but one of the fatalities. Eighteen of the 79 survivors also suffered major chest trauma.

Thirty-six fatalities suffered abdominal trauma compared to only two of the survivors who suffered a major abdominal injury.

Twenty-two survivors and 13 nonsurvivors sustained pelvic injuries. A considerable number of lower limb injuries also occurred. Twenty-two survivors and 13 nonsurvivors sustained fractured femurs, 18 survivors and 5 nonsurvivors sustained knee injuries, 31 survivors and 38 nonsurvivors sustained lower leg fractures, 26 survivors and 24 nonsurvivors sustained fractures/dislocations of the ankle, and 22 survivors and 6 nonsurvivors sustained fractures of the bones of the feet. Many of those affected suffered fractures of more than one area. Only 18 surviving passengers and 6 nonsurviving passengers had no injury to the lower limbs and pelvis.

One young child was secured on his mother's knee using a supplementary lap belt (seat 3F). Both the mother and child were injured during the impact.

ACCIDENT SCENARIOS AND SURVIVABILITY CHAINS

This accident is divided into nine separate scenarios, as shown in figure A-4.

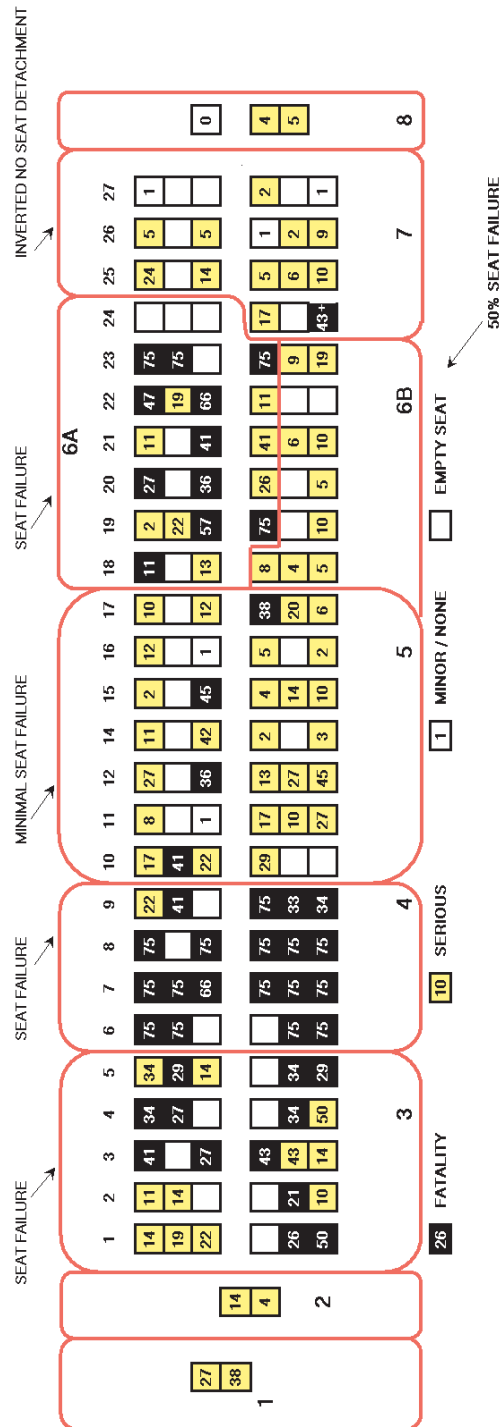
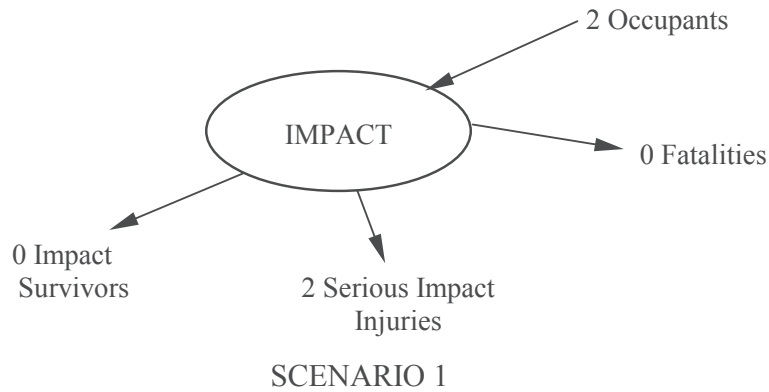


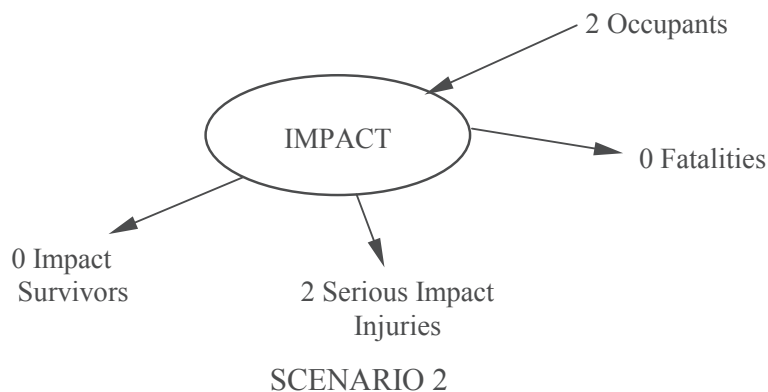
FIGURE A-4. INJURIES SEVERITY SCORES (ISS) AND SCENARIOS

All fatalities were because of impact trauma. The Accident may be divided into nine scenarios as follows:

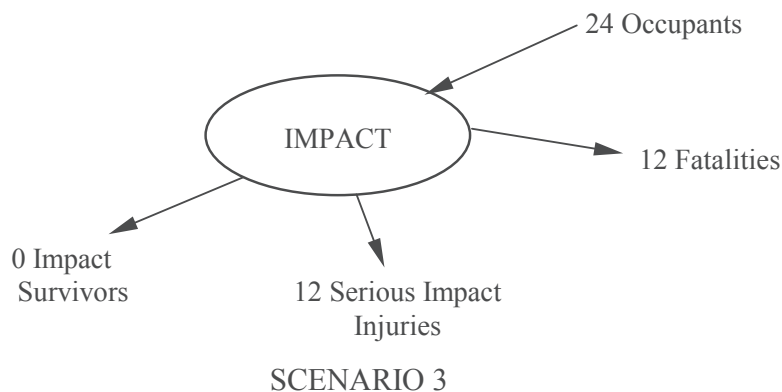
Scenario 1 represents the flight deck area containing two-flight crew, both of whom were seriously injured. The survivability chain for this area is:



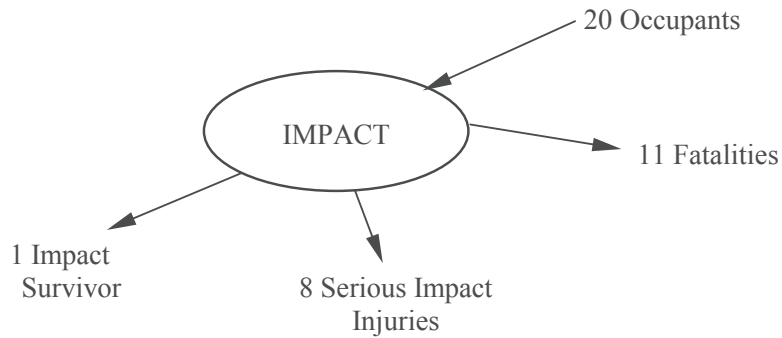
Scenario 2 represents that area of the cabin in which the two forward flight attendants were located, both of whom were seriously injured. The survivability chain for this area is:



Scenario 3 represents that portion of the passenger cabin between seat rows 1 and 5 inclusive. There were 24 passengers in this area, 12 sustained fatal injuries and 12 were seriously injured. The survivability chain for this area is:

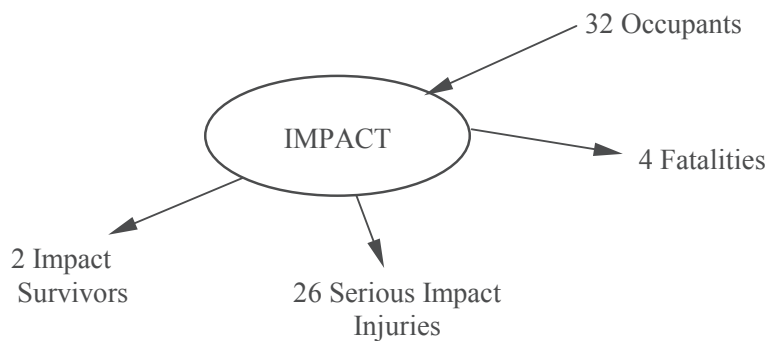


Scenario 4 represents that portion of the passenger cabin between seat rows 6 and 9 inclusive. There were 20 occupants in this area, 11 sustained fatal injuries, and 8 were seriously injured. The survivability chain for this area is:



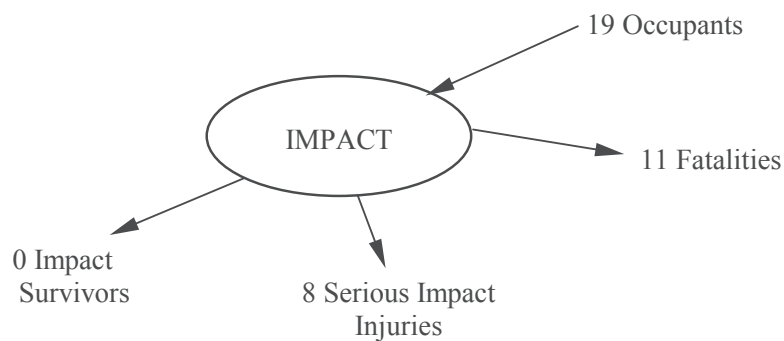
SCENARIO 4

Scenario 5 represents that portion of the passenger cabin between seat rows 10 and 17 inclusive. There were 32 occupants in this area, 4 sustained fatal injuries, and 26 were seriously injured. The survivability chain for this area is:



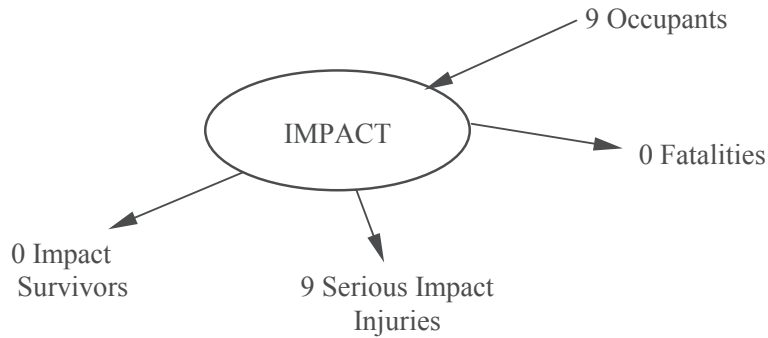
SCENARIO 5

Scenario 6A represents that portion of the passenger cabin between seat rows 18 to 24 inclusive on the starboard side of the aircraft and the aisle seats on the port side in rows 19 to 23 inclusive. There were 19 occupants in this area, 11 sustained fatal injuries, and eight were seriously injured. The survivability chain for this area is:



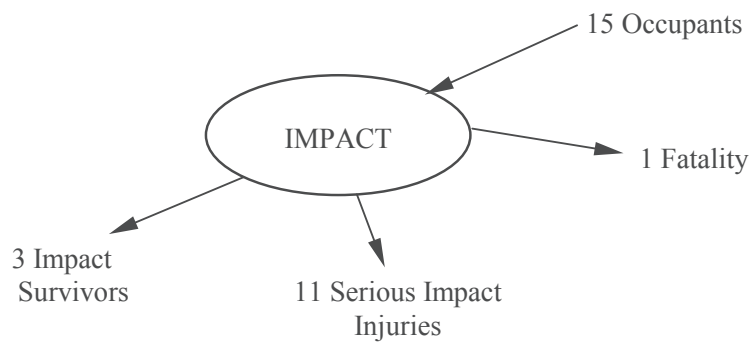
SCENARIO 6A

Scenario 6B represents that portion of the passenger cabin containing the port triple seat in row 18 and the port centre and window seats in rows 18 to 23 inclusive. There were nine occupants in this area all of who were seriously injured. The survivability chain for this area is:



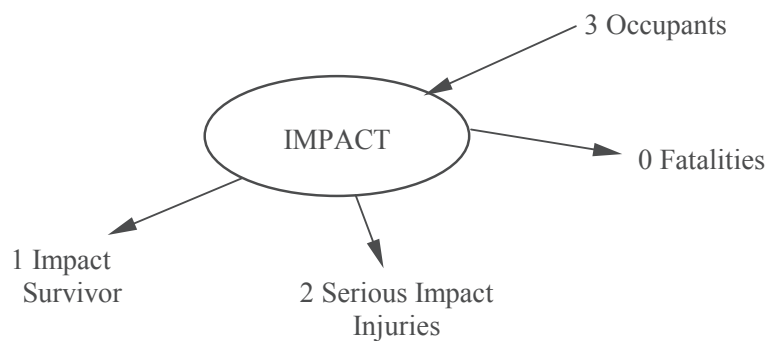
SCENARIO 6B

Scenario 7 represents that portion of the passenger cabin from seat rows 25 to 27 on the starboard side and seat rows 24 to 27 on the port side. There were 15 passengers in this area, 1 of whom sustained fatal injuries, and 11 were seriously injured. The survivability chain for this area is:



SCENARIO 7

Scenario 8 represents that area of the cabin in which the three aft flight attendants were located, two of who were seriously injured and one survived uninjured. The survivability chain for this area is:



SCENARIO 8

EFFECT OF INTRODUCING 16-g SEATS

The seats installed in the aircraft were tested in 1987 at the FAA Civil Aeromedical Institute (CAMI) to the standard of FAR Part 25 Amendment 25-64, which includes the 16-g dynamic load criteria. Although the tests were for development rather than certification, the results indicated that the seat would probably meet the certification criteria i.e., 16-g compatible seats. However, it is believed that it is unlikely that the seats would have been compatible with the required standard of HIC. The assessment of benefit is based on the assumption that there might be some reduction in head and facial injuries sustained by the passengers had the aircraft been configured with seats that were fully compliant with the 16-g criteria.

Scenarios 1, 2, 3, 4, 6B, 7, and 8

It is assessed that there would be no reduction in the extent of injuries sustained in these scenarios had the aircraft been configured with seats meeting all of the 16-g criteria.

Scenario 5

Based on the accident report data, it is assumed that all the seats in this area remained attached. If the seats had met the full HIC criteria, head, neck, and face injuries may have been substantially reduced. It is assumed that there would be no reduction in the extent of the injuries in seat row 10 due to the degree of disruption immediately in front of the occupants in this area. On this basis, the best improvement that could be expected is that there would be one fatality and three serious injuries in this scenario.

The worst situation is that there would be no improvement in the extent of the injuries sustained due to the severity of the impact. The median assessment is taken as the average of these two extremes.

The following summarises the overall assessment of the impact injuries that might result had the seats in this scenario been fully compliant with the 16-g criteria:

	Minor or No Injuries	Serious Injuries	Fatal Injuries
High	2	26	4
Median	15	15	2
Low	28	3	1

Scenario 6A

Based on the accident report data, it is assumed that seven triple seats in this area remained attached. If the seats had met the full HIC criteria, head, neck, and face injuries may have been substantially reduced. It is assumed that there would be no reduction in the extent of the injuries in seat row 18 due to the degree of disruption immediately in front of the occupants in this area.

It is further assumed that there would be no reduction in the extent of injuries due to the disruption in the starboard seats of rows 22 to 24 inclusive. On this basis, the best improvement that could be expected is that there would be five fatalities in this scenario. It is also feasible that all of the serious injuries, other than those in the four starboard triple-seats of rows 18, 22, 23, and 24, may have sustained minor or no injuries.

The worst situation is that there would be no improvement in the extent of the injuries sustained due to the severity of the impact.

The median assessment is taken as the average of these two extremes.

The following summarises the overall assessment of the impact injuries that might result had the seats in this scenario been fully compliant with the 16-g criteria:

	Minor or No Injuries	Serious Injuries	Fatal Injuries
High	0	8	11
Median	3	8	8
Low	6	8	5