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ANALYSIS OF STRUCTURAL FACTORS INFLUENCING THE SURVIVABILITY OF OCCUPANTS IN AEROPLANE ACCIDENTS

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ANALYSIS OF STRUCTURAL FACTORS INFLUENCING THE SURVIVABILITY OF OCCUPANTS IN AEROPLANE ACCIDENTS

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1 INTRODUCTION

In January 1995 R.G.W. Cherry & Associates Limited completed a research programme for the Commission of the European Communities to analyse the factors influencing the survivability of passengers in aircraft accidents. As part of this task an accident database of survivable accidents was developed containing information on over 500 accidents on in-service airliners. Subsequent to this, further work has been carried out on behalf of the UK CAA to analyse the structural factors significant to cabin safety. This report describes the methods employed in carrying out this analysis and the conclusions reached in relation to the potential safety benefit from improvements to structural survivability factors.

2 OBJECTIVES

The Objectives of the Study were to utilise the work carried out for the European Commission, and carry out additional research to:

(a) assess the range of improvement in number of fatalities *and* injuries likely to result from developments in the structural aspects of cabin safety

(b) make observations on any mechanisms of failure that might be worthy of future research into structural improvements to enhance occupant survival.

3 ANALYSIS OF SURVIVABILITY FACTORS

3.1 Method

3.1.1 *Selection of Accidents*

The analysis was carried out on the 42 accidents listed in Appendix 1. Each accident is uniquely identified by a reference known as the RIM number. They were selected to form a representative sample of all survivable accidents. The following criteria were used:

- the proportion of accidents by type (e.g. cabin fire related, ditching etc.).
- the fatality rate distribution. (Fatality Rate is defined as the proportion of occupants sustaining fatal injuries).
- the average fatality rate.

The comparisons are as follows:

(a) From an analysis of the EEC accident database it is assessed that survivable accidents may be sub-divided as follows:

42% fire related (cabin/total)
12% ditching related (planned or unplanned)
46% neither fire nor ditching related

For the 42 accidents analysed the divisions by type are:

49% fire related
12% ditching related
39% neither fire nor ditching related

(b) Figure 1 shows the fatality rate distributions, for the accidents analysed in-depth, and all accidents on the database. It may be seen that there is a reasonable 'fit' of the accidents selected compared with the ideal.

(c) The average fatality rate of the accidents analysed was approximately .38 compared with a fatality rate of between .3 and .4 experienced over the past decade for all accidents on the database.

It is considered that the accidents analysed represent a reasonably representative sample of all survivable accidents even though there are slightly more fire related accidents than an ideal sample would contain. The reduced proportion of accidents involving neither fire nor ditching is not considered to significantly effect the results of the analysis especially when it is considered that most of the fire and ditching related accidents involve impact injuries (35 of the 42 accidents were impact related). The availability of detailed information on accidents having the correct characteristics was the limiting factor in improving on the selection of representative accidents.

3.1.2 *Accident Scenarios*

The severity of impact in an accident can vary markedly throughout the aircraft. Experience has shown that considering occupant injuries on a 'whole' aircraft basis can be misleading when assessing the effects of survivability factors. It is therefore necessary to divide the aircraft into 'Scenarios'.

A Scenario is defined as:

'That volume of the aircraft in which the occupants are subjected to a similar level of threat.'

A similar level of threat need not necessarily result in the same level of injury to occupants. The extent of injury sustained can vary with numerous factors including age, gender, adoption of the brace position etc. Furthermore, the threat to occupants can vary over relatively small distances. For example, a passenger may receive fatal injuries as a result of being impacted by flying debris, and a person in an adjacent seat may survive uninjured. Dividing accidents into scenarios provides a more meaningful basis on which to analyse accidents than considering the whole aircraft due to the marked variation in survival potential with occupant location.

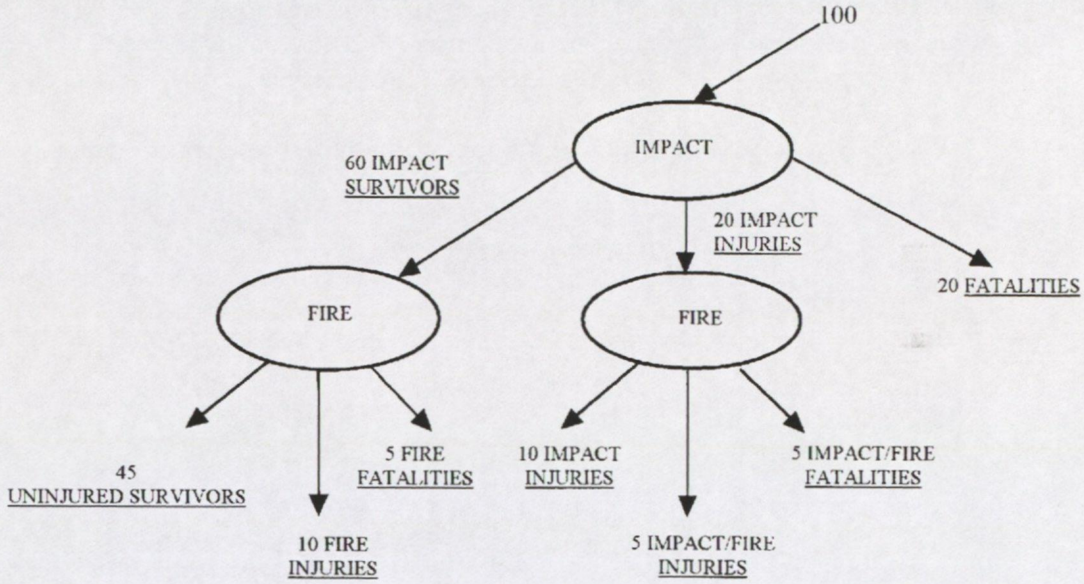
Figure 2 shows an example of an actual aircraft accident divided into Scenarios. It may be seen that survivability in, for example, Scenarios 3 and 6 is markedly different.

3.1.3 *Modelling*

A mathematical model, known as a Survivability Chain, has been developed to take account of improvements made to survivability factors. Avoidance of impact injuries is likely to result in enhanced occupant mobility with a consequential improvement in avoidance of secondary hazards due to fire or ditching. The Survivability Chain concept caters for this by treating impact injured survivors differently from uninjured impact survivors.

The following example illustrates the way in which the model may be used to determine the overall effects of improvements to survivability factors:

SURVIVABILITY CHAIN

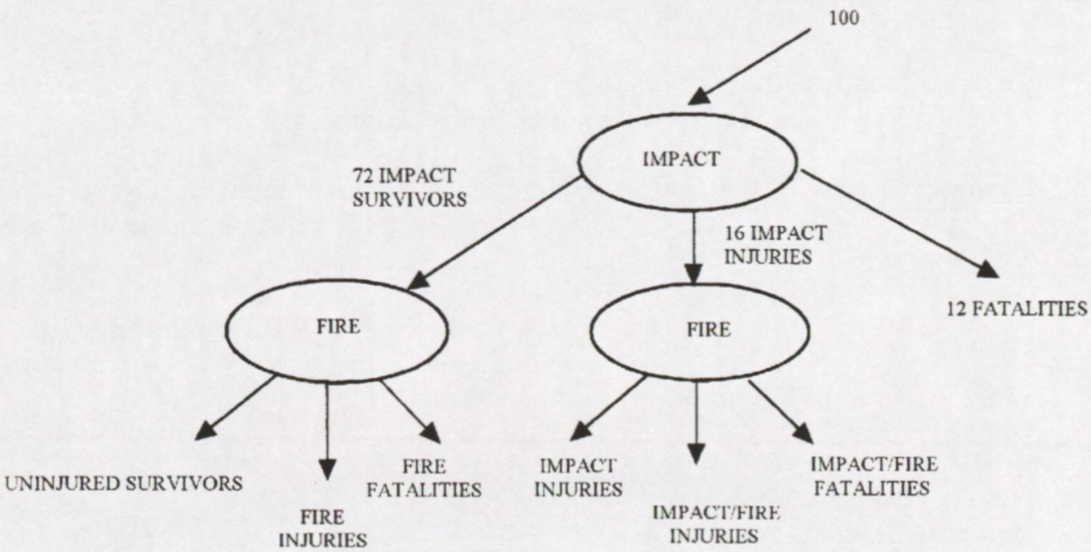


There are therefore:

- 45 uninjured survivors.
- 25 injuries, 10 as a result of the impact, 10 as a result of the fire, and 5 seriously injured as a result of the impact and fire.
- 30 fatalities, 20 as a result of the impact, and 10 as a result of the fire (5 of whom sustained non-fatal injuries from the impact).

If improvements were made to an impact-related survivability factor, such that there were only 12 fatalities and 16 seriously injured of the 100 occupants, the survivability chain then becomes:

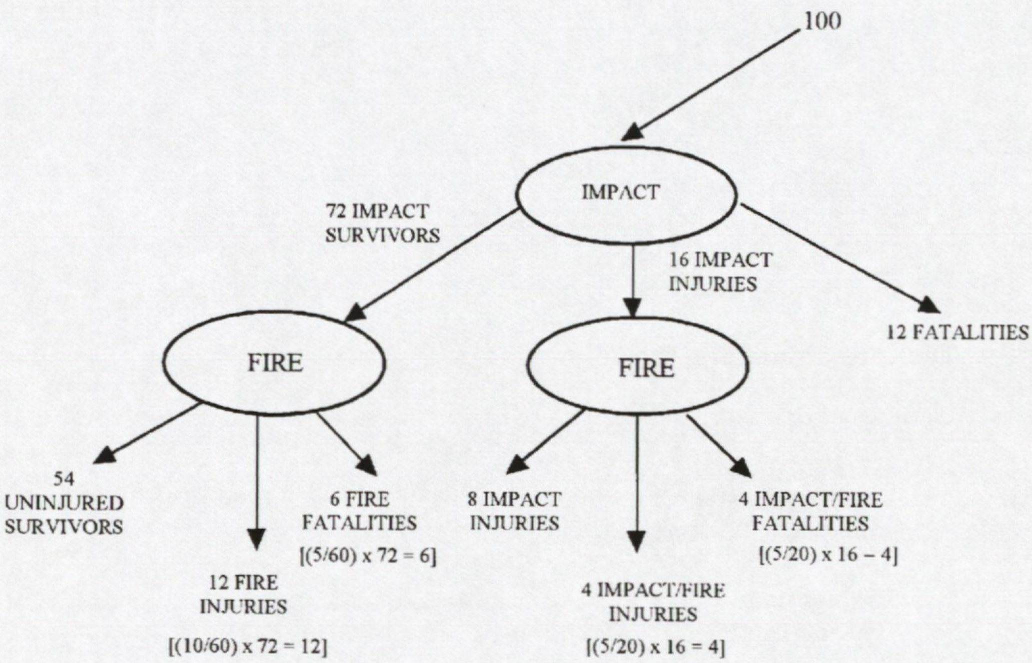
SURVIVABILITY CHAIN



It is known from the accident that 5⁄60ths of those that survive the impact uninjured and 5⁄20ths of those that sustain injuries from the impact subsequently succumb to death as a result of the fire. Furthermore, 10⁄60ths of those that survive the impact uninjured are seriously injured from fire and 5⁄20ths of those that sustain injuries from the impact also sustain injuries as a result of the fire.

On this basis an assessment of the numbers of fatalities and injuries may be made as follows:

SURVIVABILITY CHAIN



Hence the improvement to the impact related survivability factor results in:

- 54 uninjured survivors.
- 24 injuries, 8 as a result of the impact, 12 as a result of the fire, and 4 seriously injured as a result of the impact and fire.
- 22 fatalities, 12 as a result of the impact, and 10 as a result of the fire (4 of whom sustained non-fatal injuries from the impact).

It should be noted that the survivability factor improvement resulted in a reduction in *impact* fatalities of 8 and *impact* injuries of four. However the overall situation is as follows:

	Survivors	*Injuries*	*Fatalities*
Prior to survivability factor improvement:	45	25	30
Post survivability factor improvement:	54	24	22

Statistical Modelling

The software has been developed to use this model in a mathematical representation of an accident using Monte Carlo Simulations. This enables an assessment to be made of the change in numbers of survivors, injuries and fatalities resulting from predictions of the range of improvements that may be possible from changes to a survivability factor.

For each scenario a numerical assessment is made of the impact on number of fatalities and injuries as a result of changes to each of the relevant Survivability Factors. The assessment results in a prediction of the highest, mean, and lowest number of fatalities and injuries that could reasonably be expected from each of the changes.

From the example described previously the 'best' (or median) assessment was that improvements to the survivability factor relating to impact deaths resulted in an improvement in the number of fatalities from 20 to12, and the impact injuries reduced from 20 to 16. When making this determination an assessment would also be made of the 'maximum' and 'minimum' number of fatalities and injuries that are likely to result from a change in the Survivability Factor.

It is then assumed that there can be 100% confidence that the fatalities and injuries will lie in the range from the maximum to the minimum. The software makes random selections over the range 0 to 100 to arrive at a particular number of fatalities and injuries.

From this a re-evaluation of the number of survivors may be made using the Survivability Chain generated for the accident scenario. This is then compared with the actual number of survivors of the accident. The iterations are then carried out many times, for each Survivability Factor to generate a distribution. From this distribution the 2½, 50 and 97½ percentile values are selected to represent a range of the likely improvement in fatality rate for each Survivability Factor.

This simulation process is similar to that used on the EEC project and is described in greater detail in Reference 1.

Whilst it is recognised that the models are not perfect representations of an accident nor are the statistical assessments totally accurate they will provide a better assessment of the likely impact of improvements to Survivability Factors than would otherwise be derived from a simple estimate of the resultant change in number of survivors.

3.1.4 *Process*

The analysis of accidents, carried out in this project, identifies for each scenario the Survivability Factors that could have an effect on the number of fatalities and injuries. The Survivability Factors considered are shown in Table 1 and are similar to those considered in the EEC project.

In most cases the factors will have a positive effect in reducing the number of fatalities. However in some instances, improvements intended to increase survivability for a particular accident circumstance might have an adverse effect in other accidents.

This assessment to the improvements in fatality rate was carried out for the accidents on the basis of the aircraft standard at the time of the accident and entered onto the customised computer database.

Each accident was then re-analysed taking into account the improvements that might have been made to numbers of fatalities and injuries if the aircraft had been configured to the latest requirements. The effects on survivability that might be realised from improvements to the survivability factors listed in Table 1 was then reassessed. The information, relating to aircraft configured to the latest requirements, has been entered onto a separate computer database. The standard of requirements used to reassess the accidents were those contained in JAR OPS 1 and the proposed JAR 26.

3.2 Results

3.2.1 *Based on the aircraft standard at the time of the accident*

Figures 3 & 4 show the impact on Fatality Rate and Total Injury Rate (Fatal and Serious) respectively, resulting from improvements in Survivability Factor as assessed for the 42 accidents listed in Appendix 1. The survivability factors are ranked on the horizontal axis in descending order of the median prediction of their impact on fatality rate. The high, median and low prediction of effect on fatality rate is based on 1000 iterations of all accidents on the database using the model described in Section 3.1. These predictions assume that the aircraft was configured to the standard at the time of the accident and take no account of the improvements offered by the introduction of later requirements.

3.2.2 *Based on an aircraft standard applicable to later requirements*

Figures 5 & 6 show the effect on Fatality Rate and Total Injury Rate (Fatal and Serious) respectively, resulting from improvements in Survivability Factors based on an assessment of the improvements that would have been made if the aircraft were configured to the standards appropriate to JAR OPS 1 and the proposed JAR 26. The survivability factors are ranked on the horizontal axis in descending order of the median prediction of their impact on fatality rate. The high, median and low prediction of impact on fatality rate is based on 2000 iterations of all accidents on the database using the model described in Section 3.1.

The equivalent ranking of Survivability Factors, in terms of fatality or injury rate improvement for an aircraft configured to the standards of the latest requirements, based on the simpler model used in the work undertaken for the EEC (reference 1) is shown in Figure 7.

The significant differences between the work carried out for this project and the previous EEC study are as follows:

(a) The model used for this project:

- takes into account the improved ability of occupants to avoid the hazards of death by fire or drowning afforded by improvements in impact related Survivability Factors.

- predicts the change in Injury Rate (as well as Fatality Rate)

(b) The accidents contained in Appendix 1 are more representative of the population of survivable accidents.

(c) The accidents were analysed in greater depth for this project resulting in accidents being considered in a greater number of Scenarios. This, combined with slightly more accidents being analysed (42 as opposed to 39), has resulted in the number of line entries in the Survivability Factors database increasing to 469 (c.f. 265 on the EEC database).

This study has resulted in the following issues relating to the ranking of Survivability Factors in terms of fatality rate improvement:

(1) S29, Cabin Water Sprays, and S03, Seat/Floor Strength, are still assessed to be the two most significant Survivability Factors. Although their order in the ranking has been interposed in this project compared with the EEC project this is not considered to be significant when the confidence intervals are taken into account. For both studies the assessed median fatality rate improvement is similar.

	CAA project	*EEC project*
S29	.021	.017
S03	.019	.020

The issues relating to seat floor strength are discussed in greater depth in Section 4.5 of this report.

(2) The other more significant structurally related Survivability Factors S01, Rearward Facing Seats, and S02 Occupant Restraint exhibit a much higher improvement in fatality rate than was suggested in the EEC project:

	CAA project	*EEC project*
S01	.019	.009
S02	.013	.009

It was expected that the improved model used in this project would show greater benefits for structurally related survivability factors, for the reasons suggested earlier in this report, however there is a relatively large 95 percentile range, especially for S01.

(3) For the same reasons the more significant fire related Survivability Factors S14, Toxicity of Materials, and S15 Flammability of Materials, have shown less of an improvement in fatality rate from the current model than was exhibited in the earlier model.

(4) S18, Emergency and Evacuation Drills, and S26 Exit Availability (No. of Exits) remain relatively unchanged from the EEC assessment, both yielding mean fatality rate improvements in the order of .011.

(5) S24, Burnthrough of Cabin and S09, Exit Operability, both show relatively significant improvements in fatality rate.

(6) Whilst it is considered that for many of the remainder of the Survivability Factors they do not rank as high priority issues, cost benefit analysis may render them as being worthy of further consideration.

(7) The project, and the EEC Study, suggested that S11, Number of Flight Attendants, would provide little improvement in fatality rate, with the possibility of an increase in the number of occupant fatalities (due to the possibility of the additional attendants sustaining fatal injuries). If the increased number of fatalities from non-survivable accidents, due to additional flight attendants being on board, is taken into account the negative effect of additional flight attendants would be even more marked. For the purposes of this analysis it was considered that the minimum number of flight attendants was increased to one in 35 passengers. For accidents in which the flight attendant/passenger ratio was already at or beyond this level no additional flight attendants were considered.

4 OBSERVATIONS ON STRUCTURAL FEATURES

4.1 Overhead Stowage Bin Detachment

Detachment of the overhead bins can result in an impediment to the evacuation of occupants as well as the obvious risk of inflicting impact trauma.

Of the 42 accidents analysed 35 involved impact with terrain or water. Of these there were 15 accidents where overhead stowage bins were not fitted, or it could not be identified from the accident reports whether the bins became detached as a result of the impact. Of the remaining 20 accidents it was assessed that 14 involved Overhead Bin detachment. Whilst in some instances the degree of fuselage rupture and cabin disintegration made bin detachment inevitable, the overall assessment is that in approximately 70% of impact related accidents where Overhead Stowage Bins are fitted, detachment occurs.

Strength of Overhead Stowage(S05) is ranked as the seventeenth most significant survivability factor in terms of occupant fatalities and thirteenth based on occupant injuries for an aircraft configured to the latest requirements (see Figures 5 & 6).

An attempt has been made to ascertain whether there is any correlation between frequency of bin detachment and number of fatalities. The 82 scenarios analysed have been classified according to the proportion of occupant fatalities. Figure 9 shows the relationship between proportion of scenarios involving overhead stowage bin detachment and fatality rate. Whilst there does seem to be some general tendency for fatality rate to increase with increasing degree of bin detachment, as suggested by the upward slope of the line of best fit, the data is inconclusive for the following reasons:

(a) there is significant variation in the data around the line of best fit.

(b) it is to be expected that as impact severity increases the number of occupants fatally injured will increase and the probability of bin detachment will increase.

There are insufficient data available, within the accident reports analysed, to be specific about the failure mechanisms involved with bin detachment. However it is feasible that some detachments were as a result of torsional or bending loads being induced into the airframe as a result of the impact rather than simply longitudinal, vertical or lateral loads.

4.2 Pre-existing damage to Structural Components

No cases of significant pre-existing damage to structural components were identified from the 42 accidents analysed. The only pre-existing damage to any component that may have been considered as relevant to the survival of occupants, was seat frame corrosion experienced in RIM 69. However it played no part in seat detachment which occurred as a result of separation from the mounting tracks caused by the lateral impact loads.

4.3 Fuel Tank Failure

Of the 42 accidents analysed, 35 of which were impact related, there were 27 involving fuel tank rupture. All were as a result of impact with terrain or water. None were identified where the deceleration loads acting on the wing/tank resulted in tank failure. For two of the impact related accidents insufficient information was available to determine whether the tanks were ruptured. Therefore approximately 82% (27/33) of the impact related accidents were identified as involving fuel tank rupture.

4.4 Door Jamming

The data, relevant to exit failure, derived from the accidents analysed is presented in Table 2. Of the 42 accidents, 7 involved door jamming and it is assessed that 2 resulted in the loss of life of a total of 13 persons.

A summary of the pertinent data relating to exit failures is as follows:

42 accidents analysed
35 accidents involving ground/water impact
78 exits attempted to be opened
19 exits failed (approximately 24%)
11 exits failed due to structural deformation/failure (approximately14%)

Instances such as galley failures obstructing exits have been included in the eleven cases of Exit Failure due to Structural Deformation/Failure. However most were directly attributable to door frame distortion. The precise loading condition resulting in door frame distortion could not be readily determined from the data contained in the accident reports.

4.5 Seat/Floor Strength

Seat/floor strength was assessed to be the second highest Survivability Factor in terms of reduction of numbers of fatalities for aircraft configured to the standards of the latest requirements (see Figure 5), and the most significant Structural Survivability Factor (see Figure 8). In terms of reduction of total number of injuries (fatal and serious) it ranked as fifth highest overall and third highest in terms of Structural Survivability Factors. However reduction in numbers of fatalities is considered to be the more significant measure.

The factor considered most pertinent to the comparatively greater reduction in number of fatalities than injuries is that retention of seats would, in most instances, not prevent injury to occupants due to lack of upper torso restraint and flailing limbs.

Figure 10 shows the relationship between proportion of scenarios involving seat failure and fatality rate. There is a general tendency for fatality rate to increase with increasing degree of seat failure, as suggested by the upward slope of the line of best fit. However, as with overhead bin detachment, it is to be expected that as impact severity increases the number of occupants fatally injured will increase and the probability of seat failure will increase.

Figure 11 shows the frequency of seat failure modes identified from the accident reports. In many instances there are insufficient data to be precise about the exact number of seats that have failed and often the precise failure mechanism can not be identified. The pie-chart labelled 'ACTUAL' shows the frequency of failure modes for the cases where it was possible to be accurate about the number of seats failed and that labelled 'ACTUAL AND ESTIMATED' where the number of failures or the failure mode was assessed. No firm conclusions may be derived from these data, since their are no predominant failure modes of significance in either data set. However it is quite likely that the predominant failure mode of any seat/floor combination will vary with:

(a) seat/floor design

(b) the loading mechanism to which it is subjected

The following extracts from some of the accidents analysed in this study are worthy of particular note – not because they are necessarily typical of seat/floor failures, but rather because they are of interest in terms of the failure mechanism:

1)	AIRCRAFT:	B737	DATE OF ACCIDENT:	8th January '89
	REGISTRATION:	G-OBME	LOCATION OF ACCIDENT:	KEGWORTH, LEICESTERSHIRE

Floor disruption was a major factor in seat detachment which in turn was a major contribution to fatal injuries.

Paragraph 2.6.6. of the A.A.I.B. Accident Report states:

'The transverse floor beams then failed under the longitudinal and torsional crash loads, for which they were not designed.'

'... passenger seats remained in position in the areas in which the floor structure had survived intact. It was in the areas in which the floor had disintegrated that the most severe injuries occurred.'

The torsional loading on the airframe, and in particular on the floor structure, has not been assessed. However it is feasible that torsional loads may have been a significant factor in seat detachment.

2)	AIRCRAFT:	DHC-6	DATE OF ACCIDENT:	30th May '79
	REGISTRATION:	N68DE	LOCATION OF ACCIDENT:	ROCKLAND, MAINE

All of the passenger seats, except the three attached to the rear pressure bulkhead, became detached. The 'g' levels experienced were significantly beyond the strength to which the seat/floors were designed. The NTSB report states:

'Seats in the destroyed area (rows 1 and 2) exhibited massive impact damage on their forward sides and had separated in the aft direction. Seat damage in rows 3 through 5 generally showed separation failures of the seat track tiedown fittings in the forward direction. Three of the four double-unit seats (located on the right side of the aircraft) also exhibited counterclockwise rotational damage. This damage is compatible with inboard lateral movement and the rotation of the seat pans after the primary impact had caused a separation of the anchor pins from the sidewall tracks. The only side-facing unit (6C) separated from its wall tiedown structure. The seats mounted on the aft bulkhead (row 7) were the only seats that did not fail. The bulkhead attachment fittings of these seats were undamaged.'

3)	AIRCRAFT:	DC9	DATE OF ACCIDENT:	4th April '77
	REGISTRATION:	N1335U	LOCATION OF ACCIDENT:	NEW HOPE, GEORGIA

The area of the cabin above the wing box structure sustained relatively few fatalities as a result of impact trauma. It is assessed from the analysis of the Accident Report that in the area of the wing box, and immediately in front, there were 37 of the 81 passengers with no impact fatalities. By way of comparison the remaining areas of the passenger cabin are assessed to have been occupied by 44 passengers of which 31 were impact fatalities. These parts of the cabin experienced extensive detachment of the seats from the seat tracks whereas the wing box area was reported as having no seat detachments.

4)	AIRCRAFT:	DHC-6	DATE OF ACCIDENT:	4th December '78
	REGISTRATION:	N25RM	LOCATION OF ACCIDENT:	COLORADO

The NTSB accident report states:

'Five seats remained attached to their moorings in the cabin. These seats were the two aft seats in the row along the left side of the cabin and the three seats attached to the rear bulkhead. A double-seat unit was loose in the cabin, and 12 seats were outside of the aircraft; they had been removed by passengers and rescue personnel. The seat units exhibited varying amounts of damage – primarily failures of floor attachment pins, buckling of seat legs, and bending of seat pans. All seatbelts remained intact and attached to their moorings; one passenger seatbelt had been cut. The captain's seat was attached to the aircraft structure only by torn sheet metal which connected the seat pan to floor structure. The seat was tilted 90° to the left and upward from its normal position.'

It is perhaps significant that the three seats attached to the rear pressure bulkhead remained attached and that the primary failure mechanism of the other seats was the floor attachment pins. It is feasible that deformation of the floor could have been a significant factor in seat detachment.

5)	AIRCRAFT:	F-27	DATE OF ACCIDENT:	26th Sept 1970
	REGISTRATION:	N55VM	LOCATION OF ACCIDENT:	NR. VAGAR, FAROES

Although there is limited data available on this accident it would appear that the floor was disrupted significantly in the cockpit and passenger cabin. Aft of seat row 5 the floor was reported as being 'forced upwards towards the ceiling and level with the rack'. However the floor in the cargo compartment, between the cockpit and the passenger cabin, was reported as being 'intact'. No reasons for this can be offered with the information currently available.

6)	AIRCRAFT:	DC8	DATE OF ACCIDENT:	13th January '69
	REGISTRATION:	LN-MOO	LOCATION OF ACCIDENT:	SANTA MONICA BAY, CALIFORNIA

The NTSB Accident Report states:

'An examination of the seats contained in the recovered section of the fuselage showed that the two double-seat units opposite the forward galley remained in place; in the first-class cabin, only the first three rows of double-seat units on the right side (1 C&D, 2 C&D and 3 C&D) remained in position; the 1 A&B seat unit from the left side was in its approximate proper position, but broken loose from the fuselage wall; the floating portion of the tourist cabin contained triple-seat units numbered 6 through 15, without a No. 13; of these units, row 6 left side and row 15 left side were the only ones missing; all other seat units in this section remained in place.'

All but one of the first class seats were unoccupied but most became detached. By comparison most seats in the tourist cabin remained in place. The deceleration levels on impact were relatively modest. The most likely explanation of the seat/floor failures is that loads were induced into the seat restraints for which they were not designed. It is feasible that torsional and bending loads could have accounted for the seat detachments.

The significance of bending and torsional loads to seat/floor failure is considered to be worthy of further investigation for the following reasons:

- the occurrence of accidents involving significant detachment of floor mounted seats in which bulkhead mounted seats remained intact.
- the tendency for less severe seat detachment occurring in wing box areas
- the detachment of unoccupied seats with assessed low deceleration levels on impact.

There was insufficient information in the Accident Reports studied to assess the effects on seat retention of proximity of high mass items (galleys, toilets, etc.) or seat type – first class, business, economy.

4.6 Strength of Production Breaks

There were 3 of the 32 impact related accidents, involving fuselage rupture, where the rupture was identified as having occurred at the Production Break. However in the majority of cases (25) insufficient information was contained in the accident report to determine the location of the Production Break relative to fuselage rupture. Furthermore, although for some accidents fuselage rupture resulted in loss of life, in other instances it provided an exit path for the occupants that would otherwise not be available.

The Survivability Factor 'Strength of Production Breaks' (S08) is ranked lowly in terms of occupant fatalities and occupant injuries for an aircraft configured to the latest requirements (see Figures 5 & 6). However insufficient data are currently available on the accidents analysed to make any conclusions regarding this issue.

5 ASSESSMENT OF IMPACT SEVERITY

The severity of impact in an aircraft accident will determine the likely degree of damage sustained and hence, along with the other hazards occupants may experience (fire/water), the extent of Serious and Fatal Injuries. An attempt has been made to provide a measure of impact severity as a gauge to classifying the potential for occupant injury. Development of such a measure will be a useful aid in accident modelling.

5.1 Impact Severity in relation to occupant injuries

The number of Serious and Fatal Injuries can provide a measure of accident severity. Furthermore since the number of occupant injuries is available for almost all accidents on record it provides a means that may be considered as a useful comparative indicator. Scales for categorising injuries have been developed (see Reference 2) known as the Abbreviated Injury Scale (AIS). A development of this concept, and perhaps a better measure of the total injuries sustained, is Baker's Injury Severity Score (ISS). Reference 2 states:

'Baker's Injury Severity Score (ISS) published in 1974 gives a much better fit between overall severity and probability of survival. The ISS is the sum of the squares of the highest AIS score in three different body regions.'

Whilst there is likely to be more extensive data available, providing a larger sample size, the UK Air Accidents Investigation Branch Report on the accident to the Boeing 737 near Kegworth in 1989 (see Reference 3) has assessments of ISS levels for the occupants. Using this information an attempt has been made to assess the relationship between Fatal and Serious Injuries for varying ISS levels. This relationship is shown in Figure 12. It is understood that an ISS level of 16 normally results in 10% fatalities. This correlates reasonably well with the curve shown in Figure 12 which is derived assuming a Weibull Distribution.

From the detailed analysis of accidents carried out during this project the numbers of occupants sustaining Fatal and Serious Injuries has been recorded. Figure 13 shows the relationship between proportion of fatalities and injuries. The horizontal scale is simply a ranking of the accident scenarios in order of increasing proportion of Serious/Fatal Injuries. Only accident scenarios containing 9 or more occupants have been considered. The curve of best fit for the Serious and Fatal Injuries has been derived assuming a Weibull Distribution.

There are several points on the Fatalities and Injuries curve which appear to be significantly adrift from the curve of best fit. There could be several explanations for this the most likely being that the accident scenarios were imprecisely defined (see Section 3.1.2 of this Report). Improved information on the location of occupants and the extent of their injuries should provide a more accurate basis on which to assess the precise form of this curve. Some variation is, however, to be expected since the potential for injury will vary amongst individuals depending on factors such as age, gender, degree of restraint and location within a given scenario.

Figure 14 suggests the form of the relationship between Fatal & Serious Injuries and Mean ISS levels likely to be experienced in a given accident scenario. It is based on the distributions of injuries experienced on the Kegworth accident and the data derived from the study of accident reports carried out as part of this project. It should only be considered as a guide to the likely true distribution. However it is probably a close approximation, and has proven useful in this study as an indicator of the likely relationship between fatalities and injuries in the absence of more precise data.

5.2 Impact Severity in relation to 'g' levels

Table 3 lists all the accidents studied involving impact fatalities in which sufficient information could be gleaned from the data currently available. They are ranked in order of increasing fatality rate (proportion of impact fatalities). For each of the accidents the assessment of the 'g' levels, in all three axes, is listed.

No good correlation between deceleration levels and proportion of fatalities could be derived from these data.

Not included in Table 3, is accident RIM 500 since it did not include impact fatalities. This accident is of particular interest since it involved significant fuselage/cabin disruption and yet the deceleration levels on impact were relatively low.

No firm conclusions can be reached as to the reasons for this apparent discrepancy. However the following factors are considered relevant to the issue:

(a) assessments of 'g' levels usually relate to the aircraft's centre of gravity, and the actual levels can vary markedly throughout the aircraft.

(b) fuselage disruption may have a significant effect on occupant injury even with modest levels of deceleration.

It is therefore concluded that, as an indicator of impact severity in terms of potential for injury to occupants, assessed levels of 'g' are not of great value.

5.3 Impact Severity in relation to aircraft damage

Figures 9 and 10 show the relationship between proportion of accident scenarios involving overhead bin detachment, and seat detachment against fatality rate for the accidents analysed. This involved the study of 82 accident scenarios. A line of best fit is shown on the graphs assuming a linear relationship.

Whilst it may be argued that these curves demonstrate some correlation between cabin disruption and fatality rate, as might be expected, it is perhaps surprising that there is not a more marked relationship. For scenarios involving 90% to 100% fatalities, approximately 80% of the seats are detached, and yet for scenarios in which 0% to 10% of the occupants sustain Fatal Injuries, seat detachment still occurs in 50% of scenarios. A similar situation exists for overhead bin detachment.

Floor Disruption and Fuselage Rupture, in relation to fatality rate, were also studied. In the vast majority of accident scenarios the fuselage was ruptured to some degree (approximately 90%), and in all scenarios with more than 10% fatalities. No significant correlation could be found between proportion of accident scenarios involving floor disruption and fatality rate.

Based on analysing these relationships between measures of fuselage/cabin disruption and fatality rate it may be concluded that:

(a) they do not represent a good measure of the number of fatalities likely to be encountered in an accident scenario.

(b) no single factor (seat detachment, overhead bin detachment, etc.) accounts for the fatalities encountered in an impact related accident scenario – the fatalities are likely to result from a combination of these factors and others (e.g. Occupant Restraint).

5.4 Impact Severity Classification

For each of the accident scenarios studied, the impact severity was assessed using the categories shown in Figure 15. These categories were developed at an early stage in the project. The Structural Damage to Cabin Classifications was based on a subjective assessment after analysing a limited number of accidents. It was hoped that a relationship could be found between Impact Fatalities/Cabin Damage and 'g' levels experienced during the impact.

However it became evident as more accidents were studied that anomalies existed between occupant injuries and degree of structural damage to cabin as represented in Figure 15 (see Section 5.3). Furthermore as discussed in Section 5.2 there appears to be no good correlation between sustained 'g' levels and proportion of impact fatalities.

It is concluded that a more appropriate classification of impact severity should relate directly to the extent of occupant injury.

Perhaps rather than classifying Impact Severity in the manner adopted in this study it would be more appropriate to use a measure of impact injury, such as mean ISS level encountered in the scenario, since this measure has the following advantages:

(a) there appears to be a good correlation between occupant injuries and occupant fatalities.

(b) it is a direct measure of the parameter of greatest interest.

Furthermore any other measure of impact severity would involve the need to devise means for combining various factors (e.g. 'g' levels, seat detachment, overhead bin detachment, etc.).

6 POSSIBLE MODEL DEVELOPMENTS

6.1 General

The mathematical model developed for this study may be used to determine the effects on number of fatalities and injuries of varying hazard intensity.

The Survivability Chain shown in Figure 16 illustrates the principal of a possible development to the model.

Impact Severity may be expressed as a mean I.S.S. level for a given Scenario. Figure 14 shows the expected relationship between mean I.S.S. and proportion of Fatalities and Serious Injuries. Therefore for a given number of occupants of a Scenario, T, and a given Impact Intensity, the values of S, I and F in the above Survivability Chain may be derived. If there are no further hazards to the occupants (FIRE/DROWN) then the values of S, I and F represent the number of Survivors, Serious Injuries and Fatalities.

However if the impact resulted in a fire then the Survivors and Seriously Injured would be subjected to the second hazard with the potential for further fatalities and injuries. Whilst the relationship between Proportion of Injuries and Proportion of Fatalities with Fire Intensity has not yet been clearly defined it may be possible to derive such a relationship with further study of accidents. From the work carried out in this project it was found that *average* values for these proportions are as follows:

Impact Survivors

Fire Fatalities	.37
Fire Injuries	.12
Fire Survivors	.51

Impact Injuries

Fire Fatalities	.57
Fire Injuries	.18
Fire Survivors	.25

It should be noted that based on the accidents analysed the occupants that were injured by the impact had approximately half (.25/.51) the chance of surviving the fire than the impact survivors. This gives a measure of the degree to which impact injuries affect fire survivability.

A similar situation exits for ditching accidents and the *average* values of proportion of fatalities and survivors was found to be as follows:

Impact Survivors

Drown Fatalities	.17
Drown Survivors	.83

Impact Injuries

Drown Fatalities	.53
Drown Survivors	.47

Greater accuracy in modelling could be achieved if there was a good relationship established between fatalities/serious injuries and a hazard intensity index for fire and drowning as well as impact. The following proposals are made as to the manner in which such relationships might be developed:

Impact Intensity Index

The relationship between fatalities/injuries with mean I.S.S. proposed in Figure 14 could be taken as the basis for a Hazard Intensity Index. The Index should range from 0 to 75 since 75 is the highest value of Baker's Injury Severity Score.

Subject to validation of the data in Figure 14 this index requires no further development.

Fire Intensity Index

A similar index could be developed for fire intensity. However since the scale of the intensity index is arbitrary it could use a similar range of 0 to 75 as the Impact Intensity Index and relate to the same number of fatalities. The relationship with Serious Injuries is unknown and would require further analytical work to establish it.

Drown Intensity Index

Once again this index could take the same form as the Impact Intensity Index with a range from 0 to 75 relating to the same number of fatalities. Since there are very few (if any) serious injuries resulting from the hazard associated with water this relationship may be omitted.

An example of the form of the above Indices is shown in Figure 17.

6.2 Benefit Analysis Model

Using the model development proposed in Section 6.2, Survivable Accidents that have occurred in the past could be stored on a computer database. This database would contain the Hazard Severity Index for each scenario of an accident. The following example illustrates the manner in which this data could be recorded:

Scenario	*Code*
1	253500
2	205600
3	182100
4	160000
5	140000

The first two digits of the scenario code indicate the Impact Intensity Index, the next two digits the Fire Intensity Index, and the last two digits the Drown Intensity Index.

Having established this information for a large number of survivable accidents, representative of the complete population of accidents, changes to factors affecting survivability may be assessed for their impact on fatality (and injury) rate. The process for this would be to determine the degree of change to the severity index and to re-evaluate the number of fatalities using a computer based model designed for this purpose.

It is likely that Impact, Fire and Drown Intensity are not independent variables. For example, high impact accidents are more likely to result in extensive fuel tank rupture with a consequentially high probability of high intensity fire. It would be desirable to establish any such relationships.

Validation of any model developed for this purpose could be carried out by assessing the predicted change in fatality rate with that made from previous analyses.

7 SUMMARY AND CONCLUSIONS

7.1 Survivability Factors

(a) The most significant Structural Survivability Factors in terms of their degree of improvement on Fatality Rate for an aircraft configured to the standards of the latest requirements are:

S03 – Seat/Floor Strength
S01 – Rearward Facing Seats
S02 – Occupant Restraint

(b) The above three Structural Survivability Factors are also the most significant in terms of reduction in Occupant Injuries (Serious plus Fatal). However S03 Seat/Floor Strength tends to result in less of an improvement in Injuries. This is considered to be due to occupants sustaining upper torso and limb injuries even with seats remaining attached to their mounts.

(c) The five most significant Survivability Factors overall in terms of their degree of improvement on Fatality Rate for an aircraft configured to the standards of the latest requirements are:

S29 – Cabin Water Sprays
S03 – Seat/Floor Strength
S01 – Rearward Facing Seats
S02 – Occupant Restraint
S18 – Emergency and Evacuation Drills

These five Survivability Factors also rate highest in terms of Injury (Serious plus Fatal) Rate reduction.

(d) Other Survivability Factors could also prove to have significant potential if subjected to a cost/benefit analysis.

7.2 Observations on Structural Features

(a) *Overhead Bin Detachment*

Up to 70% of impact related accidents involve overhead bin detachment. However it does not appear to be a major factor in terms of occupant survival. There is insufficient data in the accident reports studied to be specific about the mechanism of failure.

(b) *Pre-existing Damage to Structural Components*

Of the 42 accidents analysed there were no cases of pre-existing damage to Structural Components identified which affected occupant survival.

(c) *Fuel Tank Failure*

Approximately 82% of the impact related accidents were identified as involving fuel tank rupture. All ruptures were as a result of impact with terrain or water.

(d) *Door Jamming*

Approximately 1% of the fatalities resulting from all the accidents analysed, were the result of door jamming due to structural deformation. Of the 42 accidents analysed, 78 exits were attempted to be opened by occupants of which 19 failed, 11 due to structural deformation.

(e) *Seat/Floor Strength*

Seat/Floor Strength is the most significant structural Survivability Factor in terms of potential for improvement in Fatality Rate. From the accidents analysed no predominant failure mechanism could be identified. The failure mechanism is likely to vary with seat/floor design and loading mechanism. Bending and torsional loads could be a significant factor in seat detachment for some accidents. From the data available no reliable conclusions could be reached on the effects on seat retention of high mass items (galleys, toilets, etc.) or seat type – first class, business, economy.

(f) *Fuselage Rupture/Production Breaks*

There were 3 accidents studied involving fuselage rupture at the production break. However for the majority of these accidents involving fuselage rupture the location of the production break relative to the rupture could not be determined from the information available. Although for some accidents fuselage rupture resulted in loss of life, in other instances it provided an exit path for the occupants that would not otherwise be available. Insufficient data are currently available to make any firm conclusions on this subject.

7.3 Assessment of Impact Severity

(a) No significant correlation could be made between occupant fatality rate and:

(i) assessed severity of deceleration levels resulting from the impact. Whilst the magnitude of 'g' levels undoubtedly affect the degree of fuselage/cabin disruption and occupant injury there are accidents involving high deceleration levels and low impact fatality rates, and accidents with low deceleration levels involving high impact fatality rates. Hence 'g' levels do not represent a good measure of impact severity in terms of occupant survivability.

(ii) levels of fuselage/cabin disruption. Seat Detachment, Floor Disruption, Fuselage Rupture and Overhead Bin Detachment were all studied in relation to impact related fatalities. No reliable and consistent relationship could be found.

(b) Impact Severity may be best assessed in terms of the degree of injury inflicted on occupants. Injury Severity expressed in terms of Baker's Injury Severity Score I.S.S. is likely to provide a good measure of occupant injury. The proportion of Impact Related Fatalities and Injuries is likely to relate well with mean I.S.S. levels sustained in an accident scenario.

8 REFERENCES

1 'Analysis of Factors Influencing the Survivability of Passengers in Aircraft Accidents', Volumes 1 – 4, R.G.W. Cherry & Associates Limited.

2 'The Abbreviated Injury Scale' 1990 Revision – Association for the Advancement of Automotive Medicine.

3 'Report on the accident to Boeing 737-400 G-OBME near Kegworth, Leicestershire on 8 January 1989' – Air Accidents Investigation Branch.

Appendix 1
Accidents Analysed

No.	RIM No.	DATE	AIRCRAFT	REG	FATALITIES	TOTAL ABOARD	LOCATION
1	11	01/02/91	B737	N388US	22	89	LOS ANGELES, CALIFORNIA
2	30	25/01/90	B707	HK-2016	73	153	LONG ISLAND, NEW YORK
3	56	03/12/90	DC9	N-3313L	8	44	DETROIT, MICHIGAN
4	57	08/01/89	B737	G-OBME	47	126	KEGWORTH, LEICESTERSHIRE
5	59	24/02/89	B747	N4713U	9	355	HONOLULU, HAWAII
6	61	10/03/89	F28	C-FONF	24	69	DRYDEN,ONTARIO,CANADA
7	65	19/07/89	DC10-10	N1819U	111	296	SIOUX CITY, IOWA
8	69	27/09/89	DHC6-300	N75GC	10	21	TUSAYAN, ARIZONA
9	76	28/04/88	B737	N73711	1	95	HAWAII
10	79	31/08/88	TRIDENT 2E	B-2218	7	89	HONG KONG
11	80	31/08/88	B727	N473DA	14	108	DALLAS, TEXAS
12	105	28/12/78	DC8	N8082U	10	189	PORTLAND, OREGON
13	107	12/02/79	NORD 262	N29824	2	25	CLARKESBURG
14	109	10/03/79	NORD 262	N418SA	3	7	MARINA DEL REY, CALIFORNIA
15	111	29/03/79	F27	C-FQBL	17	24	QUEBEC, CANADA
16	112	30/05/79	DHC-6	N68DE	17	18	ROCKLAND, MAINE
17	113	17/06/79	DHC-6-300	N383EX	1	10	HYANNIS, MASSACHUSETTS
18	115	31/07/79	HS748	G-BEKF	17	47	SUMBURGH, SHETLANDS
19	129	22/12/80	L1011	HZ-AHJ	2	291	NR. STATE OF QATAR
20	134	04/03/87	CASA 212	N160FB	9	19	ROMULUS, MICHIGAN
21	139	15/11/87	DC9	N626TX	28	82	DENVER, COLORADO

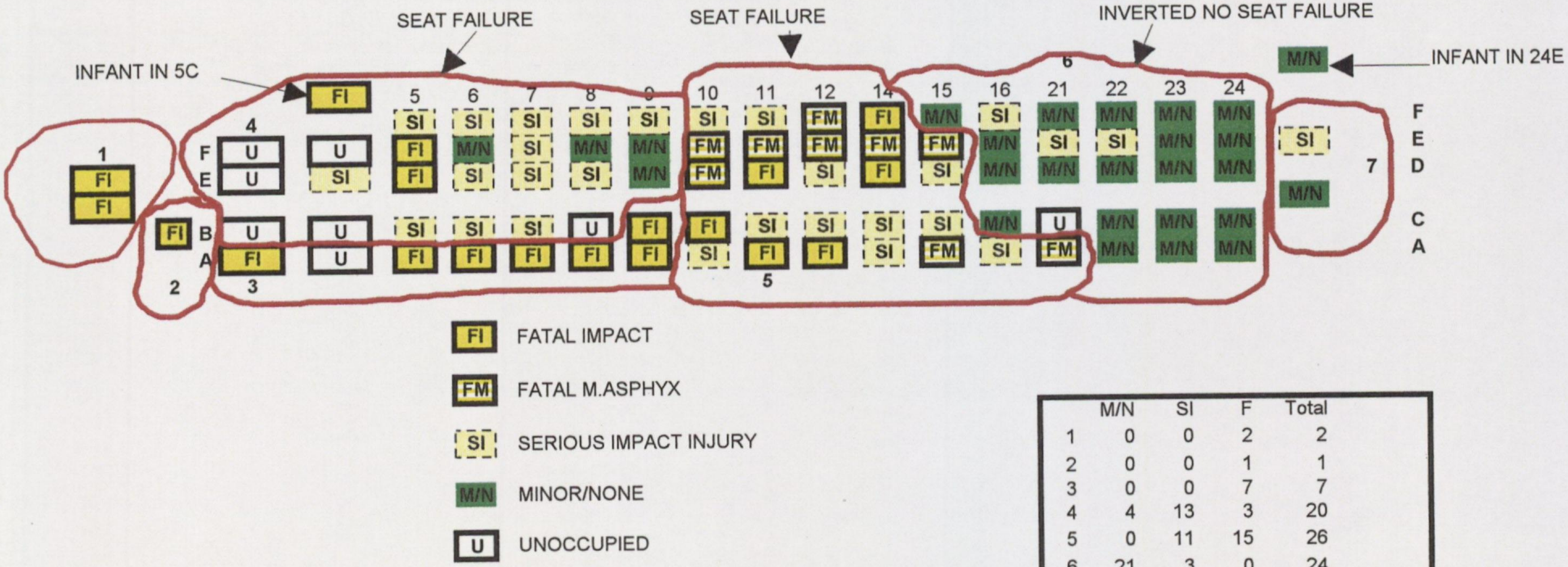
No.	RIM No.	DATE	AIRCRAFT	REG	FATALITIES	TOTAL ABOARD	LOCATION
22	143	12/06/86	DHC6	G-BGPC	1	16	LAPHROAIG, ISLAY, SCOTLAND
23	152	21/01/85	L-188C	N5532	70	71	RENO, NEVADA
24	153	02/08/85	L1011	N726DA	134	163	DALLAS, TEXAS
25	155	22/08/85	B737	G-BGJL	55	137	MANCHESTER
26	159	09/01/83	CV580	N844H	1	33	BRAINERD, MINNESOTA
27	163	02/06/83	DC9-32	C-FTLU	23	46	COVINGTON, KENTUCKY
28	174	13/01/82	B737-222	N62AF	74	79	POTOMAC RIVER, WASHINGTON D.C.
29	196	24/06/75	B727	N8845E	112	124	NEW YORK
30	200	30/08/75	F27B	N4904	10	32	GAMBELL, ALASKA
31	208	30/01/74	B707	N454PA	96	101	PAGO PAGO,SAMOA
32	216	11/09/74	DC9-31	N8984E	71	82	CHARLOTTE, NORTH CAROLINA
33	222	27/04/76	B727	N1963	37	88	ST.THOMAS, VIRGIN ISLAND
34	230	04/04/77	DC9	N1335U	62	85	NEW HOPE, GEORGIA
35	234	20/10/77	CV240	N55VM	6	26	GILLSBURG, MISSISIPPI
36	240	11/02/78	B737	C-FPWC	42	49	CRANBROOK, BRITISH COLUMBIA
37	248	04/12/78	DHC6	N25RM	2	22	NR. STEAMBOAT SPRINGS, COLORADO
38	272	23/07/73	FH-227B	N4215	38	44	ST. LOUIS, MISSOURI
39	319	03/03/72	FH227	N7818M	16	48	NR.ALBANY,NEW YORK
40	344	08/12/72	B737	N9031U	45	61	NR.MIDWAY,CHICAGO
41	490	26/09/70	F27	TF-FIL	8	34	NR.VAGAR, FAROES
42	500	13/01/69	DC8	LN-M00	15	45	SANTA MONICA BAY, CALIFORNIA

Figures

Figure 1

Fig1vol1.xlc

Example of an Accident divided into Scenarios



	M/N	SI	F	Total
1	0	0	2	2
2	0	0	1	1
3	0	0	7	7
4	4	13	3	20
5	0	11	15	26
6	21	3	0	24
7	1	1	0	2
				0
				0
tot	**26**	**28**	**28**	**82**

Figure 2

Fig2vol1.xlc

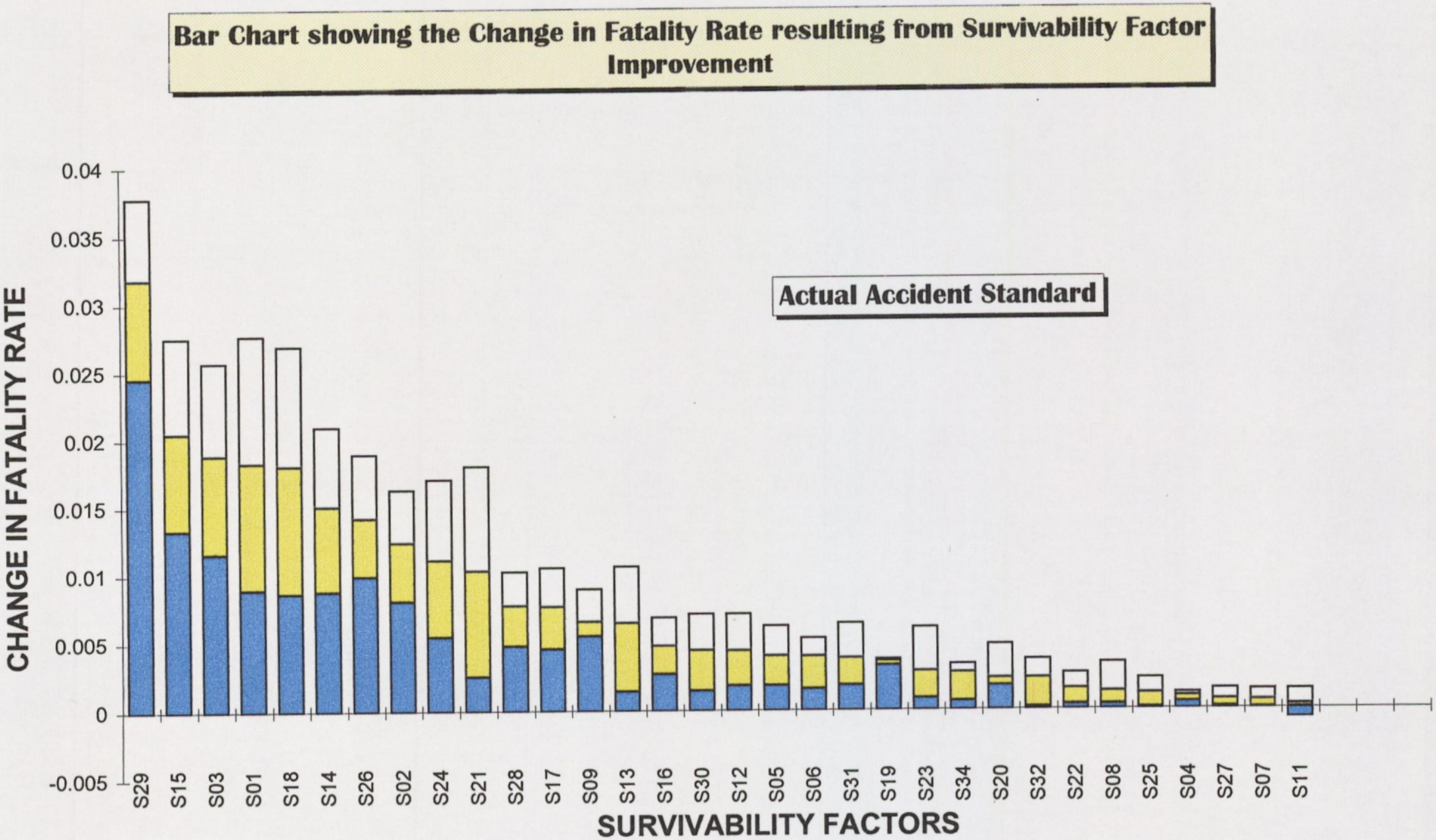


Figure 3

Fig3vol1.xlc

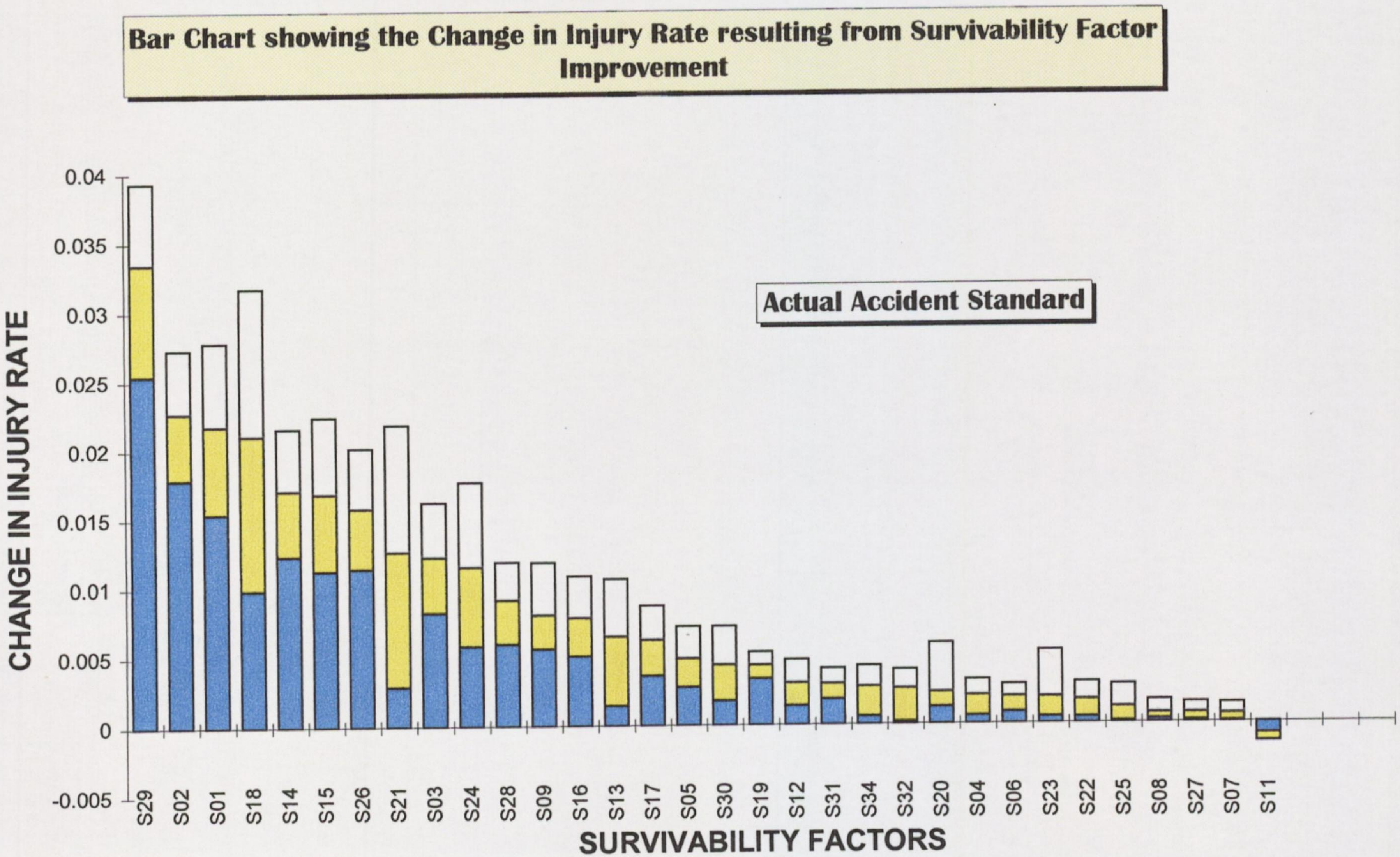


Figure 4

Fig4vol1.xlc

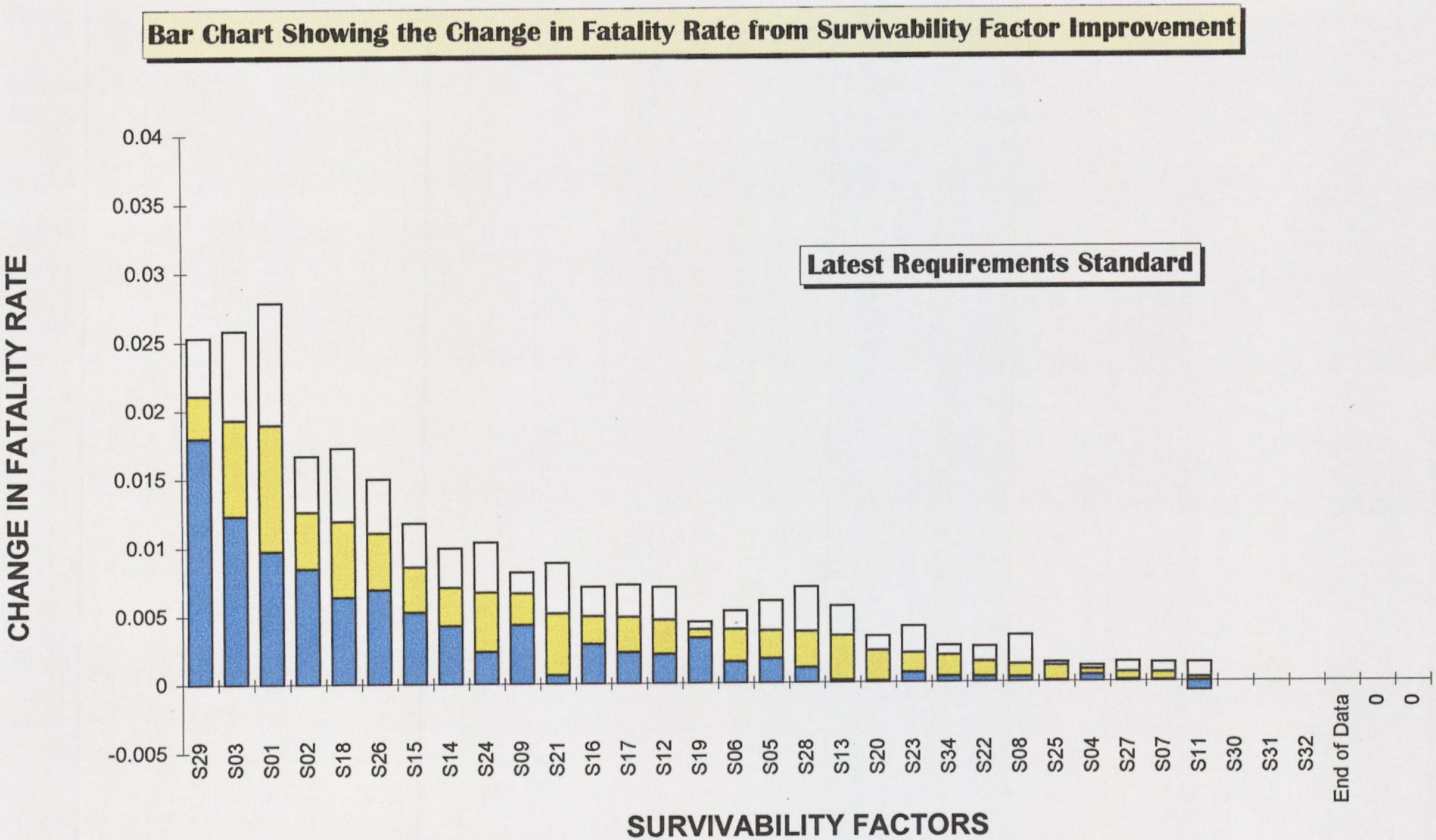


Figure 5

Fig5vol1.xlc

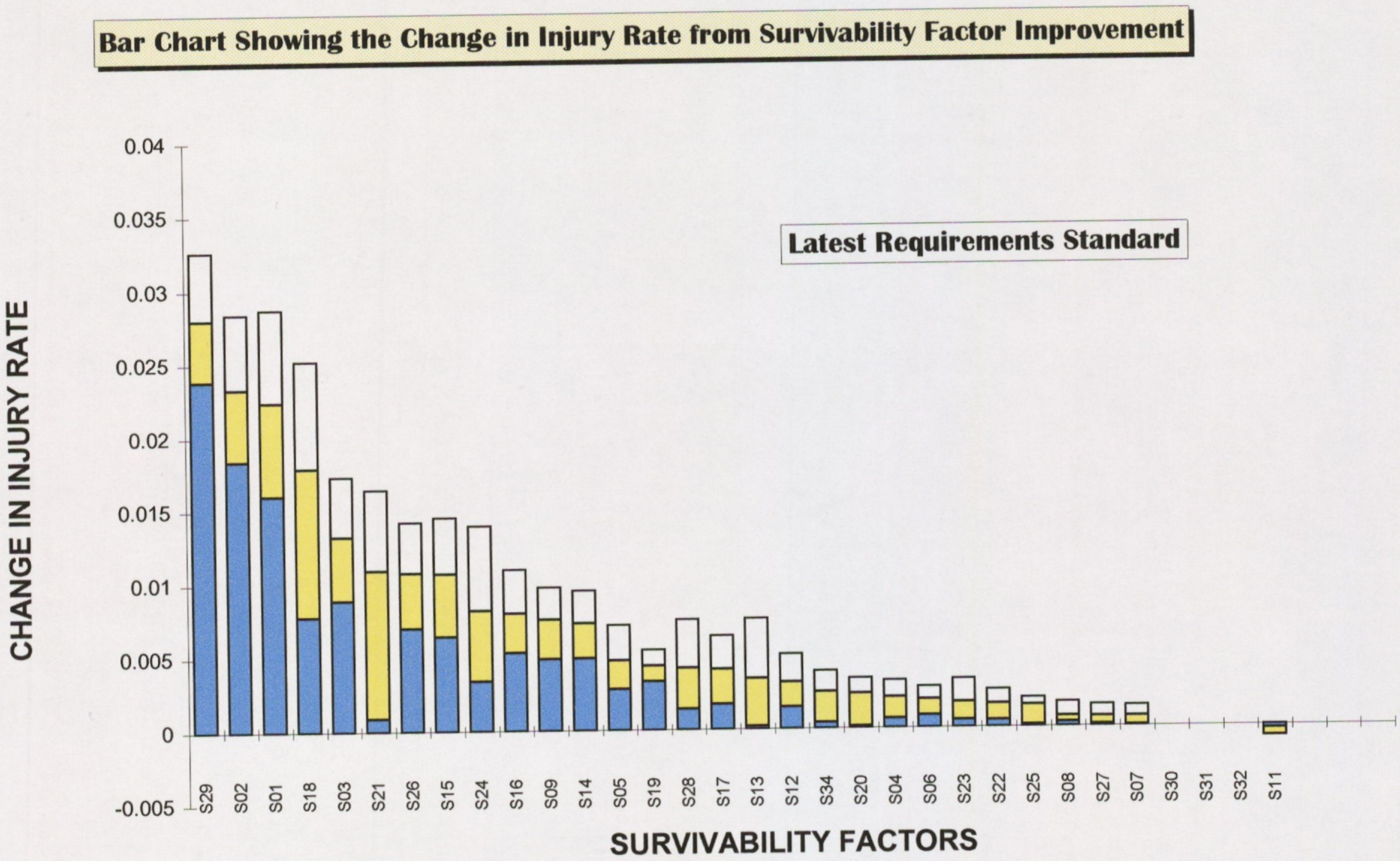


Figure 6

Fig6vol1.xlc

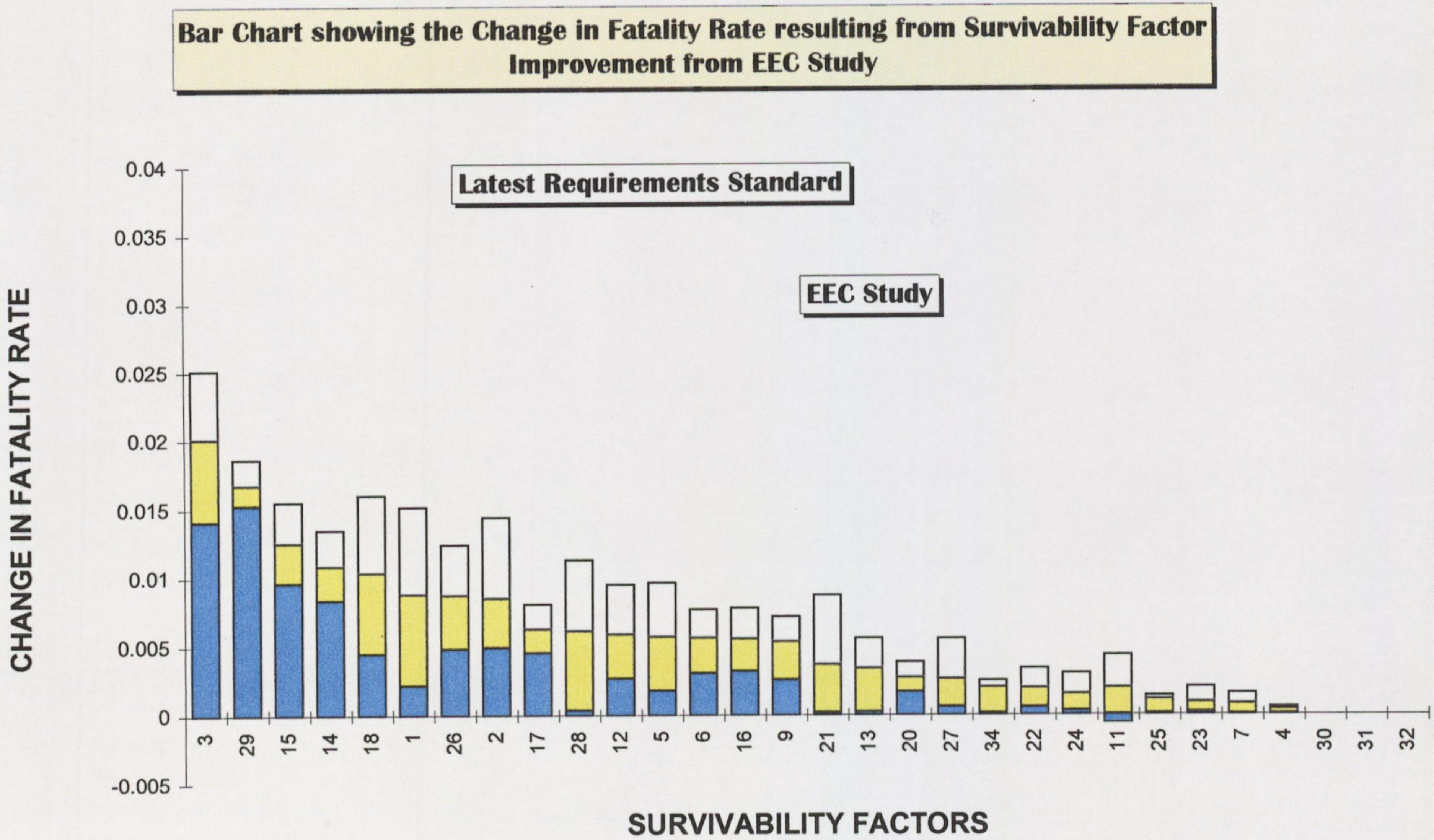


Figure 7

Fig7vol1.xlc

Potential Reduction in Number of Fatalities and Injuries Resulting from Improvements to Structural Survivability Factors

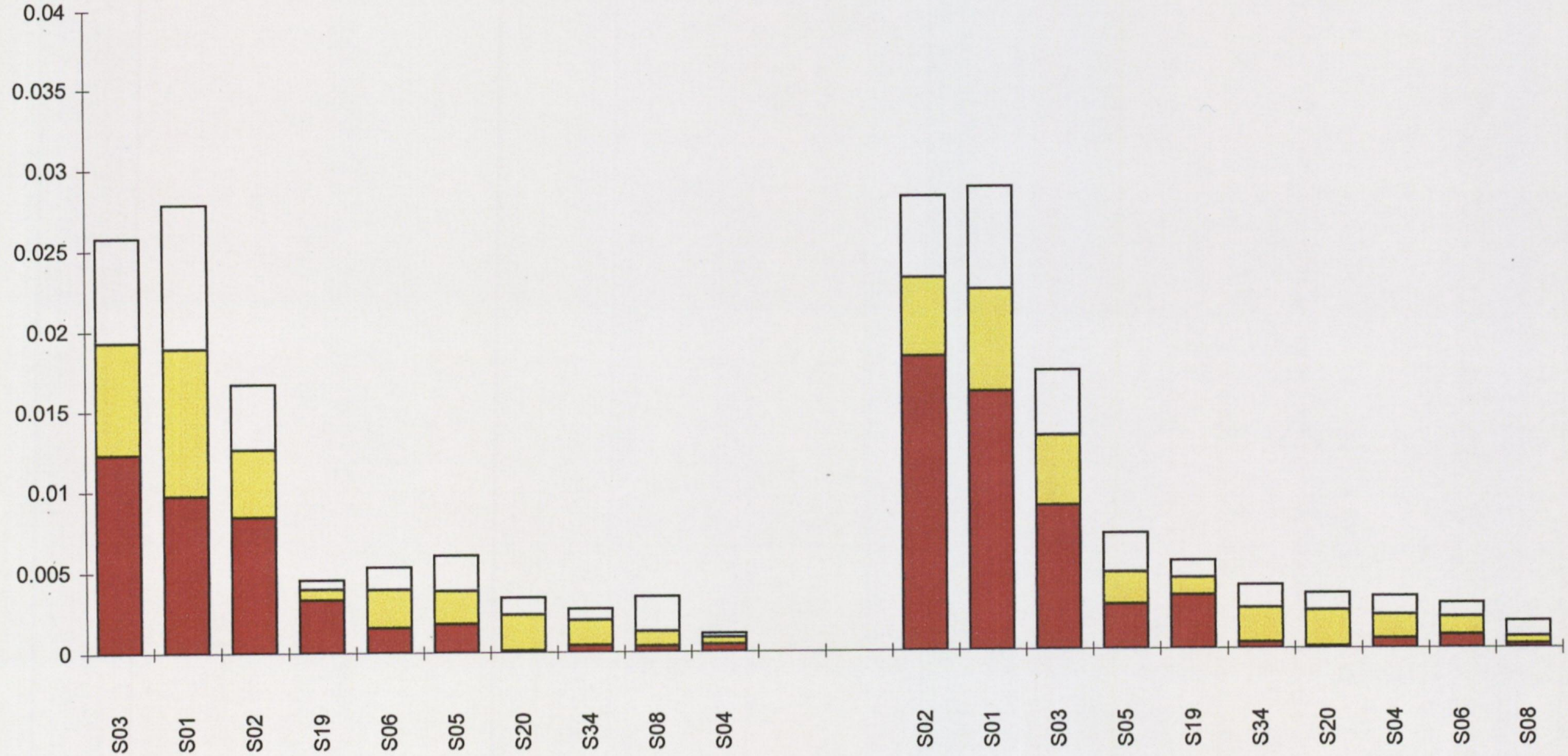


Fig8vol1.xlc

Figure 8

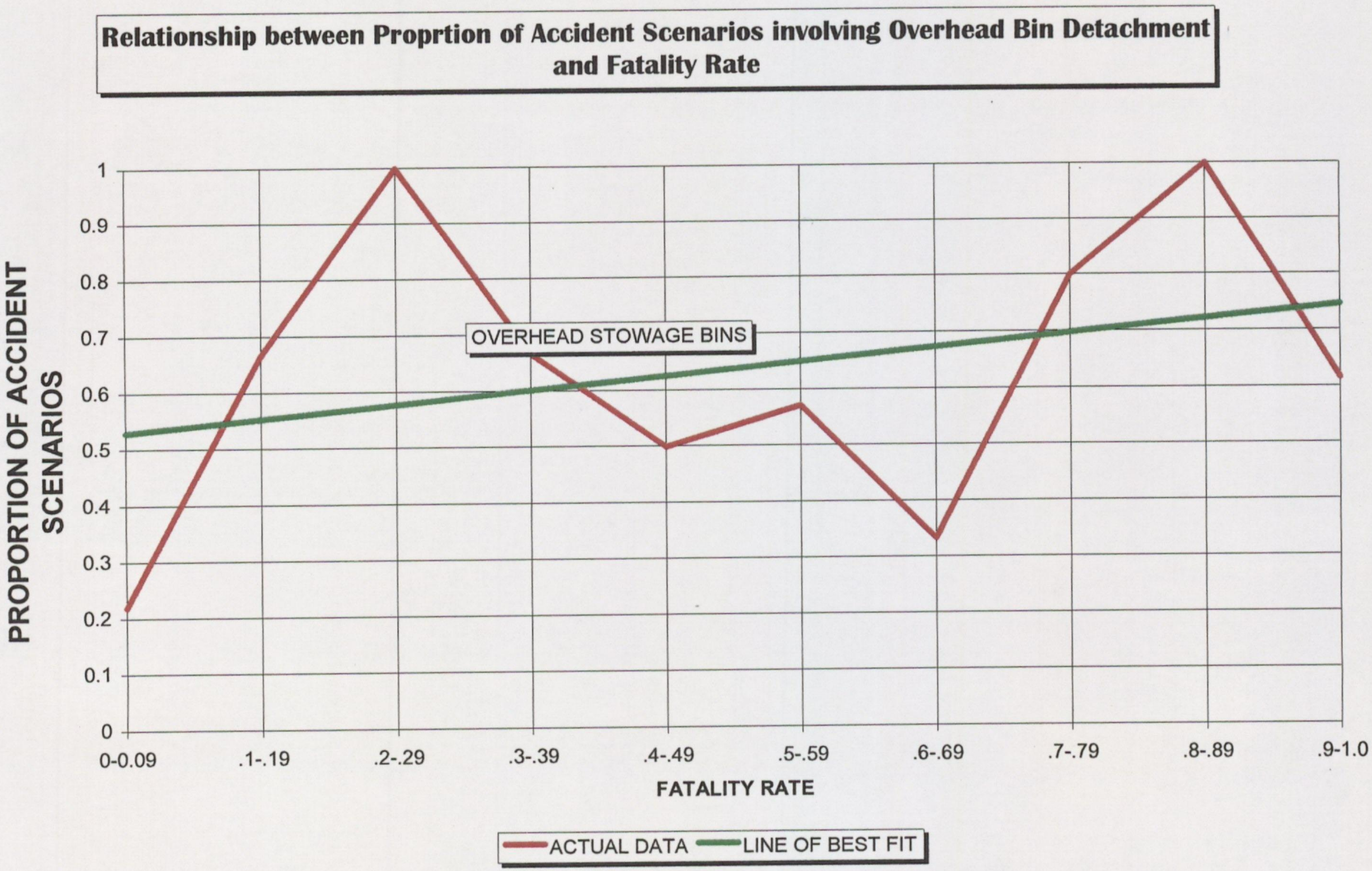


Figure 9

Fig9vol1.xlc

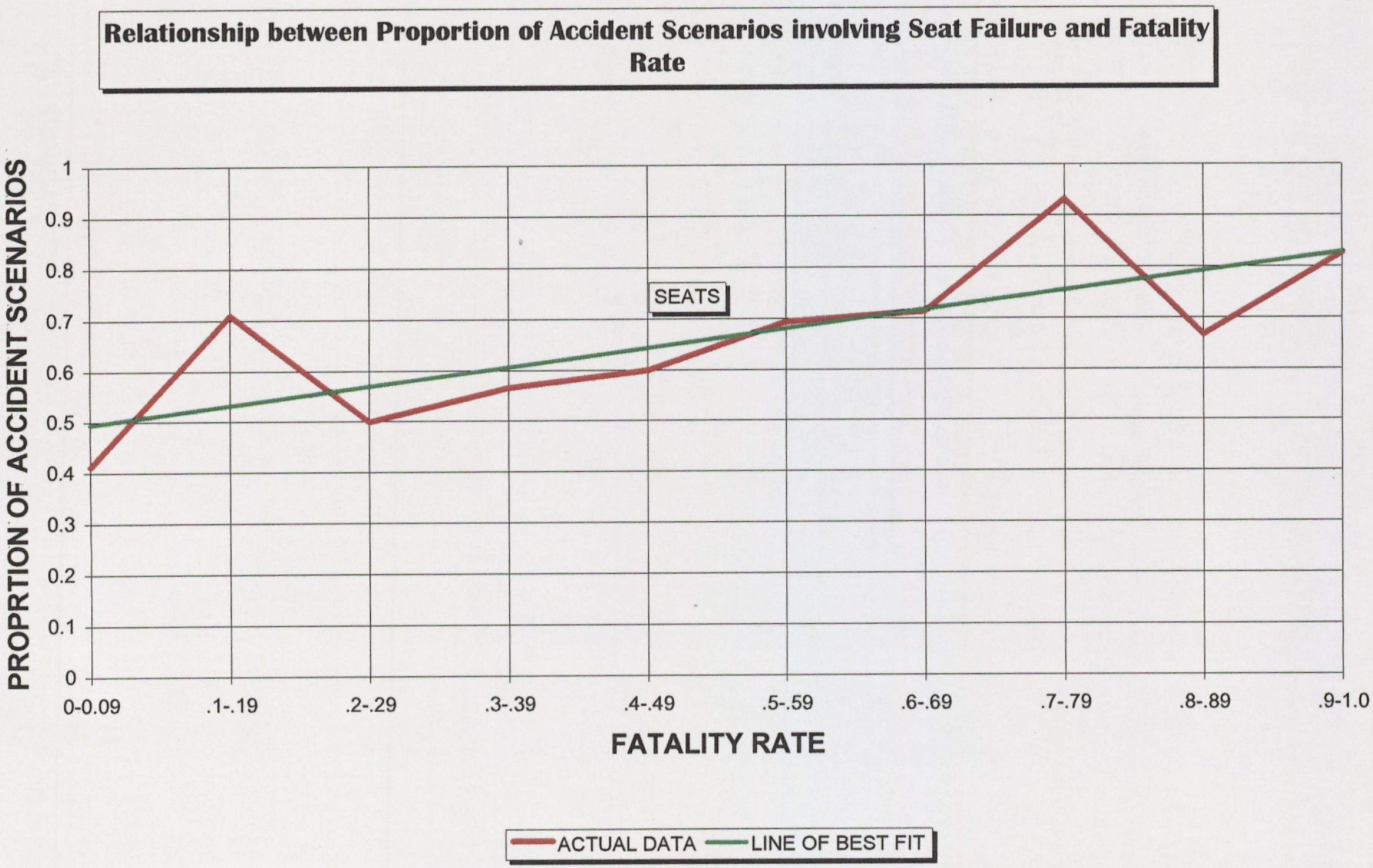


Figure 10

Fig10vl1.xlc

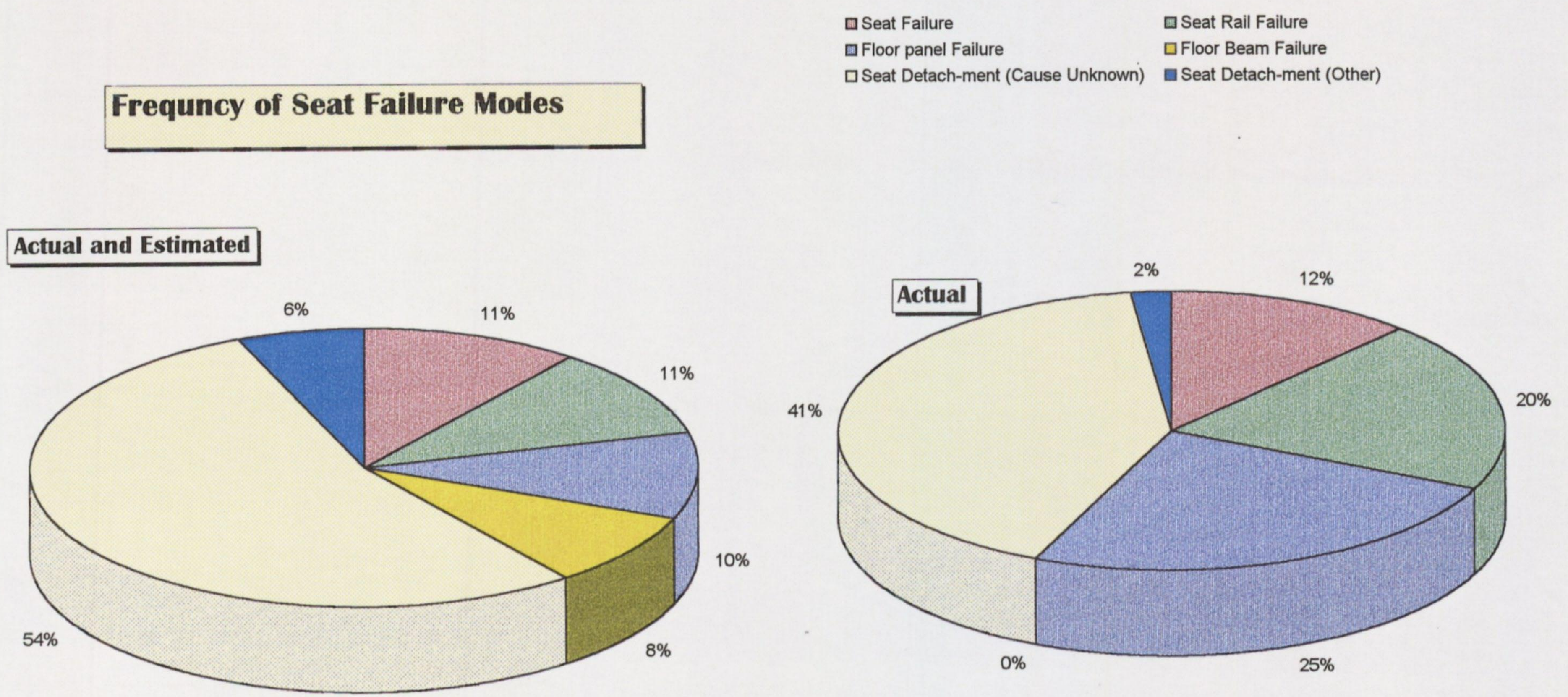


Figure 11

Seats.xlc

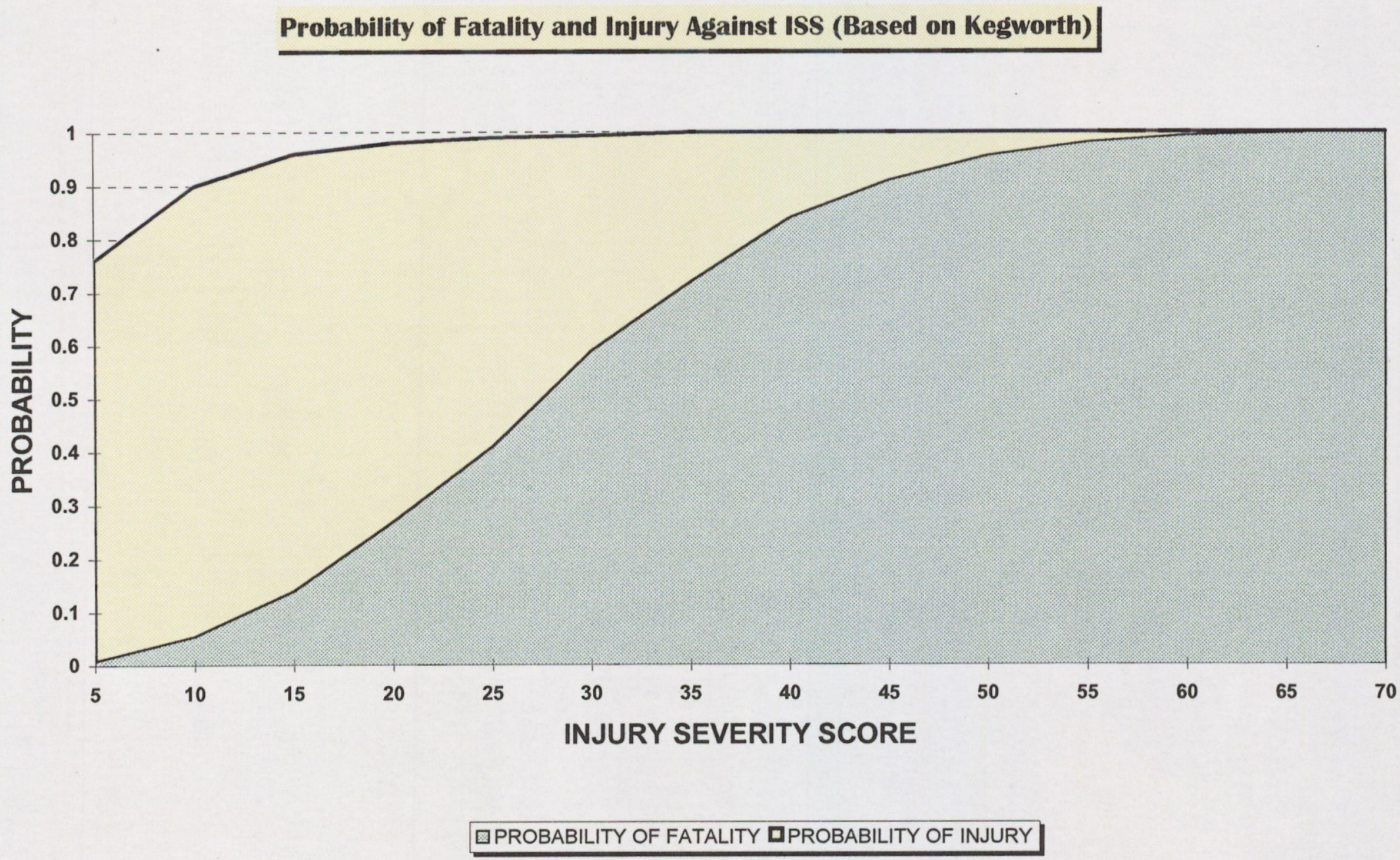


Fig12vl1.xlc

Figure 12

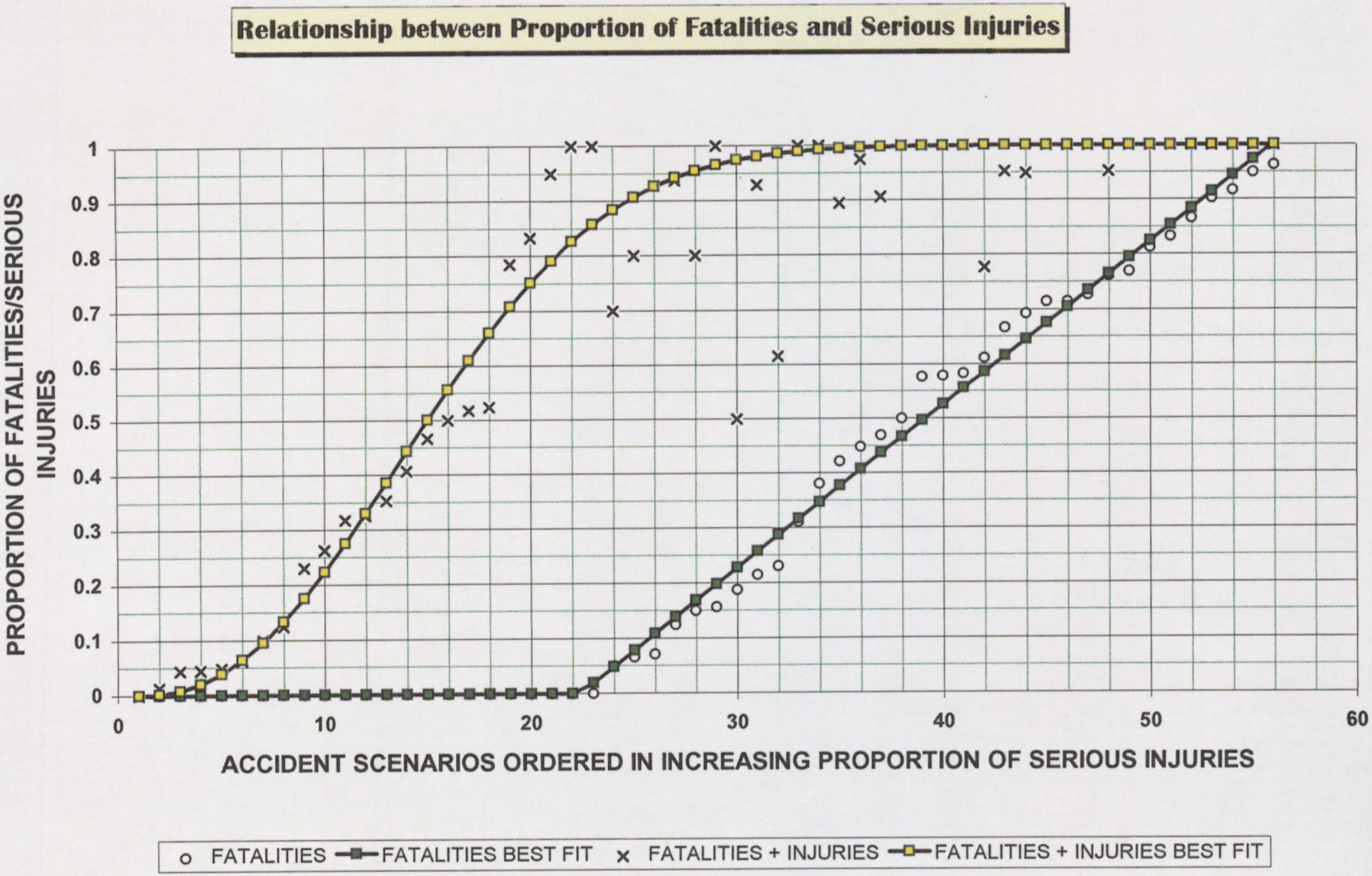


Figure 13

Fig13vl1.xlc

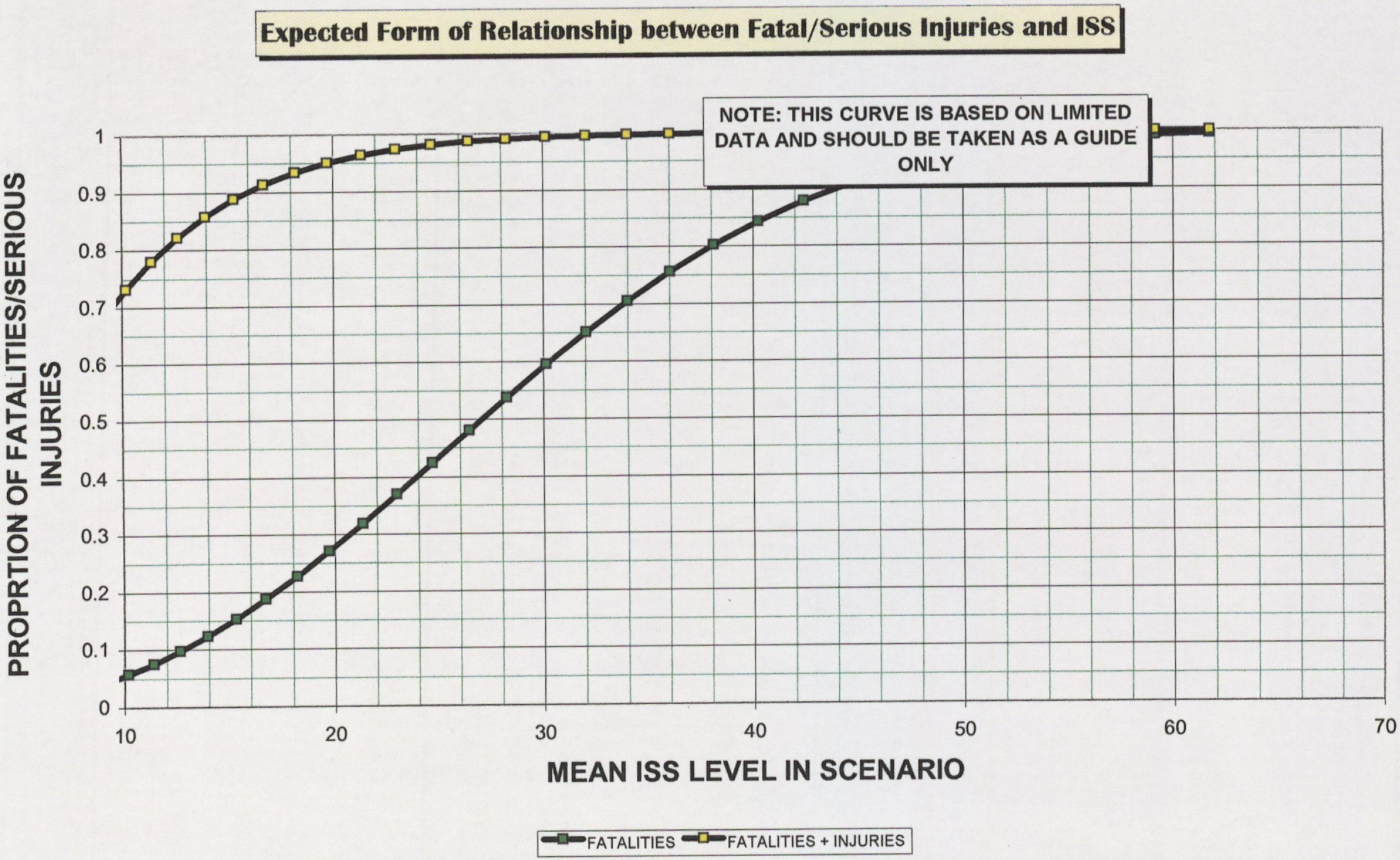


Figure 14

Fig14vl1.xlc

Impact Severity Classification

IMPACT SEVERITY CLASSIFICATION	MINOR	MAJOR	SEVERE	INTENSE	SUBSTANTIAL	CATASTROPHIC
I.S.C. NUMBER	1	2	3	4	5	6
INJURY TO OCCUPANTS	Zero Fatalities Serious Injuries 0% to 10%	Zero Fatalities Serious Injuries 10% to 50%	Fatalities 0% to 10% OR Serious Injuries 10% to 100%	Fatalities 10% to 50%	Fatalities 50% to 90%	Fatalities greater than 90%
I.S.S.	Average 0 to 1	Average 1 to 5	Average 5 to 10	Average 10 to 30	Average 30 to 60	Average 60 to 75
STRUCTURAL DAMAGE TO CABIN	No Internal Cabin Damage	Some Damage to Seats, Bulkheads, Floors or Fuselage	Some Damage to Seats, Bulkheads, Floors or Fuselage	Seats, Bulkheads, Floors or Fuselage Disrupted	Seats, Bulkheads, Floors or Fuselage Disrupted	Seats, Bulkheads, Floors or Fuselage Disrupted

Figure 15

Impclas.xls

Model Development

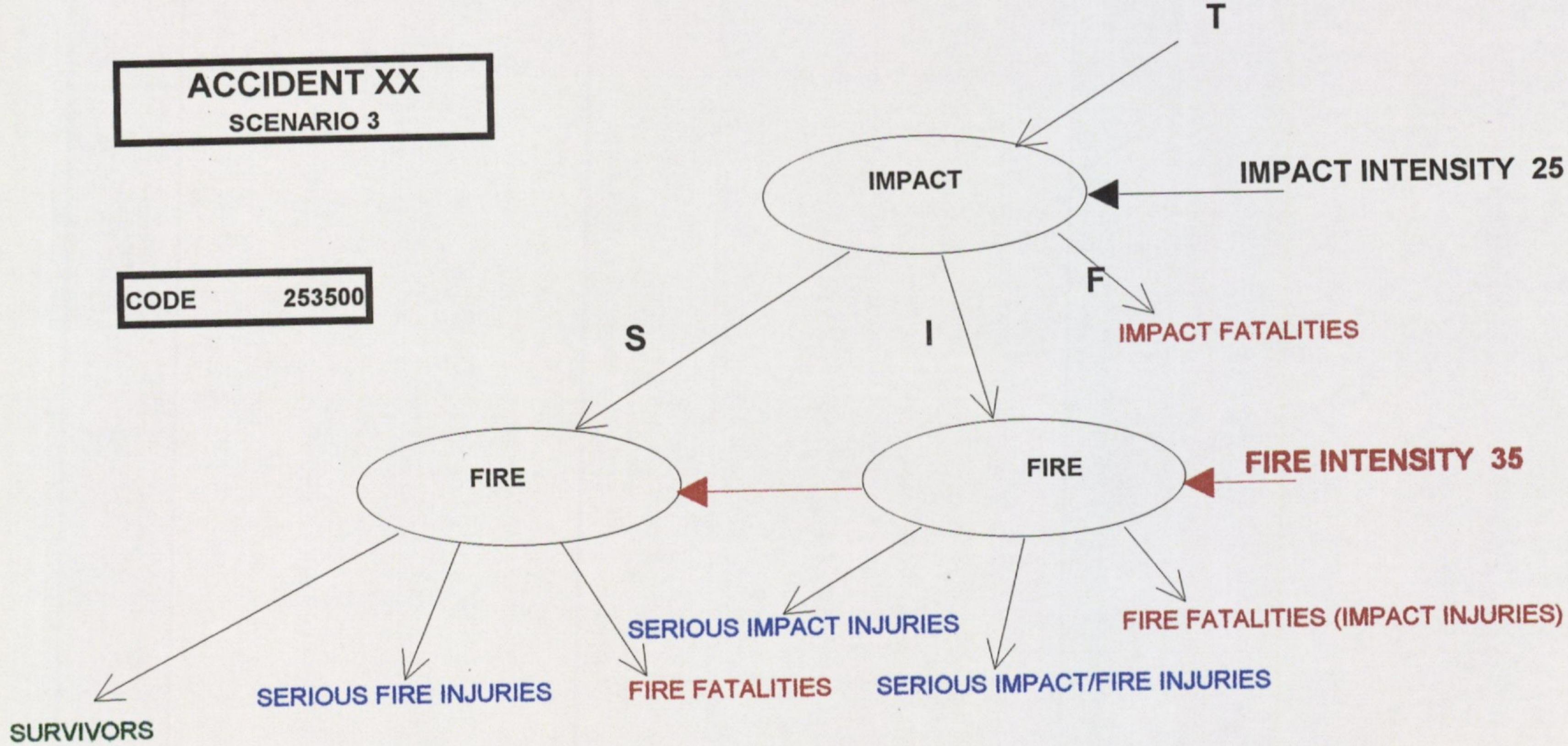


Fig16vl1.xlc

Figure 16

Form of Relationship between Injury/Fatality Rate and Hazard Intensity Index

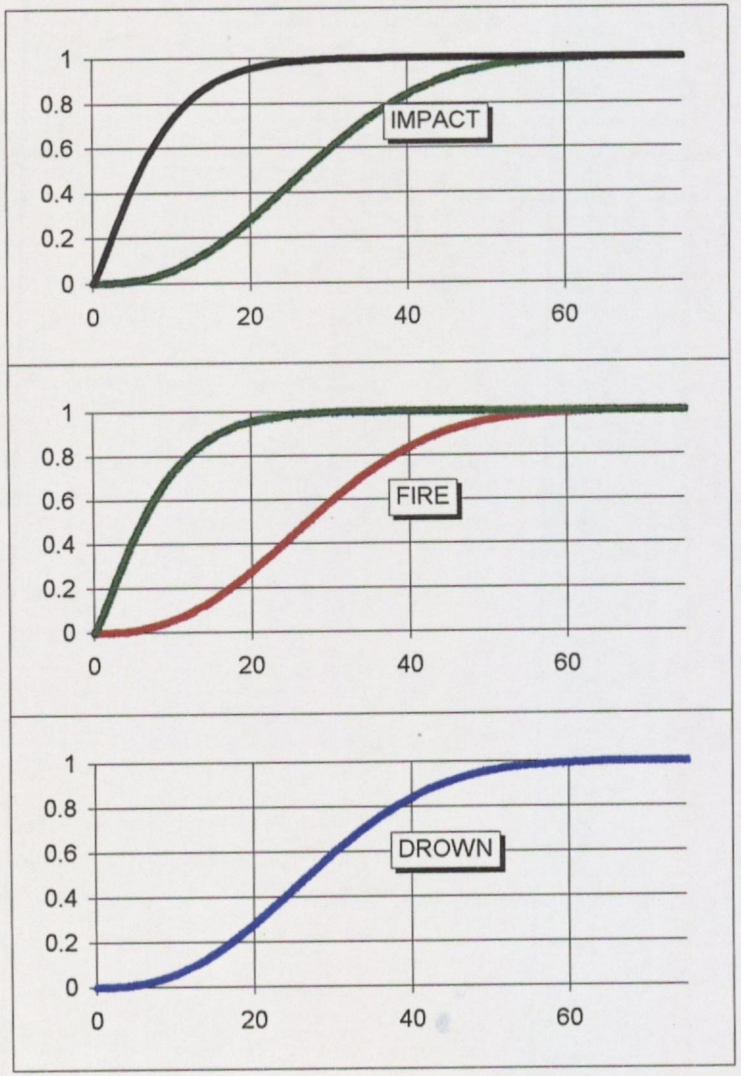


Figure 17

Figxxvl1.xlc

Tables

Survivability Factors	
1	Rearward Facing Seats
2	Occupant Restraint (Adequacy of seat belts)
3	Seat/Floor Strength
4	Infant Seats
5	Strength of Overhead Stowage
6	Struct. Strength of Cabins (Ditching/Impact Res. etc.)
7	Adequacy of Flotation means
8	Srength of Production Breaks
9	Exit Operability
10	Flight Attendant External Visibility
11	No. of Flight Attendants
12	Adequacy of Airfield Emerg. Serv.
13	Exit Route Accessibility (Floor Level Exits)
14	Toxicity of Materials
15	Flammability of Materials
16	Head Strike Adequacy
17	Pax awareness of Exit Routes
18	Emergency & Evacuation Drills
19	Distortion of Door Frames(Door Jamming)
20	Slide Operability (inc. Slide/Raft)
21	Crew Awareness of threat
22	Flight/Cabin Crew Communication
23	Cabin Crew/Pax Communication
24	Burnthrough of cabin
25	Smoke Drills
26	Exit availability (no. of exits)
27	Flotation means access
28	Smoke Hoods
29	Cabin Water Sprays
30	Exit Route Accessibility (Non Floor Level Exits)
31	Floor Proximity Marking
32	Toilet Smoke Detectors
33	(Not used)
34	Systems Crashworthiness (Oxygen, Hydraulics, etc.)

Survfact.xlw

Table 1

Door Jamming

RIM No.	TOTAL ABOARD	TOTAL FATALITIES	ESTIMATED LIVES LOST DUE TO JAMMING/ STRUCTURAL FAILURE	EXITS ATTEMPTED TO BE OPENED	EXITS FAILED	EXITS JAMMED DUE TO STRUCT. DEFORM./FAILURE
TOTALS >	3537	1349	13	78	19	11
11	89	22	1	5	1	1
30	158	73	0	4	1	1
56	44	8	0	4	1	0
57	126	47	0	0	0	0
59	355	9	0	0	0	0
61	69	24	0	2	0	0
65	296	111	0	1	0	0
69	21	10	0	0	0	0
76	89	1	0	0	0	0
79	89	7	0	3	0	0
80	108	14	12	5	2	2
105	189	10	0	10	4	0
107	25	2	0	4	3	3
109	7	3	0	1	0	0
111	24	17	0	0	0	0
112	18	17	0	0	0	0
113	10	1	0	3	2	0
115	47	17	0	4	0	0
129	289	2	0	0	0	0
134	19	9	0	2	0	0
139	82	28	0	1	1	1
143	16	1	0	2	0	0
152	71	70	0	0	0	0
153	163	135	0	0	0	0
155	137	55	0	4	1	0
159	33	1	0	4	0	0
163	46	23	0	5	0	0
174	79	74	0	0	0	0
196	124	112	0	0	0	0
200	32	10	0	0	0	0
208	101	96	0	3	0	0
216	82	69	0	1	0	0
222	88	37	0	2	0	0
230	85	62	0	3	2	2
234	26	6	0	1	0	0
240	49	42	0	1	0	0
248	22	2	0	1	0	0
272	40	38	0	0	0	0
319	49	16	0	1	1	1
344	61	45	0	1	0	0
490	34	8	0	0	0	0
500	45	15	0	0	0	0

Tab2vl1.xls

Table 2

RIM No.	PROPORTION OF IMPACT FATALITIES	VERTICAL "g"	LONGITUDINAL "g"	LATERAL "g"
11	0.01	1.43	MODEST	
79	0.01	LOW	LOW	LOW
105	0.05	HIGH	>9	
143	0.06		MODEST	
248	0.09		circa 9	
113	0.10	0.14	5.69	
344	0.15		>9	
61	0.16	15 TO 20	2 TO 3	21 TO 28
490	0.18		>9	
234	0.23		HIGH	HIGH
139	0.23	>2		
65	0.25	>2	>9	
200	0.28	>3.5	<9	
319	0.31	5 TO 15	15 TO 25	5 TO 10
57	0.37		22 TO 28	
216	0.38		HIGH	
230	0.39	HIGH	>9	
152	0.42		>9	
240	0.45		>9	
30	0.46	HIGH	>9	
69	0.48		>9	
111	0.71	9.4		
174	0.73	>12		
153	0.83	HIGH	>9	HIGH
196	0.85	HIGH		
112	0.94		40	
272	0.95		>9	

Table3.xls

Table 3