Occupant Survival Research
- Prioritisation

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Abstract

Research into improving aviation safety has historically tended to be reactive, usually as a result of an accident with solutions needing to be found for particular problems. A number of recent international aviation safety initiatives (e.g. Joint Safety Strategy Initiative) are based on a more structured approach to improving safety. This paper considers the detailed approach in the specific area of occupant survival taken by the Cabin Safety Research Technical Group to apply a systematic methodology to prioritising research projects.

1 Introduction

Research into improving aviation safety has historically tended to be reactive, usually as a result of an accident with solutions needing to be found for particular problems. A number of recent international aviation safety initiatives (e.g. Joint Safety Strategy Initiative) are based on a more structured approach to improving safety. This paper considers the detailed approach in the specific area of occupant survival taken by the Cabin Safety Research Technical Group to apply a structured methodology to prioritising research projects.

2 Background

When the major aviation regulatory bodies (FAA, JAA, TCCA and JCAB) agreed to set up the Cabin Safety Research Technical Group, it was against a background of many years of co-operation. For specific programmes such as cabin watersprays where it was clear that individual national research programmes were unlikely to produce the most useful results in a harmonised regulatory regime - there was a clear need to take a step back to look at the wider picture and that process commenced with the formation of the Group. This was followed by the first Cabin Safety Research Conference[1] held in Atlantic City in November 1995. That Conference was workshop based and open to the aviation community as an opportunity to identify safety concerns and research possibilities in the field of cabin safety.

In the time since that Conference the Cabin Safety Research Technical Group has been supporting and disseminating information on a wide-ranging portfolio of ongoing research programmes whilst moving forward towards a more structured, systematic approach to cabin safety research. The programme is detailed in our web site[2] in the cabin safety area.

In parallel with developing a systematic approach to cabin safety research, we have made use of previous studies[3,4,5,6] to guide the Group, in order to make best use of existing resources. Studies have commenced based on conclusions of the reports. The French DGAC programmes on cabin crew training and seat/floor strength are examples of topics that are being addressed with the support of the Group.

In addition, the suggestions for future research from the previous conference have been considered. A large number of suggestions actually supported existing programmes at the time, many of which are relatively long term and are still ongoing. One example of this category would be the work on computer modelling of evacuation[7] where the work has now matured to the extent that manufacturers are using the model to analyse the evacuation performance of new aircraft designs. Many high quality suggestions were received and it has not been possible to initiate work in all the topic areas. This reinforces the need for a formal prioritisation system.

A few particular successes should be noted. For example it was suggested that FAA Civil Aeromedical Institute (CAMI) and Cranfield University in the UK, both with unique experience of research in evacuation studies should collaborate more strongly. This has happened and a report, resulting from a comparative study of methodologies, will be published shortly. There was much discussion at the last conference on the problems of Type III exits and it is worth noting that an improved Type III exit is fitted on some new production aircraft. Other noteworthy items are work on improved slides and the recent activities on improving burnthrough resistance.

The formulation of a research strategy that will achieve international consensus is not a simple task. The overall philosophy of addressing research to potentially save the maximum number of lives for the minimum cost is the basis of the methodology. It does however need to be stressed that rigorous cost benefit assessment is not possible to apply at the research stage as little may be known about the benefits or costs associated with potential solutions for a hazard until the research is completed. There are many other associated problems due to lack of knowledge prior to research completion that preclude a detailed assessment of the best way forward. It has also been recognised by the Group that research resources in this specialised field cannot necessarily be available to order at short notice. National research facilities, which may be government, universities or commercial organisations, need consideration within the framework of a prioritisation system. There will additionally always be a need to react to the circumstances of a particular accident outside the framework of a prioritisation process. It is also necessary to consider that resources spent planning can also be spent directly on research that may improve safety, thus there is a balance to be made.

The systematic approach that the Group has adopted is firstly to consider all aspects of the cabin (or closely related to it) that may influence survivability, based on accidents, incidents, known areas of concern and possible future scenarios. The potential research solutions to avoid or minimise these hazards would be very numerous and no attempt is made to identify solutions for particular problems, that is a task for researchers with particular expertise to propose. With limited resources, it is necessary to prioritise the survivability factors to be addressed by research (usually followed by regulation) and a structured system for undertaking this is described in this Paper.

3 Selection of Research Topics

In order to prioritise research topics it is first necessary to identify the factors that influence occupant survival. Much work has already been carried out into the identification of these factors and a recent study carried out on behalf of Transport Canada used analytical techniques to determine the factors influencing survivability[6].

These studies were based on analyses of past accidents, or theoretical analyses of factors relevant to aircraft currently in service. Account was not been taken of factors that may be significant to future aircraft designs, nor were any of these factors claimed to be exhaustive.

The current study, described in this paper, attempted to overcome these shortcomings. The Survivability Factors generated from the previous studies were combined reducing overlap and duplication. The opinion of Cabin Safety Specialists was then sought to verify the resultant list of Survivability Factors. This was carried out by means of a questionnaire. The respondents were asked to study the list of Survivability Factors and add any additional factors they considered appropriate. The returned questionnaires were then used to generate a consensus list of Survivability Factors.

Eighty-one factors have been identified and are being prioritised by this study.

4 Prioritisation Criteria

There are many parameters that influence prioritisation. Some may be derived from existing data and others involve a degree of subjective judgement based on engineering experience. The prioritisation process must take account of previous experience gained from accidents, but should also be capable of assessing the effects of future developments in terms of aircraft design and operation.

The process, described in this paper, makes best use of data currently available, and relies on assessments being carried out by Cabin Safety Specialists for those variables that are not readily quantified by analytical techniques.

It is evident that research studies that are directed at improving occupant survival should be prioritised based on a determination of the benefit to be derived from the resultant changes. A feasibility study, funded by Transport Canada, has resulted in the development of a process which uses assessed Benefit to prioritise research topics. However Benefit may be determined in different ways. The most common of which are Perceived Benefit, Benefit and Cost Benefit.

Perceived Benefit in the context of this study is taken to mean the assessed reduction in number of fatalities, based on the experience of cabin safety specialists, afforded by improvements to a particular Survivability Factor.

Benefit in the context of this study is taken to mean the reduction in number of fatalities afforded by improvements to a particular Survivability Factor for a given time interval.

Cost Benefit in the context of this study is taken to mean the ratio of the reduction in number of fatalities, afforded by improvements to a particular Survivability Factor, to the total cost of making the improvement, for a given time interval.

The current study is intended to prioritise Survivability Factors using each of these criteria.

4.1 Perceived Benefit

For this study, the Perceived Benefit was assessed based on the subjective judgement of specialists in the field. Specialists from Europe and North America were asked, by means of a questionnaire, for their perceived benefit of making each factor the subject of a research project followed by the appropriate regulation. This is similar, in concept, to the "voting" technique used at the 1995 Atlantic City Cabin Safety Conference[1] but with a wider range of factors being considered.

In completing the questionnaire, respondents were required to assign a score between 1 and 7, to each factor, to indicate the level of perceived benefit. This score was then used to produce a ranking of Survivability Factors in Perceived Benefit order.

As of November 1998, 25 Questionnaires have been returned by respondents. The results are to be published in the final report following completion of the study.

4.2 Benefit & Cost Benefit

The variables considered most pertinent to the derivation of Benefit and Cost Benefit are summarised in Table 1.

MOST SIGNIFICANT VARIABLES IN THE DERIVATION OF BENEFIT AND COST BENEFIT	**METHOD OF EVALUATING VARIABLE**
Time for Research and Regulatory Development **A**	Questionnaire
Time to introduce change into the fleet **C**	Questionnaire
Absolute Number of Lives Saved per year **I**	Questionnaire/Analysis
Cost of development and research **R**	Questionnaire

Costs incurred due to changes **M**	Questionnaire
Available funding for research	…
Change in number of occupants per aircraft	Analysis
Change in number of survivable accidents per year	Analysis
Number of aircraft in the fleet	Analysis
Average number of seats per aircraft	Analysis
Fleet Utilisation	Analysis
Research items required for Certifications, Developments or Ministerial directives	…

Table 1: The most significant variables and their means of derivation.

Table 1 also contains the evaluation method for each of the variables. For some of the above variables, (e.g. average number of seats per aircraft, number of aircraft in the fleet) assessments must be made of their likely values over future years. This will enable an assessment to be made of the effects on Benefit and Cost Benefit. This will be carried out based on extrapolations from current data. Other variables may not be quantified as readily and as such are being assessed by means of a second questionnaire targeted at specialists in occupant survival. Each of these variables are discussed in greater detail later in the paper.

4.2.1 Simple Benefit Model

The Benefit actually achieved by any enhancement to occupant survival may be represented diagrammatically as shown in Figure 1. If the assessed number of lives saved per year, for the world fleet, for any particular factor, is **I**, then this will only be realised after the following has been achieved:

1) The necessary research is completed
2) The associated regulation has been developed
3) The change has been introduced into the fleet

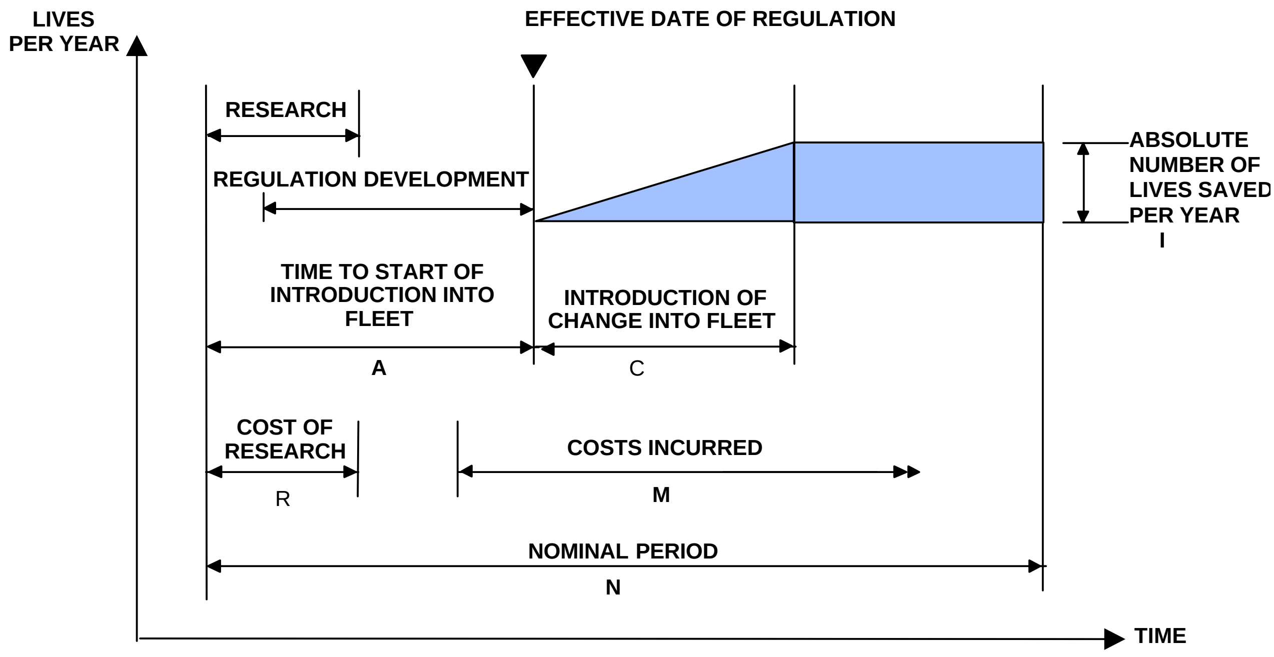

Figure 1: Variation in Benefit, in Terms of Lives Saved per Year, with Time

Time for Research and Regulatory Development **A**

The time to develop and implement change represents the assessed time to research and develop a particular Cabin Safety improvement, and to introduce the necessary Regulation. Whilst this is a difficult factor to assess it is of great importance in the determination of Benefit and Cost Benefit.

Time to introduce change into the fleet **C**

The time to introduce changes into the fleet is dependent on the cost and complexity of the improvement and the form of the Regulation that introduces the change. Amendments to JAR/FAR 25 will take a considerable time to significantly affect a change since the requirement will normally only apply to new aircraft types. However, amendments to the Operating Codes (FAR 121, JAR-OPS, etc.) will tend to become effective earlier. Hence, this is an important factor in assessing Benefit attained within a given timescale. It has been arbitrarily assumed, for this study, that the rate of introduction of change to the fleet is linear and that at the end of Period C all aircraft have been modified.

Absolute Number of Lives Saved per year **I**

This is the number of lives saved per year following the introduction of the change to the entire fleet.

4.2.2 Significance of period to be considered

It is evident from Figure 1 that the total number of lives saved, at any point in time, varies significantly with the nominal period, **N**, taken into consideration.

By way of example, consider the situation where a particular survivability factor:

- takes 5 years to carry out the research and put the necessary regulation in place
- takes a further 3 years to incorporate the necessary changes into the fleet
- and results in 10 lives being saved per year once all aircraft are modified

For any particular value of **N**, the shaded area shown in Figure 1 represents the total number of lives saved.

Obviously during the first five years, there is no benefit since the time is taken up by carrying out the necessary research and developing the appropriate regulation. After 8 years the number of lives saved = 10x3/2 = 15 which amounts to an average of 15/8=1.875 lives per year. For each subsequent year, there will be an additional 10 lives saved. The average number of lives saved per year against the period N being considered is represented graphically in Figure 2.

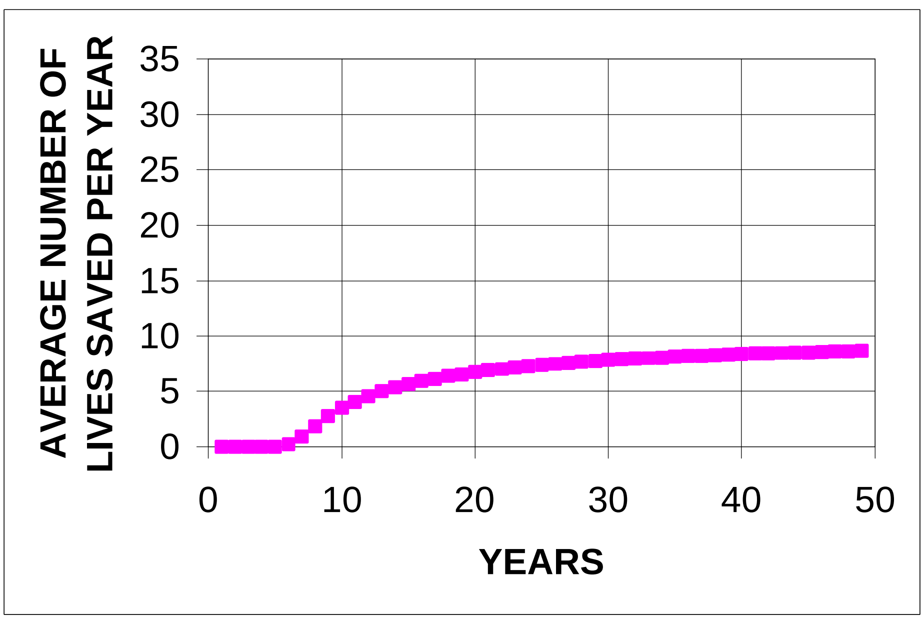

Figure 2: Variation in Average Number of Lives Saved per Year with Time

In prioritising Research Subjects based on Benefit, this nominal period, N, becomes a significant variable. Figure 3 shows how the average number of lives saved per year might vary for six examples of enhancements to survivability factors.

For each of the six subjects illustrated the average number of lives saved per year changes with time at varying rates which are dependent on the variables described in Section 4.2.1. It may be seen that if a prioritisation process is based on the achieved benefit then the outcome will vary markedly with the period considered. The process must therefore take into account the sensitivity of assessed benefit to the nominal time, **N**, considered.

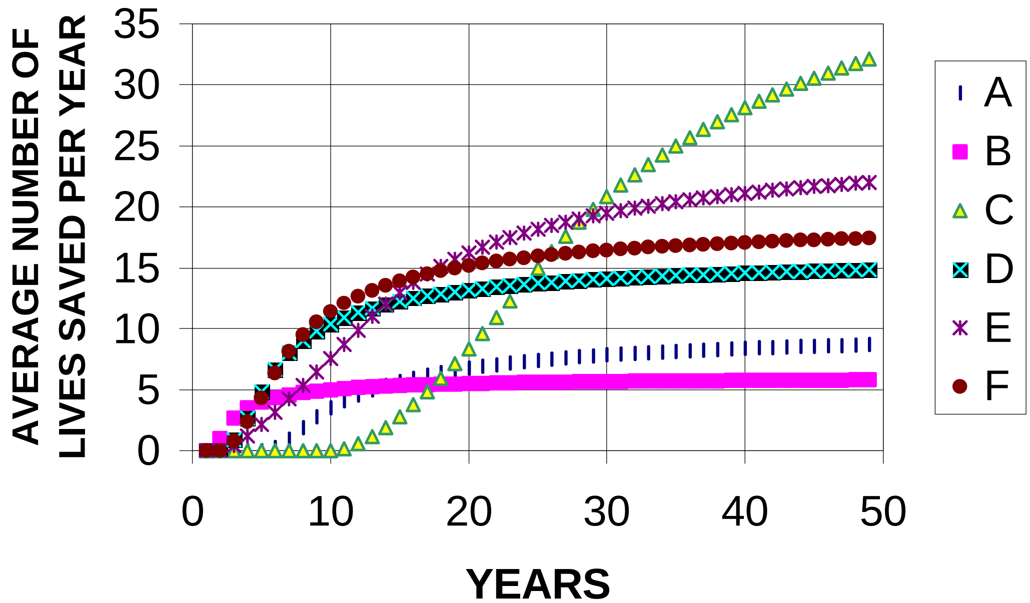

Figure 3: Variation in Average Number of Lives Saved per Year with Time for a number of safety improvements

4.2.3 Prime Cost Factors

Cost of development and research **R**

The cost of development and research is utilised in assessing the potential research projects that may be undertaken, since the total cost for all projects is limited by the Available Funding for Research. This cost is likely to be small, in comparison to that incurred by the Constructors and Operators, because of any resultant changes to the aircraft or its operation.

Cost Incurred due to Changes **M**

The costs incurred due to changes are being assessed, by means of a questionnaire using a methodology similar to the ICPTF[8] document. Whilst it is recognised that there are many shortcomings with this approach it was considered the most appropriate method available. In this process, the total cost is divided into 5 elements and each element is assigned a score in accordance with the table below:

Costs Incurred				
	1 Point	**4 Points**	**20 Points**	**100 Points**
Capital (Facilities or capital equipment)	No requirement for any new or modified facilities or capital equipment.	Requires minor modification to existing facilities or equipment. Minor investment in capital equipment may be required.	Requires minor investment in new facilities or significant modification of existing facilities or significant investment in capital equipment.	Requires substantial investment in new or modified facilities or capital equipment.
Design, Manufacture and Materials (of the change)	Negligible changes or modifications to aircraft.	Minor changes or modifications to aircraft.	Significant changes or modifications to aircraft.	Substantial changes or modifications to aircraft.
Labour (implementation of the change including training.)	Negligible increase in manhours required	Minor increase in manhours required. Basic labour requirement may be accomplished by existing workforce	Significant increase in manhours required. Increase in work force required	Substantial increase in manhours required. Significant increase in work force required
Operating Cost Increase (consumables, weight penalties, etc.)	No measurable change in operating cost	Minor increase in operating cost (>0.4%)	Significant increase in operating cost (>2.0%)	Substantial increase in operating cost (>4.0%)
Revenue Loss (departure delays, airport restrictions, loss of seats, etc.)	No measurable change in revenue	Minor loss in revenue (>0.1%)	Significant loss in revenue (>0.5%)	Substantial loss in revenue (>1.0%)

The cost elements are defined as:

Capital: Construction of new, modified or temporary facilities for design, production, tooling, training or maintenance.

Materials: Costs of product materials, product components, inventory, kits and spares associated with any change to aircraft.

Labour: Work carried out in the installation of the changes to aircraft or training of personnel.

Operating Cost Increase: Associated with fees, weight penalties, fuel, oil, and other expendables.

Revenue Loss: Departure delays, product downtime, earning capability or performance loss due to seats, range or airport restrictions.

4.2.4 Other Influencing Factors

Change in number of occupants per aircraft

This factor is considered particularly pertinent since it is likely that the passenger carrying capacity of future aircraft is likely to increase. If the number of occupants per aircraft increases it is likely that the number of fatalities in a survivable accident will increase.

Change in number of survivable accidents per year

The growth in air travel and changes in the rate of occurrence of survivable accidents and occupant survivability will affect the lives to be saved per year from any enhancements to occupant survivability factors.

Research items required for Certifications, Developments or Ministerial directives

Research items required for certifications, developments or ministerial directives are assumed to take priority over all other research tasks. As such they will simply modify the available funding for research by reducing the total by the amount required to support these activities.

Number of Aircraft in the Fleet

This factor effects the cost of any aircraft changes and has the potential to increase the number of accidents.

Average Number of seats per aircraft

Certain changes that may be carried out on aircraft may be related to aircraft size and hence this factor is an important consideration in cost determination. It does of course relate to the number of people involved in an accident.

Fleet Utilisation

Changes in aircraft utilisation have a bearing on both the determination of operating costs and the likely number of accidents per year.

Available funding for research

The Available Funding is a significant factor in that it may limit the number of projects undertaken.

5 Data Analysis

The scores from each respondent to Questionnaire 2 are being entered onto a database. Due to the complexity of determining the effect of each of the variables on Benefit and Cost Benefit a computer based mathematical model has been developed. The model also simplifies the process of determining the sensitivity of each of the variables on the assessed benefit.

6 Discussion and Conclusions

6.1 The Time for Research and Regulatory Development and the Time to Introduce Change into the Fleet are extremely significant in terms of the benefit actually realised and should be taken into account when making comparative studies of this type.

6.2 The detailed determination of Benefit is extremely difficult for any proposed change to an aircraft design or operation. Assessments of this nature are normally undertaken by a detailed analysis of past accidents. This was considered inappropriate for the prioritisation study due to the number of potential solutions to particular occupant survival factors, and the consequential size of the task in evaluating benefit.

6.3 The determination of cost, of any particular change, remains extremely difficult and its accuracy limited especially when the exact nature of the change is not defined. It is considered that a systematic prioritisation process must be used to ensure that research is directed toward the most effective areas. However, such a process should be used for guidance rather than as a prescriptive tool, in accord with the following philosophy.

> *"Cost considerations and mathematical formulas, however, should never be dispositive in making policy determinations regarding aviation safety they are one input for decision making"*

1 International Conference on Cabin Safety Research DOT/FAA/AR-95/120

2 http://www.fire.tc.faa.gov

3 Analysis of Factors Influencing the survivability of Passengers in Aircraft Accidents. R G W Cherry. Report to European Commission DGVII Jan 1995

4 Analysis of Structural Factors Influencing the Survivability of Occupants in Aeroplane Accidents. CAA Paper 96011

5 Cabin Safety Research Prioritisation. R G W Cherry. Report for Transport Canada. July 1997

6 A Study Relating to the Factors Influencing the Evacuation of Occupants from Aircraft Accidents. R G W Cherry. Report for Transport Canada. October 1996

7 The Numerical Simulation of Aircraft Evacuation and its Application to Aircraft Design and Certification. M Owen, E R Galea, P J Lawrence and L. Filippidis Paper No 97/IM/28 CMS Press

8 International Certification Procedures Task Force" NPA 21-7: Type Certification Procedures for Changed Products