

CRANFIELD UNIVERSITY

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**AIRPORT RESCUE AND FIRE FIGHTING
STANDARDS: DO THE BENEFITS JUSTIFY
THE COSTS?**

SCHOOL OF ENGINEERING

Air Transport Group

MSc THESIS

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Justify the Costs?**

Supervisor: Dr. Romano Pagliari

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Abstract

Although significant strides have been made in improving the safety of commercial air transport, fatal aircraft accidents are and will continue to be an inevitable facet of the air transport industry. Consequently, the role that Airport Rescue and Fire Fighting (ARFF) personnel play in protecting the lives of passengers and crew is a vital one. It is therefore imperative that the standards for the provision of ARFF services meet a certain minimum level. However, these services account for a significant portion of an airport's costs. Increasingly, there is pressure on airports to operate as commercial entities. Accordingly, this has presented a degree of conflict between the objectives of an airport which include reducing costs and maximising profits, and those of the ARFF service which is to save lives. Moreover, some concern has been raised by the smaller airports in the UK which hold the view that the regulations in this country are excessive and costly, particularly when compared to countries such as Australia, Canada and the USA.

This thesis examines the issues described above. Areas such as the safety environment within which commercial air transport operates; ARFF standards at the international level as well as the national regulations in Australia, Canada, the UK and the USA; the adequacy of the afore-mentioned standards and regulations; and the costs associated with meeting current ARFF standards will be analysed. Information was gathered using a variety of sources, namely trade publications, studies, accident databases and variety of regulations. Discussions were also held with industry personnel and lecturing staff of the Cranfield University. In view of the information gathered, the thesis will address the subject of whether ARFF costs can be justified in light of the benefits to be derived.

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In Memory of my Brother Danny

Glossary

Abbreviations

ACAP	Airports Capital Assistance Programme
ACI	Airports Council International
ADREP	Accident Reporting
AEIS	Aircraft Emergency Intervention Services
AIP	Airport Improvement Programme
ALARP	As low as Reasonably Practical
ARFF	Airport Rescue and Fire Fighting
ATAC	Air Transport Association of Canada
CAA	Civil Aviation Authority
CAC	Canadian Airports Council
CARS	Civil Aviation Regulations
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulation
CBA	Cost Base Assessment
CFS	Community Fire Station
CIS	Commonwealth of Independent States
CPF	Cost for Preventing Fatality
DND	Department of National Defence
Ers	Emergency Response Personnel
ERSA	Enroute Supplement Australia
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
HAL	Highlands and Islands Airports Limited
HSE	Health and Safety Executive
IAFF	International Association of Fire Fighters
ICAO	International Civil Aviation Organisation
JAA	Joint Aviation Airworthiness
N/A	Not Applicable/Available
NLR	National Aerospace Laboratory
NOTAM	Notice to Airmen
NTSB	National Transport Safety Board
O&M	Operations and Maintenance
PCA	Practical Critical Area
PFC	Passenger Facility Charge
QRA	Qualitative Risk Assessment
RFF	Rescue and Fire Fighting
RIV	Rapid Intervention Vehicle
SARP	Standards and Recommended Practices
SRG	Safety Regulation Group
TC	Transport Canada
TCA	Theoretical Critical Area

VPF
WAAS

Value of Preventing Fatality
World Airline Accident Summary

Definitions

Aerodrome

(Airport):

An area on land or water (including buildings and equipment) intended either wholly or in part, for the arrival, departure and surface movement of aircraft - **ICAO**

Accident:

An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

1. A person is fatally or seriously injured as a result of:
 - a. Being in the aircraft; or
 - b. Direct contact with any part of the aircraft, including parts which have become detached from the aircraft; or
 - c. Direct exposure to jetblast,

Except when the injuries are from natural causes, self inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

2. The aircraft sustains major damage or structural failure which:
 - a. Adversely affects the structural strength, performance or flight characteristics of the aircraft; and
 - b. Would normally require major repair or replacement of the affected component

Except for engine failure or major damage, when the damage is limited to the engine, its cowlings or accessories; or for damages limited to propellers, wing

tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

3. The aircraft is missing or is completely inaccessible.

Notes: For statistical uniformity only, an injury resulting in death within 30 days of the date of the accident is classified as a fatal injury.

An aircraft is considered missing when the official search has been concluded and the wreckage has not been located. – **ICAO Annex 13**

Aqueous

Film

Forming Foam:

(Foam meeting performance level B) – This extinguishes fires faster than protein foams but the liquid film over the fuel surface is destroyed by high fires. Not suitable for fires with large amounts of hot metal - **Ashford, Stanton and Moore**

Causal Factor:

An event or item which was directly instrumental in the causal chain of events leading to the accident – **UK CAA**

Circumstantial

Contributing

Factor:

An event or item which was not directly in the causal chain of events, but which could have contributed to the accident – **UK CAA**

Hull Loss:

Airplane damage which is substantial and beyond economic repair. Hull loss includes, but is not limited to damage in which:

1. The airplane is totally destroyed; or

2. The airplane is missing; or
3. The search for wreckage has been terminated without it being located; or
4. The airplane is completely inaccessible – **Boeing**

Incident: An occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation. – **ICAO Annex 13/Doc 9713**

Primary

Causal Factor: The dominant causal factor of the accident as judged by the group conducting the analysis. – **UK CAA**

Protein Foam: (Foam meeting Performance Level A) – Foam that is mechanically produced and capable of forming a long lasting blanket – **Ashford, Stanton and Moore**

Serious Incident: An incident involving circumstances indicating that an accident nearly occurred. Note: The difference between an accident and a serious incident lies only in the result – **ICAO Annex 13**

Theoretical Critical

Area: The distance needed between the fuselage of an aircraft and a fire in order to maintain survivable conditions within the cabin. This distance is estimated at 50ft for larger aircraft and 20ft for smaller aircraft. - **Hewes**

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Chapter 1: Introduction

1.1 BACKGROUND AND SCOPE OF RESEARCH

Although commercial aviation is a relatively safe mode of transport, the potential threat to this sector is perhaps greater than to all other transport sectors. No other form of transportation has to deal with toxic smoke or fumes and passenger compartment fires that reach lethal levels in just a matter of three minutes. In fact, post impact fires associated with aircraft accidents can reach as high as 2,500F. Furthermore, it only takes one minute before the aluminium skin is burnt through. Experiments conducted by the Federal Aviation Administration (FAA) on the effects of fuel fires on airframe structures show that a typical aircraft structure can only withstand an external fire for 30 to 60 seconds. Once the airframe has been breached, it only takes another two to three minutes before the temperature inside the aircraft reaches 1,800F. The fire spreads quickly because of the high level of ambient thermal radiation which presents ideal conditions for the life of the fire. The most significant threats to the cabin from the fire burn through are the intense heat, smoke, smoke obscuration and toxic fumes from the materials in the cabin furnishings and trim which quickly pyrolise and ignite.

According to Macey (1997), the atmosphere inside an aircraft on fire can have a wide range of effects on people. These include the following:

- The high temperatures can cause serious burns, particularly to the respiratory tract;
- Smoke can seriously restrict vision and this can reduce the chances of a person escaping the aircraft to a safer environment;
- Smoke and narcotic gases can cause rapid incapacitation and death;
- Hypoxia induced behavioural changes may result from the low oxygen levels and this in turn may result in increased respiration of the toxic atmosphere within the cabin; and

- The toxic environment and irritants in the atmosphere can result in painful symptoms to the eyes as well as the upper respiratory track and the lungs.

The narcosis that is likely to occur to someone as a result of an aircraft accident involving fire is particularly dangerous because of the relatively short time between that person exhibiting near normal behaviour and falling unconscious. Whilst the body is able to adapt to narcotic environmental conditions, exposure to such conditions beyond a certain level can cause the body's defence mechanism to collapse and this can lead to rapid and severe deterioration. The sequences of events in human narcosis are behavioural changes such as lethargy or euphoria, poor physical co-ordination (which can severely restrict a person's ability to escape), unconsciousness and finally death. Persons trapped in a burning aircraft are therefore more likely to succumb to the aforementioned threats rather than to the impact of the crash. Actually, research indicates that in many survivable aircraft accidents involving fire, 75% of the deaths that occur annually are due to the effects of the fire (Macey, 1997).

There have been numerous efforts within the air transport industry to reduce the likelihood of aircraft accidents occurring. Continued work conducted in the field of engineering has sought to ensure that aircraft are more structurally sound and that performance is enhanced. In spite of these efforts however, one has to be cognisant that air transport accidents, fatal or otherwise, are an inevitable aspect of the industry. None-the-less, injuries and fatalities can be reduced significantly with the implementation of appropriate and adequate secondary measures such as Airport Rescue and Fire Fighting (ARFF) standards, regulations and practices. As the majority of all aircraft accidents take place during the take-off or landing phase, the provision of effective and adequate emergency services at airports is one of the most critical ways in which safety within the industry may be enhanced.

The need for high standards of ARFF services can be demonstrated in the British Airtours Boeing 737-200 accident at Manchester International Airport on August 22, 1985. As this aircraft, carrying 131 passengers and six crew, was approaching take-off speed, the pilots heard a thud and thought that it may have been a bird strike or a burst

tyre. The pilots therefore immediately abandoned take-off after which, they received confirmation from the tower that there was a fire on the left engine. It was later confirmed by the investigation that the loud thud had occurred as a result of an explosion in the left wing. The explosion ignited the fuel that was leaking from the left wing tank which had been penetrated. The pilots, following airline procedure, turned the aircraft to the right and off the main runway. Unfortunately, a light wind blew the flames onto and around the rear of the fuselage. Within one minute of the aircraft coming to a halt, the fire had burned through the fuselage and had entered the cabin. Although the first Rapid Intervention Vehicle (RIV) arrived at the scene and began to discharge foam onto the aircraft 25 seconds after it had stopped and the second RIV arrived shortly after, 55 people died.

Accidents such as these and numerous others all suggest that there needs to be effective and adequate levels of ARFF standards in place. Yet, there is some debate over what the minimum standards should be. The International Civil Aviation Organisation (ICAO) has developed a series of Standards and Recommended Practices (SARP's) for airports and these are published in Chapter 9 of Annex 14. The SARP's are considered binding as Contracting States to the ICAO are expected to implement legislation based on the SARP's. However, there is provision for states to file any differences that will exist in their civil aviation regulations with the ICAO. These differences are published in the Supplements to the Annexes which are distributed to the Contracting States.

Accordingly, there are variances with respect to regulations and standards for the provision of ARFF services around the world. In countries such as the United Kingdom for instance, regulations dealing with these services tend to be very stringent, particularly when compared to other countries such as Australia, Canada and the United States of America, all of which, it must be noted, have among the lowest accident rates in the world. Consequently, the smaller and less profitable airport authorities in the UK believe that the ARFF regulations as outlined in CAP 168 are excessive and costly.

Australia on the other hand has recently undergone reformation of its civil aviation policy which covers the provision of ARFF services at its airports. During this

reformation, Australia realised that it could mandate coverage for a greater portion of its airports, but opted not to do so. One of the justifications for taking this stance was that the increase in costs associated with the provision of a specified level of ARFF services did not reduce the level of risks for passengers, crew and third parties.

According to the International Association of Fire Fighters (IAFF), the level of rescue and fire fighting services in Canada do not meet the international standards of the National Fire Protection Association nor the ICAO as in the case of the smaller airports. Changes in airport policies in 1994 have led to agreements between the municipal fire services and some medium sized airports whereby the provision of on site fire and rescue services has been abandoned. The concern that has been raised here is that the municipal services can take up to 15 minutes to respond whereas, the fuselage of an aircraft can be completely consumed by fire in three minutes. Furthermore, the SARP's as outlined in Chapter 9 of Annex 14 require a response time of no more than three minutes, that is, the time from the initial emergency call until the first vehicle arrives at the scene of the accident. However, as will be demonstrated later, Canada is about to raise the standards for some airports so that a response time of five minutes will be required. Again, the cost factor played a significant role in the determination of the level of standards that were introduced by Transport Canada.

Whilst it has been recognised that the main goal of ARFF services is to save lives, the airport authorities in the fore-going countries have raised a valid concern and that is that the benefits to the industry may not justify the costs of meeting ARFF standards. One has to be cognisant of the fact that more than ever before, airports are required to operate as commercial entities. If the safety measures to be provided by airports are too costly for them to be viable, then there is the likelihood that they will have to close and this can in turn be detrimental to air transport. Hence, there is no doubt that the benefits to be derived from the implementation of safety measures must be weighed against the costs of these measures, particularly in light of the fact that it is impossible to provide a totally safe environment.

Accordingly, the research outlined in this thesis will critically examine the following:

- Safety related issues in commercial air transport;
- ARFF standards at the international level as well as at the national regulations in Australia, Canada, the USA and the UK;
- The appropriateness of the fore-going standards and regulations;
- Costs and benefits associated with current ARFF standards, particularly at airports with passenger traffic levels of between 50,000 and 500,000 in the countries mentioned above;
- Whether the benefits to be derived from ARFF standards, regulations and recommended practices can justify the costs; and
- Alternative approaches to the provision of ARFF services at airports fitting the fore-going criteria.

1.2 LITERATURE REVIEW

The effects of fire on aircraft as well as the types of injuries and the level of fatalities associated with aircraft accidents are well documented. Much research has gone into evacuation of passengers from burning aircraft and realistic response times that are required in order to minimise the level of harm to passengers and crew in addition to the number of fatalities. There is also some literature on the need to raise the level of ARFF standards and regulations at airports, particularly in Australia, Canada and the USA. However, little work has been done on the costs to airports in the implementation and maintenance of the standards and regulations and whether the anticipated increase in benefits can justify these costs.

Braithwaite (2001) in his article ‘Aviation Rescue and Fire Fighting in Australia – is it Protecting the Customer?’ noted that to reduce the level of ARFF coverage at airports in Australia was a step in the wrong direction, given that the aims of the industry in terms of safety was to reduce accident rates. Braithwaite presents a case for the need to ensure that passengers, regardless of their airport of choice, are provided with an optimum level of ARFF coverage in the event of an accident.

O’Sullivan (2001), in his article ‘Future of Airport Rescue Fire Fighting Services’, noted that the determination of minimum ARFF standards was a difficult one to make, particularly in light of the issues surrounding the cost of a human life. Whilst this may be the case, O’Sullivan concluded that it was not logical for airports to base the level of rescue and fire protection coverage on the value of the lives of departing and arriving passengers, but rather, that the level of this coverage should be based on response and performance.

Cooke (1999) also examined the issue of rescue and fire coverage at airports particularly in the UK and the USA. In his thesis, Cooke presented arguments for raising the standards of fire and rescue services, particularly at the larger and busiest airports in the aforementioned countries.

Weir (1999) also looked at the issue of fire in aircraft accidents and advocates the need to ensure that safety precautions and safety research are assiduously carried out. Much of his writing in ‘The Tombstone Imperative – the Truth about Air Safety’ focuses on the roles that airlines and the regulators can play in the provision of a relatively safe air transport industry.

The Coalition for Airport and Airplane Passenger Safety in 1999 produced an article entitled ‘Surviving the Crash – the Need to Improve Lifesaving Measures at Our Nation’s Airports’. In this article, the Coalition also presents a case for the raising of standards of rescue and fire operations at airports in North America. The article cites the need to:

- Improve airport rescue and fire services in terms of, *inter alia*, the methods of fighting aircraft fires (i.e. the Coalition expressed the view that there is a strong need for rescue and fire personnel to fight aircraft fires from inside the aircraft as well as to extricate trapped victims);
- Reduce the required response times as well as to standardise these times; and
- Ensure that staffing levels together with fire fighting equipment and materials are adequate.

From the literature search that was conducted it was revealed that many authors recognised the need for an adequate level of rescue and fire coverage. Some authors also recognised that cost will be a factor in an airport's ability to provide a certain level of standards. However, there is little detail about the costs versus the risk implications for airports, particularly the smaller airports where traffic levels and profitability are not as high as the larger well known airports such as Heathrow in the UK and Sydney in Australia. Accordingly, this thesis will attempt to address these and other matters relating to ARFF operations.

In addition to the fore-going, it should be noted that the Health and Safety Executive (HSE) has conducted and published extensive research in the area of risk assessments. The findings of this research were reviewed and drawn on in the writing up of this thesis. 'Chapter 3: 'Risk Assessments' in particular reflects the research compiled by the HSE.

1.3 RESEARCH AIMS AND OBJECTIVES

As was noted in section 1.2, little research has been done in the area of the impact of ARFF standards on airport costs, particularly for smaller airports. To this end, the aim of this thesis is to examine rescue and fire fighting standards and practices and their implications with respect to costs, risk reduction and safety benefits. In considering the fore-going, the focus will be on airports with passenger traffic statistics of between 50,000 and 500,000 per annum in Australia, Canada, the UK (Scotland) and the USA. The specific objectives are as follows:

- To examine the safety environment within which the commercial air transport industry operates;
- To critically examine the ICAO recommendations as well as the national regulations pertaining to the provision of ARFF services in Australia, Canada, the UK (Scotland) and the USA;

- To assess the cost implications associated with rescue and fire coverage at airports with annual passenger traffic between 50,000 and 500,000 in the aforementioned countries; and
- To determine whether the costs associated with meeting current ARFF standards can be justified in light of the reduction in risks to passengers and/or other anticipated benefits.

1.4 METHODOLOGY

Information was collected from a variety of publications including the ICAO Annexes, particularly Chapter 9 of Annex 14,; other regulatory documentation pertaining to the countries included in this research; reports and other publications on accidents in the aviation sector; as well as a variety of databases, articles and other publications dealing with the issue of safety in civil aviation. These publications include those from the UK Civil Aviation Authority (CAA) Safety Regulation Group (SRG), Flight Safety Foundation, the European Transport Safety Council, Eurocontrol and the Health and Safety Executive to name a few. Information was also gathered from dissertations conducted by past students of the Cranfield University.

In addition, discussions were held with academic professionals at Cranfield University and industry personnel, a list of which is included in Appendix A. Questionnaires were developed and administered to the CAA SRG and Highlands and Islands Airports Limited (HIAL). A visit was also paid to HIAL where discussions were held with the Managing Director and the Senior Fire Officer. In the development of the questionnaires (copies of which are included in Appendix B) efforts were made to reduce bias as much as possible. For instance, rather than ask ‘How have the Rescue and Fire Fighting regulations impacted on the profitability of this airport?’ the following question was asked, ‘What are the costs and benefits of the Rescue and Fire Fighting regulations as they relate to this airport?’

A number of airports were also contacted in Australia, Canada and the USA. The purpose of contacting these airports was to gather financial information, including a break down of the costs of rescue and fire fighting services, as well as to ascertain the

impact of the relevant standards and regulations on the airports. However, no responses were received from these airports.

A number of insurance companies were also contacted with a view to ascertain the implications of a reduced level of ARFF coverage at airports on insurance premiums. Again, there were no responses from the companies that were contacted.

The information and data that was collected was carefully reviewed and analysed. Conclusions were then drawn and recommendations were developed based on this review and analysis.

1.5 STRUCTURE OF THESIS

This thesis is divided into six (6) chapters. The following five (5) chapters are organised as follows:

Chapter 2: Aviation Safety: A Historical Perspective

Chapter 2 will address the issue of safety in commercial air transport in general. Accident statistics will be reviewed at the global level and according to the main regions of the world, namely Africa, Australasia, Europe, Central and South America and North America. Matters pertaining to the enhancement of aviation safety will also be discussed and comparisons will be made with respect to air and other modes of transport.

Chapter 3: Risk Assessments

This chapter will outline the key principles involved in risk assessments; the challenges faced and the benefits of risk assessments; and how risk assessments may be used to determine whether the cost of a particular risk reduction measure is justified in terms of the benefits to be derived. Application of the risk assessment principle ‘As Low As Reasonably Practical’ (ALARP) to the provision of ARFF standards, regulations and practices at airports will also be discussed.

Chapter 4: The Regulatory Framework

The development of ARFF standards and regulations to address the matter of safety in this industry will be discussed, beginning with the SARP's as outlined by the ICAO in Chapter 9 of Annex 14. This will be followed by a discussion of the regulations relating to the countries that will be considered in this study; the issues related to the specific regulations in these countries; and compliance of the countries with the international standards. Furthermore, the appropriateness of the standards and regulations given the safety and risk related issues associated with air transportation will be examined.

Chapter 5: Costs Associated with Aviation Rescue and Fire Fighting Standards

The costs associated with meeting ARFF standards and the provision of services will be addressed in this chapter. As detailed information relating to the Aircraft Emergency Intervention Services in Canada was available, much of the chapter will focus on these costs. For the USA, Rapid City Regional Airport will be used as a case study. There will also be an overview of current issues in ARFF costs in Australia and Scotland. General cost implications for airports will also be discussed.

Chapter 6: Conclusions and Recommendations

Chapter 6 will evaluate the success of the thesis in accomplishing the research objectives. The key findings will be summarised and the main research question, which is 'do the benefits associated with ARFF standards justify the costs?' will be answered. Suggestions for further research will also be provided.

Chapter 2: Aviation Safety - A Historical Perspective

2.1 INTRODUCTION

'At the most general level, transportation accidents can be taken to comprise a loss of control over energy, caused by human fallibility. The unavoidability of both these factors suggests that we will forever be dealing with issues of travel safety.' (Macey 1997).

In order to develop or enhance safety measures within the air transport industry, there is a need for adequate information regarding all facets of aircraft accident survivability. Such information, which comes mainly from accident records, may be used in developing standards, regulations and recommended practices. Unfortunately, the quality and extent of accident records vary widely according to the source and furthermore, the information available does not cover all categories or aspects of occurrences. This may be due in part to the fact that there is no universally accepted standard for investigating and reporting accidents. Many countries simply refuse to report their accidents openly for a number of reasons some of which may be cultural, political or financial. Another area which has been overlooked and which is of particular relevance to this thesis relates to the lack of adequate reporting and/or analysis of events which could have otherwise been disastrous had they not been dealt with appropriately. The incompleteness of the information makes it difficult to properly analyse areas such as fatal accidents versus other types of accidents; on board fatalities versus third party fatalities; as well as the effectiveness of safety intervention measures.

Never-the-less, considerable work has been conducted in the compilation of accidents and incidents. Some of the more credible and comprehensive records were compiled by sources such as the UK CAA World Airline Accident Summary (WAAS) and the ICAO

Accident Reporting (ADREP) database. Much of the information outlined below used the WAAS as the original source.

2.1.1 Safety in Commercial Air Transport

Commercial air transport is one of the safest forms of transportation in terms of distance travelled. In terms of passenger hours travelled, it is safer than cycling and motor cycling. Conversely, in terms of passenger journeys, air transport is one of the least safe modes of transportation. The table below depicts passenger fatality rates (per 100 million km, journeys and hours) by mode of transport¹: It should be noted that most aircraft accidents take place during the ground, initial climb and descent phases of aircraft operations². It is therefore not surprising that accident rates in terms of passenger journeys in air transport is greater than for other modes of transport.

Table 2.1: Passenger Fatality Rates (per 100 million km, journeys and hours) by Mode of Transport

Mode	Passenger Kilometres	Passenger Journeys	Passenger Hours
Air (Public)	0.08	55.0	36.5
Bus/Coach	0.08	0.3	2.0
Rail	0.04	3.0	2.0
Car	0.80	5.0	30.0
Ferry	0.33	25.0	12.0
Cycle	6.30	12.0	90.0
Foot	7.50	5.0	30.0
Motor Cycle	16.00	100.0	500.0

Source: Infrastructure and the Environment: Safety in Air Transport Lecture Notes

Although air transport can be said to be one of the safest modes of transport in terms of distance travelled, on the rare occasions that accidents occur and in the event that they are serious, many lives can be lost as a result of one event. Most road accidents result in less than five fatalities, and rail accidents, though they may be serious, occur less frequently. Rail accidents are therefore not as dramatic as air transport related accidents

¹ Includes general aviation and military operations

or marine accidents which, to some extent, hold a profile similar to that of accidents involving aircraft.

As Macey (1997) notes, fatal accidents are an inescapable consequence of life. Hence, in order to reduce aircraft accident rates and increase survival rates in the future, there will be a need to reduce the severity of these accidents when they do occur. This will involve to a large extent reducing the number of deaths resulting from fires, smoke inhalation, toxic fumes and the impact of the crash among other things. Accordingly, ARFF operations will continue to play a significant role in the survivability aspects of aircraft accidents.

Whilst the importance of rescue and fire fighting operations in air transport accidents has been recognized, it must also be acknowledged that a comprehensive approach is paramount to the reduction and severity of such accidents. Consequently, other measures such as those relating to aircraft design, impact protection measures and operating procedures must also be addressed along with search, rescue and fire fighting initiatives. This is critical as traffic levels are likely to continue to increase. Thus, if there are no improvements to the accident rates, then one can expect accidents to occur at increasing frequencies in the future.

2.2 ACCIDENT STATISTICS WORLD-WIDE

In order to develop or enhance safety measures within the air transport industry, past events must be fully understood so that endeavours can be undertaken to prevent a similar event re-occurring. It is therefore imperative that thorough aircraft accident investigations are conducted and that the process and findings are reported. Currently, the reporting of accidents has not been as thorough as they should be at the global level. To this end, it is sometimes impossible to draw accurate conclusions as to the real risks involved in air transport and how best to reduce these risks. However, there is still much information recorded on accidents that have taken place and there are a number of databases from which adequate inferences may be drawn.

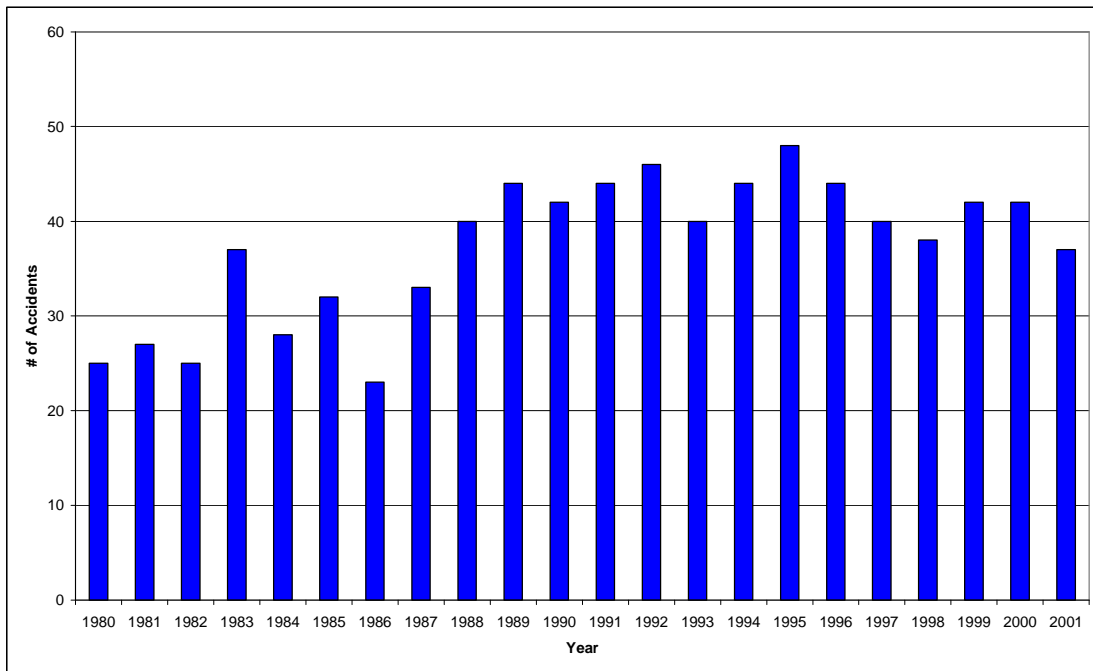
² Aircraft accidents by phase of flight is discussed further in section 2.2.2

A review of the world-wide air accident statistics has revealed that accident rates have been declining steadily since the 1950's. In a study conducted by the SRG, it was established that during the mid 1960's, the world-wide fatal accident rate for commercial passenger jets was approximately five per one million flights. By the mid 1990's this figure fell to 0.5 per one million flights, with the most significant reductions occurring during the period up to 1970. Since this time, there have only been minor decreases in the accident rates (European Transport Safety Council, 1996). Prior to 2000, fatal accident rates per million flights according to the WAAS stood at 0.46 for Western built jets and 1.19 for Western built turbo-props. The trend in the reduction in accident rates may be attributed in part to significant improvements that have been made in technology. However, it would appear as though further improvements are becoming increasingly more difficult to achieve.

Whilst there appears to be no strong correlation between the number of fatal accidents and the number of fatalities, the statistics indicate that the overall reduction in accident rates has not been accompanied by a similar reduction in the fatality rate. Between 1980 and 2001, there have been a total of 821 fatal accidents involving public transport aircraft. This represents a compound average growth rate of 32.9% (using the best fit line). Conversely, for the same period, the total number of fatalities³ was 21,833, representing a compound average growth rate of 51.2% (using the best fit line). With a total of 821 accidents giving rise to 21,833 fatalities, this implies that there was an average of just over 26 fatalities per accident or 992 fatalities per year. Figures 2.1, 2.2 and 2.3 depict the number of fatal accidents and fatalities world-wide for the period 1980 to 2001.

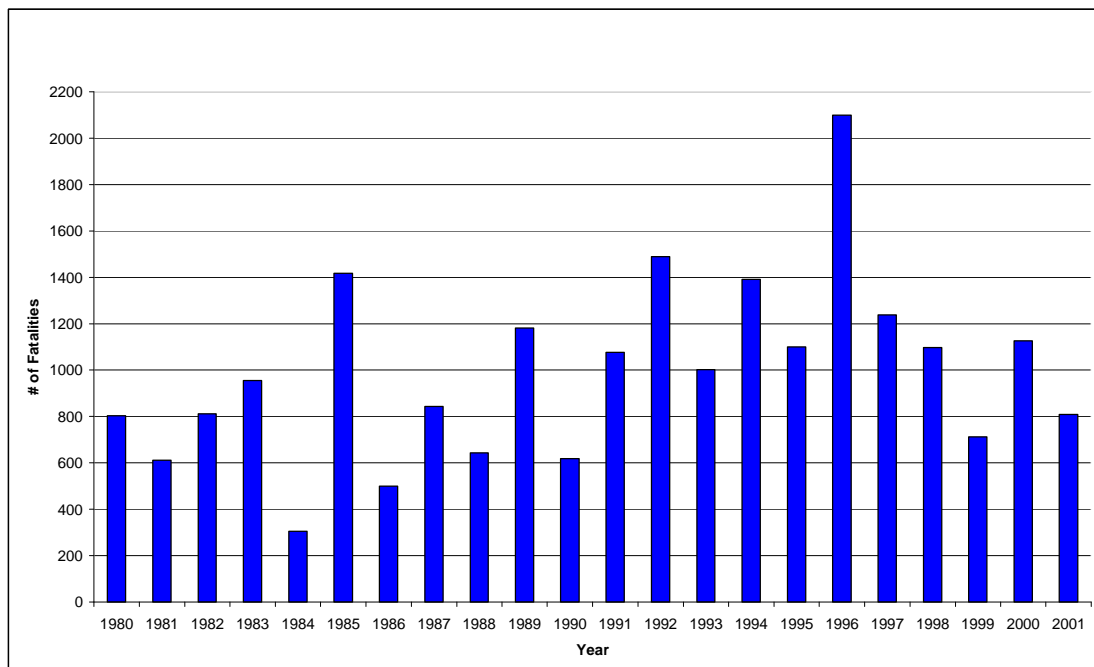
³ Excluding the Commonwealth of Independent States.

Figure 2.1: World-wide Fatal Accidents



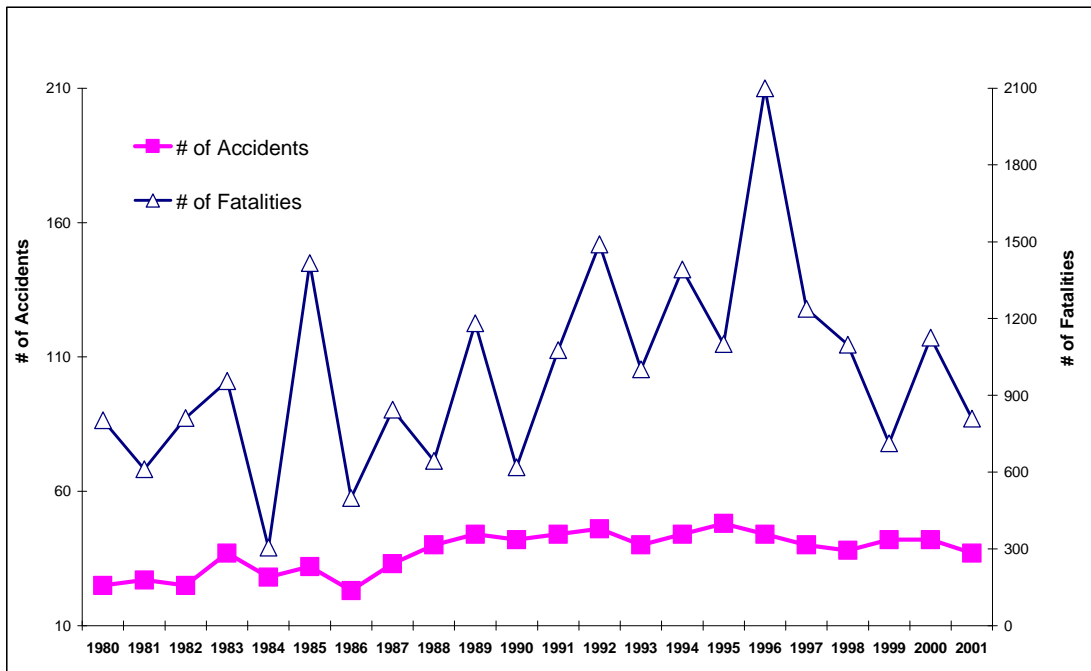
Source: European Organisation for the Safety of Air Navigation

Figure 2.2: World-wide Fatalities in Air Transport Accidents



Source: European Organisation for the Safety of Air Navigation

Figure 2.3: Evolution of Fatal Accidents World-wide



Source: European Organisation for the Safety of Air Navigation

2.2.1 Survivability Aspects

According to Aviation Safety Network, the survival rate of passengers involved in aircraft accidents have increased from 24% in the 1930's, when much fewer people travelled by air, to 35% in the 1990's+ when passenger volumes in air transport have increased significantly (see Table 2.2 below).

Table 2.2: Survival Rate of Passengers According to Decade

Decade	1930's	1940's	1950's	1960's	1970's	1980's	1990's+
% Surviving	24	24	23	21	25	30	35

Source: PlaneCrashinfo.com accident database, 1930 - 2002

Whilst there is an overall upward trend in the survival rates of passengers involved in fatal accidents, there is still much room for improvement. The European Transport Safety Council estimates that 90% of aircraft accidents are survivable or technically survivable⁴. The Council further estimates that 60% of air transport fatalities are

⁴ Technically survivable accidents refer to those in which some of the passengers and/or crew survive.

attributable to non-survivable accidents implying that approximately 40% of the deaths result from accidents that are technically survivable. Of this 40%, approximately 45% of the deaths occur as a result of smoke, toxic fumes, heat and evacuation problems.

2.2.2 Accidents by Phase of Flight

An estimated 5% of all aircraft related accidents occur en route and the causes of these accidents are usually related to mechanical and structural fatigue failure, weather or collision with terrain, namely mountains. With these types of accidents there are normally few survivors and this will have little implication for ARFF operations unless the accident occurs near the airport or within the boundaries of a particular airport.

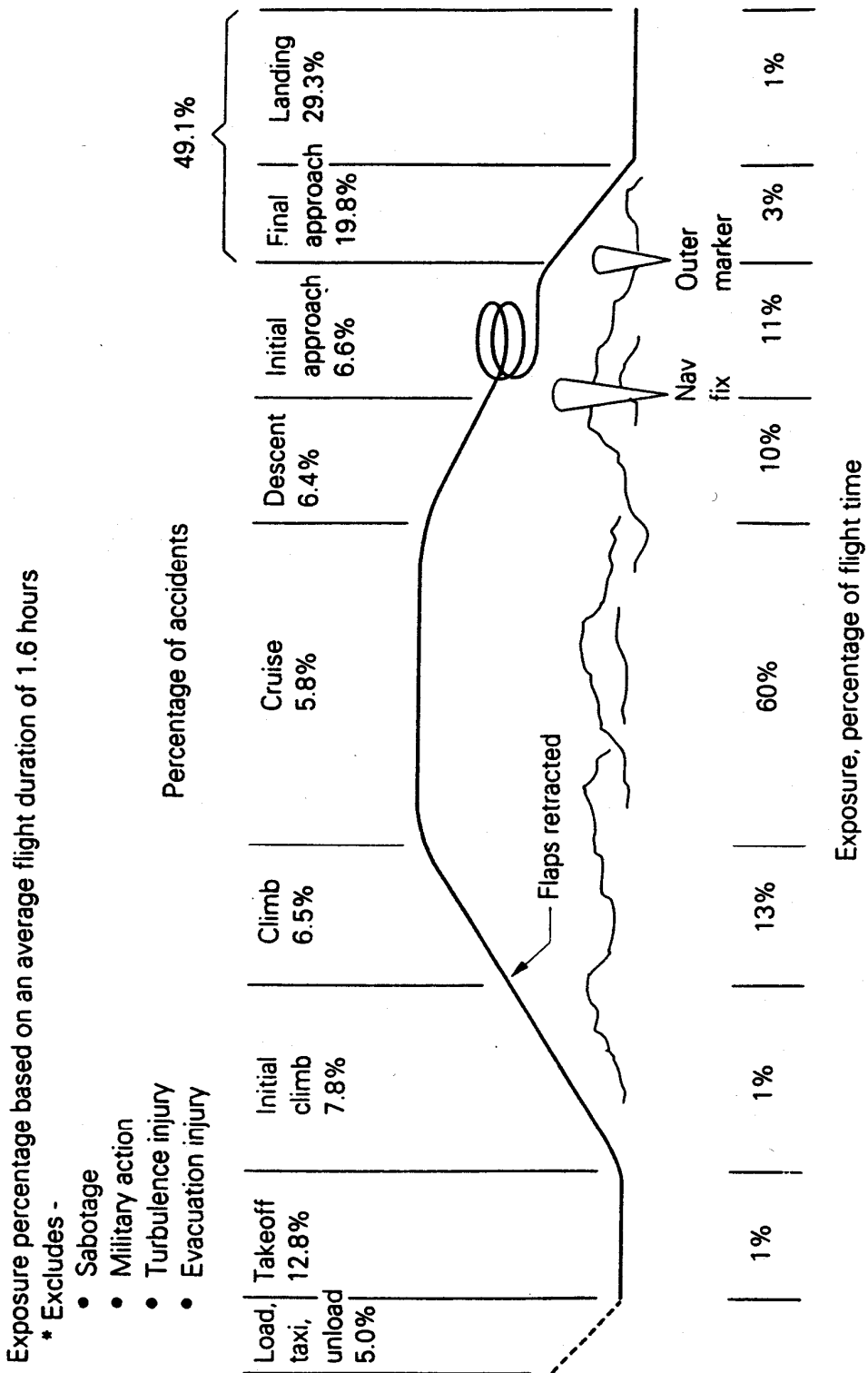
Approximately 14% of aircraft accidents take place during the final climb or initial descent phases. These accidents will have implications for the ARFF operations. Over 50% of all accidents take place during the initial approach⁵, final approach and landing phases of the aircraft operation (see figure 2.4 for a break down of accidents according to phase of flight⁶). These accidents will also present some concern for ARFF operations.

Less than 31% of all other accidents take place within 200 metres of the centre line of the active runway and within 1500 metres of the runway thresholds i.e. the Critical Rescue and Fire Fighting Response Area. At many airports throughout the world, there may be obstructions on runway approach areas and these can impede the response capabilities of the rescue and fire fighting team thereby intensifying the severity of the accident.

⁵ Within 30km of the airport

⁶ Appendix C also provides information regarding number of accidents occurring by phase of flight

Figure 2.4: Accidents by Phase of Flight



Source: Boeing/British Airways Safety Services

2.2.3 Air Accident Statistics by Country

Table 2.3 and Figures 2.5 to 2.7 reflect statistics from the ICAO on accidents occurring between 1992 and 2001. Table 2.3 provides an overview of scheduled aircraft departures and fatal aircraft accidents according to geographical region. Figure 2.5 depicts in graphical form the percentage of departures attributable to each region and Figure 2.6 shows the percentage of accidents occurring by region. According to the data provided in the table and the figures, North America had the highest percentage of departures over the period in question with 42% of all departures world-wide, followed by Europe with 29%. The Asia-Australia region accounted for 17% of the world's departures, whilst South and Central America accounted for 9%.

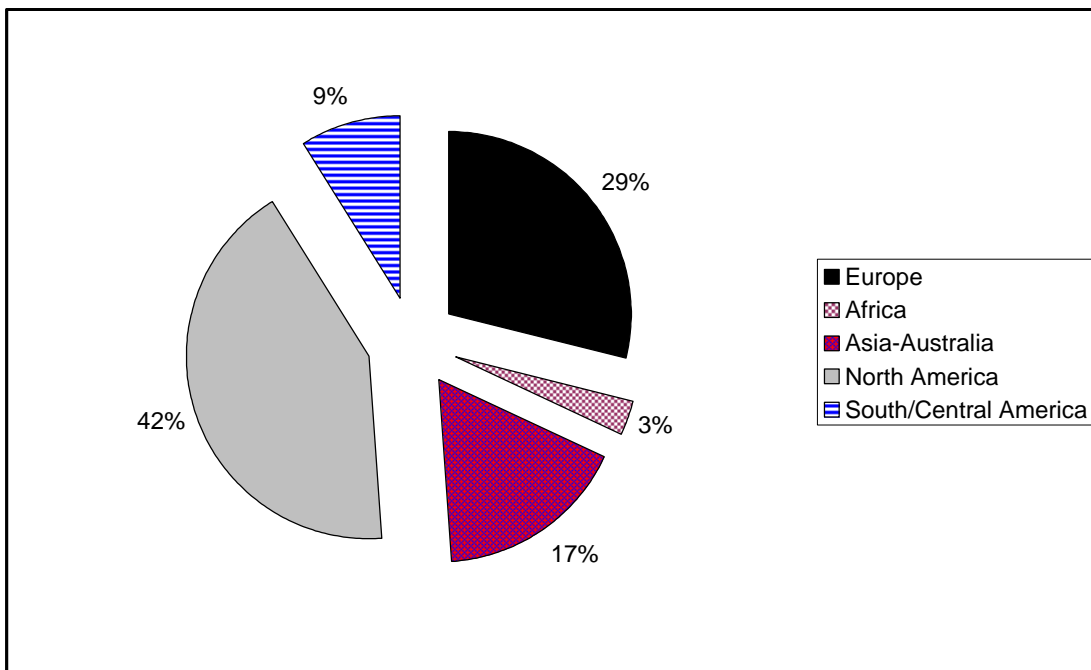
Although North America accounted for the greatest percentage of departures world-wide, it had the second lowest percentage (17.7%) of total fatal accidents. This was followed by South and Central America with 18%, Europe with 19.3% and the Asia-Australia region with 28.0%. Africa recorded the lowest percentage of total fatal accidents with 17.0%. However, when the percentage of total fatal accidents per departure is compared, Africa has the least favourable record, followed by South and Central America, and then the Asia-Australia region, all of which have higher percentages of accidents than departures. Conversely, North America followed by Europe has the lowest percentages of fatal accidents per departure. In both cases, the percentage of fatal accidents was lower than the percentage of departures. Figure 2.7 depicts the percentage of accidents versus the percentage of departures for each of the afore-mentioned regions.

Table 2.3: Accident Statistics by Region

Region	% of Departures	% of Accidents	% of Crashes per Location	# of Countries
Europe	29	19.3	19.9	46
Africa	3	17.0	15.8	53
Asia-Australia	17	28.0	26.8	59
North America	42	17.7	18.8	2
South/Central America	9	18.0	18.6	41

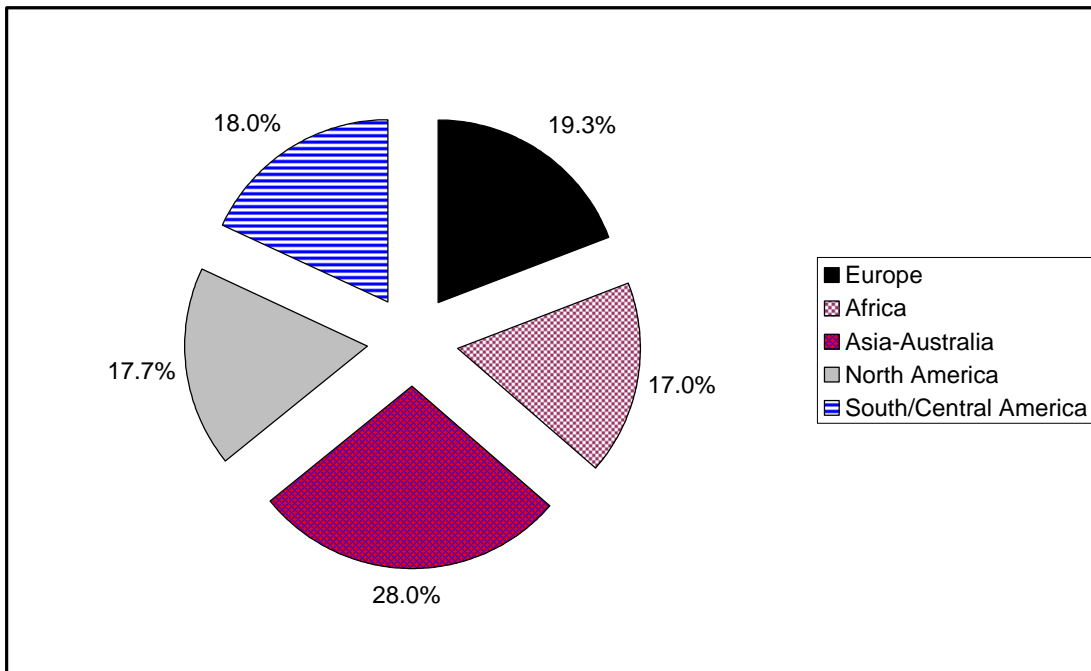
Source: Aviation Safety Network

Figure 2.5: Percent of World Departures by Region



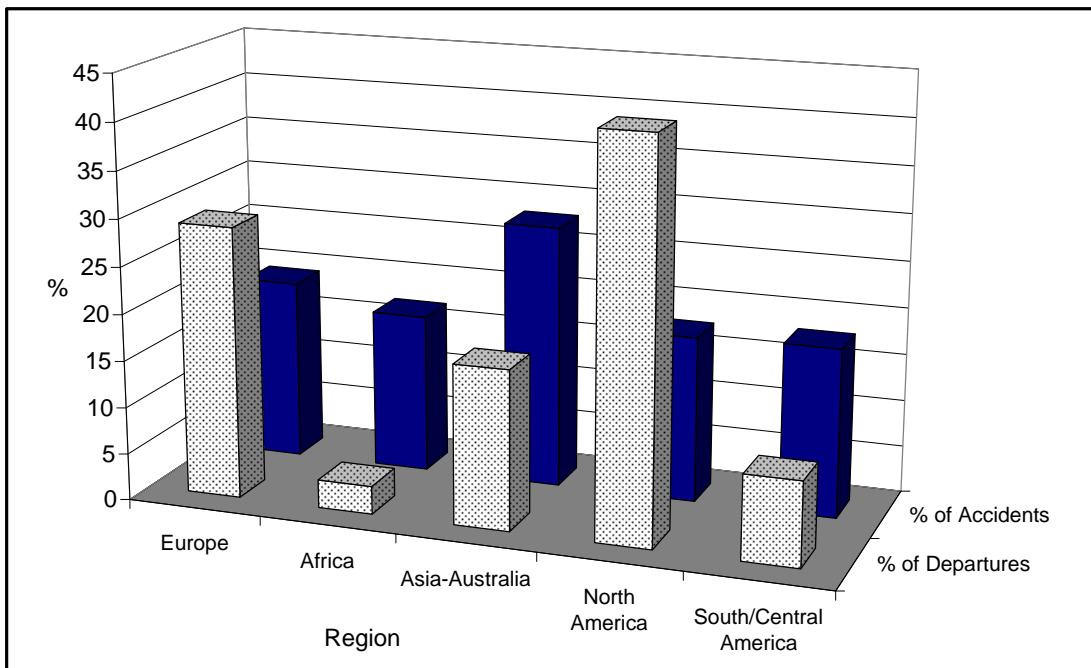
Source: Aviation Network

Figure 2.6: Percent of Accidents by Region (1993-2002)



Source: Aviation Network

Figure 2.7: Percent of Departures versus Accidents by Region



Source: Aviation Network

It would appear as though the rankings in the safety records for the regions mentioned above have been in effect for several years. In a paper produced by the SRG in 1997, a number of accidents occurring between 1980 and 1996 were analysed to determine the accident rates, measured in accidents per 100 billion passenger kilometres. An overview of the findings of this study is provided in Table 2.4. From this table, it can be seen that rankings similar to the ones described above were attained by the various regions of the world. Hence, the highest accident rates in the world have occurred in Africa and South/Central America, with rates of 7.16 and 7.09 accidents per 100 billion passenger kilometres respectively. North America had the lowest accident rate of all the regions with 0.37, followed by Europe with 0.90, Australasia with 1.20 and Asia with 1.86, all measured in accidents per 100 billion passenger kilometres.

Table 2.4 also provides greater insight into the rates of the sub-regions of the world. For instance, it can be observed that accident rates involving operators from China were significantly higher than the rest of Asia, with 2.64 accidents per 100 billion passenger kilometres as compared to 1.78 for the rest of Asia. Within Europe, operators from the Joint Aviation Airworthiness full member countries (see Appendix D) had a lower fatal accident rate than their counterparts in the rest of Europe. The accident rate for full JAA members was 0.78 as compared to 1.13 for the rest of Europe. The accident rate for Canada and the Caribbean was also significantly higher than that of the USA. It should be noted however that in the SRG study, North America comprises the USA, Canada and the Caribbean whereas, in the data obtained from Aviation Safety Network, North America comprises Canada and the USA whilst the Caribbean is included in the South and Central America region.

Table 2.4: Fatal Accidents by Operator Region

Region of Operator	All Accidents 1980-1996	Accidents During Passenger Flights (1984-1996)	Passenger-km Performed (millions) (1984-1996)	Accidents per 100 Billion Passenger-km (1984-1996)
Africa	62	27	376,893	7.16
Asia	117	79	4,241,966	1.86
China	15	11	416,433	2.64
Rest of Asia	102	68	3,825,533	1.78
Australasia	13	9	752,355	1.20
Europe	119	62	6,901,101	0.90
JAA Full Members	63	35	4,512,836	0.78
Rest of Europe	56	27	2,388,265	1.13
South/Central America	132	70	986,643	7.09
North America	177	63	16,855,158	0.37
US	154	53	16,201,683	0.33
Canada/Caribbean	23	10	653,475	1.53

Source: UK CAA Safety Regulation Group

2.2.4 Contributing Factors and Consequences

Before measures to reduce the level of accidents and fatalities can be implemented, it is important to understand the factors involved in fatal air transport accidents. The sequence of events leading to an accident may often be very complex and may involve a number of factors which ultimately led to the accident and in some way contributed to its severity. In a study conducted by the SRG the most frequently identified factors contributing to aircraft accidents were as follows:

- Lack of positional awareness in air 20.9%
- Omission of action/inappropriate action 19.7%
- Flight handling 12.9%
- Press-on-itis 7.8%
- Poor professional judgement/airmanship 3.7%
- Deliberate non-adherence to procedures 2.7%
- Design shortcomings 2.2%
- Wind shear/upset/turbulence/gusts 2.0%

- Maintenance or repair oversight/error/inadequate 1.7%
- System failure - affecting controllability 1.7%

The above primary contributing factors accounted for 75.3% of the 589 fatal accidents studied by the SRG. However, it should be noted that these are not mutually exclusive as accidents are known to have taken place as a result of a combination of factors. In addition, a number of other factors not listed above have also resulted in fatal accidents. These are known as circumstantial factors and include the following:

- Non-fitment of presently available safety equipment
- Failure in crew resource management
- Weather (other than poor visibility or runway condition)
- Inadequate regulatory oversight
- Company management failure
- Poor visibility
- Lack of ground aids
- Inadequate regulation
- Incorrect/inadequate procedures
- Inadequate training

The foregoing can have one or a combination of the following consequences:

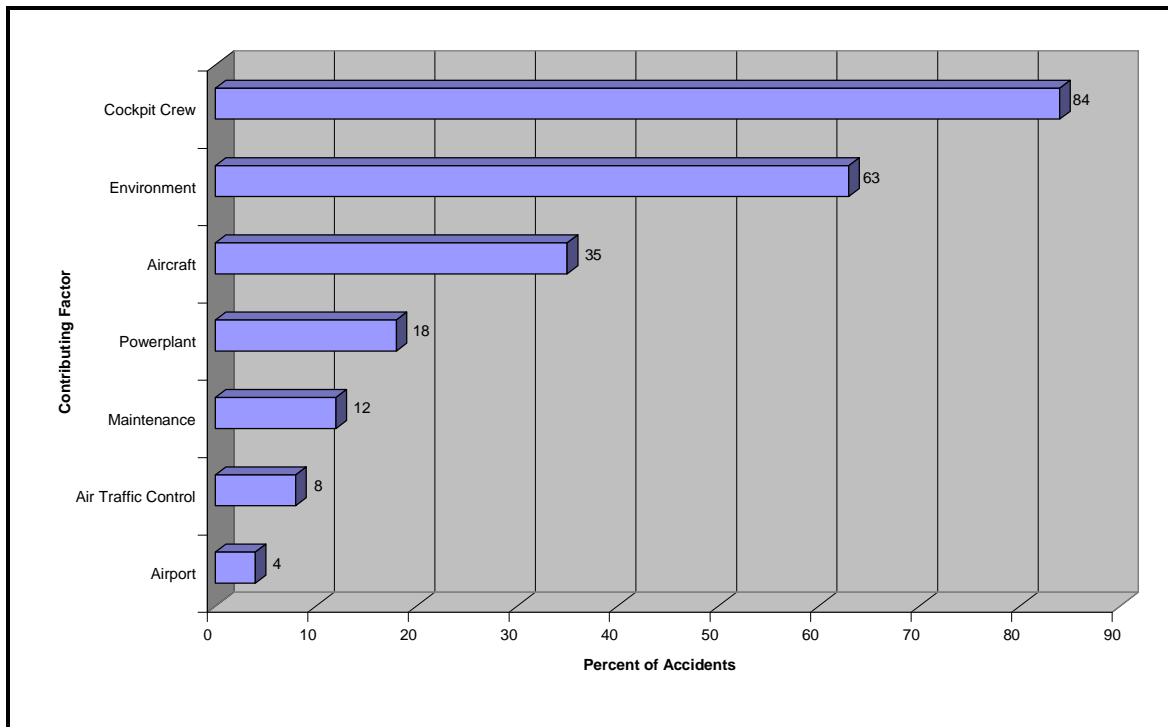
- Collision with terrain/water/obstacle
- Controlled flight into terrain
- Loss of control in flight
- Post crash fire
- Overrun
- Undershoot
- Ground collision with obstacle/object
- Forced landing - land or water
- Structural failure
- Fire/smoke during operation

It is interesting to note that the most common type of airport accident known to take place is the overrun most of which usually occurs during a rejected take-off as a result of, for example, mechanical or engine failure or a blown tire⁷. In addition, an estimated 10% of all fatal accidents were caused in part by design shortcomings and post crash fire. Note that post crash fire may be placed into the category of causal factor as it has contributed to the fatalities that have resulted in a number of accidents.

In another study conducted by the National Aerospace Laboratory (NLR) on accidents occurring between 1980 and 1998, 710 contributing factors were identified from a total of 362 fatal accidents. According to the NLR, the category entitled cockpit crew accounted for the most significant factor, contributing to 84% of the fatal accidents studied. This was followed by the environment which contributed to 36% of fatal accidents and the aircraft which contributed to 35%. Power plants and maintenance contributed to 18% and 12% of fatal accidents respectively, whilst air traffic control and airport only contributed to 8% and 4% of accidents respectively. The factors developed by the NLR are ranked in Figure 2.8. Appendix E provides additional detail as to the most common factors contributing to accidents over a greater number of years.

⁷ Many accidents involving blown tires have resulted in fire.

Figure 2.8: NRL Contributing Factors



Source: EUROCONTROL

2.2.5 Accident Intervention Measures

To reduce the accident rate, there has to be a reduction in the causal factors outlined in Section 2.2.4. However, it would be impossible to eliminate all of these factors from air transportation. Accordingly, intervention or secondary measures such as ARFF services must be provided if the fatality rates are to be reduced.

The need to improve the safety record in the air transport industry will become even more critical as passenger traffic continues to grow. According to the ICAO, passenger traffic is expected to reach 2.3 billion by 2010; aircraft-kilometres are expected to reach 34.1 billion; and aircraft departures are expected to rise to some 26.4 million (see Table 2.5). Given the forecasts for the increase in both the amount and the density of air travel, the number of deaths resulting from air accidents is also likely to escalate if effective intervention measures are not employed. The CAA predicts that should the growth in fatal accidents continue, by 2010, there will be an average of 44 fatal accidents per year. It should be noted that the fore-going figures are the best estimates of a number of sources including the CAA and the European Transport Safety Council

as there is not sufficient detailed information on air accidents to derive a valid conclusion. However, the figures do indicate a need to reduce the rate of air accidents while at the same time, increasing the survival rates for those accidents that will inevitably occur. In achieving this objective, one must be cognisant that the approach to air accident prevention and intervention is a comprehensive one, incorporating a number of elements including the following:

- Aircraft design;
- Impact protection measures;
- Fire fighting and fire/smoke protection measures both onboard and outside of the aircraft;
- Effective evacuation measures; and
- Regulations, practical minimum standards and effective enforcement policies.

Table 2.5: Summary of ICAO World-wide Air Traffic Forecasts for 2010

Total Scheduled Services	Actual 1989	Actual 1999	Forecast 2010	Average Annual Growth Rate (%)	
				1989-1999	1999-2010*
Passenger-kilometres (billions)	1,779	2,788	4,620	4.6	4.5
Passengers carried (millions)	1,109	1,558	2,300	3.5	3.5
Aircraft kilometres (millions) ¹	13,493	22,950	34,100	5.5	3.5
Aircraft departures (thousands) ¹	13,945	20,220	26,400	3.8	2.5

Source: ICAO

* Rounded to the nearest 0.5% point

¹ Excludes the Commonwealth of Independent States

Due to the limited information available with respect to past accidents, determination of the priority areas from among the items listed above is almost impossible and any attempt at a judgement has to be based on expert opinion as opposed to numerically-scientific methods. Nevertheless, the European Transport Safety Council acknowledges that the probability of surviving an aircraft accident is lower if a fire is involved. Accordingly, effective rescue and fire fighting equipment and materials, in addition to

well trained personnel, are among the critical measures required to increase the survival rate of air accidents involving fire. There is thus a need to ensure that the provision of rescue and fire fighting services at aerodromes meet certain standards. However, considering the recent trends in the commercialisation and/or privatisation of airports and hence the need for airports to operate as business entities, these standards must be attainable, not only in operational terms but also in terms of cost effectiveness. The following chapters will address these and other issues, but first it is important to examine the types of risks involved in aviation and the approaches taken in developing and implementing the regulatory framework aimed at reducing those risks.

Chapter 3: Risk Assessments

3.1 INTRODUCTION

The terms hazard and risk are often used interchangeably. However, the Health and Safety Executive (HSE) has made a distinction between the two. According to the HSE, the term hazard may be defined as *'the potential for harm arising from an intrinsic property or disposition of something.'* Risk on the other hand is defined as *'the chance that someone or something that is valued will be adversely affected in a stipulated way by the hazard.'* Risk has also been defined by the courts as the possibility of danger.

Risk is a fact of life as accidents will occur and there will be injury and loss of life as a result. Macey (1997) noted that the probability of a passenger losing their life in a commercial flight is less than one in a million implying that air travel is a low risk mode of transportation (Appendix F provides greater insight into the various probabilities of risks associated with air transport). When a variety of causes of death are analysed, one may find that the probability of dying from a surface transport accident (except for rail) is higher than the probability of dying as a result of an air transport accident. One is also more likely to lose one's life from drowning than from an aircraft accident (see Table 3.1).

Table 3.1: Average Probability of a Variety of Causes of Death

Cause	Probability (per Year)
Bee Sting	2×10^{-7}
Lightning	1×10^{-7}
Air Transport	1.2×10^{-6}
Pedestrian	1.9×10^{-5}
Car Travel	2×10^{-4}
Motor Cycle	1×10^{-3}
Drowning	1×10^{-5}

Source: Infrastructure and the Environment: Safety in Air Transport Lecture Notes

To some extent risk is also a psychological factor. Macey (1997) made a distinction between perceived and true risk. According to Macey, many people would infer from the statistics outlined in the above paragraph that air transport is an acceptable level of risk (true risk). However, given the high profile nature of the industry, air transport accidents usually receive extensive media coverage, particularly when compared to other modes of transport. The situation is compounded by the fact that with major aircraft accidents, there is likely to be multiple loss of life. Under circumstances such as these, the risks associated with aircraft accidents are less acceptable in the mind of the public (perceived risk).

3.2 CONCEPTS USED IN RISK ASSESSMENTS

3.2.1 As Low As Reasonably Practical (ALARP)

There are a number of concepts that can be used in the conduct of risk assessment. The HSE for instance uses the concept of ‘As Low As Reasonably Practical’ (ALARP) in determining the risk reduction requirements of duty holders in providing a safe environment for patrons. However, as the HSE points out, there is little guidance from the courts as to what reducing risks to as low as practically possible means. In the case of Edwards versus The National Coal Board for example, the Court of Appeal held that “...in every case, it is the risk that has to be weighed against the measures necessary to eliminate risk. The greater the risk, no doubt, the less will be the weight to be given to the factor of cost.” (HSE, 2001)

The term used in the ALARP principle is “Reasonably Practical” and not “Physically Possible”. Accordingly, some computation needs to be made in determining the risk involved in a particular situation and the level of sacrifice (whether in terms of time, money or inconvenience) that is required to avert that risk. This computation will give an indication as to whether the risk is insignificant in relation to the sacrifice, which in turn will give an indication as to whether the onus is on the duty holder to reduce that risk.

The above process is by no means an easy task, neither is it an exact science as it calls for much subjectivity. Nevertheless, there is a need for systematic approaches to comparing risks with sacrifices. The more systematic the approach applied, the more likely it is to be rigorous and transparent to regulators and other stakeholders. Given the nature of commercial air transport as a high profile industry, there is no doubt that the approach to assessing risk and implementing mitigating measures ought to be systematic, rigorous and transparent. In the case of ARFF operations, the risks involved arise mainly from extenuating circumstances over which the RFF operators have little or no control but are called on to mitigate. These extenuating circumstances therefore form a major component of the risk assessment that should be conducted for such operations and this makes the process even more challenging.

Naturally, there will be some costs associated with risk reduction measures employed by an organisation. Although these costs will be in terms of time, inconvenience and/or money, for many operators and in many situations, monetary constraints will be the key factor that has to be taken into consideration. However, the HSE holds the position that the duty holder's *'ability to afford a control measure or financial viability of a particular project is not a legitimate factor in the assessment of its costs'*. To this end, the HSE does not take into account the size of the duty holder nor their financial position when determining whether the ALARP principle was applied.

On the other hand, the HSE also holds the position that the benefits gained as a result of implementing a particular mitigating measure should outweigh the costs incurred. Whilst this may be a reasonable position to hold, often is the case that benefits or the potential benefits to be derived from a particular risk reduction measure vary according to the perceptions of the parties involved. For instance, an airport that is 'in the red' annually, may not see the need for increasing their ARFF equipment or investing in training of personnel, particularly if in the view of that airport authority, there has been few (and only minor) accidents or incidents in the past for the emergency personnel to attend. Conversely, pilots flying to that particular airport may be comforted in knowing that the ARFF team is adequately equipped to deal with an emergency should it arise.

3.2.2 The Precautionary Principle

Another principle used in conducting risk assessments is the precautionary principle. In the HSE document entitled *'Reducing Risks Protecting People: The HSE Decision Making Process'*, the United Nations Conference on the Environment and Development (UNCED) is reported to have indicated that the precautionary principle presumes the following:

'where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent degradation.'

This principle is therefore used in cases where the hazard is subject to a high degree of uncertainty. Initially, it was applied to risks assessments conducted in situations where environmental protection was necessary, particularly if global issues such as climate change and ozone depletion were involved. The principle is now more widely used across a variety of sectors and may be employed under the following conditions:

- There is empirical evidence or plausible causal hypotheses to suggest that serious harm may occur, even if the probability that the harm occurring is extremely low; and
- The scientific information gathered suggests that the degree of uncertainty is so high that it is impossible to evaluate the consequences with enough confidence to proceed to the next stage.

However, it should be noted that the degree of uncertainty may be reduced by creating plausible scenarios regarding the nature of a hazard and how it is likely to come to reality. In this way, credible assumptions can be made about the consequences of the risks and their likelihood.

In the absence of a more suitable principle for dealing with decisions to implement safety measures, this principle will be used as the basis for this thesis, along with the ALARP principle. It is felt that this principle is appropriate for this study given that,

although the probability of accidents or serious incidents in the countries under review may be relatively low, the evidence suggests that the types of aircraft accidents that are likely to occur can result in serious harm and multiple fatalities.

3.2.3 Quantitative Risk Assessment

Another approach commonly used in risk analysis is the quantitative risk assessment (QRA). The QRA is used to show the relationship between different subsystems and their reliance on the overall system. However, this method can lead to highly inaccurate or misconstrued results, particularly in cases where historical data on accidents or incidents is used. The following are some of the discrepancies that are likely to give rise to the wrong impression about a particular situation:

- The sample that was selected was too small, too narrow or too wide;
- The time period selected was too short in which case representative accidents may have been omitted; or
- The time period selected was too long in which case a number of irrelevant accidents may have been included.

Any of the afore-mentioned discrepancies will affect the robustness of the results of the QRA and consequently, may lead to decisions that do not adequately address the level of safety required. To this end, any use of the QRA method should also include operational and where appropriate, engineering analyses in making an overall decision.

3.3 TOLERABILITY OF RISKS

The HSE has also established guidelines to be used in determining the tolerability of risks for limited categories of risk such as those entailing multiple or individual fatalities resulting from accidents. According to the HSE, a risk may be categorised as unacceptable, tolerable or broadly acceptable. Before going into these categories, it is first important to examine the criteria used in categorising risks. These criteria are outlined below:

3.3.1 Equity-based Criterion

The equity-based criterion was developed on the principle that every person has unconditional rights to a certain level of protection. Consequently, limits are placed on the maximum level of risk to which an individual may be exposed. In light of this premise, if a risk assessment shows that the risk exceeds the maximum predetermined level that one should be exposed to and that additional control measures cannot be introduced to reduce the risk, then that risk is deemed to be unacceptable regardless of the benefits to be derived.

One of the inherent weaknesses of this criterion is that decisions are frequently made based on the worst case scenario, which may not represent a true picture of the situation. This often results in attaining benefits at disproportionate costs.

3.3.2 Utility-based Criterion

With the utility-based criterion, the incremental benefits to be derived from the risk reduction measures are compared to the cost of the measures. For example, statistical lives saved as a result of measures to improve the safety of an aircraft are compared to the net cost of that safety feature. Whilst efforts are made to strike a balance between that measure and the cost, the balance may be intentionally skewed towards the benefits so that a gross disproportion between the costs and benefits results.

The utility-based criterion does not take into account ethical and other considerations, as it purely looks at costs versus risk reduction measures. Neither does the criterion place an upper limit on risks. This conflicts with society's view that some risks, however remote the probability of them being realised, have dire consequences and are therefore in no way worth the benefits to be derived.

3.3.3 Technology-based Criterion

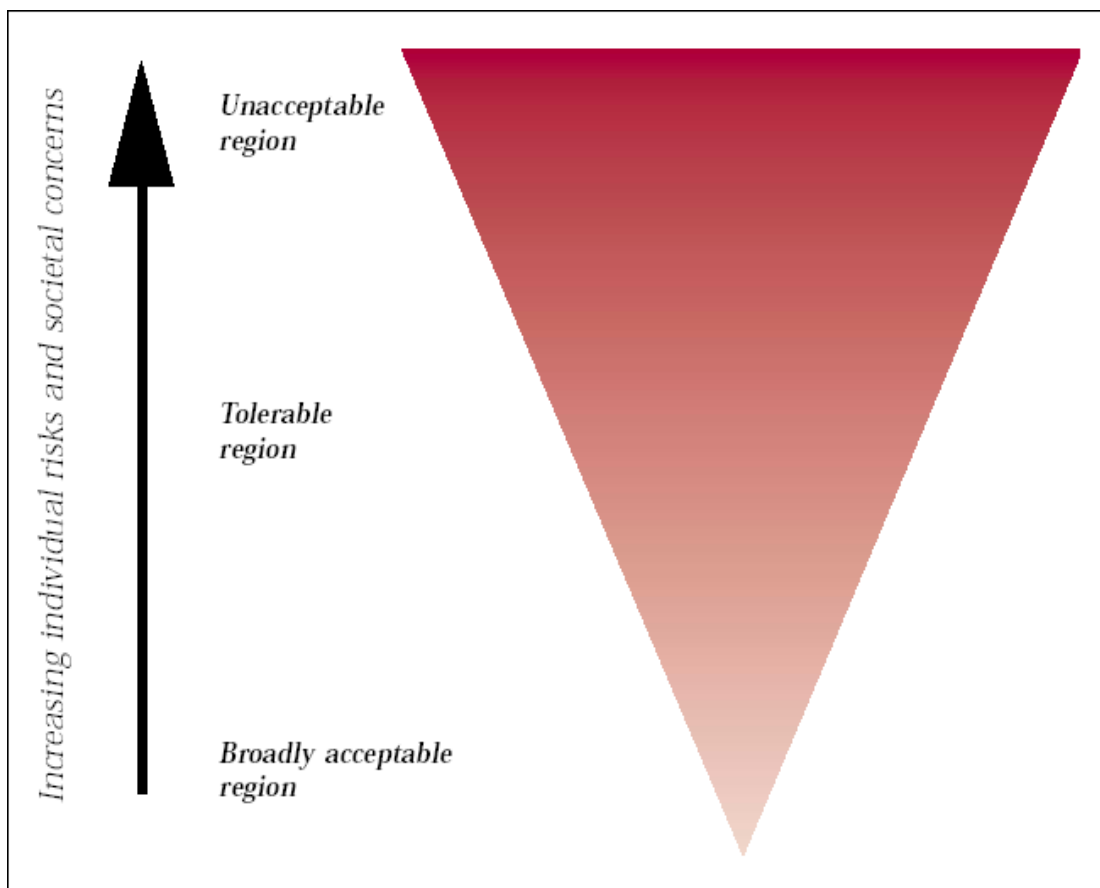
This criterion is based in the premise that a satisfactory level of risk reduction may be achieved by implementing 'state of the art' control measures at the technological, managerial and/or organisational levels. Technology-based criteria do not consider the

need for a balance between costs and benefits and is therefore not appropriate to the types of airports considered in this thesis.

3.3.4 Framework for the Tolerability of Risks

As was noted earlier, the HSE has formulated a framework for the tolerability of risks and these are based on combinations of the criteria outlined above. This framework, which is outlined in Figure 3.1, is also based on the premise that in everyday life, there are some risks that people just will not entertain and some that they will simply ignore.

Figure 3.1: Framework for the Tolerability of Risk



Source: Health and Safety Executive

The triangle in Figure 3.1 represents increasing levels of risks from the bottom to the top, measured in terms of individual risks and societal concerns. The lighter shaded region towards the bottom of the triangle represents the broadly acceptable region and

risks in this region are therefore regarded as insignificant and adequately controlled. The darker shaded region towards the top of the triangle is the unacceptable region and represents risks that society and individuals are not willing to tolerate unless measures can be implemented to push the risks further down towards the lighter shaded region of the triangle. The area between the broadly acceptable and unacceptable regions is the tolerable region and represents risks that people are willing to tolerate to secure benefits in the belief that:

- The risks were thoroughly and properly assessed in the formulation and implementation of adequate control measures to protect people; and
- The risks and control measures are periodically reviewed and appropriate action is taken.

For risks giving rise to societal concerns (e.g. risks involving multiple fatalities occurring in a single event) FN curves may be used to determine the level of risks involved. FN curves are obtained by plotting the frequency at which catastrophic events might kill N or more people against N. The HSE has recommended that if the risk of an accident causing the death of 50 or more people in a single event has a frequency of more than 1 in 5,000 per annum, then that risk should be regarded as intolerable.

3.4 DEVELOPMENT OF REGULATIONS

For risks in the unacceptable region of the framework, societal concerns may be put to rest by developing stringent regulatory instruments such as prescriptive regulations which may give rise to notifications or licensing systems. Thus, in developing regulations aimed at reducing risks, some consideration must be given to how people view risks. According to Fischhoff, Slovic, Lichtenstein et al (1978), when it comes to man-made hazards, people's reaction to risk depends on how well that risk is understood; how equitably the associated danger is distributed; how well individuals can control their exposure to the risk; and whether the risk is voluntary. In the case of air transport, the risk assumed by passengers in particular has to do with the lifestyles adopted in some cases and in other cases, there may be little choice as some professions incorporate some element of air travel. The risk taken in flying may also be considered

voluntary as passengers are willing to take such a risk in order to secure the benefits associated with flying.

Other studies have shown that the perceptions associated with risk taking also have something to do with the degree of trust that one places in regulators or those creating the risk. Accordingly, an organisation or an authoritative entity may be to a large extent trusted by members of the public to have adequate preventative and/or protective measures in place to control or mitigate the impact or the level of the risk.

However, as was indicated previously, a risk assessment is not an exact science and in many cases cannot be undertaken without the assessor having to make several assumptions relating to a number of factors. Such factors include the value of the risks, the benefits associated with taking that risk and the scope of the risk assessment study. This often presents problems in terms of achieving consensus on a particular issue as not all relevant parties will agree on judgement calls relating to the assumptions made in the assessment and may therefore have serious concerns about the outcome.

Another factor that should be taken into consideration when deciding on measures to be implemented to reduce risks include the fact that in some instances, an event may stimulate immense reactions from the public, resulting in amplification of that risk. This in turn is closely correlated to how that risk is reported by the media. Following an airline crash therefore, a large volume of information surrounding the airline industry, much of which may be over dramatised, may be disseminated to the general public. This, together with graphic images of the accident and experts challenging each other regarding what could have gone wrong, may further amplify the risks associated with air travel.

3.4.1 Societal and Individual Concerns

Hazards, like risks, generally raise a number of concerns and these may be divided into two (2) categories, namely individual concerns and societal concerns. These are discussed in the following sections:

3.4.1.1 Individual Concerns

An individual may be prepared to engage in activities that involve a high degree of risk, because they value the benefits to be derived from taking part in that activity more than they are intolerable of the risk associated with the activity. Conversely, individuals are far less tolerable of risks that are imposed on them and that they have little control over, particularly if these risks are deemed to be significant. If the risk is not voluntary and is not negligible but provides the individual and/or society with certain benefits, then it is imperative that these risks are controlled and kept as low as possible.

3.4.1.2 Societal Concerns

Risks presenting societal concerns are often associated with hazards that can result in large scale destruction and/or multiple fatalities in a single event. Such risks can also evoke large public outcry with serious repercussions for governments, regulators and those responsible for ensuring adequate provision for the protection of people. People are therefore more likely to insist that regulations pertaining to such risks are stringent. Hence, the weight factor associated with the costs for implementing appropriate measures in cases involving a high degree of risk tend to be lower than if the hazard was not likely to result in multiple fatalities. However, regardless to how remote the chances are that a particular catastrophic event will take place, one has to be cognisant that such events are inevitable.

On the other hand, when catastrophic events take place, the regulators and those responsible for implementing preventive and protective measures, as well as the processes and procedures that have been put in place, are likely to be undermined. Consequently, the public is likely to loose confidence in the system, regardless of how superior the system was. Yet, it is to these entities that the public looks to for ensuring their safety. This has the effect of placing considerable pressure on the regulators and industry authorities, who are often required to act quickly and firmly in an environment that is centred on perceptions of harm. Regulators and industry must therefore ensure that:

- They focus on serious risks or on hazards that require a greater degree of control;
- They are consistent in their approach to addressing hazards;

- The action taken is commensurate with the risks involved and there is no disproportionate imbalance either on the safety measures to be implemented or on the costs or inconvenience of implementing these measures;
- There is transparency in terms of the decisions that are made; and
- There is accountability.

The approaches discussed above are by no means exhaustive. However, what needs to be borne in mind is that whatever approach is adopted, the costs associated with each option resulting from the risk assessment, as well as the degree of risk reduction that those options are likely to achieve, should form a major component of the final outcome.

3.5 ASSESSMENT OF RISK REDUCTION

An assessment of the reduction in risks that is likely to occur as a result of taking a particular action may be analysed using any of the tools mentioned above. These tools have varying degrees of complexity and may include a cost benefit analysis. However, it may not always be possible or practical to conduct an explicit evaluation of the benefits and in such cases, there may also be a need to employ qualitative estimates and common sense.

Whilst it has been recognised that that the aim of ARFF operations is to save lives, it must also be recognised that in developing and implementing appropriate life saving measures, concern will also be centred around reducing the risk of major injury. In these instances, monetary values may be placed on the reduction in risks by comparing the value society places on the risk of major injury relative to the risk of death.

It should be noted that the cost for preventing fatality (CPF) may be different from the value of preventing a fatality (VPF). The VPF indicates what a person or organisation may be willing to pay in order to secure a risk reduction in a particular circumstance. The CPF on the other hand gives an indication of the cost of the measures that are required in a given situation. The figure for the CPF is calculated by dividing the total costs of the risk reduction measures by the total fatalities prevented.

Where possible, adequate information should be gathered on the CPF and the VPF so that informed decisions can be made. However, this is not to say that one should be indecisive with respect to protective and preventative measures simply because there may be a lack of relevant information. It is perhaps more important to ensure that the parties involved are content with the process giving rise to the decisions that are to be made. This approach is more likely to give rise to success, particularly in cases where a considerable number of stakeholders are involved. It is also important to ensure that the assumptions made are plausible and that factors such as economic, technological, political and social considerations have been taken into account. However, meeting these conditions will nonetheless present a number of challenges, particularly if stakeholders have opposing views relating to fundamental values and assumptions made in the risk assessment or have confined themselves to a single issue. The final decision should nevertheless and as much as possible reflect the ethical and value preferences of wider society in terms of what they consider unacceptable, tolerable or broadly acceptable risks. It should however be noted that there will be instances where it is more important to focus on the consequences should the risk be realised than on the likelihood that the risk will be realised.

The HSE allocates a sum of £1,000,000 (2001 figure) as the value for preventing a fatality. This figure was derived from the Department of Transport, Local Government and the Regions in the appraisal of new road schemes and should therefore not be taken as the value that society or the courts may place on the life of a real person or the compensation associated with the loss of life of a person. Further to the above, the HSE holds the view that the value to be applied to a given risk reduction measure should increase with the level and the nature of the risk.

Another approach to determining whether a particular risk reduction measure is necessary is the use of a Cost Benefit Analysis (CBA). This involves identifying and quantifying in common units (such as monetary units) all the desirable and the undesirable consequences of the particular measure to society. Monetary values are therefore attached to human life, health and all other possible consequences of a major

accident. The CBA may however present some problems to the evaluator if conventional discounting procedures are used to obtain a present value, as some accidents may affect present as well as future generations.

3.5.1 The Value of a Life

Whilst there have been significant advances in terms of the evaluation of human life over the last few years, there is still much scepticism surrounding placing a monetary value on a life. Perhaps there is some justification in this view as it should be recognised that no amount of money could compensate someone for the loss of their life. In the past, the value placed on human life was calculated based on the value of a person's probable future stream of economic output as well as a notable sum for the grief pain and suffering experienced by those affected by that person's death. However, society today is more willing to accept a small increase in the risk of death or bodily harm in return for financial gains or other benefits. Consequently, a value can be derived for the expected loss of life from a large population in advance of that life being lost.

Two techniques that have been used in the past to apply a monetary value to the life of a person have been the Revealed Preference Approach and the Stated or Expressed Preference Method. In the case of the Revealed Preference Approach, the amount that people would spend to reduce the risk that they face, or would accept in return for financial compensation is determined by observation. In the case of the Stated or Expressed Preference Method, people are asked what they would spend to reduce the risk of death or how much in terms of compensation they would accept for an increase in the risk of death given a certain hypothetical situation. However, both of the foregoing methods have produced considerable variations in the results thus raising concern in terms of the credibility of the research that was conducted in this area.

In 1987, the Department for Transport commissioned a review of the studies conducted with respect to the value of a human life, following which, a consultation paper was produced. This consultancy paper proposed that the value for a statistical life for use in

the department's appraisal of road schemes should be estimated at £500 000 (1987 value). In 1992 this figure rose to £660,000. It should be noted however that this is the minimum value used by the Department for Transportation in assessing the value of a life in the road accident scheme and therefore higher values may apply in some other risk situations. As Braithwaite (2001) notes, '*...while death per se may seem a universally unacceptable prospect, it seems fair to say that some causes of death are 'preferable' to others.*' Consequently, the foregoing premise that the higher the risk the higher the value that may be applied to the loss of a life may be justified on the grounds that acceptability of fatalities due to one cause is higher than acceptability of fatalities from another cause. Hence, as Braithwaite further notes, '*The acceptability of fatalities due to smoking-related illnesses remains higher than from accidents involving nuclear power plants. Similarly, the acceptability of fatalities due to road-traffic accidents appears to remain far higher than those due to aircraft accidents.*'

For bodily harm or any form of serious injury, a variety of 'relative utility loss indices' have been developed which compares the relative disutility of various states of injury and/or disability to normal health. The results may then be used with an established value of life to arrive at a monetary value for an injury.

The aim of the CBA is to determine whether the benefit of the measure in question is sufficient to compensate those who may be adversely affected whilst at the same time ensuring that those who stand to gain will still be better off. However, regulators tend to be more concerned with whether the additional risk reduction measures will result in increased safety and whether the costs for these additional measures are justified (HSE, 1992).

In nuclear plants for instance, where the potential effects of an accident could be long lasting and wide spread, it is extremely costly to significantly reduce the probability of an accident occurring. Nevertheless the costs of reducing the likelihood of an event occurring has to be taken into consideration. Once the regulators have been satisfied that the risks have been reduced to very low levels, there is no further insistence that

additional measures should be employed, particularly if it is perceived that the costs of these measures would be disproportionate to the remaining risks.

However, to determine whether a benefit is cost justified, one has to assess what constitutes gross disproportion. Thus, CBA's are only employed by safety regulators if the effects of safety related changes can be isolated. It is therefore important for regulators examining this issue to be cognisant of the level of expenditure involved in safety measures.

It should be noted that there is an inherent weakness in the use of the CBA as it does not encompass factors such as aversion to low probability accidents and socio-political issues, all of which are difficult to quantify in monetary terms. To overcome this, multi-attribute utility analysis using a multi-criteria outranking technique may be employed. With this technique, a scoring scheme based on the relevant factors is developed and judged by a group of informed people. To reduce subjectivity, the available options are compared with each other and a determination is made as to the preferable option(s).

3.5.2 Implementation and Evaluation

The ultimate responsibility for controlling risks will fall on the entity that creates the risk (for example, in this case, the airlines and the airports) or the entity that is in a position to do something about the risk (in this case the ARFF service). Once a decision has been made on the degree to which a particular risk needs to be controlled, measures can then be implemented with the assistance of a regulatory framework at the international, national, local and/or organisational level.

In order to gain as much support as possible for any regulatory framework, it is imperative that stakeholders are consulted and that a participatory approach is adopted in the decision making process. This will assist in ensuring that there is as little resistance as possible from the stakeholders when the regulations become effective. Once they do become effective, the regulations should be reviewed periodically and all

stakeholders should be given the opportunity to become actively involved in this review. The purpose of the review would be to ascertain the following:

- The effectiveness of the regulations in terms of enhancing safety and reducing risks;
- Implementation and operational constraints and challenges which may have implications for the effectiveness of the regulations;
- New knowledge, advances in technology, changes in the level of societal concern and other factors which may call for additional amendments to the regulations;
- Discrepancies, areas not covered or loopholes, areas of conflict and areas of ambiguity which may diminish the effectiveness of the regulations;
- Areas requiring further study that could lead to improvements in the regulations;
- The impacts of the regulations on operational, financial, economical, political and technical aspects of affected entities; and
- Lessons learnt which could guide and enhance the above-mentioned process as well as improve relations between stakeholders.

3.6 APPROACHES TO RISK ASSESSMENTS IN OTHER SECTORS

Organisations that pose major industrial hazards, i.e. *'any man-made industrial hazard which has the potential to cause large-scale injury and loss of life from a single brief event'* (HSE 1992), have adopted risk assessment approaches to safety. In the UK for instance, these organisations conduct a risk assessment of the hazards that are posed by the facility, which are then submitted to the HSE for scrutiny. Based on the findings, the HSE may then mandate that certain other precautions be taken.

In the risk assessment conducted for nuclear power stations for example, the reliability of the plant and the risk of failure are calculated with the input of engineers and scientists. The process employed here is developed based on the premise that it is not

always possible to determine exactly how reliable a particular plant will be under extreme conditions, nor is it always possible to ensure that all contingencies are taken into account in performing the calculations. Importance is therefore placed on the kinds of reinforcements and/or back-up components that are needed to deal with the unexpected. As it is recognised that back-up components in themselves do not provide protection against inherent faults, the concept of design diversity is also employed. In design diversity, back-ups are provided via dissimilar components or components that have been designed independently. Whilst this approach does offer some reduction in risk, it is more beneficial with devices that are simple than with complex devices.

The risk assessment for the types of plants discussed above also use the principle of conservatism in that the figures used are on the cautious side. Also taken into consideration is the quality of the plant itself, including the management systems employed and the operational procedures applied.

In the case of airports in the study countries, it would appear as though a similar approach to the provision of safety has not been adopted in its entirety. It would further appear as though the regulations relating to ARFF operations at airports are imposed on the operators by the regulators. This has been a major cause for concern, particularly in the case of the UK, where the regulations tend to be more stringent than in certain other countries such as Australia, Canada and the USA. Chapter 4 will take a more in depth look at the regulations that have been developed to control risks associated with ARFF.

Chapter 4: Standards and Regulations

4.1 INTRODUCTION

The main objectives of the International Civil Aviation Organisation (ICAO) are to *'develop the principles and techniques of international air navigation and to foster the planning and development of international air transport.'* (Blackshaw, 2001). The ICAO has thus developed guidelines relating to a variety of areas such as airports, aircraft worthiness, accident investigation, and safety and security. These guidelines, also known as standards and recommended practices (SARP's), are divided according to subject matter and are published in Annexes. Countries that are signatory to the ICAO convention are required to adopt and implement the SARP's. If for some reason a Contracting State is unable or unwilling to adopt the SARP's they are required to notify the ICAO of the differences which are then published and issued to all Contracting States.

4.2 ANNEX 14, CHAPTER 9

Chapter 9 of Annex 14 provides guidelines for ARFF standards and services. According to this Annex, the main objective of rescue and fire fighting services is to save lives. The Annex also recognises that the provision of rescue and fire fighting services is particularly important for accidents occurring at or in the immediate vicinity of an airport as this is where the opportunity for saving lives is greatest. However, no guidance is given on the definition of 'vicinity of the airport'. Different airports will therefore define their boundaries in different ways. For instance, Inverness Airport in Scotland is concerned with aircraft accidents occurring on the runway whereas an airport such as Heathrow will also provide partial assistance to accidents occurring within two miles of the airport perimeter road (CAP 356). Beyond this, attendance is at the discretion of the British Airports Authority Fire Service officer in charge. This however is not to say that Inverness Airport would refuse to lend assistance to aircraft accidents taking place just immediately outside of the boundary of the airport.

The Annex also recognises that there are a number of factors that will influence rescue and fire fighting operations. These include the following:

- The training received by ARFF personnel;
- The effectiveness of the equipment in use; and
- The speed at which the equipment and personnel can be put into use.

The following section addresses the main SARP's of Annex 14.

4.2.1 Aerodrome Categories

The level of protection to be provided at an aerodrome depends on the category of the aerodrome. The guidelines for these categories are outlined in Table 4.1 below. In developing the guidelines, aircraft of similar size were divided into groups. The size of the aircraft was determined based on the length of the fuselage. The median length of the aircraft in each category was then used to determine the aerodrome category number.

Table 4.1: Aerodrome Category for Rescue and Fire Fighting

Aerodrome Category	Aeroplane Overall Length	Maximum Fuselage Width
1	0m up to but not including 9m (29.53ft)	2m (6.56ft)
2	9m (29.53 ft) up to but not including 12m (39.37 ft)	2m (6.56ft)
3	12m (39.37ft) up to but not including 18m (59.06ft)	3m (9.84ft)
4	18m (59.06ft) up to but not including 24m (78.74ft)	4m (13.12ft)
5	24m (78.74ft) up to but not including 28m (91.86ft)	4m (13.12ft)
6	28m (91.86ft) up to but not including 39m (127.95ft)	5m (16.40ft)
7	39m (127.95ft) up to but not including 49m (160.76ft)	5m (16.40ft)
8	49m (160.76ft) up to but not including 61m (200.13ft)	7m (22.97ft)
9	61m (200.13ft) up to but not including 76m (249.34ft)	7m (22.97ft)
10	76m (249.34ft) up to but not including 90m (295.20ft)	8m (26.24ft)

Source: ICAO

4.2.2 Extinguishing Agents

The quantities of extinguishing agents shown in Table 4.2 below are based on the amount of liquid that is required to create conditions next to the fuselage of an aircraft that are tolerable enough to allow for the rescue of occupants, should there be an accident involving fire.

Table 4.2: Minimum Usable Amounts of Extinguishing Agents

Foam Meeting Performance Level A			Foam Meeting Performance Level B		Complementary Agents		
Aerodrome Category	Water (L)	Discharge Rate Foam Solution/min.	Water (L)	Discharge Rate Foam Solution/min.	Dry Chemical Powders (kg) or	Halons (kg) or	CO ₂ (kg)
1	350	380	230	230	45	45	90
2	1,000	800	670	550	90	90	180
3	1,800	1,300	1,200	900	135	135	270
4	3,600	2,600	2,400	1,800	135	135	270
5	8,100	4,500	5,400	3,000	180	180	360
6	11,800	6,000	7,900	4,000	225	225	450
7	18,200	7,900	12,100	5,300	225	225	450
8	27,300	10,800	18,200	7,200	450	450	900
9	36,400	13,500	24,300	9,000	450	450	900
10	48,200	16,600	32,300	11,200	450	450	900

Source: ICAO

However, as Hewes(1991) and O’Sullivan (2001) note, there have been significant discrepancies between the actual amount of extinguishing agents used in some accidents and that recommended by the ICAO. Table 4.3 shows the actual amount of water for foam production used in a number of accidents occurring between 1978 and 2001 versus the quantities recommended by the ICAO. Of the 36 accidents considered, only four accidents required less water than that recommended by the ICAO. These accidents include the following:

- May 3, 1986 L-1011 accident at Columbo;
- November 15, 1987 DC-9 accident at Denver;
- January 8, 1989 Boeing 737 accident t East Midlands; and
- October 14, 1989 Boeing 727 accident at Salt Lake City

Only in two cases was the amount of water used unknown. These were the November 18, 1980 Boeing 747 accident at Seoul and the February 14, 1990 accident at Bangalore. All other accidents required anywhere from just over one (as in the case of the November 21, 1980 Boeing 727 accident at Yap Island) to almost 11 times that recommended (as in the case of the May 3, 1991 Boeing 727 accident at Bradley).

Hewes (1991) provides some valuable insight into the development of the SARP's relating to extinguishing agents. According to Hewes, there is a theoretical critical area (TCA) of 50 feet for large aircraft and 20 feet for small aircraft, which is the distance needed between the fire and the aircraft fuselage in order to ensure that survivable conditions are maintained inside the cabin. It was upon the TCA that the computations for extinguishing agents were calculated. However, due to economical reasons, a number of countries were unable to meet these requirements. It was then brought to the attention of the ICAO that in a study conducted of 106 fires, 99 required only two thirds of the agent indicated by the calculations. To this end, the ICAO recommended that the TCA requirements should be reduced by one third and the lower requirement became known as the practical critical area (PCA). The PCA was then used to calculate the quantities of extinguishing agents.

However, although it subsequently came to the attention of the ICAO that the study mentioned in the above paragraph was based on training fires and not actual crash fires, there was no reversion to the original TCA. The lower requirements therefore remained.

The quantities of extinguishing agents to be used were also determined based on the aerodrome category, which in turn was determined based on the length of the aircraft as described above. Again, economic considerations came into play here and it was the average length of the aircraft and not the longest aircraft in each category that was used.

Whilst the statistics indicate that the recommended quantities of extinguishing agent are not adequate, they do not give an indication as to the amount that is needed to create survivable conditions that would aid in evacuation. This makes it difficult to ensure that

the intervention method adequately reflects the degree of risk associated with the level of aircraft movements.

Table 4.3: Actual Quantities of Extinguishing Agents Used in Accidents Versus Recommended

Aircraft	Location	Date	Recommended	Actual
DC-10	Los Angeles	Jan. 3, 1978	4,800	7,800
DC-8-61	Athens	Oct. 7, 1979	4,800	12,000+
L-1011	Riyadh	Aug. 19, 1980	4,800	20,000
Boeing 747	Seoul	Nov. 18, 1980	6,500	Unknown
Boeing 727	Yap Island	Nov. 21, 1980	3,300	3,500
Boeing 737	Orange County	Feb. 17, 1981	2,200	3,000
Boeing 737	Orange County	Feb. 17, 1981	4,800	13,000
DC-10	Malaga	Sept. 13, 1982	2,200	7,500
DC-9	Barquisimeto	Mar. 11, 1983	2,200	7,925
DC-9	Cincinnati	Jun. 2, 1983	5,400	7,400
DC-9/Boeing 727	Madrid	Jul. 12, 1983		18,000+
Boeing 727	Chicago	Nov. 11, 1983	3,200	15,000+
Boeing 737	Calgary	Mar. 22, 1984	2,200	12,000
Boeing 707	Edwards Air Force Base	Dec. 1, 1984	3,300	24,000
Convair 880	March Air Force Base	Jul. 17, 1985	3,300	59,000
L-1011	Dallas	Aug. 2, 1985	4,800	16,400
Boeing 737	Manchester	Aug. 22, 1985	2,200	10,000
L-1011	Columbo	May 3, 1986	4,800	2,000
Piper Aztec	Tampa	Nov. 6, 1986	60	500
CASA C-212	Detroit	Mar. 4, 1987	315	5,800
CASA C-212	Mayaguez	May 8, 1987	315	1,000
DC-9	Detroit	Aug. 16, 1987	2,200	19,900
DC-9	Denver	Nov. 15, 1987	2,200	940
DH-8	Seattle	Apr. 15, 1988	600	6,000
Boeing 727	Dallas	Aug. 31, 1988	3,300	15,000
Boeing 737	East Midlands	Jan. 8, 1989	2,200	670
DC-10	Sioux City	Jul. 19, 1989	4,800	15,000
Boeing 727	Salt Lake City	Oct. 14, 1989	3,300	3,000
A320	Bangalore	Feb. 14, 1990	4,800	Unknown
DC-9/Boeing 727	Detroit	Dec. 3, 1990	5,500	8,500+1,500
Boeing 737/Sweatingen Metroliner	Los Angeles	Feb. 6, 1991	2,800	8,000+9,000
DC-9	Cleveland	Feb. 17, 1991	2,200	15,000
DC-8	New York	Mar. 12, 1991	4,800	16,000
Boeing 727	Bradley	May 3, 1991	3,300	36,000
A320	Warsaw	Sept. 14, 1993	7,900	54,800
A340	Paris	Jan. 20, 1994	18,200	172,900

Sources: Hewes (1991) and O'Sullivan (2001)

4.2.3 Remission Factor

There is an exception to the level of rescue and fire coverage provided at airports. In cases where the number of aircraft movements in the highest category using the aerodrome is less than 700 during the busiest three consecutive months, the level of protection offered is required to be no less than one category below the determined category.

The reason behind the 700 rule as outlined above is unclear. It would however appear as though the justification for this rule is that the potential size of an aircraft fire is strongly correlated to the number of movements. This is not necessarily a logical conclusion to make and represents a compromise on safety as it lowers the amount of extinguishing agents required to contain and extinguish fires. However, it should be noted that as of January 2005, the remission factor will be removed from Annex 14.

4.2.4 Rescue Equipment

According to the ICAO, the rescue equipment provided on the rescue and fire fighting vehicles should be commensurate with the level of aircraft operations. A list of the equipment required may be found at Appendix F. Table 4.4 outlines the minimum number of vehicles that should be provided at each aerodrome category.

Table 4.4: Number of RFF Vehicles per Category

Aerodrome Category	Rescue and Fire Fighting Vehicles
1	1
2	1
3	1
4	1
5	1
6	2
7	2
8	3
9	3
10	3

Source: ICAO

ARFF vehicles should be designed to carry full loads at high speeds in all weather conditions as well as difficult terrain. Table 4.5 shows the minimum standards for ARFF vehicles.

Table 4.5: Recommended Minimum Characteristics for RFF Vehicles

	RFF Vehicles up to 4500L	RFF Vehicles over 4500 (L)
Monitor	Optimal for Categories 1&2 Required for Categories 3-9	Required
Design feature	High discharge capacity	High and low discharge capacity
Range	Appropriate to longest aeroplane	Appropriate to longest aeroplane
Hand lines	Required	Required
Under truck nozzles	Optimal	Required
Bumper turret	Optimal	Optimal
Acceleration	80km/h within 25s at the normal operating temperature	80km/h within 40s at the normal operating temperature
Top speed	At least 105km/h	At least 100km/h
All wheel drive capability	Yes	Required
Automatic or semi-automatic transmission	Yes	Required
Single rear wheel configuration	Preferable for Categories 1 & 2 Required for categories 3-9	Required
Minimum angle of approach and departure	30°	30°
Minimum angle of tilt (static)	30°	28°

Source: ICAO

4.2.5 Response Time

As was indicated earlier, the speed at which rescue and fire fighting operations is put into action is a critical aspect of increasing the survival rate of an aircraft accident. Accordingly, the ICAO recommends a response time of two minutes, but not more than three minutes for reaching the end of the runway as well as for reaching any other part of the movement area. Response time is defined in Annex 14 as the time between the initial call to the rescue and fire fighting service and the time when the first responding

vehicle(s) is (are) in place to apply foam at a rate of at least 50% of the discharged rate specified in Table 4.2. Subsequent vehicles to be used in the operation should arrive no more than one minute after the first responding vehicle. However, it should be noted that the ICAO is specific in stating that these are the recommended response times in optimum visibility and service conditions.

4.2.6 Personnel

Annex 14 states that *'All rescue and fire fighting personnel shall be properly trained to perform their duties in an efficient manner and shall participate in live fire drills commensurate with the types of aircraft and type of rescue and fire fighting equipment in use at the aerodrome, including pressure-fed fuel fires.'* Clearly and understandably, this criterion will present an additional and on-going cost for airports. The ways in which some of the study countries have dealt with these costs will be outlined Chapter 5.

In addition to the fore-going, the ICAO provides guidelines for the number and deployment of personnel. These guidelines are as follows:

- ARRF Vehicles should be staffed in such a way that they can be deployed immediately with enough staff to have them fully operated;
- Vehicles should be staffed so as to ensure that they discharge principle and complementary agent at maximum capability; and
- The control room or any other facility for ARFF related communications can continue to be operable until alternative arrangements are made under the airport emergency plan.

Note: Guidance is also provided in the areas of emergency access roads, fire stations, communications and alerting systems. These areas are not discussed at any length in this thesis given that the research has shown that there are few discrepancies with respect to the regulations in the study countries and the

recommendations in Chapter 9 of Annex 14. However, further information on these areas may be obtained from the Airport Services Manual.

4.3 REGULATIONS IN THE STUDY COUNTRIES

Australia, Canada, the USA and the UK are signatory to the ICAO and therefore are required to implement the SARP's as outlined in Annex 14. As was mentioned previously, any differences between the national regulations and the SARPs are to be filed with the ICAO and these differences are then published in the Supplementary to the appropriate Annex. However, in reviewing the regulations for each of the countries, it becomes apparent that there are a number of differences in the approach to the regulations governing ARFF operations in the afore-mentioned countries. Yet, a review of the Supplementary to Annex 14 revealed that only the USA and the UK have filed differences (see Appendix H). The national regulations and standards pertaining to the fore-going countries are discussed below.

4.3.1 Australia: The Civil Aviation Safety Regulations

Australia has recently sought to restructure the provision of Rescue and Fire Fighting Services at its aerodromes. Regulations for these services are covered by the Civil Aviation Safety Regulations (CASR), Part 139, Subpart H and the Manual of Standards. Detailed requirements relating to the CASR are set out in the Manual of Operating Standards. Generally, the CASR, Part 139, Subpart H are in keeping with Annex 14 and provide the basis for the level of coverage of RFF services at Level 1 airports (i.e. airports with annual passenger traffic of more than 350,000 per annum) in Australia. Where there are differences in the standards as outlined in Annex 14 and the standards in the Manual of Standards, then the Manual of Standards is to take precedence.

The Airports Act 1996 Section 216 states that ARFF services are to be provided by Airservices Australia, a statutory body with regulatory powers providing rescue and fire coverage at 16 locations in Australia. The only other entities that would be allowed to provide these services are those that have an approved arrangement in writing from the Minister with responsibility for Transport and Regional Services. Furthermore, the

Government of Australia has recently decided that only the Commonwealth, Airservices Australia or a contractor to the latter organisation can provide training in ARFF.

Under the restructuring initiative, the standards and practices are targeted at international aerodromes, although domestic aerodromes fitting a certain criteria, namely, those achieving a passenger throughput of more than 350,000 on commercial air transport flights in the previous financial year, are also affected. The aerodromes falling under the regulations cumulatively⁸ account for an estimated 90% of the total number of passengers on scheduled passenger flights in Australia annually (CASA, 2003). The current criterion stipulates that all aerodromes with a passenger throughput of 500,000 or more must be provided with rescue and fire coverage.

Once it has been established that a particular aerodrome must provide rescue and fire coverage, if traffic levels fall below the stated criteria, then coverage must be provided for up to 12 months or until the aerodrome falls outside of the group of aerodromes accounting for 95% of scheduled passenger traffic. This stipulation is to allow for cyclical fluctuations in traffic flows.

Accordingly, it is not unusual to find that rescue and fire coverage is provided at some aerodromes with passenger traffic of less than say 200,000 whilst some other aerodromes with traffic levels of just over 400,000 do not provide coverage. An example is Ayers Rock Airport, which has an annual throughput of just over 400,000 passengers, yet does not have to provide rescue and fire coverage, since it falls outside of the 90% criterion for the provision of this coverage.

The Civil Aviation Safety Authority (CASA) has reviewed lowering the criteria for the establishment of ARFF services at domestic airports. However, it was argued that lowering the criteria to 300,000 passengers would only increase the number of aerodromes with coverage by about 1.76% but that costs to the industry were likely to increase significantly;⁹ hence, there was no recommendation to increase coverage. The

⁸ Counted in descending order by traffic volume

⁹ There was no indication as to the level to which the costs would be increased.

CASA has therefore stipulated that for Level 2 aerodromes (i.e. those with annual passenger traffic on commercial air transport of less than 350,000 per annum) may provide ARFF services. It has also been stipulated that for Level 2 aerodromes where commercial aircraft with less than 30 seats operate, the minimum level of ARFF service should be equivalent to a Category 2 airport. For the same level of aerodromes but where commercial aircraft with more than 30 seats operate, then the minimum level of ARFF services to be provided should be equivalent to a Category 4 airport. These categories relate to response times, water capacity for foam production and foam discharge rates. In all cases, coverage must be available throughout the hours of operation of the airport, as well as up to 15 minutes after the departure of the last flight and 15 minutes prior to the arrival of the first flight. ARFF services can be discontinued at anytime provided that the CASA and Enroute Supplement Australia (ERSA) are advised, notice to airmen (NOTAM) action is taken and all regular users of the aerodrome are notified. This is known as the disestablishment criteria.

The CASA also looked at the impact of the afore-mentioned regulatory framework on a variety of stakeholders and came up with the following conclusions:

(i) Airservices Australia

The framework will give Airservices Australia greater flexibility to adjust the service offered to specific aerodromes as well as the flexibility of finding ways to reduce overhead costs. In addition, the regulatory function would be removed from Airservices Australia and transferred to CASA, thus removing any conflict of interest that would exist in having an operator regulate itself.

(ii) Aerodrome Operators

It is not envisaged that there will be any significant impact on the aerodromes except perhaps for an increase in safety benefits that will result from the establishment of minimum rescue and fire fighting standards.

(iii) Aviation Industry

It is not envisaged that the aviation industry will be significantly affected. However, there may be increased charges for the industry as a result of increased rescue and fire coverage at certain aerodromes, or as a result of the establishment of these services at airports not previously providing them. CASA is also of the view that these costs may be offset by cost savings that may be incurred from better utilisation of the training resources and service provisions offered by Airservices Australia. However, as will be seen in Chapter 5, Airservices Australia recently sought to raise its fees for the provision of ARFF services.

(iv) Travelling Public

The main impact that the foregoing regulatory regime will have on the travelling public relates to the increase in rescue and fire coverage and by extension, the increase in the safety benefits for passengers. The CASA did not foresee any increase in costs to the passengers in the near future as ARFF services were already included in the costs of the airline ticket. The CASA however indicated that efficiency incentives in the delivery of ARFF services could result in reduced costs for passengers.

(v) CASA

It is envisaged that there will be very limited increased costs for CASA in the short term in light of the fact that the regulatory function previously performed by Airservices Australia will now be transferred to this entity. Consequently, management costs associated with certain functions such as ensuring that appropriate application and audit processes are implemented; representation on a variety of committees such as those addressing fire training competencies; and the development of standards at the national and international levels will be eliminated for Airservices Australia.

4.3.1.1 An Assessment of Australia's Rescue and Fire Fighting Services

In the restructuring process, the Government of Australia took the stance that a mixture of non-prescriptive and prescriptive regulations should be adopted in the provision of ARFF services at aerodromes. Under this option, those responsible for the provision of

safety services are given enough flexibility to devise a plan for compliance with the requisite regulations. The plan however has to be endorsed by the CASA.

Prescriptive regulations are usually applied in cases where the situation is unlikely to change and where there is a straightforward solution. This approach gives one the opportunity to develop regulations in such a way so as to exploit the advantages of a voluntary/self regulating framework and a prescriptive regime. The advantages and disadvantages of these approaches may be found in the Table 4.6 below.

Whilst the foregoing approach is recommendable, little can be said about the justification used by Australia to determine which aerodromes require coverage. Australia holds the premise that since it is signatory to the ICAO, it is obligated to provide ARFF services at all international airports. However, this principle is not extended to all domestic airports. Consequently, some domestic airports that do not fit a certain criteria will not be required to provide rescue and fire coverage, even though that airport may be operating at a level similar to that of an international airport.

Table 4.6: Advantages and Disadvantages of Non-prescriptive and Prescriptive Regimes

Framework	Advantages	Disadvantages
Non-prescriptive	Providers determine the most appropriate way to implement regulatory requirements. Offers flexibility to providers to respond quickly and appropriately to particular problems depending on the nature of the emergency.	Difficult to assess quality of service.
Prescriptive	Limits providers in determining the best means of achieving the objectives. Constrains provider's ability to provide timely, suitable response to a given emergency. Focus of providers on the processes needed to achieve the objectives rather than on the goal of improving and maintaining safety. Regulator needs substantial knowledge and expertise in all areas of the operation so as to ensure regulatory requirements are complied with. Increased training costs to the regulator.	Easy to monitor and comply with due to specific and measurable criteria

Source: CASA

The regulatory framework under which ARFF services are provided indicates that some 90% of passengers are to be afforded rescue and fire coverage. Under the disestablishment of ARFF services criteria discussed above, there is a buffer of 5% to cover airports with falling traffic levels but which were previously required to provide the coverage. Together, this indicates that some 95% of scheduled passenger traffic is afforded a certain minimum level of ARFF services. The other 5% of these passengers are without the service. Given that total aircraft movements per year in Australis is about 1.2 million, this implies that there is no requirement for standard ARFF services for just over 60,000 aircraft movements. Alternatively, since airport traffic accounts for some 81 million revenue passenger movements per year¹⁰, this implies that for just over 4 million passenger movements, there is no requirement to provide standard rescue and fire coverage.

Consider therefore an airport such as Broome International which has a total passenger movement of over 236,000 per year. According to the CASR Part 139, Subpart H and the Manual of Standards pertaining to aerodrome categories, Broome International would be classified as Category 7 aerodrome, given the operation Boeing 737-800 at that airport. Naturally, an airport that meets the standards to deal with an emergency on a Category 7 aircraft should also meet the standards to deal with a Category 6 aircraft such as the Boeing 737-400. Conversely, as was noted earlier, passenger traffic at Ayers Rock is just over 400,000 per year. This airport is not required to provide ARFF services because it falls outside of the 90% criterion for the provision of services, even though Qantas Airways for example operates Boeing 737-400 aircraft there, making this a Category 6 airport.

In addition to the fore-going, some concern has been raised over the use of volunteers as ARFF personnel at some Australian airports. There are those who hold the view that there may not be enough incentive for volunteers to meet the standards recommended by international organisations or the national regulations. Whilst it may seem a plausible assumption, further research is required to ascertain whether this is correct and

¹⁰ Based on passenger movements at airports with movements above 25,000 per year for the year 2000/2001

if so, what are some of the incentives that would be required to motivate volunteers to meet the requisite standards.

To some extent, there are similarities between Canada and Australia in ARFF standards and regulations. For one, Canada also stipulates that some 90% of all commercial aircraft operations should have rescue and fire coverage. The matter will be examined in the following section.

4.3.2 Canada: Canadian Aviation Regulations

In Canada, ARFF operations are governed by the Canadian Aviation Regulation (CAR) 303, which observes some of the SARP's outlined in Annex 14. CAR 303 applies to 90% of commercial air travellers or 28 of the largest airports in Canada (see Table 4.7). Together, these airports handle some 90% of air travellers in Canada.

(i) **Hours of Operation**

An airport operator is required at the beginning of each month to establish the hours of operation of an aircraft fire-fighting service. This is to be done in consultation with air operators using the airport and the aim is to ensure that at least 90% of the commercial passenger carrying aircraft movements are afforded rescue and fire coverage, provided that the airport is notified at least 30 days in advanced of the operation of that flight.

The regulations also state that airports are required to provide a rescue and fire service for aircraft carrying 20 or more passengers and that this service should be provided until the aircraft has landed or taken off, or the flight has been cancelled. In the first instance, not all aircraft are considered in the provision of fire services and in the second instance, unlike Australia, Canada does not provide any lead way in case something happens after the flight has departed. As was noted earlier, Australia allows up to 15 minutes of coverage after the last flight has departed, and 15 minutes prior to the arrival of the first flight.

(ii) Depletion

Non-designated airports may be granted temporary exemption from the provision of ARFF services if the airport operator cannot meet the requirements of the regulations because of a shortage of personnel or unserviceable equipment either at the airport or at the CFS; or in the event that ARFF personnel are already attending another emergency¹¹. In such cases, notification is to be given to the appropriate air traffic control unit or flight service station so that a NOTAM may be issued.

Where the airport is unable to provide ARFF services for seven days or more, the airport operator is obligated to devise a plan, inclusive of timelines, indicating the corrective measures that are necessary to meet the requirements. The regulations stipulate that this plan should be devised no later than the seventh day after the onset of the condition. The airport operator is also required to submit the plan to the Minister for approval, after which, the measures may be implemented.

¹¹ These circumstances are deemed beyond the control of the airport operator.

Table 4.7: Airports Required to Provide Aircraft Fire Fighting Services

Airport	Passenger Traffic	Aircraft Movements
Calgary International	7,884,194	133,692
Charlottetown	159,000	11,600
Edmonton International	3,773,800	91,836 ¹
Fredericton	209,000 ¹	na
Gander International	467,000 ²	68,735 ²
Halifax International	2,853,778	85,012
Kelowna	850,000 ¹	81,080 ¹
London	268,000 ³	103,761 ³
Moncton	na	na
Montreal International (Dorval)	7,805,000	192,304
Montreal International (Mirabel)	990,000	33,190
Ottawa/Macdonald Cartier International	3,217,000	75,250
Prince George	na	na
Quebec/Jean Lesage International	na	na
Regina	708,094	59,010
Saint John	198,000	10,466
St. John's (Torbay)	922,000 ¹	44,347 ¹
Saskatoon/John G. Diefenbaker	762,000	88,795
Sault Ste. Marie	169,000 ³	79,990 ³
Sudbury	563,000	33,400
Thunder Bay	568,787	105,651
Toronto/Lester B. Pearson International	25,930,000	383,189
Toronto City Centre	15,077,000	296,626
Vancouver International	na	na
Victoria International	538,879	83,340
Windsor	159,000 ³	61,954 ³
Winnipeg International	2,683,000	155,912
Yellowknife	na	na

Source: ATI

1 - 2001 figure; 2 - 2000 figure; 3 - 1993 figure

4.3.2.1 CAR 308 – Aircraft Emergency Intervention Services

Under a new regulation, the CAR 308, Aircraft Emergency Intervention Services (AEIS)¹², Canadian airports with more than 2,800 passenger flights annually operated by aircraft seating at least 20 passengers will be required specific emergency response standards. Following are the requirements of the AEIS:

- A communication and alerting system;
- A vehicle capable of delivering 2,400 litres of fire fighting foam and 135 kilograms of dry chemical extinguisher;
- A firm five-minute response time from the time the alarm is sounded to the time the vehicle reaches the mid-point of the furthest runway, for either onsite or offsite aircraft emergency intervention;
- A signed agreement with any offsite community-based provider of emergency response services;
- Coverage of 100% of operations involving aircraft that seat 20 or more passengers;
- Trained personnel at the airport during the hours of operations to operate the AEIS equipment;
- In the case of community fire fighting services, a person onsite during airliner arrivals and departures to alert community fire-fighters;
- Personnel providing AEIS to be trained according to standards set by Transport Canada.

(i) Airports Affected by AEIS

The AEIS will have implications for the airports listed below¹³:

- | | | |
|-----------------|------------------|------------------|
| • Abbotsford | • Campbell River | • Castlegar |
| • Churchill | • Deer Lake | • Fort McMurray |
| • Fort St. John | • Gaspé | • Grande Prairie |
| • Hamilton | • Iqaluit | • Kamloops |
| • Nanaimo | • North Bay | • Prince Rupert |
| • Rankin Inlet | • Rouyn-Noranda | • Sept-Îles |

¹² This regulation is yet to be fully implemented

¹³ Statistics relating to passenger traffic could not be verified for these airports.

- Sydney
- Terrace
- Thompson
- Timmins
- Val d'Or
- Wabush
- Whitehorse
- Comox Valley
- Saguenay/Bagotville

With this new regulation in place, it is estimated that some 96% of the travelling public will be covered by emergency response operations. Considering that there are an estimated 4.7 million aircraft movements at all of Canada's airports and total passenger traffic is just over 86 million, this implies that there is no requirement for the provision of ARFF services for over 180,000 aircraft movements and over 3 million passenger movements. As with Australia, this is a significant number of both aircraft and passenger movements where there is no requirement for rescue and fire coverage.

(ii) Response Time

The regulations also differ from the SARPs as outlined in Annex 14, as the response time is five minutes instead of the required three. The response time is further constrained by the fact that it applies to the time the RFF vehicle reaches the midpoint of the furthest runway and not the end of the each runway or any other part of the movement area as recommended by the ICAO. As will be seen in section 4.3.3, this shortfall is also found in the regulations for the USA.

Canada also allows off site fire fighting responses through agreements with the municipal fire services. However, under these arrangements, it can take up to 15 minutes for the fire authority to respond. This situation is likely to continue for airports that do not fall within the boundaries of the AEIS regulations or the CAR 303. For those airports that will be affected by the new regulations, it is likely that under the current arrangements of using the municipal fire service, many will not be able to meet the five minute requirement. This is due to the fact that several of these airports are 5 to 15 km or 7 to 15 minutes from the nearest municipal station.

Clearly, the above is a cause for concern since it is well known that in the event of a post impact fire, temperatures reaching as high as 2,500 F can quickly engulf an aircraft. It takes just one minute before the aluminium skin can be burnt through and another two

to three minutes before the temperature inside the aircraft reaches 1,800F. Certainly, lessons can be learnt from the British Airtours Boeing 737-200 accident at Manchester Airport on August 22, 1985, where, within one minute of the aircraft coming to a halt, a fire had burnt through the fuselage and had entered the cabin. As was stated earlier, even though the first RIV arrived at the scene a mere 25 seconds before the vehicle stopped and the second vehicle arrived shortly after, 55 people, including two crew members died and 15 were seriously injured.

British Airtours Accident at Manchester Airport, August 22, 1985



Source: Lost Birds Aviation Historical Society

Another case in point, and even though it occurred much earlier there are still lessons to be learnt from it, is the British Midlands Argonaut crash on June 4, 1967. The four piston engine aircraft carrying 84 people crashed in Stockport, near Manchester, some 100 yards from the police station. Although help was immediately on hand, only twelve people were rescued before a fierce fire broke out killing the other 72 persons on board. More passengers had actually survived the crash but because they were immobilised, they were consumed by the fire. Hence, not only should the emergency services be there to extinguish fires, but also to help those who may otherwise be immobile, a situation which could mean life or death. This signifies the need for a quick response time in such situations and presents a strong case as to why the response standards should not be lowered.

However, the fact that the AEIS regulations now mean that more airports under the Canadian system will have rescue and fire coverage is certainly a step in the right direction. Also a step in the right direction is the fact that Transport Canada is seeking to ascertain the cost implications of the new regulations on the airports that are likely to be affected. This will be further discussed in Chapter 5.

4.3.3 The United States of America: FAR 139

(i) Aerodrome Category

ARFF services in the US are governed by the Federal Aviation Regulations Part 139 (Certification and Operations: Land Airports Serving Certain Air Carriers). According to these regulations, the category of an aerodrome is determined by the length of the aircraft and not its width. The indices used are A to E which would fall into ICAO's Categories 5 to 9. There is no category that is equivalent to 10. Table 4.8 depicts the indices used by the USA.

Table 4.8: Aerodrome Indices for Rescue and Fire Fighting in the US

Index	Aeroplane Overall Length
A	Less than 27m (88.58ft)
B	27m (88.58ft) up to but not including 38m (124.67ft)
C	38m (124.67ft) up to but not including 48m (157.48ft)
D	48m (157.48ft) up to but not including 60m (196.85ft)
E	At least 60m (196.85ft)

Source: FAA

The aerodrome index is also determined by the number of aircraft serving the airport on a daily basis. If there are five or more average departures of an air carrier aircraft in a single index group serving that airport in a day, then the longest index group with an average of five or more daily departures is the required index for that airport. In cases of less than five daily departures, the next lower index from the longest index group is required index for that airport. In other words, aerodromes are allowed to reduce by one category in the index if the largest aircraft operating there has less than five scheduled daily departures.

Currently, the US stipulates that ARFF services must be provided only at airports serving scheduled air carriers with aircraft that have more than thirty seats. Hence, only airports that are the equivalent of Categories 4 to 9 in the ICAO categorisation are required to provide rescue and fire coverage.

As with Canada and Australia therefore, there is a significant number of passenger movements and aircraft movements that are not afforded rescue and fire coverage. Aircraft with less than 30 seats are not immune to accidents and post crash fire hence, from a safety perspective, there is no reason why airports at which aircraft with less than 30 seats operate should not be afforded this secondary level of protection. This issue may be well illustrated by the accident involving the United Express Flight 5925 and the Beechcraft King Air A90 general aviation aircraft that took place on November 19, 1996 at the Quincy Municipal Airport in Illinois. Flight 5925, carrying 10 passengers and two crew members, was landing when it collided with the general aviation aircraft, which was carrying two people. From all reports, it would appear as though all 14 people on board the two aircraft survived the impact of the crash. Witnesses who immediately ran to the scene said that they heard sounds of life coming from the cabin of Flight 5925 and the captain actually spoke to them from the cockpit. However, a fire broke out and the occupants of this aircraft could not escape because the cabin door was jammed and could not be opened by either the witnesses or the occupants.

As the Quincy Fire Department was some ten miles away, it took them almost 14 minutes to arrive at the scene. Unfortunately, by then it was too late and all 14 people died as a result of the fire. It was concluded in the autopsy report that the 14 people had died either of carbon monoxide poisoning or the inhalation of toxic fumes from the fire. The National Transportation Safety Board (NTSB) indicated that the lack of ARFF services at the airport contributed to the final outcome of the accident. Although the airport had one fire truck, it could not be despatched because it was not staffed. The NTSB therefore recommended that the standards be increased so that airports served by aircraft with 10 seats or more would be required to provide rescue and fire coverage. With respect to the costs that would be required to increase the standards, the NTSB

also recommended that the FAA explore ways of funding these costs. However, up to the writing of this thesis, the FAA had not made any amendments to the FAR 139 to reflect the NTSB's recommendations.

(ii) Remission Factor

The FAA has indicated that there are no plans to remove the remission factor from the FAR 139 on or after January 1, 2005. Thus far, this is the only country among the ones being studied in this thesis that has formally indicated that it will not remove the remission factor from its regulations. The reason given is that there are cost/benefit considerations that need to be taken into account. Another reason given is that should there be an introduction of a large aircraft into an air carrier's scheduled service, then that air carrier's contingent would not be dependent on the airport having to acquire additional costly capital immediately. Consequently, many airports will continue to operate below the minimum standards recommended by the ICAO.

(iii) Extinguishing Agents

As with Annex 14, the standards relating to fire extinguishing agents and equipment equate to the aerodrome index. These requirements are outlined in Table 4.9. From this table it can be seen that another difference between FAR 139 and Annex 14 is that for the USA, Index B (the ICAO Category 6 equivalent), one vehicle is allowed as opposed to the two recommended by the ICAO.

Table 4.9: Fire Extinguishing Agents and Equipment

Index	Aircraft Length		Total Minimum Quantities of Extinguishing Agents		Vehicles	
	More Than	Not More Than	Dry Chemical	Water for Protein Foam	Min. # of Trucks	Discharge Rate ¹
A		27m (88.58ft)	225kg	0	1	See below
B	27m (88.58ft)	38m (124.67ft)	225kg	5700L	1	See below
C	38m (124.67ft)	48m (157.48ft)	225kg	5700L	2	See below
D	48m (157.48ft)	60m (196.85ft)	225kg	5700L	3	See below
E	60m (196.85ft)		225kg	11,400L	3	See below

Source: ICAO

¹ Truck size

1,900L but less than 7,600L

7,600L or greater

Discharge Rate (Litres per Minute)

At least 1,900 but not more than 3,800

At least 2,280 but not more than 4,560

(iv) **Response Times**

There are also differences with respect to the response times stipulated in FAR 139 and those recommended by the ICAO. Whilst the FAR has stipulated that the first vehicle should arrive no later than three minutes, subsequent vehicles are required to be on the scene within four minutes as opposed to the one minute criteria suggested by the ICAO.

Furthermore, FAR 139 states that

‘The response time required...shall achieve the following performance:

(i) Within 3 minutes from the time of the alarm, at least one required airport rescue and fire fighting vehicle shall reach the midpoint of the farthest runway serving air carrier aircraft from its assigned post, or reach any other specified

point of comparable distance on the movement area which is available to air carriers, and begin application of foam, dry chemical, or halon 1211.'

The ICAO recommendations are that the first intervention vehicle should reach the end of each runway as well as any other part of the movement area within three minutes. Again, the FAR 139 is not as concerned with response times as it should be, particularly given the fact that although the majority of aircraft accidents take place at or near an airport, it does not necessarily imply that they will all occur at the centre of the runway. Thus, if an accident were to occur at the end of the furthest runway, there is no requirement for the first intervention vehicle to get to that accident within the minimum three minute requirement.

The fact that the subsequent vehicles are allowed to arrive four minutes later also suggests that if the first vehicle expends its fire extinguishing agent before the arrival of the next vehicle(s), then the chances of survival in an already grim situation are even less. It is therefore difficult to imagine how the requirements as stipulated by the FAR 139 can provide a framework in which ARFF services can deal with major catastrophic occurrences such as the one at Manchester.

4.3.4 The United Kingdom: CAP 168

(i) Aerodrome Categories

ARFF services in the UK are covered by CAP 168 which generally complies with Annex 14. However, there are slight differences between the ICAO categories and those adopted by the UK. Whilst Categories 3 to 10 are similar, the first three Categories under CAP 168 differ. Table 4.10 below shows the first three aerodrome categories for the UK.

Table 4.10: UK Aerodrome Categories

Aerodrome Category (RFF)	Aeroplane Overall Length
Special	Fixed wing aircraft up to but not including 9m in length engaged in flying instruction; fixed wing aircraft engaged in public transport of passengers, beginning and ending at the same aerodrome, in aircraft up to 2730 kg max total weight authorised; helicopters up to but not including 15m engaged in flying instruction.
1	Fixed wing aircraft of overall length up to but not including 9m engaged in public transport of passengers.
2	Fixed wing aircraft equal to or greater than 9m in length up to but not including 12m engaged in public transport of passengers

Source: CAP 168

(ii) Remission Factor

CAP 168 also recognises the remission factor; however, the appropriate legislation states that:

‘Where the number of movements of aeroplanes used to determine the aerodrome RFF Category ...will not exceed 700 in the busiest three months of any year, licensees are permitted to reduce the scale of facilities for aeroplanes of that size to one below that determined by the size of aeroplane.’

Note therefore that the remission factor is determined by the three busiest months of the year, which may not necessarily be consecutive months as is indicated in the Annex 14. Furthermore, licensees may also be granted permission to choose the aircraft against which to apply the remission factor provided that it has been demonstrated that an optimum level of rescue and fire coverage will be made available and will take into account all types, sizes and numbers of aircraft.

The SRG has indicated that they are currently no plans to remove the remission factor from CAP 168. However, the matter will be carefully reviewed by the department in consultation with the industry in due course.

(iii) Hours of Operation

According to CAP 168, an aerodrome is required to provide rescue and fire fighting services throughout its hours of operation and 15 minutes after the departure of the last flight. As with the CAR 303 for Canada, CAP 168 recognises that there may be circumstances where, due to factors beyond the ARFF service provider's control, such as in-service mechanical failure of vehicles or equipment, or sudden illness of a member of staff, the rescue and fire coverage cannot be provided in accordance with the standards for that airport. However, unlike the case in Canada where the regulations are more lenient, CAP 168 requires that immediate action be taken to reinstate the facilities as well as to consider restricting operations. Furthermore, depletion is not permitted for Category Special and the minimum category required in the case of depletion for Categories 2 and 3 is Category 1. For all other categories, rescue and fire coverage may not be lowered to less than two categories below the stipulated category for that particular aerodrome. There is no allowance for the remission factor to be used during periods of temporary depletion.

(iv) Extinguishing Agents and Response Times

Another area in which CAP 168 differs from Annex 14 is in the use of complementary agents. According to CAP 168, up to 50% of the complimentary agent may be replaced by water for foam production to performance level B. However, the regulations do not allow any room for a reduction in the response times recommended by ICAO.

(v) Rescue Equipment

This CAP also recognises the importance of high quality training, effective equipment and speed in responding to an aircraft which has been involved in an accident or incident. Consequently, the minimum number of vehicles that would be required for the various categories of aerodromes is higher for Categories 5 and 10 than the recommendations in Annex 14. Table 4.11 shows the requirements of the UK CAA vis-à-vis ICAO.

Table 4.11: Minimum Number of Rescue and Fire Fighting Vehicles per Aerodrome Category

Aerodrome Category	No. of Rescue and Fire Fighting Vehicles (CAP 168)	No. of Rescue and Fire Fighting Vehicles (ICAO)
Special	1	1
1	1	1
2	1	1
3	1	1
4	1	1
5	2	1
6	2	2
7	2	2
8	3	3
9	3	3
10	4	3

Source: Cap 168

This chapter has demonstrated the need for a high level of standards for ARFF services if the fatality rate associated with accidents are to be reduced. However, as was discussed in Chapter 3, in making a determination as to how far one should go in reducing risks, the costs must be weighed against the benefits. If it is found that the CPF is grossly disproportionate to the cost of the risk reduction measures, then there may be some justification for the postponement of those measures. Accordingly, the following chapter will examine the costs involved in providing ARFF services to meet the standards outlined in this chapter.

Chapter 5: Cost Implications of ARFF Standards and Services

5.1 INTRODUCTION

In Chapter 4, the need for high standards in relation to ARFF services was discussed. In certain instances, it was shown how inadequate some of the standards were. Furthermore, it was demonstrated that some standards recommended by ICAO were actually lowered due to economic considerations. For countries such as Australia and the USA, economic factors also played an important part in the development of their standards and regulations.

Whilst the main aim of ARFF services is to save lives, the determination of minimum standards required to achieve this aim is not an easy feat. It would be impossible to implement measures that would save every human being involved in aircraft accidents. Several factors present constraints to achieving this objective, among which is the financial cost of safety measures. One therefore has to consider whether the costs of providing ARFF services or meeting ARFF regulations are practical. This chapter will examine the cost considerations that should be taken into account when attempting to make a determination as to whether the safety measures are justified.

5.2 CANADA

5.2.1 Study Commissioned by Transport Canada

In a study commissioned by Transport Canada, it was estimated that the AEIS regulations will cost approximately CAN\$11 million in start up costs and CAN\$1 million in annual ongoing costs across the airport system. Tables 5.1 through 5.14 provide insight into the kinds of costs required under the AEIS. In light of additional expenses airports would have to undertake, Transport Canada has set up an assistance programme known as the Airports Capital Assistance Programme (ACAP) under which,

funding will be provided to assist airports with meeting the capital costs coming about as a result of the AEIS. However, Transport Canada is of the view that the ongoing operational cost, which is estimated at CAN\$35,000 for each affected airport, can be covered by the revenues generated by the airports.

5.2.1.1 Training and Associated Costs

The estimates in Table 5.1 through Table 5.9 give an indication of the training costs needed to bring personnel in line with the requirements as set out under the regulations for the various categories of aerodromes. For each of the categories considered, training is aimed at emergency responders unskilled in the area of rescue and fire fighting. Travel expenses are calculated based on three scenarios i.e. attendance at a 'remote', a 'regional' and a 'community' specialised school. Salaries were calculated based on a \$40,000 annual cost plus a 25% overhead. The contracts for training instructors were estimated at \$400 per day plus a 25% overhead. All costs are quoted in Canadian dollars.

(i) First Year Training Costs - Category C

The training for this category is designed to provide the emergency responders with no existing fire-fighting skills with the competencies necessary to respond adequately to an aircraft emergency using a suitable onsite fire truck.

Table 5.1: Option 1 - Train-the-trainer Programme for One (1) Person

Item	Remote School	Regional School	Local School
Travel Days	6.0	5.5	5.0
Air Fare	\$1,000	\$500	\$0
Tuition Cost (5 days @ \$400 per day)	\$2,000	\$2,000	\$2,000
Travel Expenses	\$900	\$825	\$750
Salary during course and travel	\$822	\$753	\$685
5 days salary for 3 persons at airport*	\$2,055	\$2,055	\$2,055
4 foam recharges 1 st load, test and local training	\$2,000	\$2,000	\$2,000
4 dry chemical recharges C/W propellant gas	\$2,000	\$2,000	\$2,000
Total	\$10,777	\$10,133	\$9,490
On-going training requirement (50%)	\$5,388	\$5,067	\$4,745

Source: Transport Canada

* - Includes trainer

Table 5.2: Option 2 - Hire of Qualified Trainer to Deliver Onsite Training

Item	Remote School	Regional School	Local School
Travel days	6.0	5.5	5.0
Air fare per traveller	\$2,000	\$1,000	\$0
Contract for training	\$5,000	\$5,000	\$5,000
Travel expenses (2 instructors)	\$1,800	\$1,650	\$1,500
5 days salary for 3 persons at airport	\$2,055	\$2,055	\$2,055
4 foam recharges 1 st load, test and local training	\$2,000	\$2,000	\$2,000
4 dry chemical recharges C/W propellant gas	\$2,000	\$2,000	\$2,000
Total	\$14,855	\$13,705	\$12,555
Ongoing training requirement (50%)	\$7,427	\$6,852	\$6,277

Source: Transport Canada

Table 5.3: Option 3 - Training for Three (3) Emergency Responders from an Approved Institution

Item	Remote School	Regional School	Local School
Travel days	6.0	5.5	5.0
Air fare per traveller	\$3,000	\$1,500	\$0
Tuition – 5 days @ \$400 x 3 Ers	\$6,000	\$6,000	\$6,000
Travel expenses – 3 responders	\$2,700	\$2,475	\$2,250
5 days salary for 3 persons from airport	\$2,466	\$2,260	\$2,055
4 foam recharges 1 st load, test and local training	\$2,000	\$2,000	\$2,000
4 dry chemical recharges C/W propellant gas	\$2,000	\$2,000	\$2,000
Total	\$18,166	\$16,235	\$14,305
Ongoing training requirement (50%)	\$9,083	\$8,118	\$7,152

Source: Transport Canada

(ii) First Year Training Costs - Category B

The programme for this category is designed to provide the emergency responders with no existing fire-fighting skills with the competencies necessary to respond adequately to an aircraft emergency using a truck mounted fire fighting unit with a remote monitor that is operable from the vehicle cab.

Table 5.4: Option 1 - Train-the-trainer Programme for One (1) Person

Item	Remote School	Regional School	Local School
Travel days	4.0	3.5	3.0
Air fare	\$1,000	\$500	\$0
Tuition – 3 day course @ \$400 per day	\$1,200	\$1,200	\$1,200
Salary during course and travel	\$600	\$525	\$450
3 days salary for 3 persons at airport*	\$1,233	\$1,233	\$1,233
4 foam recharges 1 st load, test and local training	\$500	\$500	\$500
4 dry chemical recharges C/W propellant gas	\$1,000	\$1,000	\$1,000
Total	\$6,081	\$5,437	\$4,794
Ongoing training requirement (50%)	\$3,040	\$2,719	\$2,397

Source: Transport Canada

* - Includes trainer

Table 5.5: Option 2 - Hire of a Qualified Trainer to Deliver Onsite Training

Item	Remote School	Regional School	Local School
Travel days	4.0	3.5	3.0
Air fare	\$1,000	\$500	\$0
Contract for training	\$3,000	\$3,000	\$3,000
Travel expenses (1 instructor)	\$600	\$525	\$450
3 days salary for 3 persons at airport	\$1,233	\$1,233	\$1,233
4 foam recharges 1 st load, test and local training	\$500	\$500	\$500
4 dry chemical recharges C/W propellant gas	\$1,000	\$1,000	\$1,000
Total	\$7,333	\$6,758	\$6,183
Ongoing training requirement (50%)	\$3,666	\$3,379	\$3,091

Source: Transport Canada

Table 5.6: Option 3 - Training for Three (3) Emergency Responders from an Approved Institution

Item	Remote School	Regional School	Local School
Travel days	4.0	3.5	3.0
Air fare	\$3,000	\$1,500	\$0
Tuition – 3 days @ \$400 x 3 Ers	\$3,600	\$3,600	\$3,600
Travel expenses – 3 responders	\$1,350	\$1,575	\$1,350
3 days salary for 3 persons at airport	\$1,233	\$1,438	\$1,233
4 foam recharges 1 st load, test and local training	\$500	\$500	\$500
4 dry chemical recharges C/W propellant gas	\$1,000	\$1,000	\$1,000
Total	\$10,683	\$9,613	\$7,683
Ongoing training requirement (50%)	\$5,341	\$4,807	\$3,841

Source: Transport Canada

(iii) First Year Training Costs - Category A

The programme for this category is designed to provide the emergency responders with no existing fire-fighting skills with the competencies necessary to respond adequately to an aircraft emergency using suitable extinguishers.

Table 5.7: Option 1 - Train-the-trainer Programme for One (1) Person

Item	Remote School	Regional School	Local School
Travel days	2.0	1.5	1.0
Air fare	\$1,000	\$500	\$0
Tuition cost – 1 day course @ \$400 per day	\$400	\$400	\$400
Travel expenses	\$300	\$225	\$150
Salary during course and travel	\$274	\$205	\$137
1 day salary for 3 persons at airport*	\$411	\$411	\$411
4 foam recharges 1 st load, test and local training	\$100	\$100	\$100
4 dry chemical recharges C/W propellant gas	\$100	\$100	\$100
Total	\$2,585	\$1,941	\$1,298
Ongoing training requirement (50%)	\$1,292	\$971	\$649

Source: Transport Canada

* - Includes trainer

Table 5.8: Option 2 - Hire of a Qualified Trainer to Deliver Training Onsite

Item	Remote School	Regional School	Local School
Travel days	2.0	1.5	1.0
Air fare	\$1,000	\$500	\$0
Contract for training	\$1,500	\$1,500	\$1,500
Travel expenses – 1 instructor	\$300	\$225	\$150
1 day salary for 3 persons at airport	\$411	\$411	\$411
4 foam recharges 1 st load, test and local training	\$100	\$100	\$100
4 dry chemical recharges C/W propellant gas	\$100	\$100	\$100
Total	\$3,411	\$2,836	\$2,261
Ongoing training requirement (50%)	\$1,705	\$1,418	\$1,130

Source: Transport Canada

Table 5.9: Option 3 - Training for Three (3) Emergency Responders from an Approved Institution

Item	Remote School	Regional School	Local School
Travel days	2.0	1.5	1.0
Air fare	\$3,000	\$500	\$0
Tuition – 1 day @ \$400 x 3 Ers	\$1,200	\$1,200	\$1,200
Travel expenses – 3 responders	\$900	\$675	\$450
1 day salary for 3 persons at airport	\$411	\$411	\$411
4 foam recharges 1 st load, test and local training	\$100	\$100	\$100
4 dry chemical recharges C/W propellant gas	\$100	\$100	\$100
Total	\$5,711	\$3,986	\$2,261
Ongoing training requirement (50%)	\$2,855	\$1,993	\$1,130

Source: Transport Canada

(iv) Start-up Costs - Operations and Maintenance

In addition to the fore-going, there will be a number of other costs that the airports will be required to undertake. These include the following:

- The initial fill of agent;
- Training with the unit and with enough of the agent for one reserve refill; and
- Purchase of protective clothing or flame resistant overalls depending on the category in question.

The start-up operations and maintenance costs are further outlined in Table 5.10 below.

Table 5.10: Start Up Operational and Maintenance Costs, AEIS Affected Aerodromes

Item/AEIS Category	A	B	B2	C
4 foam recharges in support of training	\$100	\$500	\$1,200	\$2,000
4 dry c-hemical recharge for training*	\$100	\$1,000	\$2,000	\$2,000
2 complete sets of protective clothing	N/A	\$3,000	N/A	\$3,000
3 flame resistant overalls	\$450	N/A	N/A	N/A
Total	\$650	\$4,500	\$3,200	\$7,000

Source: Transport Canada

* Includes propellant gas

5.2.1.2 Ongoing Annual Operational and Maintenance Costs

The following section presents a break down in the annual operating and maintenance costs for the AEIS affected airports.

(i) Agents and Equipment

Transport Canada has estimated the costs for training agents and maintenance of protective clothing at 25% of the start up costs. These costs are outlined in see Table 5.11

Table 5.11: Ongoing Annual Operational and Maintenance Costs

Aerodrome Category	Ongoing Cost
A	\$163
B	\$1,125
B2	\$800
C	\$1,750

Source: Transport Canada

(ii) Salaries

The estimated salary costs are shown in Table 5.12. The estimated salary allowance is to cover the verification, preparation and positioning of the emergency response equipment on a daily basis. The estimated time is according to the AEIS category.

Table 5.12: Estimated Salary Allowances

AEIS Category	Hours per Week	Hours per Year	Hourly Rate*	Tot. Annual Costs
A	7	364	\$27	\$9,828
B	15	780	\$27	\$21,060
C	25	1300	\$27	\$35,100

Source: Transport Canada

* - Includes Overheads

(iii) Implementation Capital Cost

The estimated capital costs are shown in Table 5.13. These costs include ‘no-frills’ equipment which can meet the requirements of the various AEIS categories but they do not include the costs for certain tools such as hydraulic extrication tools and Axes pry bars.

Table 5.13: Implementation Capital Costs

Item/AEIS Category	A	B	B2	C
1 foam unit to AEIS specification or modification	\$500	\$500,000	\$20,000	\$300,000
1 dry chemical unit or modification	\$150	Included	\$5,000	Included
Transportation cost	\$100	\$2,000	\$2,000	\$4,000
Total	\$750	\$52,000	\$27,000	\$304,000

Source: Transport Canada

(iv) Annual Vehicle Storage and Equipment Maintenance

Table 5.14 shows the estimated costs associated with the maintenance and storage of vehicles according to the AEIS Category. Note that these costs do not apply to Category A.

Table 5.14: Vehicle Maintenance and Storage Costs

Item/AEIS Category	A	B	B2	C
Maintenance	N/A	\$500	N/A	\$3,000
Fuel	N/A	\$500	N/A	\$2,000
Insurance	N/A	\$1,000	\$1,000	\$3,000
Garage space allowance	N/A	\$1,000	N/A	\$5,000
Vehicle usage allowance	N/A	N/A	\$2,000	N/A
Total	\$0	\$3,000	\$3,000	\$13,000

Source: Transport Canada

5.2.2 'Costs to AEIS Affected Airports: The Aircraft Emergency Intervention at Airports – CAR 308 Survey of Affected Airports' Report

In February 2003, a survey on the costs to airports that were affected by the new AEIS regulations was submitted to Transport Canada. The survey¹⁴, which was commissioned by the Air Transport Association of Canada, the Canadian Airports Council and the Federation of Canadian Municipalities and conducted by Sypher:Mueller International Inc. indicated that the costs that were originally developed by Transport Canada were too conservative. Below is an outline of the key findings of the survey.

5.2.2.1 Overview

Under the AEIS, it was estimated that salary costs above the current staffing costs could be as low as \$20,000 or as high as \$282,000 but generally averaged around \$125,000 for those airports requiring additional staff. For the 17 airports that were studied, it was estimated that the total additional staffing costs could amount to \$1,290,080. However, it should be noted that this cost is below the total staffing costs for the AEIS airports as four airports included in the study already provide ARFF services. The staffing costs for these latter airports together total approximately \$1.2 million. Furthermore, airports are likely to incur additional costs for start-up operations and maintenance of \$16,300,

¹⁴ Hereafter referred to as the Sypher:Mueller Report

which includes initial fill of agents, testing and familiarisation with vehicle and equipment and protective clothing. Recurring operating and maintenance costs were estimated at \$31,000 and included vehicle maintenance and fuel, additional insurance, shelter, replacement and repair of protective clothing and foam recharges and chemical agents.

Sypher:Mueller notes that had these new regulations not been implemented, the airports would have had the choice to eliminate or even reduce the level of the service required, if it was felt that the economic environment could not support the costs associated with these services. Hence, it can be argued that the inability of airports to now select the afore-mentioned option implies that they could very well be at a competitive disadvantage against airports that are not required to provide these services. The Sypher:Mueller report did not give consideration to the fact that as more airports will now be required to provide a certain level of ARFF services, they could obtain a marketing edge over those that do not provide the services. This will be particularly valuable given the heightened awareness of safety and security issues in the aviation industry, especially after the September 11, 2001 terrorist attacks in the USA.

(i) Approaches to the Provision of ARFF Services under the AEIS

As was discussed in Chapter 4, several airports already rely on the services of the Community Fire Station (CFS) in the provision of ARFF services. However, for several of these airports the nearest CFS is some 5 to 15km or 7 to 15 minutes away. It is therefore reasonable to postulate that in order to meet the standards set out by the AEIS, alternative arrangements would have to be made. A number of options were considered during the survey. These options and their approximate costs are outlined below.

(a) Stand-by of Community Fire Service at Airport

A proposal was made to have the CFS standby at the airport for scheduled operations of aircraft with 20 or more seats. However, this option was not feasible for many airports for the following reasons:

- The CFS would be unable to achieve a proper response time for any incident occurring in the city;
- Problems were also foreseen due to the fact that the CFS was operated by volunteers;
- The flight schedule would present logistical challenges with respect to the CFS volunteers travelling to and from the airport between flights in order to conduct any other duties;
- It was too costly to have members of the CFS on standby; and
- The City was loath to take on the additional responsibility of the CAR 308.

Several airports however did agree that they would reach some form of agreement with the CFS. The agreement, which would cover the costs of staffing but would exclude vehicles and equipment, was estimated to cost between \$100,000 and \$200,000 annually.

(b) Multi-Tasking

The report noted that using existing staff to provide various aspects of the services required by the AEIS could actually reduce costs for the airport. Some airports have already implemented multi-tasking into the provision of rescue and fire coverage. However, for other airports, this was not possible for the following reasons:

- It was against union agreements;
- Maintenance employees, who could probably assist with ARFF services, were positioned to far away from the fire station to meet the five minute requirement. Furthermore, if they were to be positioned at the fire station during flight times then other vital duties would be neglected;
- Few other personnel at the airport could perform the requisite ARFF services as they already had clearly defined duties in emergency cases;
- Many airports had already reduced staffing levels to a minimum in order to cut costs. Consequently, staff were already very busy during flight times and often required overtime in order to perform their duties; and

- There is some apprehension by members of staff about undertaking ARFF duties.

Whilst the use of multitasking does not eliminate the need to hire additional staff in order for airports to meet the AEIS requirements, it does reduce the number of additional staff that would be required. It is however estimated that the salaries for existing staff that would be required to undertake the AEIS functions could increase by \$3,000 to \$5,000 annually. When the total number of staff required for this purpose was taken into consideration, it was estimated that the total increase in annual salaries could range from \$20,000 to \$35,000 per year.

Consideration was also given to airline staff acting as ARFF personnel. However, this option too had a number of drawbacks which are outline below:

- During flight times especially, airline staff are extremely busy hence it would not be practical for them to standby at the fire hall;
- The airline industry in the regions in question had a high turn over and this would render this option impractical;
- The airlines have not expressed a desire to become involved in this service; and
- Union agreements would prohibit this option.

Consequently, the multitasking option may work for some airports but not for others. It is therefore important for an airport to assess its own situation and where possible, implement the option of multitasking with respect to its ARFF services.

(ii) Additional Staffing Costs

Managers at the airports participating in the survey were asked to indicate the additional staffing costs needed to meet the requirements of the AEIS. However, for airports that already provided ARRF services, the managers were of the view that current staff levels should be adequate and hence assigned a sum of zero (0) to this item. For other airports, the cost ranged from \$20,000 to \$282,000.

(iii) Training Costs

Based on information supplied by one fire department, Sypher:Mueller International Inc. reported that a three month course would be required to train personnel in accordance with the standards outlined in the AEIS, and not a five day course as indicated by Transport Canada. According to the report, *'An under-trained person in an emergency situation will be unlikely to provide adequate response and may decrease safety by putting themselves at risk.'* To this end, training costs were developed base on a three month programme. The average cost per person for initial training was estimated at \$10,000 and this sum included tuition, travel and accommodation as well as salary. The total initial training costs for the 17 airports that responded to the survey were estimated at \$723,000, a portion of which may be funded by the ACAP. Another cost consideration that was taken into account was that of the initial training of new staff in subsequent years. This was estimated at \$98,200 per year for the 17 airports. In addition, there is also the cost of recurrent training of interveners. For the 17 airports, this was estimated at \$200,400 annually.

(iv) Capital Costs

As several airports already owned fire fighting vehicles, some of which met the requirements for the CAR 308, it was not initially envisaged that the capital costs would be as high as if they did not have vehicles. However, a number of the vehicles owned by the airports in question had not been in operation for some time and were therefore not fully serviceable. The cost of conducting a major overhaul would be at the expense of the airport. Conversely, under the ACAP, airports could acquire fire fighting vehicles provided that they were new vehicles. It is therefore anticipated that most airports would prefer to acquire new vehicles under this scheme. The costs for acquiring new vehicles ranged from \$175,000 to \$350,000. If all 27 airports that were to be affected by the new AEIS were to acquire new vehicles, then the total estimated cost would be between \$4,725,000 and \$5,950,000, a small portion of which would be funded by the airports.

(v) Shelter

Under the AEIS, airports are required to provide shelter for fire vehicles and equipment. The estimated costs of building a fire hall was anywhere between \$144,000 and

\$156,000. For those airports with fire halls but requiring renovation, the estimated costs were between \$30,000 and \$125,000. It was estimated that for the 17 airports that responded to the survey, the cost for providing shelter would be \$679,520. As airports could request assistance under the ACAP, the costs would be broken down as follows:

- Cost to ACAP \$649,520
- Cost to Airports \$30,000

(vi) Other Equipment

It was estimated that the costs for additional equipment required under the AEIS would amount to \$4,000 per airport. Taking the 27 airports that would be affected by these new regulations, the total estimated costs would amount to \$108,000, a small portion of which would be covered by the airports.

(vii) Communication and Alerting Systems

Some airports would require an upgrade in their communication and alerting systems in order to meet the AEIS standards. It was estimated that the costs for the upgrades could range from \$8,000 to \$10,000. Installation costs for those airports requiring it was estimated at \$3,500. For the 17 airports included under the study, it was estimated that the total costs for the communications and alerting systems would be \$61,500, 100% of which could be funded by the ACAP.

(viii) Depreciation

Under the ACAP, there is an allowance for replacement of eligible capital assets. However, funding has only been secured for five years and there is much uncertainty as to who will be responsible for covering various costs after this period. None-the-less, a straight line method of depreciation has been used for the capital assets and this has resulted in the costs provided in Table 5.15 below. Note that these costs are typical values for the assets under consideration and that the study estimated that the total depreciation costs for the 17 airports was \$506,000

Table 5.15: Valuation of Assets

Depreciation	Initial Value	Lifetime (years)	Depreciation Year ⁻¹
Vehicle	\$275,000	15	\$18,333
Equipment	\$20,000	10	\$2,000
Shelter/fire hall	\$200,000	30	\$6,667
Communication and alerting system	\$10,000	20	\$500
Total			\$27,500

Source: Sypher:Mueller International Inc.

(ix) Total Costs of AEIS

Table 5.16 outlines the total costs to the airports and to ACAP.

Table 5.16: Total Estimated Costs to Airports and ACAP

Expense for:	Cost
Airport – Increment for Year 1	
Vehicle	\$20,000
Additional required equipment	\$58,298
Fire hall	\$30,000
Communication and alerting system	\$0
Initial training cost	\$722,979
Total start-up costs	\$174,010
Total	\$1,005,287
Airport – Recurring Annual Cost	
Cost of CFS providing AEIS	\$400,000
Annual loss in revenue	\$30,000
Estimated additional staffing cost	\$1,290,080
Initial training costs in subsequent years	\$98,209
Average annual recurrent training cost	\$200,369
Total recurrent O&M costs ¹	\$535,239
Total depreciation	\$0
Total	\$2,553,897
ACAP – Year 1	
Vehicle	\$3,240,000
Total cost of additional required equipment	\$8,000
Fire hall	\$649,520
Communications and alerting system	\$61,500
Initial training cost	\$0
Total start-up costs	\$54,400
Total	\$4,013,420
Total depreciation	\$505,627

Source: Sypher:Mueller International Inc.

It should be noted that Table 5.16 includes a portion for depreciation for the costs to be covered by ACAP. This cost is included simply to show the level of long term funding that ACAP would need to secure in order to cover the replacement of assets. In reality, funding is provided to airports on an annual basis without an allowance for depreciation.

It should also be noted that the above costs exclude the costs associated with two airports at which the Department of National Defence (DND) already provides and covers the costs of emergency response services. The afore-mentioned estimates were therefore developed for 25 airports and not the 27 that would be affected by the AEIS. The above costs were calculated by taking the average cost per airport for the 17 airports that participated in the study and multiplying it by 25. The resultant figures therefore give an approximation as airports from which information could not be obtained may have characteristics and needs that are different from those that responded to the survey. For example, some airports are operated by Transport Canada hence their AEIS costs may vary. These airports were not included in the survey. On the other hand, three of the largest airports that were included, already provide some level of ARFF services, thus the additional costs that would be required are low in comparison with airports that do not provide any service.

The Sypher:Mueller report indicated that the additional recurrent costs to the airports could represent anywhere between 3% and 43% of total operating costs. However, it is envisaged that the new regulations will increase operating costs of most of the affected airports by between 5% and 20%. Table 5.17 below outlines the total estimated costs for the 25 airports and ACAP whereas, Table 5.18 outlines the average estimated costs per airport and for ACAP.

Table 5.17: Total Estimated Cost for 25 Airports and for ACAP

Organisation Incurring Cost	Increment for Year 1	Additional Annual Cost	Total for Year 1
Airport	\$1,596,000	\$4,055,000	\$5,651,000
ACAP	\$6,375,000	\$805,000	\$7,180,000
Total	\$7,971,000	\$4,860,000	\$12,831,000

Source: Sypher:Mueller International Inc.

Table 5.18: Average Estimated Cost per Airport and for ACAP

Organisation Incurring Cost	Increment for Year 1	Additional Annual Cost	Total for Year 1
Airport	\$59,100	\$150,200	\$209,300
ACAP	\$236,100	\$29,800	\$265,900
Total	\$295,200	\$180,000	\$475,200

Source: Sypher:Mueller International Inc.

Costs per enplaned passenger also vary according to airport depending on whether ARFF services are already provided. Most costs are over \$4 but can range from as little as a few cents to \$11.

(x) Comparison with Other Estimates

The afore-mentioned costs were then compared to other costs prepared in accordance with the following:

- CAR 308 enacted in 2002 and undertaken by Transport Canada as outlined in the previous section; and
- The fifth draft of CAR 308 for Category B airports and undertaken by the Air Transport Association of Canada (ATAC) and the Canadian Airports Council (CAC);

The comparisons between the afore-mentioned costs are outlined in Table 5.19.

Table 5.19: Comparison of Costs for Airports Affected by AEIS

Expense	Sypher:Mueller Survey	ATAC/CAC	Transport Canada
Airport Annual Recurrent Cost	\$150,200	\$77,000	\$34,000
Initial Capital Cost	\$295,200	\$350,000	\$352,000

Source: Sypher:Mueller International Inc.

Clearly, there is a significant difference between the costs derived by Sypher:Mueller, Transport Canada and the Air Transport Association of Canada for the annual recurrent

costs to airports. The differences in costs between the initial capital costs undertaken by the various concerns mentioned above are not as great. At the time this thesis was written, there was not enough information available on how the costs were derived. To this end, little can be said in terms of their justification and which are most likely to be credible. Sypher:Mueller however does try to justify the costs which it developed and noted in the report that:

‘The recurrent costs in this study compared to the earlier ATAC/CAC study are due to the inclusion of the 5-minute response time in the enacted version. The recurrent costs provided by TC are much less than those indicated by the airports and appear to be unrealistic. The survey indicated that possibly one or two airports with the lowest additional recurrent costs due to AEIS would be closer to the TC estimates, but the costs for all others will far exceed TC’s estimate.’

The Sypher:Mueller report also noted that the earlier estimates for the capital costs included a larger number of airports that would require fire halls. However, the survey undertaken by this entity revealed that most of the airports affected by the new legislation would be able to provide shelter for the vehicles and equipment, hence the lower capital costs.

5.3 Other Countries

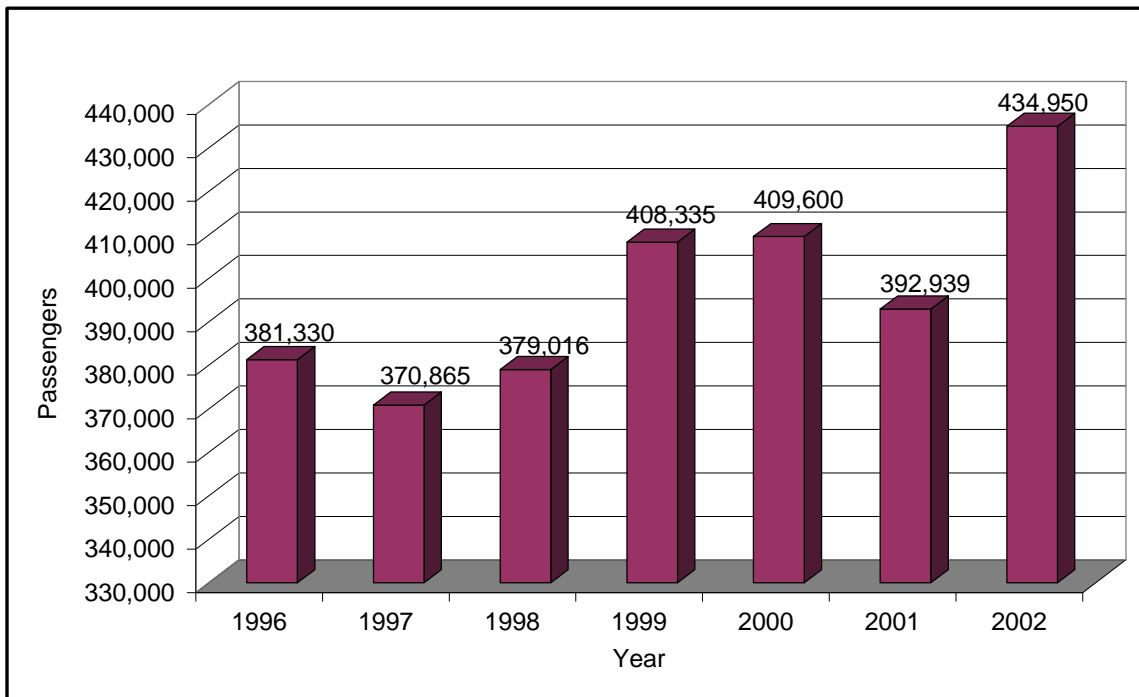
Unfortunately, costings as detailed as that obtained for Canada could not be obtained for the other countries included in this thesis. However, the best available data will be used to for further analysis.

5.3.1 United States of America – Case Study: Rapid City Regional Airport

Rapid City Regional Airport is an Air Force Base which first offered commercial services in 1938 with the operation of Inland Airlines, now Western Airlines. In 1950, the airport was relocated to its current position and between this time and 1989, passenger traffic grew from 15,000 to over 323,000. Due to this increase in traffic, a

new terminal was opened in 1989. In 2002, total annual passenger traffic surpassed the 430,000 mark (see Figure 5.1). The airport is home to 15 businesses which account for the employment of 300 persons. It has been estimated that the total economic impact of Rapid City Regional Airport is somewhere in the vicinity of US\$9.8 million.

Figure 5.1: Rapid City Regional Airport Passenger Traffic 1996-2002



Source: Rapid City Regional Airport

Rapid City Regional Airport receives grants on an annual basis from the Airport Improvement Programme (AIP) which is administered through the FAA. These funds are generated by users of the air transport system through the Airport and Airway Trust Fund. Under this fund, taxes are levied on airline tickets, aviation fuel and air freight. The money collected is used to fund eligible airport projects. Rapid City Regional Airport also receives grants annually from the South Dakota Department of Transportation – Office of Aeronautics. Any additional project costs are then funded by the airport through monies obtained from the Passenger Facility Charge (PFC) programme. The monies obtained through the fore-going mechanisms may be used to purchase ARFF vehicles and equipment. A breakdown of the funding available for eligible projects is shown below:

- FAA 90%
- State Funds 5%
- Airport Funds 5%

ARRF services and other safety and security services at Rapid City Regional Airport are provided through partnerships with the Rapid City Department of Fire and Emergency Services, the Rapid City Police Department, the Pennington County Sheriff’s Office, the South Dakota Army National Guard, the South Dakota Highway Patrol and a number of other agencies. Accordingly, the airport extends its services to Rapid City by attending to fire and medical emergencies as well as through fire prevention and public relations activities. ARFF personnel are also responsible for airport security. Table 5.20 below shows the types of activities that the ARFF personnel have had to attend to for the periods 1995 to 2002.

Table 5.20: Emergency Activity for Rapid City Regional Airport 1995 - 2002

Activity	1995	1996	1997	1998	1999	2000	2001	2002
Aircraft emergency	9	22	10	9	12	6	12	6
Medical/rescue	10	20	22	49	91	43	36	21
Air ambulance standby	14	11	26	15	11	16	7	5
Fire alarm	5	5	5	2	3	5	5	19
Fuel spill	1	4	1	1	4	1	3	N/A
Security/assist police	8	36	39	60	81	102	115	96
Fire	0	2	2	1	1	2	1	N/A
Service call/assist customer	1	5	24	30	34	42	45	17
Other	1	3	5	7	12	12	4	12
Total	49	108	134	174	249	229	228	177

Source: Rapid City Regional Airport Annual Report

In addition to the foregoing, Rapid City Regional Airport has reported that their ARFF personnel were called out deal with a hazardous material on one occasion in 2002.

In 2001, due to the September 11 terrorist attacks in the USA, the airport was required to increase its safety and security standards. Consequently, the provision of an additional two fire fighters at the terminal buildings on a 24 hour basis was among the measures implemented. This lasted for six weeks and is reflected in the costs of ARFF

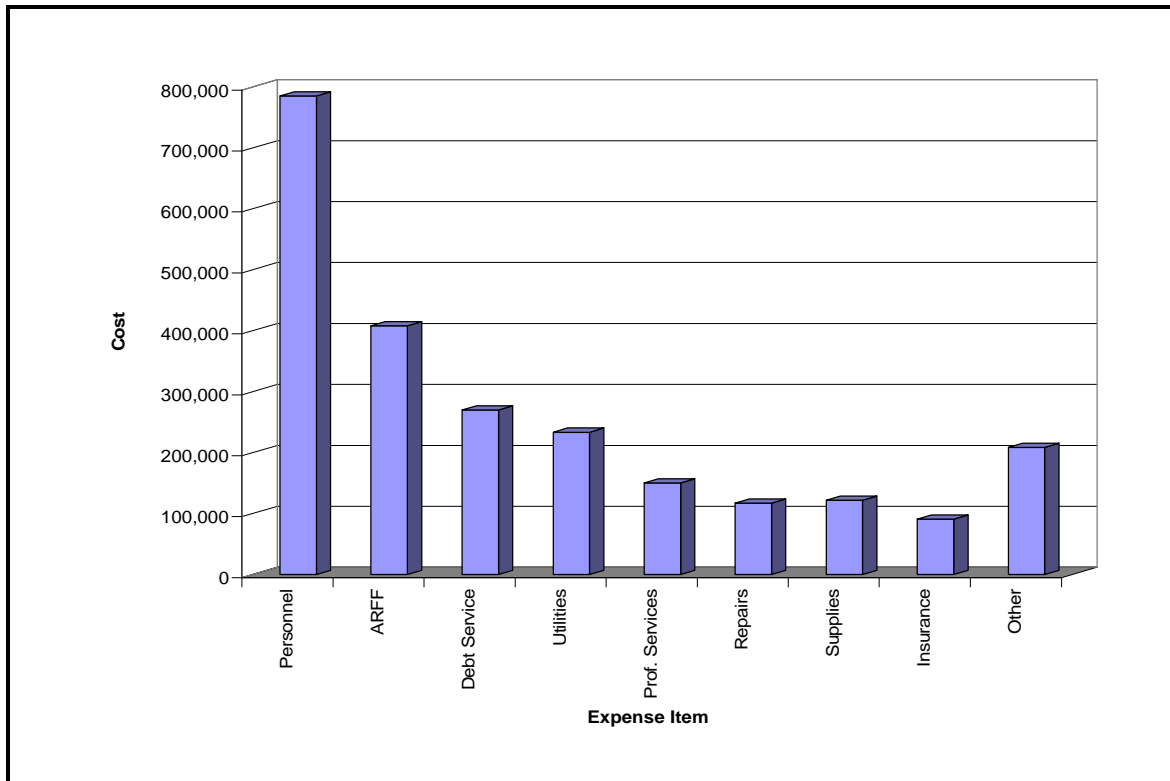
services to the airport for 2001. The total ARFF expenses for this year amounted to US\$408,028. The expenses for the airport are depicted in Table 5.21 and Figure 5.2, from which it can be seen that after personnel, ARFF costs represent the highest expenses incurred, accounting for some 17% of the total operating costs. The distribution of the various operating costs as a percentage of total costs is shown in Figure 5.3.

Table 5.21: Operating Expenses for Rapid City Regional Airport: 2001 - 2002

Operating Expense	2001 Expense (US\$)	% of Total Expense	2002 Expense (US\$)	% of Total Expense
Personnel	\$785,446	33	\$828,979	32
ARFF	\$408,028	17	\$479,368	19
Debt Service	\$270,151	11	\$201,652	8
Utilities	\$233,456	10	\$208,833	8
Professional Services	\$150,459	6	\$395,700	15
Repairs	\$117,139	5	\$95,011	4
Supplies	\$121,949	5	\$113,609	4
Insurance	\$90,817	4	\$95,767	4
Other	\$208,501	9	\$158,030	6

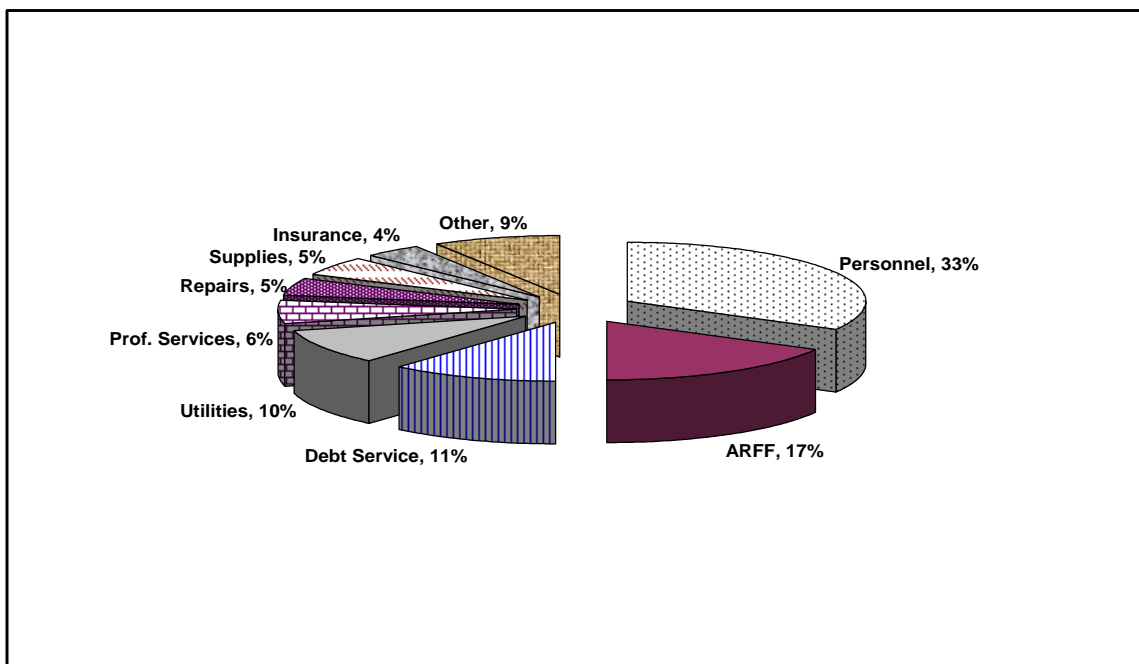
Source: Rapid City Regional Airport

Figure 5.2: Rapid City Regional Airport Operating Expenses – 2001



Source: Rapid City Regional Airport

Figure 5.3: Operating Expense as a Percent of Total Expense - 2001

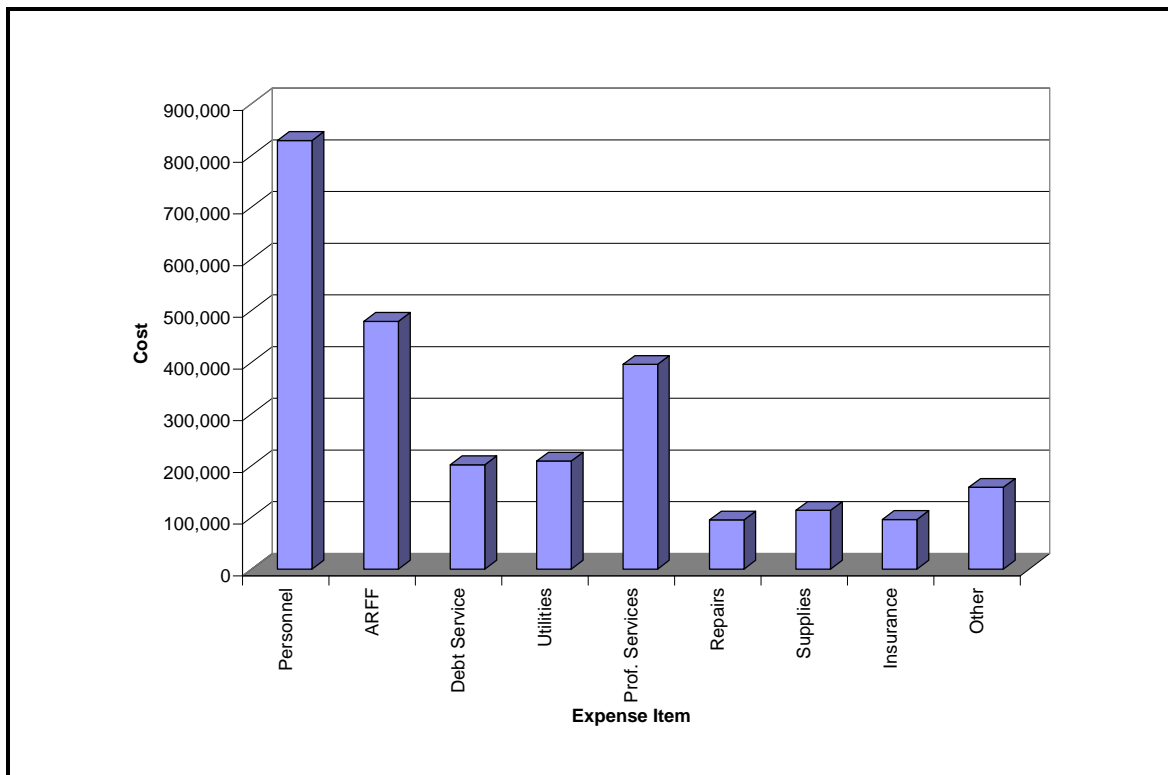


Source: Rapid City Regional Airport

In 2002, ARFF expenses increased from US\$408,028 to US\$479,368 or by 17%. ARFF expenses as a percentage of total expenses also increased, from 17% to 19%. Note that in the Sypher:Mueller report, it was anticipated that for most AEIS affected airports in Canada, ARFF services would account for between 5% and 20% of total annual recurrent costs.

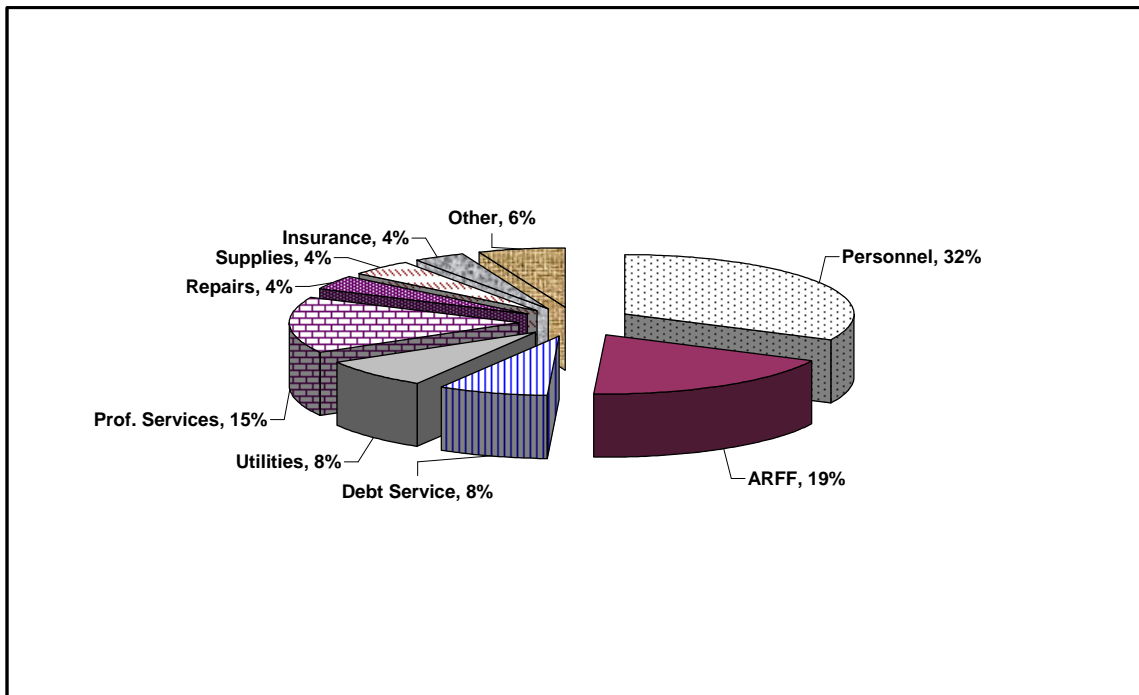
When ARFF costs are compared to passenger traffic, Rapid City Airport would have incurred expenses of approximately US\$1.04 per passenger in 2001 and US\$1.10 per passenger in 2002. Expenses for 2002 are shown in Figure 5.4 and Figure 5.5.

Figure 5.4: Rapid City Regional Airport Operating Expenses – 2002



Source: Rapid City Regional Airport

Figure 5.5: Operating Expense as a Percent of Total Expense - 2002



Source: Rapid City Regional Airport

5.3.2 Australia

Financial details on ARFF services in Australia could not be obtained. However, the research conducted revealed that Airservices Australia, which has responsibility for the provision of ARFF services at 16 locations in Australia, is in the process of increasing the costs associated with these services. Before 1998, charges for ARFF services were on a network basis. However, location specific pricing was introduced and this saw the increase of charges at 13 locations. Interestingly, the three airports with the highest activity, Sydney, Melbourne and Brisbane, saw decreases in their charges. In 2001/2002, the average price for the ARFF services was AUS\$1.63. In 2002/2003, Airservices Australia proposed that the average price should rise to AUS\$1.76, representing an increase of 8.1%. The proposal was submitted to the Australian Competition Consumer Commission who ruled that it did not object to the proposed increases in ARFF fees given that the increases more adequately reflected the costs associated with the provision of the services. Table 5.22 shows how the airports under Airservices Australia would be affected in terms of price (quoted in AUS\$).

Table 5.22: Change in Price for ARFF Services at Selected Airports in Australia

Airport	2001 Passenger Traffic	2001/2002 Price/tonne*	2002 Passenger Traffic	2002/2003 Price/tonne*
Sydney	25,813,958	\$0.64	23,150,121	\$0.69
Melbourne	16,881,010	\$1.02	15,967,430	\$1.09
Brisbane	12,466,593	\$1.38	11,773,681	\$1.46
Perth	5,162,315	\$2.19	4,766,468	\$2.40
Adelaide	4,442,638	\$2.57	4,766,468	\$2.69
Cairns	2,890,752	\$3.54	2,642,498	\$3.83
Canberra	2,107,219	\$3.26	1,841,302	\$3.58
Coolangatta	1,888,008	\$4.10	1,736,004	\$4.24
Darwin	1,077,888	\$6.58	962,589	\$7.23
Hobart	973,922	\$7.75	957,611	\$8.46
Alice Springs	715,632	\$6.20	561,509	\$6.81
Launceston	522,100	\$8.56	533,645	\$9.30
Rockhampton	286,817	\$8.73	217,539	\$9.59
MacKay	282,651	\$9.27	296,132	\$9.98
Karratha	169,916	\$12.02	144,885	\$13.21
Port Hedland	83,433	\$17.14	69,681	\$18.84

Compiled by Author from ATI, Airservices Australia

**Indicates price per landed tonne*

From Table 5.22, it can be seen that there is a general increase in unit charges for ARFF services as passenger traffic decreases (except in the cases of Hobart and Alice Springs). Accordingly, unit costs for an airport such as Port Hedland can be as much as 96% higher than an airport such as Sydney. Unfortunately, the author could not access information relating to, inter alia, the landed weight and other financial and statistical data at the airports mentioned above hence, a more in depth analysis could not be made.

5.3.3 United Kingdom (Scotland)

Expenses relating to the provision of ARFF services at HIAL are shown in Table 5.23. These costs are for the ten airports operated by this company. Additional information regarding other costs for HIAL may be found in section 5.3.4.

Table 5.23: ARFF Expenses for HIAL – 2001/2002 and 2002/2003

Expense	2001/2002	2002/2003
ARFF Supplies	£203,000	£213,000
Uniforms for ARFF personnel	£111,000	£105,000
Training of ARFF Personnel	£204,000	£183,000
Salaries/Wages	£5,000,000	£6,000,000
Insurance	£364,000	£586,000
Total	£5,882,000.00	£7,087,000.00

The above table shows that salaries for ARFF personnel account for the most significant ARFF expense item for this company. During the financial year 2001/2002, the total ARFF related salaries was £5,000,000 for the ten airports, which averages at £50,000 per airport. During the financial year 2002/2003, salaries increased by 20% to £6,000,000, averaging at £60,000 per airport. Note however that due to the various categories of aerodromes represented in HIAL, these costs will be significantly higher at some airports than at others.

It was not possible to isolate the cost of insurance based on the level of rescue and fire coverage provided at the various airports. However, this item accounted for the second highest expense item in Table 5.23. In the financial year 2001/2002, insurance stood at £364,000 for the ten airports and rose by over 60% to £586,000 in 2002/2003. ARFF supplies, which includes consumables and foam, also increased, from £203,000 to £213,000. Conversely, training and uniforms for ARFF personnel decreased by 10% and 5% respectively.

Certain costs associated with the provision of ARFF services appear higher for Scotland than they are for Canada. Unfortunately, the categorisation of costs for the airports in Canada and those comprising HIAL are not standardised, hence, adequate comparisons are not possible. Nevertheless Table 5.24 provides some insight into the costs for selected items in these two countries. For comparison purposes, the US dollar was used and the currencies were converted using rates of CAN\$1 to US\$0.737898 and GBP£1 to US\$1.6642. In cases where a range was provided for the cost, the upper limit was used

and in the case of Scotland, expenses for the financial year 2002/2003 were used. The costs have been rounded off to the nearest whole number.

Table 5.24: Cost Comparison Canada versus Scotland

Item	Cost for Canada (US\$)	Cost for Scotland (US\$)
Vehicles	\$258,264	\$1,040,125
Salaries	\$208,087 ¹	\$998,520
Initial Training ²	\$7379	\$18,306

Compiled by Author from Highlands and Islands Airports Limited, Sypher:Mueller International Inc.

¹ *Additional salary for AEIS affected airports and not total ARFF salaries used here hence this cost could be much higher.*

² *Training of an unskilled person. For Scotland this was estimated at £11,000*

5.3.4 Other Cost Considerations

It was noted in Chapter 2 that accident and incident statistics rarely provide information on the success of ARFF personnel in preventing major catastrophes. Accordingly, the true benefits of ARFF services are not counted in a real sense. This brings us to a number of other cost considerations that should be taken into account when addressing the issue of the benefits associated rescue and fire coverage at airports. These other costs will be discussed in the following sections.

(i) Capital Intensive Nature of Airports

Airports are capital intensive projects and costs can therefore range from thousands to millions for the requisite infrastructure. Capital expenditure for AEIS airports was estimated at CAN\$295,200. This was the cost only for meeting the requirements of the AEIS and did not take into account total capital costs for the airports. Capital expenditure for HIAL for the financial year 2001/2002 amounted to just over £9.5 million. This expenditure, which is outlined in Table 5.25, represents investments in new fixed assets alone. Expenditure on major items is included in the Table 5.26. In The total tangible fixed assets for HIAL stood at £28,689,000 at the end of the financial year 2001/2002. This is a considerable value that has to be considered when looking at the protection of property. To some extent, the services of ARFF will help to sustain these assets.

Table 5.25: Capital Expenditure for HIAL – 2001/2002

Airport	Capital Expenditure (£)
Barra	£36,000
Benbecula	£2,066,000
Campbeltown	£26,000
Inverness	£195,000
Islay	£359,000
Kirkwall	£2,551,000
Stornoway	£3,479,000
Samburgh	£380,000
Tiree	£304,000
Wick	£139,000
Total	£9,535,000.00

Source: Highlands and Islands Airports Limited

Table 5.26: Major Items of Capital Expenditure for HIAL – 2001/2002

Airports	Capital Works	Expenditure (£)
Kirkwall	Construction of new terminal buildings and car park	£2,169,000
Stornoway	Construction of new terminal buildings and car park	£2,523,000
Benbecula	Resurfacing of runway	£1,953,000
Benbecula, Islay, Samburgh, Tiree	Installation of new fire training grounds	£577,000
Campbeltown, Islay, Kirkwall, Stornoway, Tiree, Wick	Other training facilities	£219,000
Inverness, Kirkwall, Stornoway	Automated meteorological systems	£232,000
Benbecula, Kirkwall, Stornoway, Wick	VHF Direction Finders	£97,000
Inverness	Extension of head office	£63,000

Source: Highlands and Islands Airports Limited

(ii) Economic Impact of Airports

Another area that needs to be addressed in assessing the costs versus the benefits of the provision of ARFF services at airports is the economic contribution that airports make to the community or communities which they serve. The following section outlines the economic contribution of airports using the UK, USA and Canada as examples.

(a) United Kingdom

In addition to contributing £500 million to the balance of payments in the UK, aviation provides some 85,000 jobs directly and generates three times that amount in indirect jobs. Table 5.27 provides a breakdown of the level of direct employment associated with airports in the UK.

Table 5.27: Breakdown of Direct Employment at UK Airports

Source of Employment	Percent Employed
Airport Operator	11%
Airlines/Handling Agents	60%
Freight/Cargo	4%
Concessions	9%
Control Agencies	7%
Other (Hotels, etc.)	12%

Source: Airport Economics and Finance: Economic Impact of Airports – Economic Contribution Lecture Notes

The above table provides general information employment. It should therefore be borne in mind that airports will differ according to a number of factors including size of the airport and passenger traffic. For low density airports for instance, employment may be generated at a rate of 350 to 750 jobs per million passengers. In Table 5.28, the staff complement for each airport operated by HIAL is given. Note that these figures are for those directly employed by HIAL only.

Table 5.28: Employment Statistics for the Airport Operator HIAL (2001/2002)

Airport	Passenger Traffic	Staff Complement
Inverness	376,378	47
Barra	8,425	10
Campbeltown	9,017	11
Islay	20,357	13
Tiree	5,450	10
Stornoway	7,977	28
Benbecula	4,087	20
Wick	30,535	29
Kirkwall	97,279	27
Total	559,505	195

Source: Highlands and Islands Airports Limited

(b) USA

According to the Airports Council International (ACI), there are over 19,300 airports in the United States of which, 28% are public facilities. The airports in the USA generate US\$507 billion in economic activity and US\$33.5 billion in local, state and federal taxes annually. Approximately 1.9 million jobs are created directly as a result of the aviation industry with a further 4.8 million being created indirectly in local communities. Together these jobs account for US\$ 190 billion in earnings.

(c) Canada

The ACI estimates that airports in Canada generate CDN\$34.1 billion per year in economic activity of which, CDN\$18 billion may be attributed to indirect and induced impacts. A further CDN\$3.9 billion is generated in tax benefits. Approximately 143,000 jobs are created directly by the existence of airports and an additional 161,000 jobs are created indirectly in the local communities. The economic contribution of a number of the smaller airports is shown in Table 5.29.

Table 5.29: Economic Contribution of Selected Smaller Airports in Canada - 2000

Airport	Passenger Traffic	Earnings (CND\$)	Total Employment
Abbotsford Airport	240,000	\$206,000,000	1,385
Charlottetown Airport	166,849	\$67,900,000	385
Hamilton International Airport	243,205	\$58,000,000	1,650

Source: Airports Council International

As was mentioned previously, airports are a source of direct employment for many people. This is largely due to the airport's contribution to the generation of additional economic activity within the airport hinterland, though the impact of such activity may be greater at airports located in major cities. Examples of economic activity generated by airports include the following:

- Leisure, retail and duty free and information services industries;
- Freight companies;
- Manufacturing companies; and

- Multinational corporations.

Airports also tend to be a part of an integrated system of transportation. To this end, there are spill off effects in the construction industry in the building of road networks and rail systems for airport access. In addition, the economic activity generated results in the movement of people towards the vicinity of the airport and hence the establishment of residential areas. As this will increase the demand for housing, the impact on the construction industry is even greater. The fore-going demonstrates how vital an asset airports are to the aviation industry.

As previous studies have shown, traffic levels decrease with air transport related accidents, albeit only for a time. Whilst it is recognised that airlines appear to be affected to a greater extent than airports as a result of aircraft accidents, it must also be recognised that airports too will be affected to some degree by reductions in traffic. Any significant deterioration in the accident rates as discussed in Chapter 2 could therefore have serious implications for the industry's recovery record. In light of these issues, the following chapter will examine whether the costs reviewed here can be justified in view of the benefits to be derived from ARFF standards and services.

Chapter 6: Conclusion and Recommendations

6.1 ATTAINMENT OF RESEARCH OBJECTIVES

The research objectives of this thesis were as follows:

- To examine the safety environment within which the commercial air transport industry operates;
- To critically examine the ICAO recommendations as well as the national regulations pertaining to the provision of ARFF services in Australia, Canada, the UK (Scotland) and the USA;
- To assess the cost implications associated with rescue and fire coverage at airports with annual passenger traffic between 50,000 and 500,000 in the aforementioned countries; and
- To determine whether the costs associated with meeting current ARFF standards can be justified in light of the reduction in risks to passengers and/or other anticipated benefits.

The first two objectives were accomplished. Chapter 2, and to some extent Chapter 3, examined the risks involved in commercial air transport vis-à-vis other modes of transport as well as in general. Chapter 2 also reviewed statistics related to fatal accidents world-wide and according to region. It was demonstrated that North America, in particular the USA, had the lowest fatal accident rate, followed by Europe, Australasia, South Central America and Africa. In addition, this chapter provided insight into events leading up to aircraft accidents and survivability issues were examined.

Chapter 4 provided detailed information relating to Chapter 9 of Annex 14, the SARP's for ARFF services. The way in which ICAO approached the development of certain standards, specifically those pertaining to aerodrome categories and extinguishing

agents was discussed. It was conveyed that the amounts of extinguishing agents recommended by the ICAO was not adequate in a number of cases and examples of accidents where the amount of extinguishing agents used surpassed that recommended in Annex 14 were given to demonstrate this point. The national regulations for Australia, Canada, the USA and the UK were also examined. In Australia, Canada and the USA, concern was raised that there were still far too many passengers that were not being afforded rescue and fire coverage, even though Canada recently upgraded their regulations so that more airports would be required to provide ARFF services. The response times for Canada and the USA also presented causes for concern. In the case of Canada, AEIS airports were required to respond within five minutes as opposed to three minutes. In the USA, the second RIV was required to respond within four minutes as opposed to the one minute recommended by the ICAO.

The third objective was also accomplished to some extent as detailed costs were obtained for airports in Canada with passenger traffic of between 50,000 and 500,000 per annum. However, information was not as forthcoming with the other countries. Never-the-less, enough information was available to provide insight into the costs associated with meeting the requisite ARFF standards. Moreover, other cost considerations such as capital costs and the economic impact of airports on the communities which they serve were discussed at length.

Whilst it would have been ideal to compare similar ARFF costs at various airports in Australia, Canada, the UK and the USA, the data was not readily available to allow for this. Additionally, the fact that there is no universal standard when it comes to the collection and categorisation of these costs makes comparisons between airports and between airports in different countries even more difficult to accomplish.

Based on the fore-going information as well as the concepts outlined in Chapter 3, the following section will now address the main research question and that is whether the costs associated with meeting ARFF standards can be justified in view of the benefits to be derived.

6.2 KEY FINDINGS AND CONCLUSION

In determining whether the costs of meeting the standards associated with rescue and fire coverage at airports can be justified, it is important to ascertain the objectives of ARFF services. According to the ICAO, the main aim of ARFF services is to save lives, an objective which has been recognised in the national regulations of the countries examined in this thesis. However, as was discussed in Chapters 2 and 3, fatal aircraft accidents are an inevitable aspect of the industry. Consequently, the objective outlined above is not 100% attainable, as some lives will be lost in air transport accidents. This is not to say that intervention efforts such as rescue and fire coverage should be reduced. On the contrary, efforts should be made to save as many lives as possible. To accomplish this, the quality of ARFF services around the world must be of a high standard.

Having examined the SARP's in Chapter 9 of Annex 14, as well as a number of regulations in Australia, Canada, the USA and the UK, it may be concluded that there are instances where the standards need to be enhanced in order to accomplish the goal of saving as many lives as possible. Such areas include for example the quantities of extinguishing agents recommended by the ICAO and the response times stipulated in the regulations for Canada and the USA.

As was discussed in Chapter 4, the final recommendations relating to the amounts of extinguishing agents to be used by the various categories of aerodromes as outlined in Annex 14 was based on a study involving training fires and not actual crash fires. Hence, there is some concern over whether fire fighters would be adequately prepared to control and extinguish major aircraft fires so as to save as many lives as possible, given the amounts of extinguishing agents recommended. This concern has been realised to some extent in a number of accidents where the actual amount of the agent used exceeded that recommended by the ICAO by up to 11 times (see Table 4.3).

At the national level in the countries reviewed, response times and the level of fire coverage afforded by some airports presented some concern as well. In Canada, the CAR 308 stipulates that the response time for airports affected by these regulations is

five minutes. In the USA, the FAR 139, whilst complying with the three minute recommendation for the first RIV, require the second vehicle to be on the scene within four minutes of the first instead of one minute. Furthermore, both the CAR 308 and the FAR 139 require that the vehicles be able to reach the midpoint of the furthest runway and not each end of the furthest runway, or any part of the movement area, in the stipulated time. The afore-mentioned clauses in these regulations therefore serve to increase the real response time vis-à-vis the recommendations outlined by the ICAO and this in turn will increase the overall risks for passengers and crew.

It cannot be stressed enough the importance of speedy responses to aircraft accidents. A number of accidents were discussed to demonstrate this, including:

- The 1985 British Airtrours Boeing 737-200 accident at Manchester Airport;
- The 1967 British Midlands Argonaut crash at Stockport near Manchester; and
- The 1996 collision between the United Express Flight 5925 and the Beechcraft King Air A90 at Quincy Municipal Airport in Illinois.

In spite of the leniency with respect to the ARFF standards in the USA vis-à-vis the UK, the USA still has the best record when it comes to fatal accident rates world-wide (see section 2.2.3). This leads one to wonder whether it is prudent to reduce rescue and fire coverage in light of the costs associated with the provision of these services, and have efforts and financial resources redirected to perhaps other more pertinent safety measures. On the other hand, it may be argued that whilst the USA has the lowest fatal accident rate world-wide all things considered, there is still much room for improvement and this may only be accomplished through more stringent regulations. Whatever the case, one has to bear in mind that there may be several factors leading to the USA accomplishing this record, each having their own merit. Unfortunately, further insight into the USA's record achievement is beyond the scope of this thesis.

Having ascertained the objectives of ARFF services and having demonstrated that there is a need for a high level of standards, the cost of providing the services should then be examined. Whilst it has been recognised that the main objective of ARFF services is to

save lives, it must also be recognised that increasingly, airports are being pressured operate as commercial entities with emphasis on profitability. This creates the need for a balance between the objectives of ARFF services and those of the airport. The benefits to the industry should therefore justify the minimum costs associated with rescue and fire coverage at airports. The term minimum is used here because there may be instances where costs can be reduced as the airport could be spending too much money unnecessarily on achieving the requisite standards.

In Chapter 5, it was shown the annual costs associated with ARFF services for AEIS affected airports in Canada could be as high as CAN\$475,200 (US\$350,649¹⁵) per airport. Using the Transport Canada figure, initial capital expenditure per airport was estimated at CAN\$352,000 (US\$259,740). At Rapid City Regional Airport in the USA, annual operating expenses ranged from US\$408,028 in 2001 to US\$479,368 in 2002. This accounted for 17% of Rapid City's total operating expenses in 2001 and 19% in 2002. ARFF expenses for HIAL during the financial year 2002/2003 averaged at £708,700 per airport, up from £588,200 during the previous year. Capital expenditure for this company during the financial year 2001/2002 was £9,535,000 (US\$15,868,147¹⁶) and rose to £9,227,000 in 2002/2003 (US\$15,355,573).

As O'Sullivan notes, it would be unrealistic to base the level of rescue and fire coverage at airports on the value of the passengers who arrive and depart. One also has to accept that it would not be possible to save the lives of all persons involved in catastrophic aircraft accidents occurring at or near the vicinity of an airport. However, as the aim of ARFF services is to save lives, then the value of a human life, with its inherent difficulties and ethical issues, must somehow come into play. Unfortunately, there is no universally acceptable formula to determine what proportion of passengers should be used to arrive at a value for comparing the lives of passengers passing through an airport with the costs of providing ARFF services. The survivability rates could be used to determine what percentage of passengers is likely to survive aircraft accidents and this rate could in turn be used to arrive at the requisite value. However, this approach

¹⁵ Rounded to the nearest whole number

¹⁶ Rounded to the nearest whole number

will present a number of difficulties, particularly in light of the fact that the evidence suggests that the survival rates should and could be higher than they are currently.

None-the-less, when the costs associated with meeting ARFF standards outlined above are compared to the value of a life as used by the DETR in their road accident scheme (that value in 1992 stood at £660,000 (US\$1,098,732)), they are less than the latter value except in the case of Scotland. It can therefore be argued that it is less expensive for an airport in Canada and the USA to provide rescue and fire coverage that meet international and national standards, than it is for society to loose the life of a single human being. In addition, the costs for these two countries are also less than the VPF of £1,000,000 (US\$1,664,200) as assigned by the HSE. This provides further support to the argument that the benefits justify the costs in these two countries.

Whilst it is noted that the Author is being extremely conservative in just focussing on the value of the life of one person, it would appear that the benefits of meeting the ARFF standards here did not justify the costs during the financial year 2002/2003. However, one has to remember that the value of a life used here was based on the 1992 figure as a more up-to-date figure could not be accessed. Consequently, it is logical to assume that the value of a life in this Century would have increased significantly over this 1992 figure. Furthermore, air transport is a global industry and therefore requires a global approach to enhancing safety. Accordingly, it would not be feasible to have varying standards that are dependent on the costs of meeting those standards in different parts of the world. Thus, the argument that the costs associated with meeting the requisite ARFF standards can be justified by the benefits derived from those standards still holds.

Note: The danger that arises from the above is that the costs of ARFF services at airports are likely to increase annually. Hence one may find that that the principle of comparing costs to the value of a life may give different results from one year to the next, even though the circumstances surrounding the level of standards required for optimum safety levels have not.

Although statistics could not be obtained to demonstrate the role that ARFF personnel play in curtailing potentially disastrous situations, this should in no way diminish the significance of rescue and fire coverage in the protection of plant and property. As was discussed in Chapter 5, airports are capital intensive facilities with costs ranging from thousands to millions of dollars. In the case of HIAL, capital expenditure for the financial year 2001/2002 was over £9,500,000 (US\$15,868,147). At the end of this same financial year, total tangible fixed assets stood at £28,689,000 (US\$47,681,494). In 2002/2003, capital expenditure stood at £9,227,000 (US\$15,355,573) and total fixed was just over £34 billion (US\$57 billion). Thus, when the issue of capital costs and fixed assets for airports are taken into consideration, it can be argued that it is much less expensive for an airport to offer ARFF services at the required standards than it is for that airport to lose its assets to a fire.

Other factors also have to be taken into consideration. So far, only the annual ARFF costs have been considered. One may therefore have concerns that in the long run, these costs add up and when compared to the probability of an accident occurring at a particular airport over an extended period, then the costs cannot be justified. Accident statistics show that the probability of a major event occurring is extremely low. According to Planecrashinfo.com for instance, the chances of being killed in an aircraft accident ranges from 1 in 400,000 for an international jet in the developing world to 1 in 8 million for an advanced world domestic jet (see Appendix F).

Unfortunately, these statistics are not infallible and moreover, they do not indicate at which airport an accident will take place or when it will take place. Furthermore, in applying the precautionary principle, we know that although the probability of harm occurring appears to be extremely low, there is enough evidence available to prove that serious harm can result from air transport accidents. The facts are that accidents will take place and whilst lives and property will be lost, measures can be implemented to reduce that loss. One of the advantages of having past events to study is that they demonstrate what went wrong and how it can be avoided in the future. The lessons learnt can therefore lead to improved ARFF standards and services thereby placing airports in a better stead to reduce the severity of accidents. Thus, in the absence of

more detailed information to suggest otherwise, this thesis will conclude that the benefits of ARFF services justify the costs of providing those services.

6.3 RECOMMENDATIONS

6.3.1 Risk Assessment Based Approach

Undoubtedly, the research conducted in this thesis shows that there is a need for a high level of standards, particularly with respect to response times, extinguishing agents, equipment and ARFF personnel. On the other hand, one still has to be cognisant that each airport is unique and may therefore have different needs. The regulations both at the international and national levels should take account of this factor by emphasising more of a risk assessment based approach to the provision of ARFF standards. This would involve adopting a framework similar to that of the nuclear industry where, in the UK for example, a risk assessment of the hazards posed by the facility is conducted and submitted to a monitoring entity, in this case, the HSE. The assessment is then critically reviewed and analysed by the monitoring entity, which, based on the findings, may mandate that certain other precautions be taken. It is important that the fore-going function is carried out by an entity that does not have a regulatory function so as to avoid any conflict of interest. However, this could lead to an increase in costs, duplication of effort or further fragmentation of industry, depending on the special circumstances of the country. To either avoid or reduce the chances of this happening, the possibility of associating the monitoring function with an existing agency performing like functions should be explored.

Whilst in the afore-mentioned approach it is recognised that it is not always possible to ensure that all circumstances are taken into account, importance is none-the-less placed on the types of reinforcements or back-ups that are needed to reduce the severity of aircraft accidents taking place in the vicinity of an airport. Furthermore, the airport is seen as a whole, with all the departments integrated. All aspects of the facility, including the management systems and operational procedures are therefore considered in conducting the risk assessment.

The risk assessment based approach also allows for greater use of a prescriptive and non-prescriptive regulatory regime similar to the one adopted by Australia. Airports therefore benefit from the advantages of flexibility allowed under the non-prescriptive regime, whilst at the same time ensuring that passengers are afforded a high level and rescue and fire coverage as dictated by the prescriptive guidelines.

6.3.2 Costs

At this stage, it is impossible to ascertain the overall cost implications of the risk based approach for airports. As was seen in Chapter 5, ARFF costs account for a significant portion of an airport's cost. For Canada, these costs averaged between 5% and 20% of total operating expenses. For Rapid City Airport, they ranged from 17% to 19% over a two year period. In the case of Australia, the unit costs for ARFF services provided by Airservices Australia generally increased as passenger traffic decreased. In the latter case, airports that were least likely to be able to afford it were paying higher unit costs for ARFF services than airports that were more likely to be able to afford it. Due to the fees charged by Airservices Australia, the probability that airports not required to provide ARFF services will opt not to do so in the interest of costs, is likely to increase. This could therefore lead to further reductions in coverage and hence increased risk for passengers in Australia. Thus, rather than placing emphasis on reducing standards, the focus should be on finding ways to reduce costs.

(i) Financial and Technical Assistance

As was mentioned previously, there is a trend towards some degree of privatisation of airports. However, most airports around the world still have some form of government ownership. This, together with the significant role that airports play in the economies of the communities which they serve, is justification for the relevant government entities to seek ways of providing some level of financial and technical assistance to their airports, particularly the smaller ones. This may be accomplished through programmes similar to, for example, the PFC and AIP in the US and the ACAP in Canada. Governments can also assist airports by supporting research and development programmes aimed at devising low cost equipment that can still allow small airports to meet national and international standards.

(ii) Cost Reduction Methods

Airports too must play a role in ensuring that costs are kept to a minimum without having to compromise safety. As was pointed out in the case of Canada, certain cost reduction measures may work well with one airport but not another. Airports must therefore be vigilant and resourceful in determining what is suitable for them. Possible cost reduction measures may entail the formation of partnerships with other safety and security agencies which emphasise costs and tasks sharing. Specific areas where partnerships may be useful include the following:

- Recruitment;
- Training facilities as well as certain basic level training that may be required by all rescue and fire personnel; and
- Bulk purchasing, for example of equipment, materials and uniforms where possible.

In addition, the possibility of doubling with the local fire service should still be explored. One may find for instance that given the more stringent response times for ARFF as compared to regular RFF for the rest of the community, a solution may be to have the fire service for the community and the airport stationed at the airport. With this option, it would be essential to ensure that materials, equipment and staffing levels are adequate to attend emergencies both on and off the airport throughout the hours of operation of the airport.

(iii) Environmental Management Programmes

As was mentioned previously, an airport may not be prudent in its expenditure policies and practices. This could result in significant wastage and hence increased costs. Full environmental audits may point to areas where the airport could reduce costs by stemming wastage. Environmental programmes such as those offered by Green Globe, United States Agency for International Development (USAID), United Nations Environment Programme (UNEP), the Organisation of American States (OAS) and Caribbean Action for Sustainable Tourism (CAST) have all helped various sectors of the travel and tourism industry to realise cost savings in a variety of areas without

having to compromise the safety of travellers. It would therefore be worthwhile for programmes such as these to be targeted at small airports with a view to reducing costs without compromising safety related standards.

6.3.3 Multi-tasking

With this option, personnel other than ARFF personnel are trained to meet the standards outlined in the regulations. At Barra Airport in Scotland for example, all staff are essentially ARFF personnel. If multi-tasking is employed, ARFF personnel may also be cross trained to perform other airport related functions. This allows for optimum utilisation of employees as, depending on the degree of cross training, staff may be rotated periodically so that certain members are not over worked whilst others have very little to do. Moreover during periods of staff shortages in certain departments, other staff members may be available to fill the void. However, it is recognised that union agreements and labour laws may prevent some airports from pursuing this option.

6.3.4 Stakeholder Participation

In reviewing the regulations at the national level in Australia, Canada, the UK and the USA, it became apparent that in many cases, regulations are set and then airports are left to comply. Whilst there are instances where the regulators solicit input from airports, this generally occurs after a determination has been made on the clauses for the regulations. In order to gain as much support as possible for the regulatory framework under which they operate, it is important that airports are consulted and allowed to actively participate in the decision making process. Accordingly, the onus is on the regulators to establish the mechanism whereby the interests of all stakeholders are taken into consideration when developing regulations.

6.4 SUGGESTIONS FOR FURTHER RESEARCH

This section provides a number of suggestions where further research can be conducted in the area of aviation safety, particularly with respect to airports.

- A comparative analysis of the national ARFF standards and practices in the developed world vis-à-vis the developing world (taking into consideration fatal

accident rates and fatality rates) and measures that would be needed to improve safety in the developing world. Barriers to improving safety in the developing world and how can these be overcome should therefore be considered.

- Examination of the main primary and secondary safety measures in developed countries and their effectiveness at enhancing safety.
- An investigation into the impact of primary and secondary safety measures on the profitability of airports and airlines.
- An examination of aviation safety initiatives in the USA and factors leading to this country attaining one of the lowest fatal aircraft accident rates world-wide.
- An investigation into whether Green Globe and other environmental certification programmes can help small airports realise cost savings and enhanced profitability without compromising safety.
- An investigation into the constraints associated with small airports meeting ICAO and/or national standards and how can these constraints be reduced or removed.
- Formulation of an appropriate modus operandi for determining the value of the benefits of ARFF services (and other secondary measures) and how the method developed should be applied in CBA's for Airports.

6.5 For Further Reading

- Asia-Pacific CSWG, *Response from the Asia-Pacific Cabin Safety Working Group to the Review of "Airport Fire Fighting Services in Australia" by Russell V. Smith for the Civil Aviation Authority*. Asia-Pacific Cabin Safety Working Group, December 1998
- Lee, P., *The Price of Saving Passenger Lives with Reference to Asia Pacific and Latin America*. MSc. Thesis, Cranfield University, 2000

- Muir, Prof. H., “Airplane of the 21st Century: Challenges in Safety and Survivability”. In *Proceedings from the International Conference on Aviation Safety and Security in the 21st Century*, George Washington University, January 12-15, 1997, http://www.gwu.edu/~cms/aviation/track_i/muir.htm
- Ross, J., “Barra Beach must Match Heathrow”. *The Scotsman*, June 6, 2003, <http://www.thescotsman.co.uk/business.cfm?id=627072003>
- Yueh-Ling H., *An Analysis of the Impact of Accidents on Airline Performance*.

References

ACI, *The Economic Impact of Canadian Airports 2002*. Airports Council International, Washington, 2002, http://www.aci-na.org/docs/canada_impact.pdf

ACI, *The Economic Impact of US Airports 2002*. Airports Council International, Washington, 2002, http://www.aci-na.org/docs/US_Econ_Impact.pdf

Airservices Australia, *Detailed Supporting Information to Airservices Australia's 2002/2003 Pricing Proposal to the Australian Competition and Consumer Commission*. Airservices Australia, July 2002, http://www.accc.gov.au/airport/air_services/deta_supp_info.pdf

Airservices Australia, *Draft Notification of Change in Prices*. July 2002, pp 3 http://www.accc.gov.au/airport/air_services/draf_noti_a.PDF

Ashford, N., Stanton, H. P., Moore, C. A., *Airport Operations*. New York, Chichester: Wiley, 1984

Aviation Safety Network, *Airliner Accident Statistics by Region*. 2002, <http://www.aviation-safety.net/statistics/byregion.html>

Aviation Safety Network, *ASN Aviation Safety Database*. 2003, <http://aviation-safety.net/database/index.html>

AVSTATS, *Air Transport Statistics Regular Public Transport Services Airport Traffic Data 1991/92 – 2001/2002*. AVSTATS, Department of Transport and Regional Services, Canberra, August 2003, <http://www.btre.gov.au/avstats/docs/2001-02airports.pdf>

Blackshaw, C. J., "Introduction: The Nature of Aviation Law and Regulation". *Introduction to Air Transport Lecture Notes*, Cranfield Universtiy, March 2001

Boeing, *Statistical Summary of Commercial Jet Airplane Accidents World Wide Operations 1959 – 2002*. Airplane Safety, Boeing Commercial Airplane, Washington, 2002

Braithwaite, Dr. G., *Aviation Rescue and Fire Fighting in Australia – Is it Protecting the Customer?* Journal of Air Transport Management, Vol. 7 Issue 2, March 2001, pp 111 - 118

CAA, *Aviation Safety Review*. CAP 673, Safety Regulation Group, Civil Aviation Authority, London, May 1997

CAA, *Licensing of Aerodromes*. CAP 168, Civil Aviation Authority, London, 2001

CAA, *Global Fatal Accident Review 1980-1996*. CAP 681, Safety Regulation Group, Civil Aviation Authority, London, 1998

CAAPS, *Surviving the Crash – The need to Improve Life Saving Measures at our Nations Airports*. Coalition for Airport and Airplane Passenger Safety, Washington, 1999

CASA, *Regulatory Standards for Aerodrome Rescue and Fire Fighting Service: Civil Aviation Safety Regulations (CASR) - Part 139, Subpart H and Manual of Operating Standards Sections 1 to 30*. Civil Aviation Safety Authority, Australia, 2000

Cooke, R. I., *Airport Rescue and Fire Fighting Services: Should the Standards be Raised and if so How?* MSc. Thesis, Cranfield University, September 1999

Department of Industry and Trade, *Fire and Rescue Operations at Heathrow Airport: Report of the Working Party*. CAP 356, HMSO, London, 1971

ETSC, *Increasing the Survival Rate in Aircraft Accidents: Impact Protection, Fire Survivability and Evacuation*. European Transport Safety Council, Brussels, 1996

Eurocontrol, *Safety Regulation Commission Document: Aircraft Accidents/Incidents and ATM Contribution – Review and Analysis of Historical Data*. Third Edition, European Organisation for the Safety of Air Navigation, Belgium, December 2002

FAA, *Federal Aviation Regulations Part 139: Certification and operations: Land airports serving certain air carriers*. Federal Aviation Administration, Washington, 2002, <http://www.risingup.com/fars/info/139-index.shtml>

Fewings, R., *Infrastructure and the Environment: Safety in Air Transport*. Lecture Notes, Cranfield University, 2002

Fischhoff B., Slovic P., Lichtenstein S., et al, “How Safe is Safe Enough? A Psychometric Study of Attitudes Towards Technological Risks and Benefits”. *Policy Sciences*, 1978, 9, 127-152

Hewes, V., “Updating Airport Emergency Capabilities”. *Flight Safety Foundation Airport Operations*, Vol. 17 No. 5, September/October 1991, pp 1-6

Highlands and Islands Airport Limited Annual Report 2001/2002, <http://www.hial.co.uk/annual-report.html>

HSE, *Principles and Guidelines to Assist HSE in its Judgements that Duty-holders have to Reduce Risk as Low as Reasonably Practical*. Health and Safety Executive, 1992

HSE, *Reducing Risks Protecting People: HSE’s Decision Making Process*. Health and Safety Executive, HMSO, London 1992

HSE, *The Tolerability of Risk from Nuclear Power Stations*. Revised Edition, Health and Safety Executive, HMSO, London, 1992 pp 12-15 and 48-53

IAFF, *Air Passenger Safety: The Need to Implement Effective Aircraft Rescue and Fire Fighting Standards in Canada*. IAFF, 1998

ICAO, *Emergency and Other Services*. Annex 14 to the Convention on International Civil Aviation, 3rd Edition, International Civil Aviation Organisation, Montreal, 1999

ICAO, *Airport Services Manual, Part 1 Rescue and Fire Fighting*. 3rd Edition, International Civil Aviation Organisation, Montreal, 1990.

ICAO, *Aircraft Accident and Incident Investigation*. Annex 13 to the Convention on International Civil Aviation, Doc9713, International Civil Aviation Organisation, Montreal 1994

ICAO, *Scheduled Passenger Traffic Forecasts 2003 – 2005*. International Civil Aviation Organisation, Montreal, 2001

JAA, *Membership: ECAC, EU, JAA EFTA and Eurocontrol*. January 2003, <http://www.jaa.nl/whatisthejaa/diagram2.pdf>

Macey, Dr. P., *Probabilistic Risk Assessment Modelling of Passenger Aircraft Fire Safety*. Ph.D. Thesis, Cranfield University, April 1997

O’Sullivan, J. J., “Future of Airport Rescue Fire Fighting Services”. *Journal of Aviation Management*, 2001, pp 88-109

Pagliari, Dr. R., *Airport Economics and Finance: Economic Impact of Airports – Economic Contribution*. Lecture Notes, Cranfield University, 2003

PlaneCrashInfo.com. *Accident Statistics*. 2002, <http://www.planecrashinfo.com/cause.htm>

Rapid City Regional Airport Annual Reports 2001 – 2002, <http://www.rcgov.org/Airport/Annual%20Report/reportlinkpage.html>

Sypher:Mueller, *Aircraft Emergency Intervention at Airports – CAR 308 – Survey of Affected Airports*. Sypher:Mueller International Inc., Ontario, 2003

Transport Canada, *Aircraft Emergency Intervention Service (AEIS) Cost Estimates*. Transport Canada, Ottawa, 2003, <http://www.tc.gc.ca/civilaviation/Regserv/Affairs/carac/Technical/AA/DR/AppFmay99.htm>

Transport Canada, *Aircraft Rescue and Fire Fighting at Airports and Aerodromes: Canadian Aviation Regulations (CAR 303)*. Transport Canada, Ottawa, 2003, <http://www.tc.gc.ca/mediaroom/backgrounders/b02-A061b.htm>

Transport Canada, *Canadian Aviation Regulations Part III – Aerodromes and Airports: Subpart 8 – Aircraft Emergency Intervention at Airports*. Transport Canada, Ottawa, 2003, http://www.tc.gc.ca/aviation/regserv/carac/CARS/html_e/doc/nav308e.htm

Transport Canada, *New Regulations for Aircraft Emergency Intervention Services at Medium Sized Airports*. Transport Canada, Ottawa, June 2002, http://www.tc.gc.ca/mediaroom/releases/nat/2002/02_h061e.htm

Weir, A., *The Tombstone Imperative: The Truth About Air safety*. London: Simon and Schuster, 1999

Appendix

A. List of Persons Contacted

- Dr. Mark Eddowes, Managing Consultant, AEA Technology Park
- Dr. Graham Braitwaite, Senior Lecturer and Director of Safety and Accident Investigation, Cranfield University
- Mr. Frank Taylor, Director of Cranfield Aviation Safety Centre, Cranfield University
- Mr. Robert McCleod, Managing Director, HIAL
- Mr. Paul Hardiman, Senior Airport Fire Officer, HIAL
- Mr. Norman Ross, Accountant, HIAL
- Mr. Ray Kaduck, Aviation Consultant, Policyshop.com, Canada
- Mr. Jason Rothwell, Flight Standards Officer, SRG, CAA
- Mr. Jason Ivey, Fire Officer, SRG, CAA

B. Questionnaires

The interviewee technique was used for the following questionnaire

Highlands and Islands Airports Limited

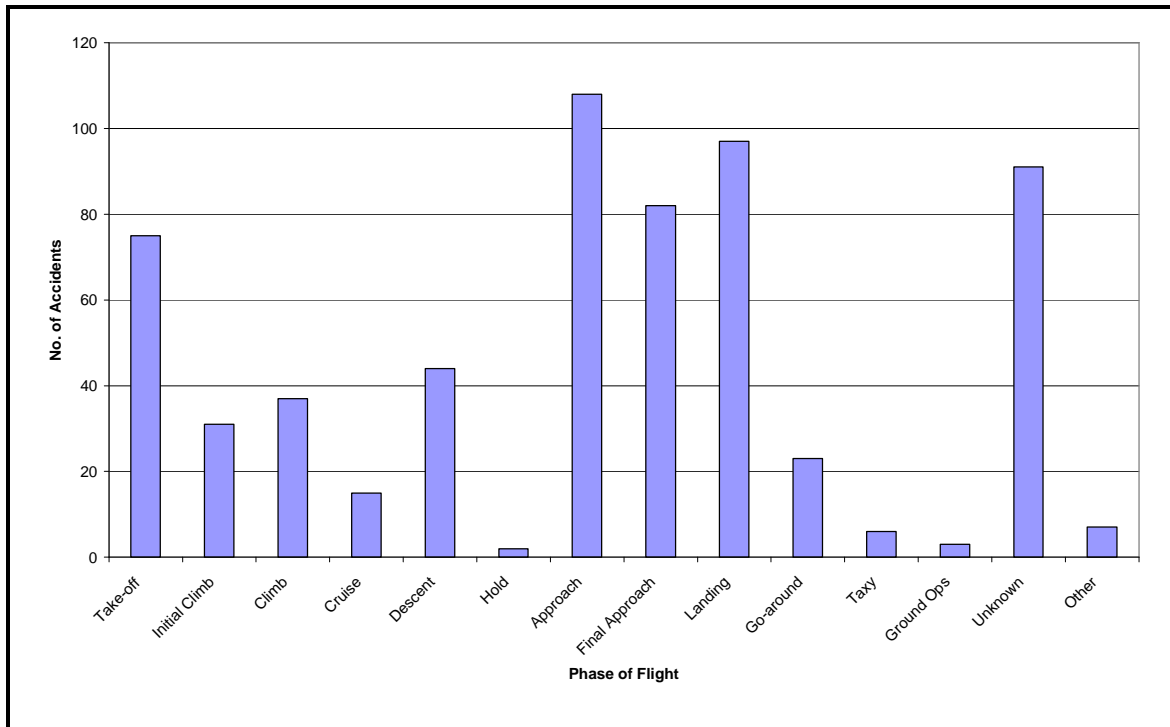
1. What have the costs and benefits (or advantages and disadvantages been) with respect to the current Rescue and Fire Fighting regulations as outlined in CAP 168 (particularly in terms of:
 - a) operations
 - b) profitability
 - c) ability to provide a safe environment for passengers and workers)
2. How appropriate do you find the current Rescue and Fire Fighting Regulations?
3. How would you rate your rescue and fire fighting policy/programme in terms of:
 - a) securing a safe environment
 - b) enhancing the profitability of your airports)
4. What are some of the safety related challenges/problems that you have encountered in the past?
5. What would you change about the regulations under CAP 168 if you were given the opportunity?
6. What are the main concerns that you have with respect to the proposed changes to the Rescue and Fire Fighting Regulations?
7. What costs and benefits do you foresee as a result of the proposed changes to the regulations?
8. What are the main opportunities that you foresee in implementing the proposed changes to the Rescue and Fire Fighting Regulations?
9. Are you aware of any studies that may have been conducted with respect to the likely impact that the proposed changes to the Rescue and Fire Fighting Regulations may have on the smaller airports and if so what were the main findings?
10. What programmes or policies do you have in place should an undesirable catastrophic event take place?
11. What in your opinion would be the best solution or approach to addressing the issue of Rescue and Fire Fighting Operations at smaller airports, particularly in light of the costs involved? If there were no regulations relating to aerodrome rescue and fire fighting services, what approach would you see most fit for these services?

Due to time constraints and at the request of the SRG, this questionnaire was self administered.

CAA Safety Regulation Group

1. What prompted the proposed changes to the Rescue and Fire Fighting Regulations for Aerodromes?
2. How soon are these regulations likely to come into effect and what remains to be done before they become effective?
3. How effective would you say that the current Rescue and Fire Fighting Regulations as outlined under CAP 168 are?
4. What are the main problems/challenges with respect to CAP 168?
5. How effective and appropriate do you envisage the new regulations will be, particularly with respect to:
 - d) operations of various categories of airports
 - e) profitability of various categories of airports
 - f) ability to provide a safe environment for passengers and workers
6. What challenges do you foresee with respect to the proposals for the Aerodrome Rescue and Fire Fighting Regulations?
7. What benefits do you foresee with respect to the proposals for the Aerodrome Rescue and Fire Fighting Regulations, both from the stand point of safety and operations of aerodromes?
8. How were these proposals developed? What kind of assessment was conducted to test their appropriateness? How involved are stakeholders in the development and review of regulations? How often are regulations reviewed?
9. What in your opinion would be the best solution or approach to addressing the issue of Rescue and Fire Fighting Operations at smaller airports, particularly in light of the costs involved?
10. Are you aware of any studies that may have been conducted with respect to the likely impact that the proposed changes to the Rescue and Fire Fighting Regulations may have on the smaller airports or airports in general and if so what were the main findings?

C. Number of Accidents by Phase of Flight



Source: UK CAA

D. Countries by Region

Source: UK CAA

African Region

Algeria	Lesotho	Swaziland
Angola	Malawi	Tanzania
Benin	Mali	Togo
Botswana	Mauritania	Tunisia
Burkina Faso	Mauritius	Uganda
Central African Republic	Morocco	Zambia
Chad	Mozambique	Zimbabwe
Cisekei	Namibia	
Comoros	Niger	
Dem. Rep. of Congo	Nigeria	
Djibouti	Rep. Bophuthatswana	
Egypt	Rwanda	
Ethiopia	Sao Tome and Principe	
Gabon	Senegal	
Gambia	Seychelles	
Ghana	Sierra Leone	
Guinea	Somalia	
Guinea-Bissau	South Africa	
Ivory Coast	Sudan	

Asia

Afghanistan	Japan	Pakistan
Bahrain	Jordan	Palestine
Bangladesh	Korea	Philippines
Bhutan	Kuwait	Qatar
Brunei	Laos	Saudi Arabia
Cambodia	Lebanon	Singapore
China	Macau	Sri Lanka
Hong Kong	Malaysia	Syria
India	Maldives	Taiwan
Indonesia	Mongolia	Thailand
Iran	Myanmar	Vietnam
Iraq	Nepal	Yemen
Israel	Oman	

Australasia

American Samoa	Marshall Islands	Papua New Guinea
Australia	Nauru	Solomon Islands
Cook Islands	New Caledonia	Tonga
Fiji	New Zealand	Vanautu
French Polynesia	North Marianas Islands	Western Samoa
Guam	Pacific Islands	
Kiribati	Palau	

Europe (Full JAA Member – Countries Joining before SRG Study: See Table 2.4)

Austria	Germany	Luxembourg	Spain
Belgium	Greece	Monaco	Sweden
Denmark	Iceland	Netherlands	Switzerland
Finland	Ireland	Norway	United Kingdom
France	Italy	Portugal	

Europe (Full JAA Members – Countries Joining after SRG Study: See Table 2.4)

Hungary

Malta

Poland

Romania

Slovenia

Turkey

Europe (CIS Countries)

Armenia

Kazakhstan

Tajikistan

Azerbaijan

Kyrgyzstan

Turkmenistan

Belarus

Rep. of Moldova

Ukraine

Georgia

Russian Federation

Uzbekistan

Rest of Europe

Albania

Estonia

Lithuania

Bosnia-Herzegovina

Faroe Islands

Macedonia

Bulgaria

Gibraltar

Montenegro

Croatia

Greenland

Serbia

Cyprus

Latvia

Slovakia

Czech Republic

Lichtenstein

Yugslavia

North America

Anguilla

Dominica

St. Kitts & Nevis

Antigua and Barbuda

Dominican Republic

St. Lucia

Aruba

Grenada

St. Pierre & Miquelon

Bahamas

Guadeloupe

Trinidad & Tobago

Barbados

Haiti

St. Vincent & the Grenadines

Bermuda

Jamaica

Turks & Caicos Islands

Canada

Martinique

USA

Cayman Islands

Montserrat

Virgin Islands

Cuba

Puerto Rico

South/Central America

Argentina	El Salvador	Panama
Belize	Falkland Islands	Paraguay
Bolivia	French Guyana	Peru
Brazil	Guatemala	Suriname
Chile	Guyana	Uruguay
Colombia	Honduras	Venezuela
Costa Rica	Mexico	
Ecuador	Nicaragua	

E. Notable Causes by Category

Source: PlaneCrashInfo.com

Table A.1: Air Traffic Control

Date	Location	Airline
06/13/1947	Leesburg, Virginia	Pen Central Air
11/11/1949	Arlington, Virginia	Eastern / U.S. Air Force
04/14/1958	Castel de Fels, Spain	Aviaco
07/21/1961	Shemya, Alaska	Alaska Airlines
02/08/1965	New York, New York	Eastern Airlines
03/05/1969	San Juan, Puerto Rico	Prinair
01/14/1970	Mt. Pumacona, Peru	Faucett
02/06/1970	Samarkand, USSR	Aeroflot
12/20/1972	Chicago, Illinois	Delta/North Central
09/09/1976	Adler, Russia	Aeroflot / Aeroflot
09/10/1976	Gaj, Yugoslavia	Inex / British Airways
08/11/1979	Dneprodzerzhinsk, USSR	Aeroflot
04/19/1983	Keninakan, Russia	Aeroflot
02/01/1991	Los Angeles, California	USAir/Skywest
05/19/1993	Medellin, Colombia	SAM
11/07/1996	Lagos, Nigeria	Aviation Dev. Corp.
09/26/1997	Buah Nabar, Indonesia	Garuda Indonesian Airlines

Table A.2: Design Flaw

Date	Location	Airline
03/31/1933	Bazaar, Kansas	Trans Cont. & Western Airways
10/24/1947	Bryce Canyon, Utah	United Airlines
11/11/1947	Gallup, New Mexico	American Airlines
06/17/1948	Mt. Carmel, Pennsylvania	United Airlines
08/29/1948	Winona, Minnesota	Northwest Orient Airlines
05/02/1953	Jalalogori, India	British Overseas Airways
01/10/1954	Elba, Italy	British Overseas Airways
04/08/1954	Off Stromboli, Italy	Trans Canada Airlines
02/05/1955	Calabar, Nigeria	West African Airways
09/29/1959	Buffalo, Texas	Braniff Airlines
03/17/1960	Tell City, Indiana	Northwest Orient Airlines
07/05/1970	Toronto, Canada	Air Canada
07/06/1982	Moscow, Russia	Aeroflot
07/30/1992	New York, New York	Trans World Airlines
04/06/1993	Over the Pacific Ocean	China Eastern Airlines
03/03/1991	Colorado Springs, Colorado	United Airlines
09/08/1994	Aliquippa, Pennsylvania	USair

Table A.3: Bird Strike

Date	Location	Airline
10/04/1960	Boston, Massachusetts	Eastern Airlines
11/23/1962	Ellicott, Maryland	United Airlines
09/15/1988	Bahar Dar, Ethiopia	Ethiopian Airlines
04/18/1990	Off Panama	Aero Perlas
09/22/1995	Anchorage, Alaska	U.S. Air Force
04/19/2000	Pepo, Congo	Centrafricain Airlines

Table A.4: Cargo Hold / Cabin Fire

Date	Location	Airline
07/09/1945	Florence, South Carolina	Eastern Airlines
06/17/1948	Mt. Carmel, Pennsylvania	United Airlines
08/02/1949	Jaquirana, Brazil	Varig
01/09/1964	Zarate, Argentina	Aero Litoral Argentina
07/09/1964	Parrottsville, Tennessee	United Airlines
07/26/1969	Biskra, Algeria	Air Algerie
08/14/1972	Konigs, East Germany	Interflug
08/31/1972	Magnitogorsk, Russia	Aeroflot
07/11/1973	Paris, Orly, France	Varig
11/03/1973	Boston, Massachusetts	Pan American
11/26/1979	Ta'if, Jeddah, Saudi Arabia	Pakistan Inter. Airlines
08/19/1980	Riyadh, Saudi Arabia	Saudi Arabian Airlines
12/24/1982	Guangzhou, China	CAAC
06/02/1983	Covington, Kentucky	Air Canada
07/02/1986	Syktyvar, Russia	Aeroflot
05/09/1987	Warsaw, Poland	LOT
11/28/1987	Mauritius, Indian Ocean	South African Airways
01/13/1990	Pervouralsk, Russia	Aeroflot
07/12/1995	Gumey, New Guinea	Milne Bay Air
05/11/1996	Everglades, Florida	ValuJet
09/02/1998	Peggy's Cove, Nova Scotia	Swissair

Table A.5: Sabotage - Explosive Device

Date	Location	Airline
03/28/1933	Dixmude, Belgium	Imperial Airways
10/10/1933	Chesterton, Indiana	United Airlines
05/07/1949	Sibuyan Sea, Philippines	Phillipine Airlines
09/09/1949	Sault-aux-Cochons, Canada	Canadian Pacific Airlines
08/12/1952	Palmeria de Goias, Brazil	Trans Aero Nac.
04/11/1955	Great Natuna Island, Sarawak	Air India
11/01/1955	Longmont, Colorado	United Airlines
07/25/1957	Daggett, California	Western Airlines
04/17/1959	Puerto Kino, Mexico	Tigres Voladores
09/08/1959	Poza Rica, Mexico	Mexicana
11/16/1959	Gulf of Mexico	National Airlines
01/06/1960	Bolivia, North Carolina	National Airlines
05/10/1961	In Amenas, Libya	Air France
05/22/1962	Unionville, Missouri	Continental Airlines
12/08/1964	Tripuani, Bolivia	Aerolineas Abaroa
07/08/1965	Dog Creek, British Columbia	Canadian Pacific Airlines
11/22/1966	Aden, Yemen	Aden Airways
02/09/1967	Mexico City, Mexico	Cubana
10/12/1967	Rhodes, Greece	British European Airways
12/22/1969	Nha Trang, Vietnam	Air Vietnam
02/21/1970	Zurich, Switzerland	Swissair
04/21/1970	Manila, Philippines	Philippine Airlines
11/21/1971	Penhu Island, Taiwan	China Airlines
01/26/1972	Hermsdorf, Czechoslovakia	JAT
06/15/1972	Pleiku, Vietnam	Cathay Pacific Airways
03/19/1973	Ben Me Thout, South Vietnam	Air Vietnam
04/21/1973	Patabangan, Philippines	Philippine Airlines
12/17/1973	Rome, Italy	Pan American Airways
09/08/1974	Ionian Sea, Greece	Trans World Airlines
01/01/1976	Al Qaysumah, Saudi Arabia	Middle East Airlines
10/06/1976	Bridgetown, Barbados	Cubana
02/19/1979	Barentu, Ethiopia	Ethiopian Airlines
06/27/1980	Tyrrhenian Sea, Italy	Itavia
12/21/1980	Rio Hacha, Colombia	Trans. Aereos del Caribe
09/23/1983	Mina Jebel Ali, UAE	Gulf Air
06/23/1985	Atlantic Ocean, Ireland	Air India
04/02/1986	Athens, Greece	Trans World Airlines
05/03/1986	Colombo, Sri Lanka	Air Lanka
11/29/1987	Andaman Sea	Korean Airlines
03/01/1988	Johannesberg, South Africa	Comair
12/21/1988	Lockerbie, Scotland	Pan American Airways
09/19/1989	Bilma, Niger	Union des Trans. Aeriens

Table A.5: Sabotage - Explosive Device Cont'd

Date	Location	Airline
11/27/1989	Bogota, Colombia	Avianca
07/19/1994	Colon, Panama	Alas Chiricanas
12/11/1994	Pacific Ocean, Okinawa	Philippine Airlines
07/09/1997	Suzano, Brazil	TAM
03/03/2001	Bangkok, Thailand	Thai Airways

Table A.6: Hijacking (resulting in fatalities)

Date	Location	Airline
07/16/1948	Pacific Ocean	Cathay Pacific Airways
11/01/1958	Nipe Bay, Cuba	Cubana
04/28/1960	Calabozo, Venezuela	Linea Aero. Venezolana
1/23/1971	Sokcho, South Korea	Korean Airlines
12/06/1971	Tikaka, Sudan	Sudan Airways
05/18/1973	Chita, Russia	Aeroflot
09/15/1974	Phan Rang, Vietnam	Air Vietnam
05/23/1976	Zamboanga, Philippines	Philippine Airlines
06/27/1976	Entebbe, Uganda	Air France
12/04/1977	Kampung Ladang, Malaysia	Malaysia Airlines
06/14/1985	Athens, Greece	Trans World Airlines
11/24/1985	Luqa, Malta	Egyptair
09/05/1986	Karachi, Pakistan	Pan American Airways
12/25/1986	Ay, Saudi Arabia	Iraqi Airways
07/24/1987	Geneva, Switzerland	Air Afrique
04/05/1988	Combi, Cyprus	Kuwait Airways
10/02/1990	Guangzhou, China	Xiamen/China SW Airlines
08/28/1993	Khorag, Tajikistan	Tadzhikistan Nat. Airlines
12/26/1994	Algiers, Algeria	Air France
11/23/1996	Moroni, Comoros Islands	Ethiopian Airlines
07/23/1999	Tokyo, Japan	All Nippon Airways
09/11/2001	New York, New York	American Airlines
09/11/2001	New York, New York	United Airlines
09/11/2001	Arlington, Virginia	American Airlines
09/11/2001	Shanksville, Pennsylvania	United Airlines

Table A.7: Fuel Starvation

Date	Location	Airline
05/18/1935	Michigan	Knowles Flying Service Flint
12/31/1935	Egypt	Imperial Airways Alexandria
05/06/1936	Macon, Missouri	Transcon. & West. Air
01/14/1936	Goodwin, Arkansas	American Airlines
07/02/1937	Lae, New Guinea	Purdue Res. Found.
11/28/1938	Off Point Reyes, California	United Airlines
02/09/1943	Gander, Newfoundland	British Overseas Airways
12/28/1946	Michigan City, Michigan	American Airlines
01/05/1947	Carmel, New Jersey	Nationwide Air Trans.
01/11/1947	Lympne, England	BOAC
01/07/1948	Savannah, Georgia	Coastal Air Lines
01/30/1948	Near Bermuda	British So. Am. Airways
12/28/1948	San Juan, Puerto Rico	Airborne Transport
08/15/1949	Lurga Point, Ireland	Transocean Airlines
07/28/1950	Porte Alegre, Brazil	Penair do Brasil
04/30/1952	Delhi, India	Deccan, Airways
05/26/1952	Atar, Mauritania	British Overseas Airways
06/19/1954	Folkestone, England	Swissair
12/22/1954	Pittsburgh, Pennsylvania	Johnson Flying Service
04/04/1967	Stockport, England	British Midland Airways
05/02/1970	St. Croix, Virgin Islands	Antillian Airlines
12/05/1970	Delhi, India	Jamair
02/01/1972	Tegal, Indonesia	Penas
07/24/1973	Honolulu, HI	Air Hawaii
08/11/1974	Ouagadougou, Upper Volta	Air Mali
10/20/1977	Gillsburg, Mississippi	L & J Company
12/02/1977	Al Bayda, Lebanon	Balkan Bulgarian Airlines
12/28/1978	Portland, Oregon	United Airlines
09/04/1982	Rio Branco, Brazil	Cia Bras. de Tratores
07/23/1983	Gimli, Manitoba, Canada	Air Canada
09/03/1989	Sao Jose do Xingu, Brazil	Varig
01/25/1990	Cove Neck, New York	Avianca
09/11/1990	Off Newfoundland, Canada	Faucett
06/26/1991	Sokotu, Nigeria	Okada Air
11/15/1993	Kerman, Iran	Magistralnye Avialinii
09/18/1994	Tamanrasset, Algeria	Oriental Airlines
09/26/1994	Vanavera, Russia	Cheremshanka Airlines
09/11/1995	Jalalabad, Afghanistan	Ariana Afghan Airlines
10/31/1995	Piedras Negras, Mexico	TACSA
04/05/1996	Petropavlovsk, Russia	Krasnoyarskie AV
01/13/1998	Tor Kach, Pakistan	Ariana Afghan Airlines
03/24/2000	Kadirana, Sri Lanka	OMSK

Table A.8: Lightning

Date	Location	Airline
07/22/1938	Stulpica, Romania	LOT
08/31/1940	Lovettsville, Virginia	Penn Central Airlines
01/17/1951	Civitavecchia, Italy	Alitalia
06/26/1959	Varese, Italy	Trans World Airlines
08/29/1960	Dakar, Senegal	Air France
07/19/1961	Azul, Brazil	Aerolineas Argentinas
12/19/1962	Warsaw, Poland	LOT
08/12/1963	Lyon, France	Air Inter
12/08/1963	Elkton, Maryland	Pan American Airways
12/24/1971	Puerto Inca, Peru	Lineas Aereas Nacionales
05/09/1976	Madrid, Spain	Iran Air Force
02/08/1988	Mulheim, Germany	NFD
06/22/2000	Shitai, China	Wuhan Airlines

Table A.9: Pilot Incapacitation

Date	Location	Airline
10/30/1959	Waynesborough, Virginia	Piedmont Airlines
12/14/1962	Burbank, California	Flying Tiger Line
10/06/1965	Centennial, Wyoming	United AL
04/22/1966	Ardmore, Oklahoma	American Flyers Airlines
03/13/1967	East London, South Africa	South African Airways
01/14/1970	Mt. Pumacona, Peru	Faucett
06/18/1972	Staines, Surrey, England	British European Airways
10/13/1972	Krasnaya, Polyana, USSR	Aeroflot
02/09/1982	Tokyo, Japan	Japan Airlines
03/31/1995	Balotesti, Romania	Trans. Aeriene Rom.

Table A.10: Pilots Shot by Passenger

Date	Location	Airline
05/07/1964	San Ramon, California	Pacific Airlines
12/04/1977	Kampung Ladang, Malaysia	Malaysian Airlines
12/07/1987	San Luis Obispo, California	Pacific Southwest Airlines

F. Aircraft Accident Fatalities: The Probabilities

Source: PlaneCrashInfo.com

Mortality Risk by Scheduled Service

Type of Carrier	Probability of Death
Advanced World ¹ Domestic Jet	1 in 8 million
U.S. Commuter ²	1 in 2 million
Developing World ³ Domestic Jet	1 in 500,000
International Jet Within Advanced World	1 in 5 million
International Jet Between Advanced World and Developing World	1 in 600,000
International Jet Within Developing World	1 in 400,000

¹ Home offices in economically and technologically advanced politically democratic countries such as Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, USA and UK.

² Includes service by reciprocating-engine aircraft and turboprop aircraft.

³ Home offices in countries other than those included at ¹.

Probability of being on an airline flight that results in at least one fatality:

- Top 25 airlines with best records 1 in 3.72 million
- Bottom 25 airlines with worst records 1 in 149,000

Probability of being killed on a single airline flight:

- Top 25 airlines with best records 1 in 7.71 million
- Bottom 25 airlines with worst records 1 in 558,000

G. Guidance Material Related to Rescue Equipment Carried on RFF Vehicles

Equipment for Rescue Operations	Airport Category			
	1-2	3-5	6-7	8-9
Adjustable wrench	1	1	1	1
Axe, rescue, large non-wedge type	-	1	1	1
Axe, rescue, small non-wedge or aircraft type	1	2	4	4
Cutter bolt, 61cm	1	1	1	1
Crowbar, 95cm	1	1	1	1
Crowbar, 1.65m	-	-	1	1
Chisel, cold, 2.5cm	-	1	1	1
Flashlight	2	3	4	8
Hammer, 1.8kg	-	1	1	1
Hook, grab or salving	1	1	1	1
Saw metal cutting or hacksaw, heavy duty, complete with spare blades	1	1	1	1
Blanket, fire resisting	1	1	1	1
Ladder, extending (of over-all length appropriate to the aircraft type in use)	-	1	2	2 or 3
Rope line, 15m length	1	1	-	-
Rope line, 30m length	-	-	1	1
Pliers, 17.8cm, side cutting	1	1	1	1
Pliers, slip joint, 25cm	1	1	1	1
Screwdrivers, assorted (set)	1	1	1	1
Snippers, tin	1	1	1	1
Chocks, 15cm high	-	-	1	1
Chocks, 10cm high	1	1	-	-
Powered rescue saw complete with two blades; or – pneumatic rescue chisel complete – plus spare cylinder, chisel and retaining spring	1	1	1	2
Harness cutting tool	1	2	3	4
Gloves, flame resistant pairs (unless issued to individual crew members)	2	3	4	8
Breathing apparatus and cylinders	-	2	3	4
Spare air cylinders	-	2	3	4
Hydraulic or pneumatic forcing tool	-	1	1	1
Medical first aid kit	1	1	1	1

Source: ICAO

H. Extracts from ICAO Supplement to Annex 14, Volume 1 (Third Edition)

Differences Filed by the United Kingdom and the USA

Chapter 9, Section 9.2, Rescue and Fire Fighting

'United Kingdom

9.2.10 *At all aerodromes, up to 50% of the complimentary media may be replaced by water for foam production to performance level B.*

USA

9.2.1 *Rescue and fire fighting equipment and services such as those specified in this section are required only at airports serving scheduled air carriers with aircraft having more than 30 seats. Such airports generally equate to ICAO Categories 4 through 9.*

9.2.3 *There is no plan to eliminate, after 1 January 2005, the current practice of permitting a reduction of one category in the Index when the largest aircraft has fewer than an average of five scheduled departures a day. The reduction in category is a rudimentary cost/benefit consideration and also facilitates the introduction of large aircraft into service by not making the air carrier's planning contingent on the airport's immediate acquisition of additional equipment.*

9.2.4/9.2.5 *The level of protection at United States airports is derived from the length of the largest aircraft serving the airport. This is similar to the Annex 14 procedure, except that maximum fuselage width is not used.*

Remark: Unites States indices A-E are close equivalentents of the Annex's categories 5-9. The United States does not have an equivalent to Category 10. The United States will consider the

requirements of Category 10 when it adopts a new index for very large aircraft. Further harmonisation with the Annex will be considered in the future.

9.2.10 *The required fire fighting equipment and agents by index are shown in Table 4¹⁷.*

The substitution equivalencies between complementary agents and foam meeting performance level A are also used for protein and fluoroprotein foam. Equivalencies for foam meeting performance level B are used only for aqueous film forming foams.

9.2.18/9.2.19 *At least one apparatus must arrive and apply foam within 3 minutes, with all other required vehicles arriving within 4 minutes. Response time is measured from the alarm at the equipment's customary assigned post, to the commencement of the application of foam at the midpoint of the farthest runway.*

Remark: The United States values a rapid response and the presence of professional fire fighters at the earliest possible time to deal with incipient conditions.

9.2.29 *For ICAO Category 6 (U.S. Index B) the United States allows one vehicle.'*

¹⁷ See Table 4.9