THE COSTS OF AIRCRAFT ACCIDENTS IN AUSTRALIA :

WITH PRELIMINARY ESTIMATES FOR 1980.

PREPARED FOR THE

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BY

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ABSTRACT

This report documents a six-month study to develop a framework of societal costs of aircraft accidents in Australia for the purpose of assisting the Department of Aviation in relating costs and benefits in resource management decisions and for assisting the Bureau of Air Safety Investigation in the management of aviation safety promotion programs.

A detailed set of unit and total cost estimates for Australia in 1980 is presented together with a literature review and recent work on approaches to valuing human life.

Two cost components, fatalities and aircraft hull damage/loss, account for about 96.5% of total annual costs of $31 million.

The costs of fatalities and injuries are based on the value of future lost work efforts and are to be considered as minimum values only. Intangible social costs such as pain and suffering are not expressed in dollar terms.

Also the use of average cost levels is limited because of the skewed distribution of most accident cost characteristics.

Further research directed towards refinement of the data and the conceptual and empirical bases of these estimates is recommended.

KEYWORDS
ACCIDENT COSTS, AIRCRAFT, SOCIETAL, DIRECT COSTS

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CONTENTS

CHAPTER		PAGE
	Report Documentation Form	(i)
	Acknowledgements	(ii)
	Contents	(iii)
	List of Tables	(iv)
	Preface	(v)
CHAPTER 1	INTRODUCTION	1
1.1	Introduction	
1.2	Reasons for Costing Air Accidents	
1.3	Outline of Study	
CHAPTER 2	CONCEPT OF SOCIAL COST AND REVIEW OF LITERATURE	5
2.1	The Concept of Social Cost	
2.2	Approaches to Accident Costing and the Value of Human Life	
2.3	Review of Recent Cost Studies Literature	
CHAPTER 3	FRAMEWORK FOR AIRCRAFT ACCIDENT COST ESTIMATES	15
3.1	Introduction	
3.2	Data Availability/Reliability	
3.3	Description of Accident Cost Estimates	
	3.3.1 Fatalities	
	3.3.2 Serious Injuries	
	3.3.3 Aircraft Damage/Loss	
	3.3.4 Family and Community Losses	
	3.3.5 Search and Rescue	
	3.3.6 Accident Investigation	
	3.3.7 Losses to Others	
3.4	Summary of Costs	
3.5	Accident Costs by Flying Category	
CHAPTER 4	CONCLUSIONS AND RECOMMENDATIONS	28
4.1	General Comments	
4.2	Conclusions/Recommendations on Data Sources	
4.3	Main Findings of Report	
APPENDICES		
A:	Glossary	32
B:	Bibliography and References	34
C:	Costing Methodology for Fatalities and Injuries	35
D:	Summary of a Recent Value of Life Model.	47

LIST OF TABLES

TABLE NO.		PAGE
1.	AVERAGE ACCIDENT COSTS AUSTRALIA, 1980 - PRELIMINARY ESTIMATES (7% DISCOUNT RATE)	24
2.	SUMMARY OF TOTAL AIRCRAFT ACCIDENT COSTS, AUSTRALIA 1980 (7% DISCOUNT RATE)	25
3.	SUMMARY OF AVERAGE ACCIDENT COSTS, AUSTRALIA 1980 (7% DISCOUNT RATE)	26
4.	AIRCRAFT ACCIDENT COSTS - CATEGORIES OF FLYING (1980/1978/1976)	27
5.	AIRCRAFT ACCIDENTS INVOLVING CAUSALTIES, AUSTRALIA 1976-1983	42
6.	ACCIDENT FATALITIES - SEX AND AGE DISTRIBUTION, MEAN INCOME BY AGE GROUPS - AUSTRALIA 1980	43
7.	PRESENT VALUE OF FUTURE INCOME AT MEDIAN AGES - 1980 (7% DISC. RATE, 3% PRODUCTIVITY) EFFECTS OF AGE GROUP WEIGHTING ON DISCOUNTED INCOMES - AUST. 1980	44
8.	AIRCRAFT ACCIDENTS, SERIOUS INJURY SEX/AGE DISTRIBUTION - 1980	45
9.	SERIOUS INJURY, HOSPITALISATION PERIODS - 1980	46
10.	EFFECTS OF SELECTED 'VALUE OF LIFE' RESULTS ON AVERAGE ACCIDENT VALUATIONS - (AUST. 1980)	50

PREFACE

The task of valuation of accidents for public policy purposes is beset by many problems, especially those relating to the valuation of human life and safety. The main purpose of this work is to guide accident countermeasure research in determining safety priorities, a task which involves many different skills. Yet the economic valuation input in the past has been notably deficient and often misleading in its contribution to accident analysis. There are, however, grounds for optimism in recent research developments affecting both conceptual and empirical approaches to accident valuation and other areas of hazard such as pollution and public health.

The present study attempts to apply some of these systematic concepts in the important area of aircraft safety and accident research, and while it represents a first stage in such a process, in my view it breaks useful new ground. Most of the relevant precedents for this work are found in road accident studies. Road accident costing has a long record of conflict between theory and practice. There are many definitions of cost, the choice of which becomes critical once they are used to decide "how much safety is enough?" The main error of past use of cost estimates has been to assume that the financial cost of accidents occurring involuntarily in some way represents the value society places on the avoidance of accidents.

The conceptually correct approach for investigation of safety measures is based on willingness to pay to avoid specific risks to life and property: the problem has been how to measure this. The approach adopted by the author here is to specify a comprehensive societal cost categorisation which includes a minimum "value of life" measure based on foregone income. This is a useful compromise which produces plausible results. Inevitably, these estimates and those of material resource costs will benefit from more experience with aircraft accident data series and applications of the estimates. In my view this report should provide useful economic input for researching aircraft accident priorities, and deserves appropriate follow-up.

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SOCIAL AND ECONOMIC COSTS OF AIRCRAFT ACCIDENTS

Chapter 1

INTRODUCTION

1.1 Introduction

This report presents the results of a study of the societal costs of aircraft accidents [1] in Australia giving preliminary cost estimates for 1980. The study, at the instigation of the Director, Bureau of Air Safety Investigation, was achieved through the attachment to the Bureau of an Assistant Research Officer (Graduate Economist) for the period September 1983 - February 1984. This is the first time in Australia that any formal research of this type, to assess the total costs of air accidents, has been carried out. The study is by no means exhaustive given the limited resources and timespan available to undertake what is considered a complex and somewhat controversial field of research. Serious consideration should be given to follow-up research and refinement of the data.

The basic task of the Bureau of Air Safety Investigation (BASI) of the Department of Aviation is the investigation of all aircraft accidents and incidents involving civil aircraft operating within Australian flight information regions. The fundamental objective of the investigation of an accident or incident is the prevention of accidents. This investigation activity does not seek to apportion blame or liability.

Among a number of main functions of the Bureau is the provision and maintenance of a statistical recording system of aircraft accident and air safety incident data and the development of analyses of the data for safety enhancement programes. The potential application of accident cost estimates will be to assist the Bureau and more generally the Department of Aviation with decisions relating to the planning and evaluation of air safety programs.

Prior to this study, the only real measure of aircraft accident severity was the incidence of accidents. This study will provide a quantitative dimension to the measurement of severity, with total accident costs reflecting the magnitude of the problem to Australian society in dollar terms.

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(1) For precise definition of "accident", refer to Glossary at Appendix A.

1.2 Reasons for Costing Aircraft Accidents

Decisions must be made within the public sector on how best to deploy resources to the various increasing requirements of different policy areas. With an environment of increased constraints on expenditure and the trend to more accountability, public sector decision-makers have the task of allocating priority among competing projects. This is particularly the case in such policy areas as health care and road or air safety where 'output' is measured in terms of lives saved or reduced mortality. Since it is evident that resources available for air safety are not infinite, the immediate implication is that some limit has to be set to the amount of resources which society can devote to saving life.

A cost study such as this is an attempt to examine how we might set about answering the question: how much is society prepared to pay to save lives or reduce the risk of death? Some approaches to the way we could answer this question and attempt to place a value on human life are discussed further in Chapter 2.

Quite clearly, aircraft accidents impose a significant loss of both human and material resources to the community. It is the continuing responsibility of government and other agencies to allocate funds for programs to improve safety in aviation. In the interests of achieving a degree of social efficiency in the allocation of these funds, the application of benefit-cost analysis might be possible for each program or project. The benefits of aviation safety improvements could be related to presumed decreases in probabilities of accidents with a consequent decrease in deaths, injuries and damage to property. Before measuring such benefits, it is necessary to identify the total costs to society of deaths, injuries and damage to property resulting from past accidents. Further work would then be required to link these costs to expected reductions in probabilities of accidents as a result of accident prevention initiatives of the Department of Aviation.

1.3 Outline of the Report

The overall study is an attempt to arrive at a preliminary estimate of the total cost of aircraft accidents in Australia for a recent period.

The concept of social cost, as it relates to aircraft accidents is considered in Chapter 2 and the distinction between financial, economic and social costs is outlined. The three main approaches to what is termed the valuation of life problem are then outlined together with a description of the methodology generally used in the costing of accidents. In relation to the valuation of human life, the existence of a relatively large and often controversial literature is acknowledged. This study has adopted the traditional human capital approach in the context of accident evaluation. Chapter 2 also includes a short summary review of some recent accident cost estimation studies for the U.S.A., Canada, New Zealand and Australia. In the case of Canada, the subject is a recent aircraft accident cost study, whilst for the U.S.A., New Zealand and Australia, road accident cost studies are reviewed.

Chapter 3 sets out a framework for the estimation of unit costs cross-classified by cost category and by accident/ injury severity for aircraft accidents in Australia. Preliminary estimates of average and total costs are shown for the year 1980. For the purposes of this study, casualty costs are confined to fatalities and serious injuries as opposed to the method in road accident studies which has made use of Abbreviated Injury Scale (AIS) from 1-minor to 6-fatal. The reason for this is twofold: first, time does not permit a more involved breakdown of injury severity using the Cornell Scale and could perhaps be the subject of further research; second, aircraft accident casualties by their nature are more readily grouped into either the fatal or serious injury category.

Estimates of hospital, medical and related costs are presented, data for which were obtained by contacting the hospitals concerned. In addition, road accident hospital costs were used based on the assumption that for serious injury, these costs would be similar to those involving serious injury as a result of aircraft accidents.

Aircraft loss and damage costs are then considered and most of the information in relation to these costs was sourced from insurance companies. The efficacy of deriving an average insured value for weight categories of aircraft so as to have a working value for all accidents is also discussed. The sources of all other costs in the framework are then briefly considered.

Chapter 4 makes some general comments and presents the conclusions from the report together with appropriate recommendations. The recommendations relate to the need for further research which might refine and further improve the costing methodology presented here which could allow the development of a cost model to be used as a working tool to assist with decision-making for aviation accident prevention programs.

Appendix A contains a glossary of terms and definitions.

The bibliography in Appendix B lists some of the more significant work that has been undertaken on the subject of accident costing and value of human life. These references were considered to be the most appropriate for the purposes of this study.

Appendix C details the estimation procedure for foregone income and other costs of fatalities and serious injuries and shows the effect of adjusting income levels to reflect those of private pilots.

In Appendix D a brief description is given of a recent value of life model which may provide a significant advance in determining a more realistic value of human life. Use is made of this model to show the effect on the value of human life and average accident valuations for Australia in 1980.

Chapter 2

CONCEPT OF SOCIAL COST AND REVIEW OF LITERATURE

2.1 Concept of Social Cost and Aircraft Accidents.

The terms "societal costs", "socio-economic costs" and "social costs" as used in cost studies imply an attempt to distinguish between social costs and conventional financial costs within the economic system. This brief discussion is intended to provide an outline of the concept of social cost, particularly in relation to aircraft accidents. There are in fact, three distinct concepts of cost which overlap creating some confusion and controversy in public sector decision-making, namely financial costs, "real" economic or resource costs, and social costs.

Financial costs are the recorded transactions or accounting costs associated with day to day receipts and payments in the economy. Real economic or resource costs (also known as "opportunity costs") are a measure of the value of scarce resources produced and consumed in the economy. Economic costs therefore exclude some financial transactions such as the sale and purchase of land or the cost of a used motor vehicle to an individual or firm since no new scarce resources are produced or consumed in the transaction which is merely a transfer of existing resources.

The concept of social cost is a more embracing term and generally more difficult to measure. Social costs - and benefits - refer to the value of those goods and services generally provided by the public sector of the economy i.e. by governments and public authorities, and their costs and/or benefits may not be confined to the producer or consumer. Supply of these goods and services cannot be efficiently or adequately achieved by the private sector and so has therefore become the responsibility of the public sector and includes such categories as roads, education, defence and airways/airports facilities.

The concept of "spillover" effects or externalities which occur as a result of private economic activity, (e.g. generation of environmental pollution) is recognised as a further category of social cost involving the imposition of external costs upon society which are not fully met by the producer or consumer. This is also advanced as an argument for government intervention in the allocation process.

The costs associated with aircraft accidents belong in the social cost category because they include external cost effects upon society such as publicly provided hospital, police and accident investigation services and also a significant component of non-market and intangible costs including pain and suffering, grief to families and inconvenience to the community. Therefore in terms of opportunity cost concepts, accident "costs" for this study fall within the broad term societal costs, meaning that they include social and economic costs associated with aircraft accidents.

It should be borne in mind that the purpose of accident costing is to identify and measure the real resources displaced as a result of accidents but quite clearly not all factors can be so identified or measured in monetary terms. This study adopts a "social" cost framework similar to the 1976 U.S. study by Faigin(1) and the 1981 Australian study of road accident costs by Atkins(2). The approach of these two studies is to support the estimation and classification of accident costs (according to appropriate cost definitions etc.), but to emphasise the error of treating accident costs as a measure of the value of safety.

2.2 Approaches to Accident Costing and the Value of Human Life.

This section presents an overview of the approaches to accident costing and a brief assessment of the theoretical and conceptual issues relating to attempts to value human life. The economic interest in establishing this value of life, or more precisely the value of saving a random life, is to ensure the efficient allocation of resources (e.g. to safety) in the public sector. There is now a good deal of literature and academic work available on what is probably the most controversial aspect of accident costing - the problem of assigning a value to human life. This is not an attempt to provide a full account of all the theory and its ramifications; those interested may refer to the bibliography for further reading on the subject.

There are two principal methods of deducing the "costs" of accidents:

(1) ex post or loss accounting approach which is based on a measurement mainly in national income accounting terms.

(2) ex ante or "willingness to pay" concept based on the amount in dollar terms that individuals (society) are prepared to pay to reduce the risks of future accidents.

Either approach includes elements amenable to direct valuation but both leave a number of issues where the evaluation basis and costings are not clear cut.

Ex post Approach.

The most common approach is an "accounting" or "after the event" historical costing of accidents in which a list of cost categories are identified and a monetary value calculated for each category. Clearly, the costs of some losses such as death, serious injury and pain and suffering are difficult to quantify having dimensions outside the scope of economic valuation. Even in the case of other more "measurable" categories such as aircraft damage/loss or S.A.R. activity, the relevant data may not be accessible or could be prohibitively expensive to gather.

Prior to the more formalised benefit-cost analysis, the implications of the ex-post cost studies were that society should be prepared to pay at least as much to prevent accidents as their cost. Since resources are scarce even in the prevention of loss of life and serious injury, benefit-cost analysis has refined this approach and stressed the need to concentrate on measuring reductions in social costs so as to allow the evaluation of benefits. In principle, it should then be possible to allocate limited available resources to selected safety projects so as to obtain the maximum improvements in safety possible (within given technology etc.).

The main drawback in ex post accident costing has been the approach to valuation of loss of life. Determining a monetary value for human life is probably the most contentious issue in accident costing but despite its emotional connotations, society must and does place a value on life in its public expenditure decision making. Although many would consider that the value of human life is "infinite", the fact that not all possible safety projects or programs are actually implemented is clear evidence that society does implicity place an upper limit on this value, (and the values implicit in such choices represent social valuations of life).

For example, investment expenditure limitations in respect of road/air safety, public health, fire prevention etc., reveals an implicit value of life which can be interpreted as the appropriate "public sector value". In practice this estimate might show an excessively wide range. Mooney (4) cites implicit values of a single life ranging from $40 million from building regulations to less than $100 associated with certain medical diagnostic testing.

For valuation of human life, the human capital or foregone income method is the one most frequently applied in ex post accident studies. This method has been the underlying valuation philosophy of most accident cost studies to the present time. This is where a fatality is considered to represent a loss to society of the expected future income (production equivalent) between the time of premature death and the end of the normal working lifespan. Thus the value of life is equated with individual productivity in the form of a discounted stream of future earnings. This method of valuation produces a 'lower bound' estimate of the value of life. The methodology raises a number of issues which need to be resolved:-

(i) Definition of income - if we wish to indicate the benefits to be derived from saving a person from death then the gross income figure is used. In this case we are approaching the problem from an ex ante standpoint where the individual involved is relevant because if his life is saved he will continue to be a member of society, will continue to enjoy his consumption and his consumption will be part of the benefit to society. Therefore, given that the use to be made of the concept is in valuing the benefits from investment in life-saving activities, the appropriate income figure is the gross amount.

Another difficulty with the income concept is the question of how to value accident losses for homekeepers, the unemployed and others not working for monetary reward. One solution is to attribute the mean annual gross income level for those in the workforce to all members of the accident sample. In this way, homekeepers and the unemployed are attributed an opportunity cost income level equal to the workforce average for each age group.

A further consideration in relation to the income concept used is the possibility of differentiating between high and low income recipients affected by accident categories. For example, in aircraft accident costing it might be more appropriate to derive a mean annual income representative of the aviation community at risk. This income adjustment issue will be taken up in the costing methodology.

(ii) Productivity rate - an allowance is normally made for the expected growth in real earnings through time and this is built into the calculation of the future earnings stream. The foregone income calculations are however, least sensitive to this parameter.

(iii) Discount rate - the adjusted stream of life time earnings has to be "discounted" to convert it to 'present value' terms. This simply means that the value at the present time of earnings in the future is less than similar earnings now. The appropriate rate has been and still is subject to some controversy. There are two possible approaches to selection of a discount rate:

the first is to use a market rate (i.e. "opportunity cost of capital", e.g. 8%-11%), the second is to use a rate based on the concept of social time preference. While the first is a pragmatic approach (i.e. emphasising that resources for safety must compete with other current uses), the second bases its criterion for the cost of resources on how individuals value the future (suggested at around 4%-5%) and claims to present a superior signal for the use of resources than that provided by the market. Variations in discount rates have a marked effect on the present values of foregone income.

Note: Discounting is not an adjustment for inflation, both these discount rates would exist with zero inflation.

(iv) Age and sex distribution - this is another parameter which has some effect on the resultant level of foregone income. In the case of road accident fatalities and injuries in Australia, calculated average foregone income was over 30% greater than the population average income. This difference mainly reflects the disproportionately large number of younger males in the accident statistics compared to the average population. Aircraft accident victims in Australia are predominantly male but show a more normal distribution across the age range.

After allowing for these various adjustments, the calculated present value stream of future earnings then represents the 'human capital' value of life. One further point needs to be made: there might be a temptation to suggest that an individual could be replaced by an unemployed person. This proposition is not valid because the quantity to be measured is the value of life activity of the deceased individual. Premature death or disablement results in a loss to society of the value of life activity of that individual.

Ex ante Approach.

The alternative approach to the valuation of aircraft accidents is the ex ante or "willingness to pay" concept. It states that the value to an individual of a reduction in risk of death or injury is the amount he would be willing to pay for the change in risk. From such marginal valuations, it is possible to infer a valuation of life, or more strictly a value of life saving which represents an appropriate measure of the benefits to society from preventing accidental deaths.

Although this method is considered conceptually more appropriate for valuing life, the main problem has been - at least until recently - the difficulty of obtaining satisfactory empirical estimates of willingness to pay for changes in individual risk. The most successful approach to date appears to be in deriving values of life from behavioural studies, although there have been some significant theoretical contributions. In addition, there still remains the problem of incorporating willingness to pay valuations of life saving into the overall framework of tangible and other social costs resulting from accidents.

Willingness to pay estimates of the value of life usually turn out to be at least an order of magnitude larger than "ex post" estimates but they would appear however, to represent valuations closer to aggregate social values of life saving.

Recent Approaches to Valuation of Life

Major weaknesses associated with present methods of costing accidents and valuing human life have been discussed briefly: the "ex ante" approach has generally ignored resource costs and 'spillover' effects or externalities associated with accidents while the "ex post" or 'human capital' approach is subject to distortion by the use of an incorrect valuation for its major cost component, i.e. loss of life. The method normally used for applied studies in road accidents involves measurement of the ex post resource costs of accidents to which is added the human capital assessment of the value of lives lost. Most researchers reject the human capital approach to valuation of life as theoretically incorrect and inappropriate.

However, a recent research paper by ARTHUR(8) develops a model which provides some scope for reconciliation of the two approaches to valuing life. This development together with other recent research might render feasible the estimation of operational values of life saving in practice. These methods are outlined further in Appendix D.

<u>Summary</u>: Valuation of Life Problem.

It needs to be emphasised that there is no apparent readily available, ideal solution to the problem of valuation of human life. Past efforts to value life in some cases have been somewhat misconceived. This has increased the difficulty in attempting to take economics into this field and to use it to improve decision-making in life-saving activities. No single method has been evolved which will allow the benefits in reductions of mortality to be measured in a satisfactory manner. The best solution is to take an approach which is most likely to lead along the correct path despite the conceptual and theoretical limitations. Application of the preliminary cost estimates for 1980 aircraft accidents in evaluation and accident project assessment is considered feasible given recognition that the fatality and serious injury costs represent <u>minimum</u> values.

2.3 Review of Some Recent Accident Cost Studies.

Most of the accident cost studies carried out have been undertaken during the past decade and generally have followed a common approach in the estimation procedures. Up until the last two or three years, accident costing has been virtually confined to the road accident situation but with the recent release of a Canadian aircraft accident cost study and with a similar study currently being completed in the U.S., the trend will be towards an analysis of accident "costs" for all transport modes. Unfortunately it would appear that the number of innovative contributions is very low and it is also evident that some of the main differences between conceptual issues and empirical studies have not been resolved. In fact what has occurred is that some researchers have proceeded unencumbered by a conceptual framework and measured empirical costs in the hope that they will provide information about accident reduction priorities. Alternatively, others have attempted to refine to theoretical purety the concept of willingness-to-pay for reduction in risk and have not (at least until recently) been much help to safety policy or accident countermeasure investigation.

The study undertaken by FAIGIN (1) in 1976 provided a road accident social cost framework for the United States with cost estimates for 1975. The Faigin study completed a program of accident cost research initiated by the National Highway Traffic Safety Administration (NHTSA) within the U.S. Department of Transportation. The work involved a thorough researching of available accident cost data and other information to produce what are probably the most detailed and reliable estimates of accident effects and costs given the limitations of existing information.

Major features of the study include:

(i) the development of an expanded range of societal cost categories, each classified by six classes of injury severity according to the "Abbreviated Injury Scale" (AIS) developed by the NHTSA with the assistance of the American Medical Association et al. The purpose of classifying accidents by injury severity was in response to the grossly misleading use of "average accident costs", particularly for road accidents.

(ii) the omission of estimates for "pain and suffering" which were contained in the 1971 U.S. preliminary estimates. It was considered that no dollar value could be estimated which truly reflected this "cost" mainly because court awards for pain and suffering appeared to be strongly related to a judgement of culpability.

(iii) more thorough research into the effects of (non-fatal) injuries upon work time lost and levels of permanent impairment in the case of more serious injuries.

The unit cost framework outlined in the Faigin report represents possibly the best attempt to bridge the gap between "loss accounting" and willingness-to-pay measures. Mainly for this reason, one of the most recent Australian studies undertaken by ATKINS (2) adopted a similar unit cost framework. The Atkins' study of social and economic costs of road accidents in Australia was commissioned in 1979 by the Office of Road Safety of the Department of Transport. It provides a unit cost framework by injury severity level showing preliminary estimates for 1978.

The main objective of the study was to review the scope of previous work on the valuation of accident costs with the aim of extending the coverage and measurement of road accident costs in Australia to reflect a comprehensive concept of social cost and welfare. Atkins provides a cost framework using the AIS Scale as in the Faigin Report although this was considered "ambitious" given the limitations of existing Australian data sources. Nevertheless, to use it as the basis of a set of preliminary accident cost estimates for Australia, it was considered desirable to retain the most complete conceptual framework available.

Atkins emphasised that the study recognised and suffered from deficiencies inherent in the cost formulations, a fact also acknowledged by Faigin in her report, these being mainly that social cost estimates can represent only minimum estimates of the true value society places upon the benefits from accident reduction. Therefore it is pointed out that use of the cost estimates, however accurate as indicators of the benefits to be gained from accident reduction, is subject to some limitations.

Another recent study also commissioned by the Office of Road Safety involved the Melbourne roadside pole collision research study by FOX et al (10) in 1979. Although by intention only a partial coverage of road accidents in a metropolitan area, the study was of major size and significance which collected and analysed cost data and then applied detailed accident cost estimates in benefit-cost evaluations of proposed accident countermeasure programs. Fox et al adopted with some modification the social accounting framework of costs contained in the U.S. study of Faigin.

Because of controversy surrounding the method of valuation of foregone income of victims, three sets of average accident costs were presented: current resource costs only; total resource costs net of consumption expenditure; and total resource costs. Data was collected from 879 pole accidents which required classification of costs by injury severity. The study suggested that with annual social costs of $23 million per year resulting from pole accidents, a range of accident countermeasures should be developed and evaluated according to benefit-cost criteria.

A research paper by LAWSON (7) in 1978 details a set of accident cost estimates for Canada for the years 1976 and 1978 and provides assessment of the theoretical literature relevant to accident cost concepts and estimates. Lawson argues that the theoretically correct concept of estimating costs is "willingness to pay" and that "ex post" costing weakens the effectiveness of evaluating safety program benefits in accident reduction. He concludes like most other authors that measurement of emotional losses, pain and suffering, etc. due to accidents, although a valid social cost, has so far eluded acceptable quantification, ensuring that remaining "loss accounting" methods will produce only minimum cost estimates which require caution in their application to safety program evaluation.

A New Zealand study in 1976 by SHERWIN (11) presents some generalised total cost estimates for road accidents in N.Z. for 1975, together with an assessment of the estimation task. Total costs were estimated at between N.Z. $160 million and N.Z. $170 million for that year of which foregone <u>net</u> income comprised about 16%, (compared with Aust. 31% for 1978), and property damage was about 42% (Aust. 30%, 1978). The net income figure used would produce a lower foregone income, i.e. value of life. Sherwin used a modified form of the "life model" approach developed earlier as a basis for computing present value of foregone incomes. He did not quote <u>average</u> accident costs and highlighted a significant feature of accident statistics, namely that they are generally characterised by highly skewed distributions. This shows that the general use of average cost measures is often meaningless and may therefore be of limited usefulness in public decision-making.

A study sponsored by the Transportation Development Centre for Transport Canada and undertaken by a team headed by Peat, Marwick and Associates costed aircraft accidents in Canada for 1976-79. In addition, a costing model was developed which enables computation of the cost of any aircraft accident on the Accident/Incident Data System (AIDS) file of the Aviation Safety Bureau.

The study was an attempt to quantify the benefits to be derived from investments in safety improvements and aviation safety programs. It was found that just three cost components account for about 90% of total annual costs of around $100 million: fatalities and injuries, aircraft hull damage and loss and search and rescue. The study team adopted the human capital (foregone income) method for valuation of life with the qualification that it represents minimum values only. Pain and suffering and other non-quantifiable items are not expressed in dollar terms.

The overall social cost framework follows a traditional accounting approach incorporating a number of cost components although there is no allowance for losses to others, family, community, etc. attributable to aircraft accidents, nor for any detailed costing for legal and court proceedings. The study determines two values of life; option A to be used for general population ($176,500), and option B for aviation sub-section or targetted population ($298,200). There is no reference to recent work carried out by researchers such as Arthur in relation to attempts to define a more realistic value of life by relating the foregone income approach to that of "willingness to pay" concept. The report suggests the need for refinements to the costing model and ways of translating accident costs to program benefits are considered.

Chapter 3

FRAMEWORK OF COST ESTIMATES FOR AIRCRAFT ACCIDENTS.

3.1 Introduction

In this chapter a description of preliminary cost estimates is given for aircraft accidents in Australia for 1980. The estimates, while adding a quantitative dimension to the measurement of accident severity, will enable the assessment of some basic losses to society as a result of aircraft accidents. A number of cost components are identified which will provide some indication of the scope of the human problem. However, it must be emphasised that the total of individual cost estimates presented here should not be interpreted as the value placed on a human life or as the total cost of a fatality or injury to society. Neither is it the total amount that society might be willing to spend to save a life or to prevent an injury. The cost components and the total of these components must be regarded as an indication of the significance of the aircraft accident problem. Though the societal cost estimates can be useful in a benefit-cost context, it should be recognized that a benefit-cost ratio or net benefit figure is only one component of a relatively considerable number of social and technological factors that must be considered in evaluating the worth of an accident prevention program.

The general approach in this study is similar to that adopted by both Faigin in the U.S. and the Australian study by Atkins, that is, a social cost framework incorporating the human capital approach to loss of life together with tangible or directly measurable costs. However, given the limited time and resources that were available, estimates for some cost categories have been excluded. Nevertheless the more significant cost components are included and these should adequately reflect the magnitude of the losses to society as a result of aircraft accidents.

The cost elements can be separated into two main groups:

1. "Costs" of Fatalities and Injuries
   - lost production/consumption
   - hospital and medical costs

2. Other Direct Accident Costs
   - aircraft hull damage/loss
   - search and rescue
   - accident investigation costs.

Among the other direct and indirect cost categories not included because of time constraints and practical problems of data gathering were the following:

- legal and court costs
- insurance administration costs
- general property damage
- lost productivity of damaged aircraft
- overall financial impact on aviation industry.

Although in themselves these cost elements may consume or displace significant resources, they are not large compared to other costs and are unlikely to have a high resolving power in terms of total aircraft accident costs.

In addition, mention should be made of non-quantifiable an intangible accident effects, termed "costs" which include pain and suffering, grief to others, loss of personal relationships etc. These qualitative losses represent a real loss of social welfare, both to individuals and society at large and despite attempts by courts to value these losses in compensation determinations, generally they defy satisfactory measurement. Therefore, like most other accident cost studies, no attempt is made here to place a monetary value on these losses.

3.2 Data Availability/Reliability.

The data necessary to undertake this cost study was derived from a number of sources. In some cases it was readily available but occasionally it was necessary to request vital information and statistics from organisations or individuals outside the Department. Because there is no central recording of casualty information such as types and extent of injuries, hospitalisation periods, time off work etc, efforts had to be made to gather such information on an individual accident basis. In the case of road accidents, a lot of this information is available from bodies such as the Motor Accidents Board of Victoria.

The most basic and essential statistical information required for the estimation of unit and total costs is the number of aircraft accidents and accident victims and type of aircraft. This was obtained from the BASI Accidents and Incidents (A & I) reporting system computer file. The A & I file contains data available for analysis for the past 15 years accounting for approximately 68,000 Australian aircraft accident and incident records. Some of the data required for this study were accessed through the computer file but obviously not all the information stored is directly useful for costing purposes. A significant amount of information required to assist with costing was extracted directly from accident report files held within the BASI file registry.

Income statistics were obtained from the Australian Bureau of Statistics for calculation of loss of foregone income. Information relating to hospital and medical costs was sought from hospitals involved with accident casualties and generally this was a sucessful exercise. Precise costing, as to be expected, was not available but hospitalisation periods were supplied for all accident victims.

Some problems were encountered with determination of search and rescue costs. The Finance Branch of the Department of Aviation was able to supply gross figures for air/sea SAR which are not a true cost of actual resources consumed as a result of specific aircraft accidents. Efforts to ascertain SAR costs of accidents also indicate that there is no procedure to record total search costs for individual accidents. Further reference is made to this in the recommendations in Chapter 4.

It was necessary to contact a number of aviation insurance companies to obtain reliable information regarding loss and damage of aircraft.

Given the scope of this report and its limitation as to the major cost components it can be satisfactorily concluded that sufficient reliable data and information was available to conduct a viable preliminary cost study of aircraft accidents.

3.3 Description of Accident Cost Estimates.

3.3.1 Fatalities

The actual costing methodology for fatalities and serious injuries is detailed in Appendix C and recent studies on the value of life which could have significant implications for the cost of a fatality are discussed in Appendix D.

Table 1 shows a matrix of unit or average accident costs for nine cost categories each separated according to either a fatal or serious injury accident. This study finds that the average cost of a single fatality as a result of an aircraft accident was $482,000 ($1980). It can be seen that the foregone income component constitutes a major proportion (67%). This compares with a foregone income proportion of 74% (at 7% discount rate) in the case of a fatality in a road accident in 1978 (Atkins). Table 1 includes in addition to tangible costs, other non-market cost estimates such as the value of lost income (and services) of accident victims to families and the community and losses to employers and others. The derivation of each of the unit cost estimates is discussed below.

3.3.2 Serious Injuries

The costs of injuries have three main components:

1. hospital costs
2. medical care costs
3. lost earnings and productivity.

Only monetary losses are considered so the resultant values should be regarded as the minimum cost of the injury. The calculated average cost of a serious injury as a result of an aircraft accident was $37,800 ($1980).

It can be seen clearly from Table 1 that the most significant tangible cost component for serious injury is the loss of or damage incurred by the aircraft. Thus whereas this component constitutes around 66% of total injury costs in aircraft accidents, in the case of road accidents, vehicle loss/damage contributes only about 17% of injury costs. This significant difference could be expected because the absolute cost of aircraft is much higher than cars and serious car accident injuries can occur with relatively minor vehicle damage and this is less likely with aircraft.

Despite this, it should be appreciated that serious injuries resulting from aircraft accidents draw upon significant hospital and medical resources. In 1980, just 26 serious injury patients accounted for nearly 1,000 hospital bed days or an average of around 37 days per casualty. Hospitalisation periods covered a wide range - from 2 days to over 6 months. Many of the more serious of these admissions involved spinal injuries including one case of partial permanent disability due to paraplegia. For these cases the average unit cost for hospital services shown in Table 1 would not reflect the costs as a result of surgery and other specialist treatment.

No adequate data was available to assist with the estimation of medical costs due to serious injury. It was considered feasible therefore to use road accident injury medical costs on the assumption that they would incur a similar cost.

Lost earnings and productivity is a further cost of serious injury and increases significantly with degree of injury and/or disablement. These costs are imposed upon not only the victim but employers and society at large. For the purposes of this study, only working days lost due to hospitalisation were considered. It is conceivable that a number of casualties spent many weeks and months convalescing after being discharged from hospital. This foregone income figure therefore should be considered as very much a lower bound estimate.

3.3.3 Aircraft Damage/Loss.

This particular accident cost category is the most significant in terms of direct tangible costs. Hull damage/loss was estimated for the following:

1. all aircraft involved in fatal accidents
2. most of the aircraft in accidents involving serious injury
3. most of the twin-engine aircraft incurring substantial damage or were a total loss but nil injury to occupants.

Information provided by aviation insurance companies on aircraft hull damage/loss for 1980 showed that gross claims exceeded $5.7 million. Given that not all aircraft were included in the above sample, the true cost was probably in excess of $6 million.

However, the losses for 1980 are probably higher than average because two Supplementary Airline turbo-prop aircraft were destroyed; a Beech King Air 200 and a Swearingen Metroliner amounting to a loss worth over $2.5 million. A Beech King Air 200 was also destroyed in a fatal accident during 1983.

The breakdown for costs of destroyed/damaged aircraft is as follows:

ACCIDENT TYPE	VALUE OF LOSS $M
FATAL - 26 Aircraft	2.75
SERIOUS INJURY - 20 Aircraft	0.69
NIL INJURY - Twin Engine, 29 Aircraft	2.26
Total Loss	5.70

As shown, aircraft damage/loss totalled approximately $2.75 million in fatal accidents. The average cost per fatality (57 fatalities) is therefore around $48,250. The cost per serious injury is $24,640 and these figures are included in the average unit costs in Table 1.

Another possible method of estimating the value of the loss of aircraft is to segregate aircraft into various weight categories and derive an average value for each category. This was the approach adopted by the consultant team in the Canadian cost study. They determined average aircraft values according to ICAO weight categories but only for aircraft below 5,700kg. For aircraft above this weight, individual values were determined. Closer inspection revealed however that the average values were generally very low for some of the types of aircraft that would fit into the particular weight category.

The problem essentially is that average figures are usually very misleading and that is particularly the case here where such a diverse range of aircraft fall into a particular weight category.

This problem would need to be resolved in any future study especially if a computer costing model is to be developed.

3.3.4 Family and Community Losses.

This cost category represents the production losses as a result of accidents outside the normal working week and accounts for work and services performed for the family and home and for voluntary services to the community. The losses are significant and are amenable to measurement on the opportunity cost principle. This method of valuation represents an estimate of foregone "non-market" services contributed by accident victims.

The average time devoted to identified functions (e.g. home maintenance and other household tasks, upbringing of children etc) was estimated in 1976 in the U.S. by Faigin (1) as 10 hours per week for home and family and 2 hours per week for voluntary community activity, representing 30% of the working week.

Thus the proportion of 30% of market income derived by Faigin is adopted as the basis of family/community losses in Table 1 representing 30% of foregone income costs in the same table.

It is worth mentioning that a 1976 study by Needleman (12) suggested that a major shortcoming in value of life models was failure to take into consideration the valuation of risk of death by all those <u>other</u> than the person at risk. Using medical data on human kidney transplants, Needleman was able to infer a relative valuation of life by the patient's relations representing about 45% of the individual's <u>own</u> valuation of life. If the valuation estimate for friends is included, Needleman's 1976 study suggests a 50% increase over the individual's own valuation of life saving which represents the total <u>community</u> willingness to pay to prevent a death (as distinct from ex post "cost"). Thus in recognition of this finding, the Faigin estimate of 30% of foregone income for family/community losses would appear conservative.

3.3.5 Search and Rescue

As mentioned previously, problems were experienced in obtaining data on SAR activity. In the first instance, there is no recorded tally of SAR flying hours on the BASI A & I computer file, although there is provision to record this information on the Department's central computer. This still doesn't solve the problem of determining the direct costs associated with activated searches because of involvement by a number of different organisations and the large number of incidental expenses. The consultants undertaking the Canadian cost study considered it appropriate to divide the total costs of SAR i.e. all overheads and fixed costs, by the number of incidents for which a search was coordinated.

For this study, only direct flying costs will be considered. In 1980 there were four major searches as a result of fatal aircraft accidents and a minor search involving serious injury. With approximately 250 hours flown in search activity during 1980 at a cost of $200 per hour (aircraft operating costs, foregone wages and production etc) gives a direct cost of $50,000. This would realistically be a minimum figure and with 7 fatalities resulting from accidents involving searches, the cost is approximately $7,000 per fatality.

This estimate is somewhat crude but must suffice until more accessible information is available on SAR activity costs.

3.3.6 Accident Investigation.

These costs represent the direct variable resource costs relating to accident investigation of all aircraft accidents. A breakdown of costs for specific accidents is not recorded, so again it was necessary to determine an approximate average for all accidents. This was done by dividing the total direct costs of investigation for 1980 ($70,000) by the total number of accidents (253). The estimate in row 8 of Table 1 shows this average unit cost. Some fatal accidents would consume more investigation resources than this figure indicates. However, it should be recognised that there need not be any correlation between accident severity and investigation costs. The average cost for investigation shown in Table 1 might appear low but as an average figure does not represent the true level of effort and resources involved. It is to be expected that considerable variation would occur in these costs with accident severity and that therefore average figures are misleading.

3.3.7 Losses to Others.

This cost category is a non-market estimate similar in concept to category 2 (losses to family/community). It represents the losses to employers and others as a result of aircraft accidents including labour replacement and training, time spent in visiting patients, transport, home-care, etc. It is therefore an estimate of the opportunity cost of the time spent in all these and other accident-generated activities. The estimates in Table 1 are based on the U.S. National Highway Traffic Safety Administration study (1971) and adopted by Faigin and Atkins. It is calculated as 10% of lost income for serious injury and 1.2% of foregone income for a fatality.

3.4 Summary of Costs.

The unit cost estimates described above are expressed in 1980 dollars. Various factors such as inflation would necessitate the re-calculation of these unit costs for years subsequent to 1980 in order to show accident costs in current dollars on an ongoing basis.

Table 2 shows that the estimated total cost of aircraft accidents in Australia was approximately $31 million in 1980. Foregone income was the largest cost category comprising 60% of total costs followed by losses to the family and community at 18% while aircraft loss and damage accounted for 18.5% of costs. At just on 1% medical and hospital costs were a relatively small proportion of the total.

By category of accident, fatalities represented a very high proportion at 89%, injuries 3.4% and accidents in which aircraft were damaged or destroyed with nil injuries to occupants were 7.3% of total costs.

Using the information summarised in Table 2, an abbreviated set of unit accident costs is shown in Table 3, both according to average costs per person and per accident.

It can be seen that while a single fatality has been costed at over $482,000, the average cost of a single fatal accident for 1980 was in excess of $1 million. However, the average cost of all accidents for 1980 was only about $122,000. Thus the unit cost of a fatal accident was about 9 times that of the average accident cost but this should not be interpreted without knowing more about the distribution of the different types of accidents.

3.5 Accident Costs by Flying Category.

Table 4 shows approximate costs of accidents, as a proportion of total costs attributed to the various categories of flying. The information provided in the table gives some indication of the specific areas where resources need to be directed to reduce accident costs. The cost estimates in column 5 are based on the 1980 dollar estimate for the cost of a fatality as calculated in Appendix C of this report. These estimates are therefore a lower bound approximation and subject to the shortcomings of estimating the value of a human life.

The table shows an approximate measure of relative frequency of accidents for each category of flying, i.e. accidents per hours flown. The aim is to determine an indication of relative priority, e.g. (probability of occurrence) x ("cost" of accident). This is, however, only the first step. Even if figures are reliable we need technical and professional investigation of the cost effectiveness of reducing specific accident risks, e.g. Type A.

The three years selected show a considerable variation in the proportion of total costs attributed to some of the categories of flying.

Most noticeable is the cost of "private/business" accidents which varied from 77% of costs in 1976 to 32% in 1980, reflected by the significant difference in the fatality rate for this category of flying. However, for the period 1977-81, private and business flying accounted for 32% of total flying hours but 48% of accidents and around 55% of total societal costs of accidents.

Another point of interest is the dramatic effect on costs as a result of commuter (now Supplementary Airline or SAL) accidents. The commuter accident in 1980 with 13 fatalities contributed over 20% of total costs for that year although flying activity for the category was only 7.4% of the total hours and accidents were only 2.1% of the total. Quite clearly, the magnitude of economic and social costs both in absolute and relative terms as a result of such multiple fatality accidents suggest that significant resources should be directed to preventing further accidents of this nature.

It can be seen from the table that gliding operations contributed significantly to accident costs in 1980 at 10% of total costs whilst accounting for around only 4.4% of flying hours. The statistics were similar again for 1981 when gliding contributed approximately 10% to total accident costs. The costs of fatalities and serious injury trauma as a result of gliding operations suggest that increased attention needs to be given to accident countermeasure programs for this category of flying. The number of spinal injuries would also suggest the need to look at the crashworthiness of this type of aircraft.

TABLE 1

AVERAGE ACCIDENT COSTS AUSTRALIA 1980 PRELIMINARY ESTIMATES (7% DISCOUNT RATE)		
COST CATEGORY	FATAL $	SERIOUS INJURY $
1. Foregone Income	323,500	4,400
2. Family, Community Losses	97,050	1,320
3. Hospital	810*	4,810
4. Medical	470*	1,210*
5. Rehabilitation	960*	680*
6. Aircraft Damage/Loss	48,250	24,640
7. Search and Rescue	7,000	---
8. Accident Investigation	280	280
9. Losses to Others	3,880	440
TOTAL	482,200	37,780

* Denotes 1978 estimates drawn directly from Atkins Road Accident Study, and adjusted by suitable index for 1980.

Note : Serious injury hospital costs based on 26 hospital cases.

TABLE 2

SUMMARY OF TOTAL AIRCRAFT ACCIDENT COSTS : AUSTRALIA 1980 (7% DISCOUNT RATE)				
COST CATEGORY	FATALITIES $	SERIOUS INJURIES $	AIRCRAFT LOSS/DAMAGE $	TOTAL $
Foregone Income	18,439,500	114,480	---	18,553,980
Family/Community Losses	5,531,850	34,320	---	5,566,170
Hospital, Medical etc	127,700	177,980	---	305,680
Aircraft Loss/ Damage	2,750,250	687,000	2,264,000	5,701,250
Other Costs	636,120	46,480	---	682,600
TOTAL	27,485,420	1,060,260	2,264,000	30,809,680

TABLE 3

SUMMARY OF AVERAGE ACCIDENT COSTS
AUSTRALIA 1980 (7% DISCOUNT RATE)

COST CATEGORY	FATALITIES $	SERIOUS INJURIES $
1. Per Person		
Foregone Income	323,500	4,400
Family/Comm Losses	97,050	780
Medical, Hospital etc	2,240	6,700
Aircraft Loss/Damage	48,250	24,640
Other Costs	11,160	720
TOTAL	482,200	37,240
2. Per Accident	$	$
Foregone Income	737,580	5,200
Family/Comm Losses	221,270	1,370
Medical, Hospital etc	5,100	8,090
Aircraft Loss/Damage	110,000	31,230
Other Costs	25,440	2,110
TOTAL	1,099,390	48,000

TABLE 4

AIRCRAFT ACCIDENT COSTS - CATEGORIES OF FLYING
(1980/1978/1976)

CATEGORY	HOURS FLOWN ('000's)	%	ACCIDENTS NO.	% of TOTAL	COSTS (APPROX) $M	%
(1980)						
COMMUTER	139.6	7.4	6	2.1	6.5	21
CHARTER	330.2	17.6	25	8.9	2.0	7
AGRICULTURAL	130.8	7.0	30	10.7	3.0	10
FLYING TRAINING	345.7	18.4	27	10.0	-	-
OTHER AERIAL WORK	276.0	14.7	47	16.7	5.5	18
PRIVATE/BUSINESS	573.1	30.5	118	41.6	10.0	32
GLIDING	82.0	4.4	28	10.0	3.0	10
ROTARY WING	114	6.0	3	15	2.0	6.5
(1978)						
COMMUTER	109.7	6.7	5	1.8	-	-
CHARTER	234.7	14.3	19	6.9	4.5	14
AGRICULTURAL	127.7	7.8	23	8.4	1.0	3
FLYING TRAINING	339.4	20.7	38	13.8	3.0	10
OTHER AERIAL WORK	188.2	11.5	47	17.2	5.5	18
PRIVATE/BUSINESS	539.9	33.0	117	42.7	16.0	52
GLIDING	97.0	6.0	25	9.1	1.0	3
ROTARY WING	56.7	3.5	5	9.8	2.5	8
(1976)						
COMMUTER	80.0	5.6	1	0.4	-	-
CHARTER	242.6	16.9	20	7.3	0.5	2
AGRICULTURAL	83.7	5.8	14	5.1	0.5	2
FLYING TRAINING	303.1	21.0	36	13.1	-	-
OTHER AERIAL WORK	176.9	12.3	22	8.0	2.0	6.5
PRIVATE/BUSINESS	461.7	32.0	152	55.7	24.0	77
GLIDING	90.4	6.3	28	10.2	1.0	3
ROTARY WING	36.9	2.5	0	2.2	-	-

<u>SOURCE</u> : BASI SURVEY OF ACCIDENTS 1980, 1978, 1976. COST FIGURES BASED ON 1980 COST ESTIMATES IN THIS REPORT.

<u>NOTE</u> : ROTARY WING FIGURES ARE SEGREGATED AS AN AIRCRAFT TYPE RATHER THAN CATEGORY OF FLYING. HOURS FLOWN AND ACCIDENTS FOR ROTARY WING ARE INCLUDED IN THE FLYING CATEGORIES LISTED.
COST PERCENTAGES ACCOUNT FOR ONLY THE COSTS OF FATALITIES AND NOT ACCIDENTS INVOLVING INJURY OR AIRCRAFT DAMAGE ONLY AND THEREFORE DO NOT NECESSARILY TOTAL TO 100%.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 General Comments

The accident societal cost framework presented in this study incorporates a number of identified resource costs which are displaced as a result of aircraft accidents. In addition, certain non-market and intangible accident "costs" are incorporated which reflect an attempt to measure the (minimum) required extra compensation above market cost levels which the community would be willing to allocate to achieve accident reductions. However, in the light of some of the conceptual and empirical problems discussed in Chapter 2, this study supports the view that the loss accounting approach to accident cost measurement - whilst useful in some areas of accident policy - is by itself of limited usefulness in respect of its principal objective : the evaluation of accident reduction programmes.

Moreover, debate which has arisen concerning the acceptability of certain "intangible" cost components such as pain and suffering, losses to families, the community, employers etc., reflect the unsatisfactory nature of financial or economic resource cost estimates as a measure of the social benefits to be gained from accident reduction.

As pointed out earlier in the report, the conceptually correct measure of what the community would be willing to pay for accident reduction is a direct measure of the demand for such a risk reducing benefit. The "costs" of fatalities and injuries together with the economic resource costs of aircraft accidents represent only the minimum estimates of what the community would be willing to pay for accident counter-measures.

To further complicate the problem, there is almost no doubt that certain ethical and moral considerations would be raised in any accident policy evaluation. Does society really value lives saved consistent with the present value of foregone income by age? For example, in the calculus of Appendix C, the lives of younger to middle-age males, who are disproportionately involved in aircraft accidents, are "worth" more in income terms than younger females. Also, on this basis the aviation sub-group, for example private pilots, have a higher life valuation than other groups in the community. Is it therefore correct to suggest that more resources be allocated to saving lives of private pilots than commercial airline travellers? Is it possible that the community at large has the perception that the risk of death as a result of an aircraft accident is greater than other modes of travel? Many might have an innate fear of dying in an aircraft accident than in other categories of accidents. Knowledge of community attitudes to these questions would help to indicate the demand for air safety and assist accident policy planning. So while the foregone income calculations may reflect an unemotional assessment based upon individual cases, the community as a whole may consider that morally all lives are equal in their right to be saved, regardless of age differences or economic/social status. Further research in this area may be warranted to clarify some of the issues.

In the meantime, the values for foregone income suggest that accidents resulting in fatalities or serious injury are of greater relative importance to society than other categories of social cost such as aircraft damage/loss accidents. In Table 2 of Chapter 3, the two categories of foregone income and losses to the family and community together account for over 78% of total accident costs whilst aircraft loss/damage is 18%. These three categories thus represent around 96% of calculated costs. Clearly then, any variation in their estimation procedures and sources will tend to overshadow refinements to other remaining cost categories such as medical costs, accident investigation and losses to others. Also inclusion of other cost estimates such as insurance administration, legal and court etc., is not likely to significantly add to total accident costs.

4.2 Conclusions/Recommendations on Data Sources

The following conclusions and recommendations are made in respect of the adequacy of data sources for each of the cost categories considered.

(i) Foregone Income Resulting from Fatalities and Serious Injuries : a more recent income survey would need to be done to update the present estimate. Also, a survey of incomes pertaining to the aviation sub-group would allow a more precise 'value of life' option B estimate reflecting Australian conditions.

(ii) Family and Community Losses : estimated at 30% of (i) by the Faigin study (U.S. 1976). Research is needed to provide an estimate for Australian conditions.

(iii) Hospital, Medical and Related Costs : there is no centralized source of medical cost data in relation to casualties from aircraft accidents. In the case of road accident casualties, the only known source of such data is the Motor Accidents Board in Victoria. In relation to aircraft accident casualties, the information held at the Department of Aviation's Medicine Branch would not be sufficient to assist with any detailed costing. Therefore, in view of the fact that serious injury cases resulting from aircraft accidents usually contact the hospitals concerned for further assistance regarding hospital and related costs.

(iv) Aircraft Damage/Loss : information on aircraft insurance claims was obtained from the major aviation insurance companies. These companies would be the most fruitful source of aircraft damage/loss estimates in any future research. The possibility of establishing a joint "data bank" should be investigated.

(v) Search and Rescue : accessible cost data for this component was not available. Some SAR information is stored on the Department's central computer which could be of use in any further research. It would be useful if the SAR OPS section maintained a running account of the cost of SAR activities in relation to aircraft accidents, if this was at all practicable.

(vi) Accident Investigation : because of the large number of incidental expenses involved in aircraft accident investigation it is not feasible to cost out these expenses on an individual accident basis, except perhaps in the cases of major accidents. More precise recording of investigation costs would facilitate future research. However, this component of accident costs should not be seen out of context as it does not show a true measure of the investigation effort.

(vii) Losses to Others : no data is available for Australian accidents so the U.S. data was used. A socio-economic survey of the workforce and the effects of accidents on industry in Australia is needed.

(viii) Pain and Suffering : no Australian studies are available so this cost was considered beyond the scope of this preliminary study. Two approaches are possible which could facilitate estimates for Australia

(a) a survey of compensation awards for death or personal injury in relation to aircraft accidents in Australia

(b) a theoretical study in addition to the survey to assess whether it would be appropriate to relate "pain and suffering" derived from (a) as a proportion of foregone income.

4.3 Main Findings of Report

The major findings of this report can be summarized as follows:

(1) The average cost of a single fatality as a result of an aircraft accident was calculated at $482,000 ($1980), with a cost of $38,000 ($1980) for a serious injury.

(2) The total ex post costs to the community of aircraft accidents was approximately $31 million in 1980.

(3) Recent value of life studies suggest that the total community willingness to pay to avoid all aircraft accidents could be as high as $100 million. (This is not to say that accident countermeasure expenditure of $100 million is warranted.)

(4) Quite significant hospital and medical resources are displaced despite the relatively few serious injury cases.

(5) Aircraft damage and loss (around $6 million in 1980) is a significant proportion of total costs even including accidents not involving casualties.

(6) The "private/business" category of flying accounts for a disproportionate amount of total costs over the longer term.

(7) Accident costs resulting from gliding activity significantly increased in 1980, despite the below annual average number of hours flown.

(8) Approximately half the number of serious injury cases involved spinal injuries requiring lengthy hospital and/or rehabilitation periods. Four out of six cases of serious injury as a result of gliding activity in 1980 sustained spinal injuries including one cord injury (paraplegia).

Finally, it is concluded that the framework of unit costs in Table 1 proposed in this study, from which the preliminary estimates of total accident costs were derived, provides a set of minimum social cost estimates for Australia capable of useful application in the evaluation of air safety programmes. (Where the "minimum" mostly relates to the foregone income definition, i.e. foregone income equates to willingness to pay.) However, these estimates need careful qualification in their use and further refinement in any future research.

APPENDIX A

GLOSSARY

NOTE: The following definitions are taken from ICAO Annex 13, 1981 to "International Standards and Recommended Practices:.

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 those persons have disembarked and in which

(a) any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached to the aircraft; or

Note: Specifically excluded are: death from natural causes and fatal or serious injury to any person on board whether self-inflicted or inflicted by another person, or to ground support personnel before or after flight, or fatal or serious injury which is not a direct result of the operation of the aircraft, or which concerns stowaways.

(b) the aircraft suffers substantial damage or is destroyed; or

(c) the aircraft is missing or is completely inaccessible.

FATAL INJURY - Any injury which results in death within 30 days.

SERIOUS INJURY - Any injury other than a fatal injury which:

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

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

(c) involves lacerations which cause severe haemorrhage, nerve, muscle or tendon damage; or

(d) involves injury to any internal organ; or

(e) involves second or third degree burns, or any burns affecting more than five percent of the body surface.

MINOR INJURY - Any injury other than as defined under 'Fatal Injury' or 'Serious Injury'.

DESTROYED - Consumed by fire, demolished or damaged beyond repair.

SUBSTANTIAL DAMAGE - Damage or structural failure which adversely affects the structural strength, performance or flight characteristics of the aircraft and which would normally require major repair or replacement of the affected component. The following types of damage are specifically excluded: engine failure; damage limited to an engine or its accessories, or to propeller blades; bent fairings or cowlings; small dents or puncture holes in the skin; damage towing tips, antennas, tires, or brakes.

MINOR DAMAGE - Damage other than as defined under 'Destroyed' or 'Substantial Damage'.

APPENDIX B

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APPENDIX C

This appendix details the methodology used to quantify the fatality and injury costs of aircraft accidents. Because of their relative importance and greater complexity, it was considered desirable to treat them separately. The tables within this appendix provide the more detailed support data and calculations and illustrate the process of deriving the final cost figures.

1. FATALITIES

The basic accident statistics of interest in the present study are presented in Table 5. This shows all accident and casualty statistics for each year from 1976 through to 1983. The year under study (1980) had both fatal and total number of accidents close to the eight year average although the number of fatalities at 57 was higher than average (due to a major commuter accident at Sydney Airport in which 13 were fatally injured). There were 56 general aviation and 5 gliding fatalities totalling 61, however for the purposes of this study, 4 New Guinea nationals killed in an Australian registered aircraft in New Guinea will not be included. Gliding fatalities and serious injuries were included and in 1980 these contributed significantly to accident costs.

The method used to determine the cost of fatalities is the human capital or foregone income approach as discussed in Chapter 2 which has been used in most major accident cost studies including Faigan and Atkins. The value of lost production for fatalities is heavily dependent on the age and sex distribution of fatalities together with population mean income for Australia in 1980.

There have been arguments against distinguishing sex and age in the calculation of average productivity loss for fatalities and injuries but the distinction will be made in this study for the following basic reasons:

(i) the distribution by sex of aircraft accident fatalities differs from the overall sex distribution of the general population. (Of the total number of persons killed in aircraft accidents in 1980, 80 percent were males).

(ii) having calculated an average productivty loss, that value is applied to every victim thus satisfying the criteria of equity.

(iii) use of male-only income as a proxy for all productivity losses probably cannot be justified as yet : when there is a thorough mix of men and women in what are now considered as sex-defined roles and occupations changes in the mean income level may eventually result in a higher average productivity loss.

Using the income data in Table 6 the production calculations are carried out from age 15 through to age 64 only, increasing at 3 percent per year for productivity with a 7% discount rate. The results of these calculations in Table 7 show the net present value of the future income stream for each age group and each sex. These were then weighted in proportion by fatalities for each age group and sex giving the results shown in column 3 of Table 7. From the average direct productivity loss per fatality in each age group it was possible to calculate the overall gross income foregone per fatality which in 1980 was $245,072.

This general approach provides an estimate of the discounted value of future work efforts which could be uniformly applied in all government decision making. However, within this conceptual approach there are alternatives which might be adopted for aircraft accident victims. From the policy viewpoint, the alternatives vary according to the extent that distinct values of human life are developed for sub-sectors of the total population. Attempts at this may in fact be difficult due to rather limited data to differentiate the sector(s) by income as well as demographic status.

The Canadian research team actually carried out surveys of air travellers, obtained income figures for commercial aircrew and derived an income profile of private flyers from a sample of readers of Canadian Aviation. The team decided to treat aircraft accident victims as a separate group and therefore employed these methods to determine income and demographic profiles. Earnings ratios between the general population and aircraft accident subgroups were calculated although a number of shortcomings and simplifying assumptions were acknowledged with this technique.

The earnings ratios that were derived are as follows:

SUBGROUP	EARNINGS ADJUSTMENT FACTOR FOR SUBGROUP POPULATION
ALL COMMERCIAL CREW	1.62
PILOTS AND COPILOTS	2.25
OTHER CREW	1.03
COMMERCIAL PASSENGERS	1.15
PRIVATE PILOTS (EMPLOYED MALES)	1.32
ALL AIR ACCIDENT VICTIMS	1.34

(SOURCE : THE COSTS OF AIRCRAFT ACCIDENTS IN CANADA)

The rationale behind this approach is to prescribe a uniform value for all lives lost in air accidents and thus compromise the principle that a single value of human life should be uniformly applied in all government decision making. It also gives a more appropriate indicaton of the actual value of lost production associated with air fatalities. For this study, this alternative option will be adopted using the Canadian earnings adjustment ratios on the assumption that these could be realistically applied in the Australian situation. Canadian and Australian per capita incomes are similar and until resources are available for research on incomes for the aviaton sector in Australia, the Canadian ratios will be used as a lower bound estimate for Australia.

Thus we have the non-adjusted value of life figure which could be used in all government safety programs -

Alternative A - $245,070

Applying the earnings adjustment ratio derived for private fliers of <u>1.32</u> to used in all aviation safety programs gives -

Alternative B - $323,500

2. SERIOUS INJURY

For the purposes of this study, only the costs of serious injury are examined as explained in Chapter 2. Also no separate cost categorisation will be made for spinal cord injuries involving some form or degree of paralysis. There was one such case in 1980 and therefore no allowance has been made for this injury in the costing. The basic serious injury statistics are given in Table 8. It is interesting to note that the overwhelming majority of serious injuries involved males and 35% of the total was within the 20-29 age group.

(i) Hospital Costs

No centralised records are kept containing information on all serious injury victims as a result of aircraft accidents. Because this study takes into consideration only the accidents from one year which involved hospitalisation of just 26 cases, it was considered feasible to contact all the hospitals concerned for further information. Precise costing figures were unavailable but with the knowledge of hospitalisation periods and an average daily hospital cost, a satisfactory estimate can be achieved. The estimate provided must be treated as a lower bound estimate; no costs for the specialist surgery and other services have been adequately allowed for and given the nature of some of the injuries, these costs must have been significant. In addition no information was able to be gained on a 57 year old male who sustained spinal injuries. Table 9 provides the hospitalisation period profile.

Total hospital costs estimated as follows:

Total no. of inpatient hospital days = 962
Average daily inpatient hospital charge = $130 (1980)
(NOTE: Large metropolitan public hospitals would exceed this).
Estimated Total hospital costs = $125,060 (26 cases)
Average unit cost (26 admissions) = $4,810.

This average unit cost of $4,810 compares with $7,100 for unit costs of road accidents (Australia 1978) under AIS level 3 "severe - not life-threatening". (Atkins study).

(ii) Medical Costs

These were derived from the 1978 road accident study with an appropriate adjustment to 1980.

Average medical cost road accidents (serious injury) 1978 = $1000
Adjusted to 1980 = $1,210
Estimated Total medical costs = $33,880. (28 victims)

(iii) Rehabilitation Costs

As with medical and hospital costs, the cost to the community of rehabilitating accident victims is difficult to measure. The most obvious cost is lost earnings and production discussed below. Significant resources are displaced particularly in the rehabilitation of spinal injury patients and those suffering some degree of permanent disablement. Quite clearly this is very much the situation with aircraft accidents as Table 8 shows. Also the period of hospitalisation is no real indicaton of the rehabilitation period required: the gliding accident victim hospitalised for 4 days with a spinal injury required nearly 4 months rehabilitation and the victim hospitalised for just 2 days with a comminuted fracture of the tibia required a number of months rehabilitation.

The case of the accident victim permanently disabled also as the result of a gliding accident, would have involved very significant rehabilitation costs. Thus the figures used below derived from the ATKINS road accident study must be regarded as very much a lower bound estimate.

Average rehabilitation cost
road accidents (serious injury) 1978 = $560
adjusted to 1980 = $680

Estimated Total rehabilitation costs (28 victims) = $19,040.

(iv) Lost Earnings and Productivity Costs

While hospitalised or disabled and rehabilitating, injured victims may not be able to work or perform home and community services. The costs of this lost productivity are borne directly by the victim, the victim's employer, family and community or else indirectly through insurance premiums paid to private or public agents.

No statistics are readily available on time lost from work due to serious injury as a result of aircraft accidents. Therefore productivity loss only as a consequence of hospitalisation will be considered in this study. Once again this will be a lower bound estimate.

Using the 1980 mean income figures shown in Table 6, the weighted average 1980 income per serious injury is calculated as $13,456. This is then adjusted by the earnings ratio of 1.32 to reflect the aviaton subgroup which brings the average figure to $17,760.

The imputed daily salary is then

$$\frac{\text{average 1980 income per injury}}{\text{working days per year}}$$

$$= \frac{\$17,760}{260}$$

$$= \$68$$

Studies have suggested that the average cost of a day's absenteeism to employers is <u>1.75</u> times the average daily salary. This allows for direct costs of absenteeism as well as indirect costs such as hiring and training of replacement personnel and efficiency losses resulting from work disruption. This adjustment ratio was used in the Canadian cost study to calculate the costs of injury and will be used here.

The adjusted average daily salary (production loss) for 1980 is then $119.

Lost productivity is then calculated as total no. of days hospitalisation x daily salary.

= 962 x $119

= $114,480

average foregone income per serious injury

$$= \frac{\text{total foregone income}}{\text{no. of hospitalised patients}}$$

$$= \frac{\$114,480}{26}$$

= $4,400

(v) Summary of Serious Injury Costs

The total costs arising from serious injury as calculated by this study are given below. As pointed out, lack of data and underlying assumptions contribute to possible errors with each component cost and any final total figure is therefore only at best an indication of the magnitude of injury costs. It could be reasonably assumed however that the final cost figure is very much a lower bound estimate, particularly when no allowance is made for non-quantifiable costs such as pain and suffering etc.

Summary of injury costs:-

Hospital Costs	:	$125,060
Medical Costs	:	33,880
Rehabilitation Costs	:	19,040
Lost Productivity due to Hospitalisation only	:	$114,480
Estimated Total Injury Costs	:	$292,460

CONCLUSION

While it is beyond the scope of this report to examine the nature and extent of injuries resulting from aircraft accidents or the crashworthiness of aircraft, some brief comments ought to be made which might be considered as the subject for further research.

- Hospitalisation periods extend over a very wide timespan which indicates that within the definition serious injury, the nature and extent of injuries sustained in aircraft accidents is very diverse.

- The incidence of spinal injury is very high, over 50% of cases.

  These injuries range from compressed vertabrae fractures to one case of cord injury resulting in paraplegia. Of the five serious injuries resulting from gliding activities, four sustained a spinal injury including the paraplegic case. This suggests the need for a look at the crashworthiness of smaller light aircraft and particularly gliders.

- More information on rehabilitation periods would assist in illustrating the problem of serious injury trauma and help determine a more accurate cost of the injuries especially when considering that spinal injuries often require lengthy rehabilitation periods.

TABLE 5

AIRCRAFT ACCIDENTS INVOLVING CASUALTIES AUSTRALIA 1976-1983					
	ACCIDENTS		CASUALTIES		
YEAR	FATAL ACCIDENTS	TOTAL ACCIDENTS	FATALITIES	INJURIES	TOTAL
1976	19(2)	243(28)	53(2)	557(29)	610(31)
1977	19(2)	221(27)	43(2)	482(30)	525(32)
1978	26(1)	249(25)	57(1)	578(35)	635(36)
1979	19(2)	243(29)	33(2)	464(34)	497(36)
1980	23(4)	253(28)	56(5)	522(32)	578(37)
1981	18(4)	233(25)	48(5)	544(25)	592(30)
1982	28(2)	221(20)	53(2)	520(23)	573(25)
1983	24(1)	285(27)	54(1)	720(26)	774(27)

SOURCE : BUREAU OF AIR SAFETY INVESTIGATION A & I COMPUTER FILE. (1983 FIGURES ARE PROVISIONAL).

NOTE : GLIDING STATISTICS SHOWN IN BRACKETS.

TABLE 6

ACCIDENT FATALITIES - SEX AND AGE DISTRIBUTION MEAN INCOME BY AGE GROUPS - AUSTRALIA 1980					
AGE GROUP	NUMBER OF FATALITIES			MEAN	INCOME
	M	F	TOTAL	M $	F $
0-15	3	1	4		
15-20	2	-	2	6903	6435
20-24	1	-	1	11894	10407
25-29	5	2	7	) 14995	12488
30-34	7	3	10	)	
35-39	6	-	6	) 16269	11979
40-44	13	2	15	)	
45-49	4	2	6	) 16396	11129
50-54	3	1	4	)	
55-59	-	-	-	15504	11979
60-64	2	-	2	13805	11469

SOURCE : AGES OF FATALITIES FROM ACCIDENT REPORT FILES.
MEAN INCOME FOR SELECTED AGE GROUPS FROM AUSTRALIAN
BUREAU OF STATISTICS INCOME SURVEY.

TABLE 7

PRESENT VALUE OF FUTURE INCOME AT MEDIAN AGES - 1980 (7% DISCOUNT, 3% PRODUCTIVITY)				
EFFECTS OF AGE GROUP WEIGHTING ON DISCOUNTED INCOMES - AUSTRALIA 1980				
AGE GROUP	MALE $	FEMALE $	WEIGHTED BY FATALITIES	PROPORTION OF FOREGONE INCOME
0-15	126,000	117,000	123,750	8,684
15-20	157,992	147,138	157,992	5,543
20-24	259,455	227,018	259,455	4,551
25-29	317,003	264,004	301,845	37,068
30-34	299,352	249,303	284,337	49,883
35-39	301,615	222,082	301,615	31,749
40-44	273,583	201,441	263,916	69,452
45-49	239,668	163,948	214,453	22,574
50-54	200,187	135,874	184,108	12,920
55-59	141,987	109,705	-	-
60-64	75,466	62,694	75,466	2,648
AVERAGE GROSS INCOME FOREGONE PER FATALITY :				245,072

TABLE 8

AIRCRAFT ACCIDENTS, SERIOUS INJURY SEX/AGE DISTRIBUTION - 1980						
AGE GROUP	MALE	%	FEMALE	%	TOTAL	%
0-15	1	100	-	-	1	3.6
15-20	2	100	-	-	2	7.1
20-24	4	100	-	-	4	14.3
25-29	5	83	1	17	6	21.4
30-34	1	50	1	50	2	7.1
35-39	7	100	-		7	25
40-44	1	50	1	50	2	7.1
45-49	-	-	-	-	-	-
50-54	3	100	-	-	3	10.7
55-59	1	100	-	-	1	3.6
>60-	-		-		-	
TOTAL	25	89	3	11	28	100

<u>SOURCE</u> : BUREAU OF AIR SAFETY ACCIDENT REPORT FILES

NOTE : OF 28 SERIOUS INJURIES,
1 NOT HOSPITALISED (MINOR COMPRESSED # OF T_{10})
1 NOT CONFIRMED AS HAVING BEEN HOSPITALISED

TABLE 9

SERIOUS INJURY, HOSPITALISATION PERIODS
AIRCRAFT ACCIDENTS - 1980

SEX	AGE	HOSP. PERIOD (DAYS)	INJURY COMMENT	ACCIDENT CATEGORY
M	50	>6 MONTHS (187)		FATAL
*M	17	>4 MONTHS (145)	SPINAL	NON-FATAL
M	23	>4 MONTHS (144)		NON-FATAL
*M	36	4 MONTHS (120)	SPINAL (PARAPLEGIC)	NON-FATAL
M	27	>6 WEEKS (44)	SPINAL	NON-FATAL
M	29	6 WEEKS (42)	SPINAL	NON-FATAL
M	36	>5 WEEKS (37)		NON-FATAL
M	42	>4 WEEKS (30)		NON-FATAL
M	54	>3 WEEKS (24)	SPINAL	FATAL
M	37	>3 WEEKS (22)		NON-FATAL
F	40	>2 WEEKS (18)	SPINAL	NON-FATAL
*M	31	>2 WEEKS (18)		NON-FATAL
*F	29	>2 WEEKS (17)	SPINAL	NON-FATAL
M	29	>2 WEEKS (16)		FATAL
M	29	>2 WEEKS (16)	SPINAL	NON-FATAL
M	24	2 WEEKS (14)	SPINAL	NON-FATAL
M	37	2 WEEKS (14)	SPINAL	NON-FATAL
M	54	2 WEEKS (14)		NON-FATAL
M	36	>1 WEEK (10)	SPINAL	NON-FATAL
M	35	>1 WEEK (9)		FATAL
M	38	5 DAYS		FATAL
M	20	4 DAYS	SPINAL	NON-FATAL
*M	22	4 DAYS	SPINAL	NON-FATAL
M	19	3 DAYS	SPINAL	NON-FATAL
M	13	3 DAYS		NON-FATAL
*F	31	2 DAYS		NON-FATAL

<u>SOURCE</u> : PATIENT RECORDS FROM HOSPITALS CONCERNED

NOTE : ASTERISK INDICATES GLIDING ACCIDENT

APPENDIX D

SUMMARY OF A RECENT VALUE OF LIFE MODEL

As mentioned in earlier sections of this report, the most difficult and controversial aspect with the development of a framework of accident costs is that of determining the value of a human life. Two approaches are possible: the foregone income or human capital approach which is essentially a value of labour (lost production) or the ex-ante willingness to pay approach for reductions in risk of death.

Although the human capital method has usually been adopted for accident costing, the willingness to pay approach is considered conceptually more appropriate. But this approach has generally ignored resource costs and externalities associated with accidents while the human capital approach to the value of life distorts the ex post or 'loss accounting' method of accident costs. However, some scope may now exist for reconciliation of the two methods although further work and empirical testing needs to be done. The development of an elasticity measure[1] which relates willingness to pay to foregone income may resolve the difficulties with the two approaches and is briefly considered below. It is not intended to lay bare the full model here or even attempt to examine the total work undertaken. The interested reader should consult the references.

A number of authors, notably Blomquist (13) and Arthur (8) point to the existence of a relationship between the willingness to pay concept of value of life and some measure of lifetime earnings. This is in the form of an elasticity of lifetime utility[2] with respect to lifetime consumption. The estimation and acceptance of this elasticity concept may be a vital step towards the feasibility of estimating an operational value of life saving in practice.

Blomquist in his 1979 Paper looks at the typical individual's value of a small change in the probability of his survival. Using a simple life-cycle model, the value is shown to be implied by consumption activity which affects risk. Blomquist uses probit analysis of car seat-belt use to estimate the amount that an individual is willing to pay to reduce risk. His model gives an implied average value of life of $370,000 in 1978 dollars. The foregone earnings approach to value of life (V) holds that the value of life and the present value of expected future labour earnings (EARN) are equal and should change on

(1) Elasticity is the relative response of one variable to a small percentage change in another variable, i.e. it expresses the relationship between any two variables.
(2) Utility is the ability of a good, in this case human life, to satisfy human wants.

a dollar-for-dollar basis. This implies that the elasticity of V with respect to EARN is one. But Blomquist goes on to show that his "value of life" estimate is contrasted with the foregone-income approach by demonstrating that a surplus value above earnings exists and the elasticity of the value with respect to earnings is less than one.

It was found that drivers with high earnings place a higher value on their lives and in turn are more likely to use seat belts. Also use of seat belts is found to be greater, the greater their productivity in preventing injury. The probit analysis of seat belt use produced statistically significant and reasonable results.
It was found that if the expected earnings for the average driver is increased 10 percent from the mean value, seat belt use would increase from 23 to 25 percent. From the life-cycle model, this resulted in the value of life, V increasing by 3.1 percent. Thus, since the 10 percent increase in expected earnings produced a 3.1 percent increase in V, the elasticity of the average value of life with respect to foregone earnings is about +0.3 and not 1.0 as in the foregone income approach to value of life. This finding, according to Blomquist, is consistent with the notion that people get more from life than what they derive from market consumption.
Using a different theory and different body of evidence, the value of life estimated in Blomquist's paper is of the same order of magnitude as that of the other study based on the willingness-to-pay approach. By sampling the population at large (automobile drivers) the problem was avoided of basing inferences about the willingness to pay on groups of people such as those involved in hazardous occupations and who may have atypical risk attitudes.

The Blomquist Paper apart from its very useful derivation of an elasticity value of about 0.3, also adds further evidence that people are willing to pay (accept) a determinable, finite amount for an increase (a decrease) in the probability that they will continue living.

There are a number of recognised weaknesses in the approach of the willingness to pay models to the valuation of life including the partial equilibrium[(1)] assumptions of benefit cost analysis which ignore the chain of wider economic transfers set up through society when life is lengthened. Prolongation of life is not costless to wider society; those who live longer consume longer and this extra consumption must be financed by production of the younger workforce. Proper approaches to valuing life should account for intergenerational transfer costs, i.e. the Social Security burden on the young.

(1) Partial equilibrium is the theory that individual sectors of the economy are not related to other sectors in terms of price or production.

Arthur in a recent paper seeks a method to valuing life which is fully actuarial, based on welfare theory and includes economic transfers across society.

The model in its presentation is somewhat complex but its application to road or aircraft accidents looks very promising. Arthur manages to extend the concept of willingness to pay to that of a general equilibrium growth model which attempts a major synthesis of the value of life allowing for intergenerational transfers of costs, economic growth and demographic structure.

Since Arthur recognises the elasticity concept and the work of Blomquist, the development of his empirical model provides an actuarial calculation of foregone income which could be considered suitable as the basis for an operational estimate of the value of life. Although the elasticity concept is supported by a number of authors and would seem a plausable proposition, its verification will require behavioural support. A method needs to be devised where it is possible to observe the elasticity relationship linking human capital valuation and willingness to pay for risk reduction.

The elasticity concept has potential significance for the lower bound estimates of the social valuation of accidents presented in this report.

A final set of estimates of the cost of aircraft accidents is therefore produced which shows the effects of the selected values of the elasticity of lifetime consumption.

Table 9 shows the effect of the elasticity parameter values using 0.6 and 0.3 (Blomquist suggests 0.3).

These values increase the average valuation of a fatality from 1.6 to 3.3 times the level of the minimum estimate shown in Table 1, the upper value being over $1.6 million.

The elasticity values have a similar effect on the cost of a serious injury.

The resulting total community willingness to pay to avoid all aircraft accidents is estimated to rise from $31 million to between $50 million and $97 million for the indicated elasticity values. Thus it is clear that the overall results derived from the recent empirical work of Arthur, Blomquist, et al quite significantly raise the priority which should be accorded to preventing fatal and serious injury aircraft accidents.

TABLE 10

EFFECTS OF SELECTED 'VALUE OF LIFE' RESULTS ON AVERAGE ACCIDENT VALUATIONS (AUSTRALIA 1980)			
Casualty Class	For Elasticity Values of:		
	E = 1	E = 0.6	E = 0.3
	$	$	$
Fatalities	482,000	803,000	1,606,000
Serious Injuries	38,000	62,000	123,000
Total Willingness to Pay of Society to Avoid (all) Accidents	$31m	$50m	$97m