THE COST OF FOG AT CANBERRA AIRPORT

by

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ABSTRACT

The airport at Canberra, the capital of Australia, is subject to fog during the winter months. Fog causes delay to passengers and aircraft, and is particularly disruptive since it occurs during the morning peak travel period. The purpose of this thesis is to find appropriate methods of evaluating the cost of delay to both passengers and aircraft, and to evaluate the cost of probable delay due to fog for a typical year, 1978-79. Possible technical and non-technical countermeasures are examined.

Meteorological data show that there is a risk of fog occurrence in the morning hours from January to October. The risk is greatest in May, June and July. The risk of fog is highest in the early morning and tapers to zero by 12.30 p.m. Aircraft delay follows this pattern, and the airport is closed longer for arrivals than for departures. Estimates are made of the likely risk of delay at half-hourly intervals by month.

The components of the cost of delay are the value of passenger time and the value of aircraft time. In this study the time of business air travellers is valued by a method developed by Carruthers and Hensher (1976), which assumes that the value of time savings is made up of four components:

(1) productivity effect (i.e. the average value of an hour's working time and the average value of work done during an hour's business travel);

(2) relative disutility costs (i.e. the costs or benefits to the employee of travel in the employer's time);

(3) loss of leisure time (i.e. uncompensated to the employee); and

(4) compensation (i.e. a transfer from the employer to the employee).

Non-business travellers' time is arbitrarily valued at half that of business travellers.

Aircraft time is valued at the marginal cost of operating DC9 aircraft on the Canberra-Sydney and Canberra-Melbourne flight stages. Marginal cost is taken as direct operating costs including a capital amortization factor, less some fuel costs, plus a factor to recognise that fog delay occurs at peak travel times.

The cost of delay to passengers and aircraft is evaluated using official data on the number of passengers, and airline timetables, to estimate the number of flights and passengers likely to experience delay. The total cost of delay in 1979 values was $A236 393. Of this, 85 per cent was cost to airlines and 15 per cent was cost to passengers.

Technical and non-technical countermeasures to overcome delays caused to aircraft by fog were examined. Of these a system called Interscan which provides precision guidance in landing seems likely to be adopted in new generations of aircraft. Alternative solutions include the scheduling of flights so that some aircraft overnight at Canberra and are thus available for the first morning flights to Sydney and Melbourne. This procedure has been adopted for many years and provides a good compromise between the need to meet the demand and the risk of delay. Another alternative would be to relocate the airport, but possible sites within reasonable distance of Canberra are equally subject to fog. Fog-dispersal techniques are not favoured since they are prohibitively expensive and not particularly effective.

The conclusion of the study is that although fog at Canberra Airport inconveniences passengers and airlines on a few days each year, the costs of delay to both passengers and airlines are relatively small. They average about 4 cents per year per passenger, and about $A100 000 to each of the two main airlines annually.

Professor W.G. Waters II
Supervisor

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FOREWORD AND ACKNOWLEDGEMENTS

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Marion W. Ward
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CHAPTER 1

INTRODUCTION

Canberra, the national capital of Australia, is located in a well-defined upland basin some 237 airline kilometres southwest of Sydney and 470 airline kilometres northeast of Melbourne. In winter, particularly May, June and July, the area is subject to morning fogs. These are frequently severe enough to cause delays to aircraft movements at Canberra Airport. Canberra experiences more delays due to fog than any other airport in Australia.

These delays cause inconvenience to airline passengers, both incoming and outgoing, and system disruptions to airline schedules. If the cost of delay to passengers and airlines could be estimated, this would give an indication of the expenditures on countermeasures which could be justified.

1.1 Objectives of the Study

The objectives of the present study are to evaluate the cost to passengers and airlines of delays due to fog at Canberra Airport for a typical year; and to provide a brief examination of possible technical and non-technical countermeasures so that their potential costs can be compared with the costs of fog delays.

1.2 Significance of the Study

So far as is known this study is the first attempt in Australia to evaluate the cost of delay due to fog at an airport. In obtaining such an estimate the study gives an indication of the approximate annual cost to the community of fog, and hence an indication of the cost that would be justified in countermeasures. The study may also have wider applications in the evaluation of the cost of delay due to fog or other recurrent adverse weather conditions, either within Australia or elsewhere.

1.3 Methodology

The cost of delay due to fog at Canberra Airport has two main components:

(1) the cost of time lost by passengers affected by delay, and

(2) the cost to the airlines of delay to aircraft.

1.31 Valuation of Travel Time Lost

The valuation of travel time is a topic which has been of concern to economists, largely in relation to time savings which can be made through transport (particularly road) improvement programmes, and in a few studies related to air transport. The relevant literature is reviewed in Chapter 3. In the present study, passengers through Canberra Airport are divided into two categories: those travelling for business reasons and those travelling for non-business reasons. The time lost through delay to fog by business travellers is valued by the method devised for a study of a second Sydney Airport in 1973, as reported by Carruthers and Hensher (1976) and Hensher (1977). In Hensher's words: "The value of business travel-time savings is defined in terms of a composite employee-employer-community value using the argument that savings in total resources resultant from savings in travel time is related to the opportunity cost of travel by an employee to the employer, the disutility cost of travel to the employee, and the net benefit directly to the community from such time savings" (Hensher, 1977:2).

The main new element in Carruthers and Hensher's work compared with earlier studies is the inclusion of a productivity effect, that is, an allowance for work done during the travel period.

A significant proportion of the travellers passing through Canberra Airport are non-business travellers. Their time also has some value, less than that of business travellers' time, since they are by definition not travelling for business reasons, are not being paid (directly) for their journey, and generally are not working during their journey. The problem of how to value the time of non-business travellers is further discussed in Chapter 3 (Section 3.7). In this study the value of non-business travellers' time is arbitrarily set at half that of business travellers' time.

1.32 Valuation of Aircraft Delay

Delay to aircraft is estimated as the marginal cost of operating DC9 aircraft on the Canberra-Melbourne and Canberra-Sydney flight stages. The marginal cost is taken as direct operating costs (which include a capital amortization factor), less an amount for fuel costs avoided when aircraft are delayed on the ground, and plus an amount in recognition that fog delays occur during peak travel times, when the earnings of the aircraft would be greater than average.

1.4 Study Outline

Chapter 2 presents the available relevant meteorological, passenger and flight data for Canberra Airport. The literature on the valuation of travel time savings and the cost of business travel is reviewed in Chapter 3. The costs of delay to passengers and airlines are evaluated in Chapter 4.

Chapter 5 considers possible countermeasures, and Chapter 6 summarises the findings and conclusions of the study.

1.5 Limitations of the Study

The main limitations of the study are the unavoidable limits of time and resources which one person could devote to it. No large survey of passenger behaviour was carried out, instead the analysis is based on objective data on the probability of fog occurrence and the number of passengers and aircraft flights affected. No new method of evaluating travel time is proposed, but values derived from a recent empirically based Australian study are used.

Secondly, the problem is confined to delay due to fog once potential travellers have arrived at the airport. Any effects of fog on travel time to and from the airport have been disregarded, since in the uncongested streets of Canberra this is not a significant cause of delay.

Thirdly, data on the length of delays to aircraft due to fog are available only for two years. These data are used in conjunction with much longer records of the probability of fog occurring. If longer records of delay had been available they would probably have shown a more even distribution of delay over the winter months and may have increased the final estimation of the cost of delay.

CHAPTER 2

THE EXTENT OF FOG DELAY AT CANBERRA AIRPORT

This chapter is divided into two sections. The first presents data on the frequency and duration of fog at Canberra Airport. The second documents the volume of air traffic through Canberra Airport, and estimates that proportion of it occurring during fog-prone hours.

2.1 Occurrence of Fog and Airport Closure

Meteorological information on the occurrence of fog at Canberra is given in Section 2.11, while related information on airport closure is presented in Section 2.12 below.

2.11 Meteorological Data

Information on the occurrence of fog at Canberra is given in a booklet prepared by the Bureau of Meteorology: *Fog Risk in Canberra*, 1973. This is based on records for 32 years (1940-1972). Although later information is available in unconsolidated form, discussions with meteorologists at the Australian Bureau of Meteorology confirm there has been no significant change in fog patterns since 1972. Hence generalisations from the consolidated published data are likely to be valid.

In meteorological terms fog is considered to exist when misty conditions reduce visibility to 1000 metres or less. In recent years advances in the instrument landing systems with which larger aircraft are now routinely equipped have permitted aircraft with such equipment to land in conditions of poorer visibility. Thus in 1976/77 visibility of 800 metres was required for landing but by 1978/79 this distance had been reduced to 400 metres for appropriately equipped aircraft. In effect the equipping of aircraft with instrument landing systems is one measure which has already been taken to reduce the costs of delay because of fog.

Table 2.1 gives the number of fog days at Canberra from 1940-72. The average per year is 47, and the range is from a low of 23 in 1967 to a high of 100 in 1961. Figure 2.1 illustrates this.

TABLE 2.1: ANNUAL NUMBER OF FOG DAYS IN CANBERRA, 1940-72

Year	Fog Days	Year	Fog Days
1940	40	1956	32
1941	58	1957	31
1942	46	1958	31
1943	35	1959	61
1944	56	1960	81
1945	27	1961	100
1946	24	1962	94
1947	40	1963	70
1948	79	1964	31
1949	39	1965	42
1950	52	1966	41
1951	40	1967	23
1952	34	1968	26
1953	49	1969	62
1954	24	1970	50
1955	28	1971	46
		1972	41

Source: Bureau of Meteorology: *Fog Risk in Canberra*, 1973:3.

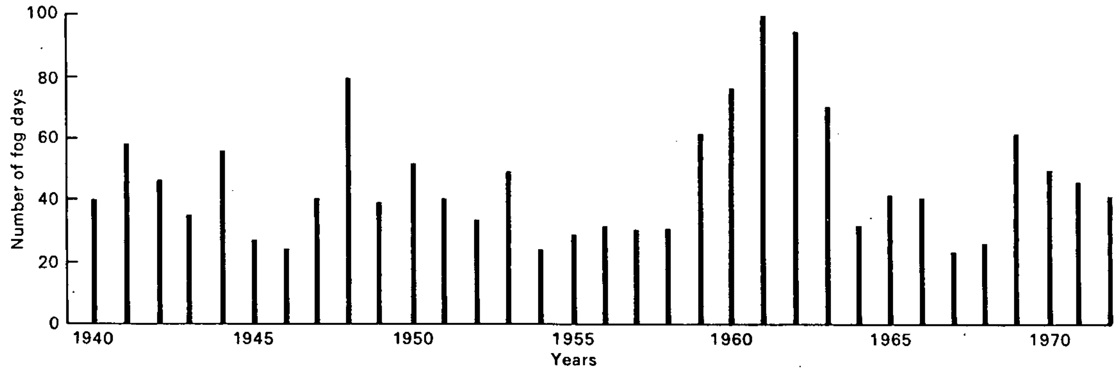

FIGURE 2.1: NUMBER OF FOG DAYS, CANBERRA, 1940-72

A feature of this pattern is its wide variability, which is common to fog occurrence in all areas of Australia.

The data in Table 2.1 refer to the meteorological definition of fog. No comparable data are available for the years 1940-72 for the number of days the airport was closed, although it could be assumed that in those years the two sets of data would have been similar. In 1978 there were 24 days, and 29 days in 1979, on which the airport was closed for a period of time to airline aircraft because of fog. This information is too sparse to permit specific comparison, but it could be assumed that for aircraft equipped with modern instrument landing systems the number of days on which the airport is closed for their operation for some period during the day would be lower than the number of fog days defined meteorologically.

The meteorological data are given here to demonstrate the monthly and diurnal characteristics of fog occurrence in Canberra. In evaluating in Chapter 4 the cost of delay the length of delay is obtained from duration of airport closure (Section 2.12 below).

The monthly pattern of occurrence of fog days shows a smooth trend to a peak in the late autumn and winter months of May, June and July. Table 2.2 and Figure 2.2 show the average, greatest and least occurrences of fog days at Canberra over the 1940-72 period.

As with the annual occurrence, the monthly occurrence also shows high variability. Further analysis by the Bureau of Meteorology indicates that as well as being the months with the highest average of fog, May, June and July are also the months with the highest average and greatest numbers of runs of consecutive fog days (Bureau of Meteorology, 1973:4).

TABLE 2.2: AVERAGE AND EXTREME NUMBERS OF FOG DAYS AT CANBERRA, 1940-72, BY MONTH

Month	Number of Fog Days		
	Greatest	Average	Least
January	7	1.2	0
February	5	1.2	0
March	11	2.9	0
April	13	4.2	0
May	18	7.5	2
June	16	7.6	1
July	19	7.6	2
August	17	4.9	0
September	11	4.1	0
October	13	3.2	0
November	7	1.5	0
December	6	0.6	0
Year	100	47	23

Source: Bureau of Meteorology, 1973:3,8.

The diurnal pattern of fog occurrence is typically: formation from about 9 p.m. on, building up to a peak of occurrence at 7 a.m. and disappearing by 12 noon. Figure 2.3 (Bureau of Meteorology, 1973:6) gives a comprehensive summary of the percentage fog risk at all hours in all months, and shows that the greatest risk of fog is in the hours around sunrise in all months, and that May, June and July are the worst fog months. More fog occurs at 7 a.m. (Eastern Standard Time) than at any other hour. The span of fog free hours is much greater in summer than in winter months, and the persistence of fog through the morning is greater in May, June and July than in other months.

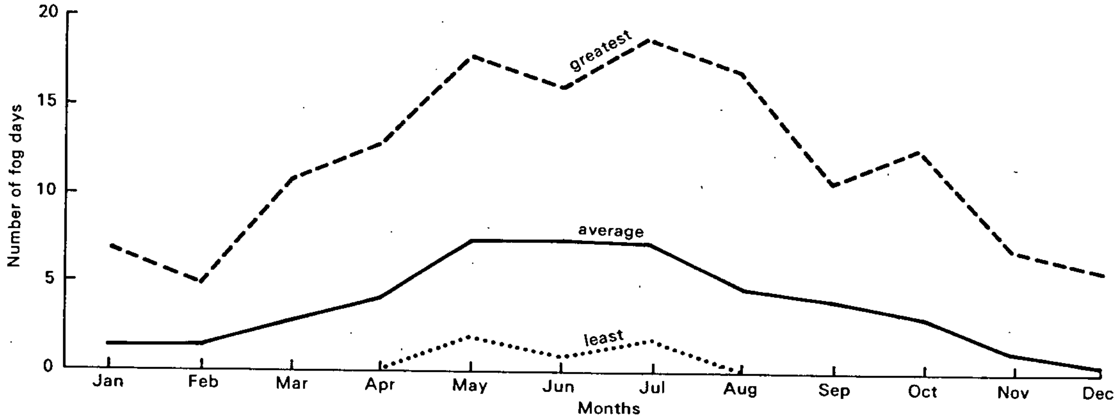

FIGURE 2.2: AVERAGE, GREATEST AND LEAST NUMBER OF FOG DAYS AT CANBERRA, 1940-72, BY MONTH

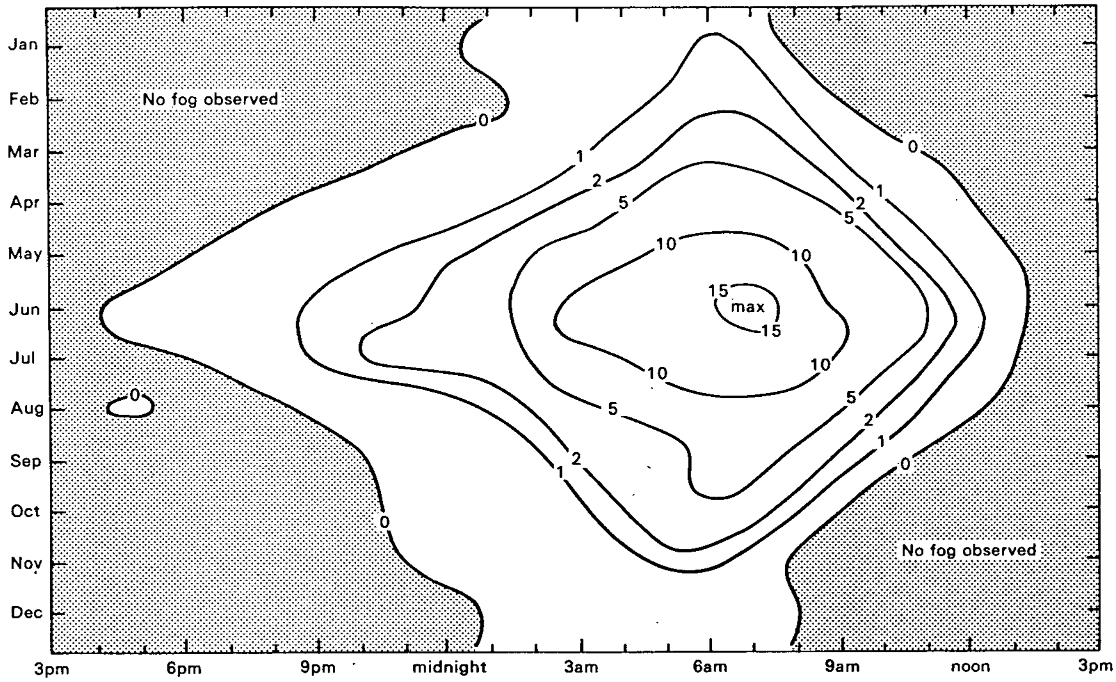

FIGURE 2.3: PERCENTAGE FOG RISK AT CANBERRA, BY MONTH AND HOUR, 1942-72

Meteorological data (Bureau of Meteorology, 1973:7) on the occurrence of fog at Canberra between 6 a.m. and 12.30 p.m. for the 30 year period 1942-72 are converted into percentage risk of occurrence and presented in Table 2.3.

TABLE 2.3: PERCENTAGE RISK OF FOG OCCURRENCE, CANBERRA, BY MONTH AND HALF-HOUR

Time*	Month											
(a.m.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.00	1	1	2	5	10	12	11	6	3	2		
7.30		1	2	4	7	10	10	5	2	1		
8.00			1	2	6	7	9	4	1	1		
8.30			1	1	4	6	8	3	1			
9.00				1	3	5	6	2	1			
9.30					2	4	5	1				
10.00					1	3	3	1				
10.30					1	2						
11.00						1						

* Times are Eastern Standard Time.

The table shows that, for example, during the month of June there is a 12 per cent likelihood of fog occurring at 7 a.m., but by 11 a.m. this risk is reduced to 1 per cent. Data from this table are used in Chapter 4 to introduce a measure of the risk of fog occurrence at different times of the day into the evaluation of the cost of delay due to fog.

2.12 Airport Closure due to Fog 1978-79

Records are available from Air Traffic Control, Canberra Airport, of the length of time Canberra Airport was closed to operations due to fog for years 1978 and 1979 only. Table 2.4 and Figure 2.4 summarise this data, which refer only to closure for airline aircraft which are equipped with instrument landing systems. Such aircraft are able to take off in poorer visibility conditions than are permitted for landing, hence the period of closure for arrivals is longer than that for departures. In Table 2.4 duration of closure is counted only after 7 a.m. before which time there are no scheduled airline arrivals or departures. The duration of periods of closure shown in this table (and graphically in Figure 2.4) reflect the more general meteorological data on occurrence and duration of fogs. All closures occurred between March and October, the peak occurrences being in June and July, when duration as well as frequency of closures were greatest. The data also show the tendency for closures due to fog to occur over several consecutive days at a time, which reflects the stable anticyclonic winter weather conditions which favour fog formation in Canberra.

Because the variability in the occurrence of fog is high, the two-year period for which airport closure data are available is, strictly speaking, too short to provide reliable estimates. Nevertheless, in the absence of better data, it is used in the evaluations of Chapter 4. The evidence does indicate that the airport is closed to arrivals roughly 2.6 times as long as for departures. Hence it is necessary to calculate the costs of delay to arriving and departing passengers separately, as is done in Chapter 4.

TABLE 2.4: DURATION OF AIRPORT CLOSURE FOR ARRIVALS AND DEPARTURES OF AIRLINE AIRCRAFT (AFTER 7 A.M.), 1978 AND 1979

(In minutes)

Month/Day		1978 Arrivals	1978 Departures	1979 Arrivals	1979 Departures
March	5	75	-	-	-
	29	160	70	-	-
April	5	35	35	-	-
	14	-	-	70	-
	27	-	-	238	-
May	1	24	-	-	-
	3	-	-	115	90
	10	-	-	190	45
	13	125	114	-	-
	19	311	105	-	-
	26	396	355	-	-
	27	195	-	-	-
June	5	-	-	370	308
	6	-	-	70	-
	11	-	-	22	-
	12	230	-	332	17
	13	96	-	420	115
	14	-	-	164	60
	15	-	-	20	20
	16	190	115	115	115
	18	-	-	315	255
	22	390	145	-	-
	24	-	-	87	-
	26	-	-	57	-
July	4	-	-	182	169
	5	-	-	350	50
	6	-	-	350	305
	7	-	-	240	-
	8	233	-	-	-
	11	-	-	293	120
	16	-	-	57	-
	20	125	-	285	270
	24	-	-	145	55
	28	-	-	200	75
	29	173	-	-	-
	30	115	-	-	-
	31	260	128	-	-
August	4	123	18	107	10
	5	20	-	235	50
	7	-	-	265	236
	15	172	-	-	-
	21	125	34	-	-
	25	12	-	45	45
September	16	175	43	-	-
	19	-	-	60	60
October	1	129	-	-	-
Total for Year		3869	1162	5399	2925

Source: Records of Air Traffic Control, Canberra Airport.

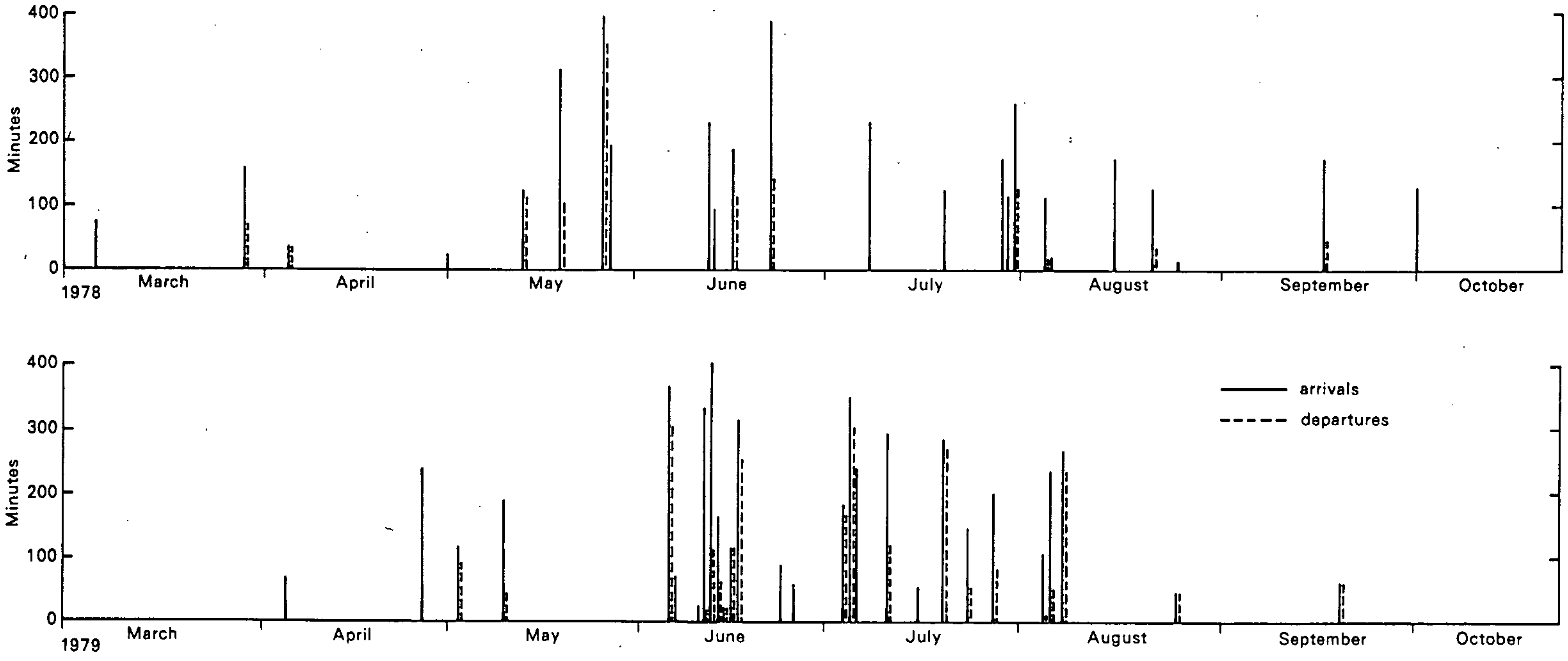

FIGURE 2.4: CANBERRA AIRPORT CLOSURE (ARRIVALS AND DEPARTURES) 1978 AND 1979

2.2 Volume of Passenger and Aircraft Movements at Canberra Airport

2.21 Total Passenger Movements 1973/74-1978/79

Table 2.5 gives the total number of passenger movements through Canberra Airport in recent years. In 1978/79 just less than a million passenger movements took place at Canberra Airport.

TABLE 2.5: PASSENGER MOVEMENTS THROUGH CANBERRA AIRPORT, 1973/74-1978/79

Year	No. of Passenger Movements
1973-74	934,069
1974-75	981,815
1975-76	901,837
1976-77	881,668
1977-78	966,388
1978-79	964,013

Source: Aust. Bureau of Statistics: Rail, Bus and Air Transport (annual): Table 36. Air Transport Internal Traffic and Aircraft Movements at Principal Airports (annual).

2.22 Monthly Pattern

Some further information is available to illustrate monthly variation in outward passenger movements from Canberra. Table 2.6 gives a breakdown of outward passenger movements by month for both major airlines for the year from July 1978 to June 1979, and the total is graphed in Figure 2.5.

The leading months are September, March and May. September and May contain winter school holidays, which annually account for traffic peaks.

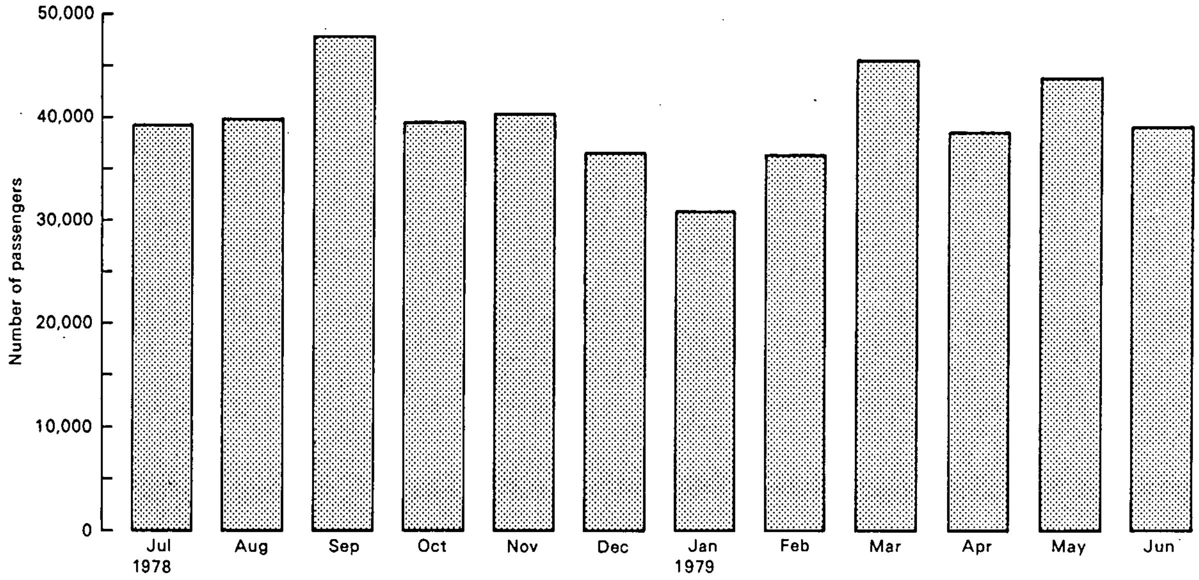

FIGURE 2.5: TOTAL NUMBER OF OUTWARD PASSENGERS, TAA AND ANSETT, JULY 1978 TO JUNE 1979

TABLE 2.6: OUTWARD PASSENGER MOVEMENTS FROM CANBERRA BY TAA AND ANSETT, JULY 1978 TO JUNE 1979

Month	Ansett	TAA	Total	Per Cent of Total
1978				
July	21 655	17 534	39 189	8.19
August	20 373	20 495	40 868	8.54
September	20 639	27 341	47 980	10.03
October	18 434	20 697	39 131	8.18
November	18 809	21 255	40 064	8.38
December	15 287	21 186	36 473	7.62
1979				
January	15 671	16 314	31 985	6.68
February	16 726	19 561	36 287	7.58
March	19 399	25 760	45 159	9.44
April	18 108	20 760	38 868	8.12
May	20 878	23 112	43 990	9.19
June	16 240	22 292	38 532	8.05
Total			478 526	100.00

There is no readily apparent explanation for the March peak in 1979, Easter having occurred in April that year. The summer holiday months of December, January and February rather surprisingly show the lowest numbers of outward passengers, while the remaining winter months show close to average figures with no marked winter decline. Discussion with airline officials confirms that the 1978-79 pattern is typical for other years.

If it is assumed that an approximately equal number of inward passengers (as outward) are carried by the two main airlines there is a difference of just less than 7000 passengers (0.73 per cent) from the total of 964 013 for 1978-79 in Table 2.5, and this may well represent the number of passengers carried in private aircraft. Fog delays will also affect private air travellers. Accordingly, in the evaluation of Chapter 4 the official total number of passengers for 1978/79 (964 013) is apportioned to each month according to the percentage distribution given in Table 2.6.

2.23 Aircraft Movements, 1979

Analysis of the 1979 winter timetables of the two main airlines serving Canberra shows a weekly total of 308 flights into or out of Canberra, 154 inwards and 154 outwards.[1] Of these, six are Fokker Friendship services and the remainder are DC9 services.

On a weekly basis, 67 of the out-going and 51 of the incoming flights leave or arrive at Canberra between 7 a.m. and 12.30 p.m., that is, 43.5 per cent of the departing flights and 33.1 per cent of the arriving flights occur during fog-prone hours.[2]

Table 2.7 shows the times of departure and arrival of the scheduled flights during the fog-prone hours.

Converted to an average daily basis, the data imply that an average of 9.6 outward and 7.3 inward aircraft movements occur during the fog-prone hours of 7 a.m. to 12.30 p.m.. For convenience it is assumed that these are all made by DC9 aircraft, which are the aircraft normally used for Canberra-Sydney and Canberra-Melbourne flights.

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1 Eighteen flights per week between Canberra, Orange and Dubbo in Navajo aircraft are omitted.

2 Each airline arranges its schedules so that at least one, and sometimes two, of its DC9 aircraft are at Canberra Airport overnight to be available for the early morning outward flights to Sydney and Melbourne.

TABLE 2.7: WEEKLY NUMBERS OF SCHEDULED FLIGHTS DURING FOG-PRONE HOURS

Time	Departures	Percentage	Arrivals	Percentage
a.m. 7.00- 7.30	15	22.39	-	-
7.30- 8.00	6	8.96	3	5.88
8.00- 8.30	6	8.96	-	-
8.30- 9.00	-	-	-	-
9.00- 9.30	-	-	15	29.41
9.30-10.00	21	31.34	13	25.49
10.00-10.30	1	1.49	6	11.76
10.30-11.00	11	16.42	-	-
11.00-11.30	-	-	-	-
11.30-12.00	7	10.44	7	13.73
p.m. 12.00-12.30	-	-	7	13.73
Total	67	100.00	51	100.00

Source: Calculated from timetables, TAA and Ansett.

2.24 Number of Passengers during Fog-prone Hours

The pattern of passenger movements at Canberra Airport shows strong diurnal peaks. Operating companies estimate that 30-35 per cent of the daily movement occurs between 7 and 8.30 a.m., and another 30-35 per cent between 5 and 6.30 p.m. (Personal Communication: TAA Manager, Canberra, 3 September 1980). The remaining 30-40 per cent occurs in the off-peak hours in the middle of the day and in the evening. Although substantiating data are not available, it appears reasonable to assume that the ratio of passenger movements is the same as the proportion of aircraft flights, that is, that 43.5 per cent of the outward passenger movements, and 33.1 per cent of the inward passenger movements occur during the morning fog-prone hours. Detailed estimations of the numbers of passenger movements are given in Chapter 4.

2.25 Proportions of Business and Non-business Travellers

In assessing the value of delays to passengers due to fog it is important to know the proportional split between business and non-business travel. For this study it was not possible to carry out an elaborate survey of passengers, but with the cooperation of the two major airlines operating at Canberra Airport an informal survey of passengers affected by fog delays at Canberra Airport was carried out during the months of May, June and July 1979. During these months, for days when fog delays occurred, the counter staff of both airlines, under the direction of their respective airport managers, recorded the length of the delays experienced, the total number of passengers affected, their assessment of the proportions travelling for business or non-business reasons, the number of cancellations (one airline only), and the number of affected passengers with domestic or international connections. The results indicated that of a total of 13 078 passengers affected, 7157 or 54.7 per cent were business travellers.[3] In addition the surveys indicated that approximately 5 per cent were international travellers.

2.26 Cancellations

The surveys reported a surprisingly low level of cancellations, only 222 out of a total of 13 078 affected passengers, or less than 2 per cent. Such surveys, however, cannot include persons who, being aware of the risk of delay due to fog during the winter months, chose the alternatives of travelling during non-fog-prone hours or using the alternative modes of road or rail.

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3 It is relevant to compare this figure with that found by Hensher, namely that, in 1973, 52 per cent of all domestic air travel in Australia was undertaken for business reasons (Hensher, 1977:1).

CHAPTER 3

THE VALUATION OF TRAVEL TIME

The preceding chapter shows that Canberra Airport (uniquely among major airports in Australia) is subject to closure because of fog for periods which vary from a few minutes to several hours during the winter months. The effects of this are felt: (1) by departing travellers who may be forced to wait for some time before leaving Canberra; (2) by arriving travellers who may either experience delay in the completion of their flights or may be forced to wait for sometimes quite long periods at Sydney or Melbourne airports before their morning flights are able to depart for Canberra; and (3) by the airlines themselves, their normal schedules are disrupted with possible repercussions on flights to other destinations. Ground facilities, particularly at Canberra, also experience periods of relatively severe congestion. Usually the disruption is largely cleared by midday, but on rare occasions some passengers may have to be accommodated in hotels overnight.

The general likelihood of delay due to fog at Canberra in winter is well known, and individuals will obviously make their own decisions about their choice of mode and time of flight. A strategy sometimes employed by travellers with onward connections or important morning appointments is to travel to or from Canberra the preceding night, thereby incurring extra hotel costs. The airlines, however, do not lose revenue from these passengers. This study has not attempted to measure the extent of the alternative strategies which may be adopted by passengers, but account is taken in the evaluation of the loss of revenue to airlines from passenger cancellations.

The main effect of fog at Canberra Airport is the delay experienced by both incoming and outgoing passengers and by aircraft. Hence it becomes desirable to attempt to evaluate the time lost by both passengers and aircraft.

3.1 The Value of Passenger Time: General Principles

We first consider the premise that time has value. Obviously this is true for those travellers who choose to fly to or from Canberra as opposed to using the cheaper but slower modes of travel available, namely rail or road. But does time itself have value? Several authors argue that time itself has no value. Thomson (1974:56) suggests that it is "the opportunity to undertake certain desirable activities that is of value". Harrison and Quarmby (1969:173) state "the expression 'the value of time' is commonly used as a shorthand for the value to be attached to saving time". Hensher and Hotchkiss (1974:255) say "time *per se* does not have a value. What is valued is the activity that takes place during the time in question". It can therefore be argued that those travellers who choose to fly to and from Canberra rather than use surface modes are placing a value on the time saved equal to or greater than the difference in cost between air and surface modes. Time itself, then, has no intrinsic value, only the use people make of time has value to them.

Every individual possesses a fixed amount of time (24 hours per day), and also has choice as to how that time is used. Broadly a person's use of his or her time is divided between work and leisure. These two activities do have value, and can be traded. Out of each person's daily time ration, time spent travelling must fall into one or other of the two categories, work or leisure. Attention has therefore been focussed on savings in travel time, since the reduction of time spent travelling means an addition to the time an individual may devote either to work or leisure.

The present study deals with a different aspect of travel-related time. We are concerned here with the loss of time through delays which arise after the traveller has started the journey. The net result is to lengthen the total journey time, and therefore its perceived cost. The situation of the fog-delayed air traveller appears to be similar to that of a road traveller who is caught in congested traffic, and whose journey is thus longer than it would be when the route is uncongested. This means that the traveller has suffered a reduction in the time he has available for other uses, i.e. either work or leisure activities.

There appears to be no reason why this additional time expended should be valued in a different manner from time savings brought about by improvements to transport facilities. As with time savings due to, say, road improvements however, there may be arguments for valuing shorter and longer time delays differently. Hence the critical question for this study is how to value travellers' time appropriately, allowing for the fact that some of those passengers affected are travelling for work reasons and others for non-work reasons. Thus we need to examine means of placing a value on both work and leisure time.

3.2 Methods of Valuing Time

The problem of how to value time has engaged the attention of economists concerned with transport since the 1950s.[1] Moses and Williamson

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1 Earlier studies used values which were little more than guesses, such as the figure of $U.S.1.55 per hour for the value of travel time of the 1.8 occupants of the average private passenger vehicle in 1960. This figure is reported to have been obtained as an adjustment to an earlier figure of $U.S.1.00 per hour in 1949 (Mohring, 1976:25). The latter figure would seem to have borne some relation to the average wage rate of the time. (Quoted by Mohring (1976:25) and Moses and Williamson (1963:248) from American Association of State Highway Officials, Committee on Highway Planning and Design Policies: *Road User Benefits for Highway Improvements* (Washington D.C., 1960:100-126).

(1963:248) identify two basic methods of valuing time spent in travel:

(1) the *income* or *productivity approach*, which values travel time according to the worth of time in work, and

(2) the *pure cost approach*, in which travel time savings are valued according to money cost differentials between two or more modes of travel (or between alternative routes for the same mode) which have different time and cost outlay characteristics.

3.21 The Productivity Approach

The classic approach assumes that people make a direct trade-off between income and leisure. Thus it seems reasonable to assume that there is a direct relationship between the value of time and the marginal wage rate. Harrison (1974:69) shows that this approach is invalid for the following reasons:

(1) People have only limited freedom to vary their hours of work and hence "the level of the marginal wage sheds little light on the value placed on working or not working by the individual employee";

(2) Taxation, social insurance, and additional costs to the employer mean that what the employer pays and the employee receives as a marginal wage rate differ;

(3) The marginal wage rate does not necessarily measure the financial loss from not working (it will overestimate it if there are work-related costs);

(4) This approach implies that the disutility of work is equal to the disutility of travel, but this is not necessarily so. Given a choice people may prefer a small increase in travel time to a small

increase in working time, or the converse, particularly perhaps in circumstances of fog delay.

In addition, the direct income-leisure trade-off approach does not allow for a situation where some or all of the travel time may be used productively by the traveller.

These objections meant that a second approach had to be found in which the value people place on their time is deduced from their behaviour.

3.22 The Pure-Cost or Behavioural Approach

In this approach the choice people make between alternative modes or routes is observed and used to evaluate travel time. That is, people are assumed to trade-off travel time (more usually *savings* in travel time) against cost (e.g. fares) or other travel conditions for which a monetary equivalent can be deduced.

Many studies have been carried out using this approach. Most have been studies of daily commuting, since in aggregate, the journey to work accounts for by far the largest part of the travel time of an individual or local or national economy.

Examples of surface transport studies are those by Beesley (1965), Lisco (1967), and Lee and Dalvi (1969). Studies concerned with the value of travel time of air travellers are discussed below (Section 3.5).

3.3 Results of Earlier Studies

Jennings and Sharp (in Heggie, 1976:132-63) have collected and standardised for comparison the results of a number of studies of time saving values in surface modes carried out in Britain, Europe, and Australia between 1957 and 1974 (Jennings and Sharp, 1976:135-7). The list includes both theoretically derived (i.e. earnings related) and behavioural choice-based results, and the former appear to show a somewhat higher range of values than the latter. Many different techniques were used in the various studies; the results are reproduced as Table 3.1.

As might be expected, the results vary widely. Jennings and Sharp attribute the lack of consistency to: "The number of variables considered; difficulties in selecting accurate samples; variance in actual preferences; discrepancies between perceived and calculated values of explanatory variables; and also because basic assumptions may be unsound" (Jennings and Sharp, 1976:134).

3.4 Unresolved Issues

A number of issues in the valuation of time savings in transport remain unresolved. They are discussed in the following sections.

3.41 Relation of Time Savings Values to Income Levels

The relation between the value of time savings and income levels has not been decisively resolved. Jennings and Sharp (1976:139) cite Beesley (1965) as finding time savings to be valued at 30-50 per cent of hourly income; Quarmby (1967) at 20-25 per cent, and Lee and Dalvi (1969) at 15-45 per cent. To this may be added the values adopted by the Roskill Commission on the Third London Airport, which are quoted by Carruthers and Hensher (1976:166) as ranging from 94 to 167 per cent of the estimated hourly wage rate. Jennings and Sharp (1976:139) quote the LGORU study (1970) as follows: "The value of an individual's travel time may be

TABLE 3.1: SUMMARY OF TIME SAVINGS VALUES AT 1968 U.K. PRICES

Source	Year of Data Collection or Investment Appraisal	Mode	Value of Unit of Time Saved (per hour/person)	
(a) Commuter or non-work time				
Merlin & Barbier	1961	PT, car		27
		Car, PT		48
Victoria Line Study	1962	-		31
Quarmby	1966	Car/bus	Minimum value	7
			Maximum value	25
Beesley	1963	PT	Minimum value	12
			Maximum value	19
		Car	Minimum value	12
			Maximum value	25
LGORU	1967/68	Average of bus/train/car	Combined data	43
			Liverpool	39
			Manchester	32
			Leicestershire	84
			Leeds	22
Lee & Dalvi	1966	Car		66
		PT		40
Edinburgh Study	1969	Train		41
		Car		59
Solent Travel Study	1970	Hydrofoil	All journeys/	
			Minimum	34
			Maximum	39
		Hovercraft vs ferry Less than 25 km	Minimum	11
			Maximum	12
Dawson & Everall	1969	Car	Small	26
			Medium	53
			Large	119
Henscher & Hotchkiss	1970	Ferry		17
Roskill	1968		Minimum	11
			Maximum	34
Commonwealth Bureau of Roads	1974		Car	11
			Bus	11
Department of the Environment	1974		In-vehicle	17
			Walking and waiting	34

(contd. over)

Source	Year of Data Collection or Investment Appraisal	Mode	Value of Unit of Time Saved (per hour/person)	
(b) Pure leisure time				
Dawson & Smith	1957	Car	Minimum value	50
			Maximum value	68
Solent Travel Study	1970	Hydrofoil Hovercraft vs ferry		Negative
Dawson & Everall	1969	Car	Medium	72
			Large	75
Channel Tunnel Study	1973	-		16
(c) Work time				
Victoria Line Study	1962	-		43
Solent Travel Study	1970	Hydrofoil Hovercraft vs ferry	All journeys less than 25 km	Negative
			Minimum	63
			Maximum	72
Dawson & Everall	1969	Car	Medium	201
			Large	298
Roskill	1968	-	Minimum	*146*
			Maximum	*258*
Channel Tunnel Study	1973	-		*70*
Commonwealth Bureau of Roads	1974	Car		*146*
		Light truck		*71*
		Articulated vehicle		*90*
Department of the Environment	1974	All workers		*128*
		Car drivers		*146*
		Car occupants		*127*
		Rail users		*157*
		Bus users		*77*
		London Underground users		*139*
		Light goods vehicle driver		*64*
		Light goods vehicle occupant		*55*
		Heavy goods vehicle driver		*70*
		Heavy goods vehicle occupant		*58*
		Bus drivers		*72*
		Bus conductors		*66*

Note: The figures in italics are theoretical values, in that they have been estimated from earnings. Other figures have been derived from observations of preferences of travellers in a situation of choice. All values were converted into sterling and recalculated on a constant price basis with 1969 = 100. The Index of retail prices for 'All Items' was used to adjust values, subsequent indices being linked without making any allowances for changes in weights.
PT = Public Transport.

Source: Jennings and Sharp (1976:135-37).

dependent on his income. No reliable numerical relationship was, however, obtained". Studies in Italy and France are cited as finding the value of commuter time savings as 75 per cent of the average wage rate (Dawson and Everall, 1972; Merlin and Barbier, 1962).

This variety of results suggests that no one method is infallible in placing a value on time, that people place different values on travel time according to the purpose of their journey and other factors, and that intercountry comparisons are unlikely to be valid since differences in life-styles and attitudes may escape measuring techniques. The implications for the present study are that while there is no generally accepted method for arriving at some specific proportion of the average wage rate which would be widely acceptable for the value of time, studies which investigate closely related circumstances in the same country are likely to be more relevant than those for other modes in other countries at more distant dates.

3.42 Relationship of Work and Leisure Time Values

A second unresolved issue is the relationship between the values of work and leisure time. Harrison and Quarmby (in Layard 1974:179-80) state that the traditional economist's starting point for the consideration of the value of leisure time has been the labour market: in a free market for labour the marginal value of leisure to the consumer is equal to what he forgoes by way of extra earnings. But this has been criticised (e.g. by Moses and Williamson, 1963) on the ground that the length of the working week is given for individuals, so one can only deduce that since many people do work, the total utility gained from earnings outweighs the total loss of leisure. Nothing can be deduced about the marginal values of work and leisure time, and these cannot be presumed to be equal.

The traditional approach is also incorrect in ignoring the disutility attached by the consumer to the work situation: people attach different degrees of disutility to different categories of work. From this it can be argued that the marginal utility of leisure time is equal to the wage rate less the marginal disutility of work, and hence the value of leisure time should be some amount below the average wage rate. In the case of travel time the disutility which people attach to travel will be different from that which they attach to work and may even be negative (that is, people value the journey for itself). Hence a time saving could have zero or negative value. It seems unlikely, however, that this would be the case with delays in a journey due to fog. Most people would be expected to dislike enforced delay, and consequently place a positive if not high value on the time lost.

3.43 Linear or Non-linear Values for Time

A third unresolved issue is the question of whether all savings in travel time have the same value. It is possible to argue that small savings in travel time have a lesser value than large savings, since people cannot plan to make advantageous use of them for either leisure or work purposes. Thus a case can be argued for valuing small savings at a lower value than larger savings. In the case of losses of time by air travellers due to fog delay this non-linear valuation of time may well apply, that is, long delays will have a higher value to the travellers affected than will short delays. In the present study a linear value of time is assumed for passengers' and aircraft time.

3.5 Studies of the Value of Air Passengers' Time

Most studies on the value of travel time have used surface transport modes as the basis of their enquiry. A few studies have been concerned with the value of air passengers' time. Among them are the Commission on the Third London Airport (The Roskill Commission, 1971), Gronau's study of travelling time in relation to the demand for passenger airline transportation (1970a and b), and a consultants' study for a Second Sydney Airport of which the methodology and results are reported by Carruthers and Hensher (1976) and more fully elaborated in Hensher (1977).

The Commission on the Third London Airport (1971) was noteworthy in raising a number of issues, not all of which were conclusively resolved. These issues included the possibility that useful work might be done while travelling (a possibility not restricted solely to air travel); that savings in travel time might result in increased leisure rather than increased working time; that the rational business traveller will so organise his time that only marginal activities are exchanged for travel time and hence savings in travel time will increase productivity only at a marginal rather than an average rate; that businessmen are employed to do a job rather than to work a fixed number of hours and hence increased travel time would result in increased leisure time; and that a businessman travelling and not working is not contributing to his employer's profits, and hence reduction in travel time would lead to an increase in profit (reported by Carruthers and Hensher, 1976:165). Carruthers and Hensher conclude "The residual doubt in the minds of the Commission can be seen from the wide range of values adopted in their report, ... and their stated sympathy with the view that the valuation of time is nothing more than an educated guess" (Carruthers and Hensher, 1976:166).

Carruthers and Hensher's study was part of an investigation of the proposed development of a second Sydney Airport. It aimed "to derive a sounder basis for the valuation of business travel time savings ... [and] to establish resource values for evaluation, rather than behavioural values for predictive modelling, although a behavioural value was also obtained" (Carruthers and Hensher, 1975:166). As well as determining the unit value of ordinary working time, the main issues that had to be considered were:

(1) the effect of some business travel being done in the employee's rather than the employer's time;

(2) the allowance to be made for work done while travelling; and

(3) whether travel time savings result in a saving of working time of average or marginal productivity.

In their calculations the authors used an average rather than a marginal cost function.

Carruthers and Hensher's approach was that the value of time savings was made up of four component parts:

(1) productivity effect;
(2) relative disutility cost;
(3) loss of leisure time;
(4) compensation.

The determination of the distribution of time saving benefits between the employee, the employer and the community was an important objective of the study.

3.51 Productivity Effect

The productivity effect measured the average value of an hour's working time, and the average value of work done during an hour's business travel. The first was estimated by summing the individual's salary, other non-salary benefits, directly attributable overhead costs, travel and accommodation expenses, together with the expected return to these expenditures, and this then divided by the number of hours worked. The value of work done while travelling was estimated from the proportion of travel time spent working and the productivity of that work compared to equivalent 'ordinary' working time (Carruthers and Hensher, 1976:168).

3.52 Relative Disutility Cost

This was included to bring into the valuation any costs or benefits of travel to the passenger himself, who may experience gain or loss of utility from travel in his employer's time (Carruthers and Hensher, 1976:169).

3.53 Loss of Leisure Time

For travel taking place in the employee's own time which is not later compensated there is a loss of leisure time. The authors recognised that there was uncertainty as to the appropriate value to put on leisure time, but opted to use already available estimates (Carruthers and Hensher, 1976:169).

3.54 Compensation

Compensation for travel is recognised as a transfer from the employer to the employee. It enters into the total annual costs used in estimating the productivity effect, and since some compensation for travel is taxed, such payments are included in direct community costs.

3.55 Results of Sydney Airport Study[2]

With this theoretical basis the authors carried out an empirical study on business travellers at Sydney Airport, and obtained values for business travel time savings for six stages of the journey (access to the airport, in-flight, and egress from the airport on both outward and return flights) and various passenger types (domestic and international, whether travelling in employers' or employees' own time, and whether compensated or not).

A mean value of business travel time was obtained by weighting by the proportion of each type of passenger for each trip stage. The values of business travel time savings for domestic and international passengers were, respectively, 68.5 per cent and 30.3 per cent of their average gross salary rates (Carruthers and Hensher, 1976:179-81). These values include an allowance for work done while travelling (the productivity effect). If this is not included, higher values of 85.1 per cent and 33.0 per cent were found respectively.

3.6 Relation to the Present Study

The Second Sydney Airport Study gave careful consideration to the problem of putting a value on the travel time of business air passengers.

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2 As noted earlier, the study has been described in detail in a book by D.A. Hensher, *Value of Business Travel Time* (1977). Further reference is made to this work in Chapter 4 of the present study, but the results as reported by Carruthers and Hensher (1976) are identical with those in Hensher (1977).

Through the productivity effect it includes a recognition of the fact that some productive work is often carried out by business travellers while making air journeys. The sample of business air travellers from which its empirical information was obtained was similar to the type of business travellers passing through Canberra Airport, and the date of the study was relatively recent.

For these reasons it was decided to use the values obtained in the Second Sydney Airport Study, suitably adjusted for the six-year interval since the earlier study was carried out, as the values for business air travellers' time in the present study.

3.7 Evaluation of the Time of Non-business Travellers

The problem remains of evaluating the time of non-business travellers affected by fog delays at Canberra Airport. Carruthers and Hensher were not concerned with non-business travellers, at least in the two publications studied here.

In the present study we are concerned with valuing time lost through delays due to fog. For evaluating the non-business traveller's time there would appear to be two options: either the non-business traveller's time is worth nothing, or it does have a value at least to the traveller himself.

If we accept the first option, then we are concerned only with the approximately 54 per cent of passengers who are thought to be business travellers, and the evaluation disregards the others.

If we accept the second, the question becomes what is the value of the non-business traveller's time? If we apply Carruthers and Hensher's four components of the value of time, two do not apply to non-business travellers, namely the productivity effect and compensation for time spent travelling. In the present case, however, where the time loss concerned is caused by fog delay, non-business travellers may well experience a relative disutility cost, and a loss of leisure time. This would indicate that if a value is to be placed on their time it should be less than that placed on the business travellers' time. In this study an arbitrary value of *half* the value of business travel time is allocated to non-business travel time.

3.8 Value of Aircraft Time

The valuation of time lost to aircraft use through fog delay requires an appropriate measure of the cost of providing scheduled air services between Canberra-Melbourne and Canberra-Sydney by DC9 aircraft. When an aircraft is delayed on the ground beyond its scheduled departure time the airline owning it suffers a loss of its earning capacity, because theoretically if the aircraft was not delayed it could be in use elsewhere earning revenue for the airline. (In practice scheduling and other considerations make this an over-simplification.) The question becomes one of determining the opportunity cost of the delay time.

A reasonable approximation for this opportunity cost is the marginal cost of operation. According to Gannon (1979:111) the orthodox approach to airline costs is to divide the various airline cost sources into two categories: direct operating costs (DOCs) and indirect operating costs (IOCs). DOCs are costs associated with, and directly related to, the provision and operation of an aircraft flight. They include costs for fuel and oil[3], crew, aircraft capital amortization and maintenance, insurance, air navigation charges, and in-flight services. Indirect costs are costs that primarily derive from ground services such as reservations and sales, advertising, maintenance infrastructure and general administration. (Some on-ground services (or part of them) such as baggage handling and ticketing are, of course, closely related to flights. In addition, cabin crew (hostesses) are often included in IOCs not DOCs.) In Australia, Gannon suggests that in 1977 DOCs represented about 55 per cent of total airline costs. (In the United States, Douglas and Miller state that in 1971 aircraft operating costs accounted for 57.6 per cent, aircraft ownership costs 16.1 per cent, traffic costs 20.0 per cent and overhead costs 6.2 per cent of total operating costs of all U.S. domestic trunk carriers (Douglas and Miller, 1974:8). These proportions, however, are thought not to be representative of the much less competitive Australian situation.) The marginal cost is equal to the DOCs, which, Gannon specifies, include capital amortization costs.

In this study it has been decided to use Gannon's estimates of DOCs for DC9 aircraft operating the Canberra-Melbourne and Canberra-Sydney flight stages, less 10 per cent for fuel costs avoided. An arbitrary increase of 15 per cent is, however, added in recognition that delays due to fog occur during busy periods. Time delays during peak travel periods incur higher than average opportunity costs, since at these times aircraft are carrying more than average numbers of passengers and hence earning higher than average revenues.

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3 Fuel costs are of course avoided while aircraft are delayed by fog on the ground, but in fog conditions some part of the delay occurs in the air.

Accordingly the values given in Table 3.2 are used in the evaluation of aircraft time delays in Chapter 4.

TABLE 3.2: DIRECT OPERATING COSTS AND ADJUSTMENTS FOR CANBERRA-MELBOURNE, CANBERRA-SYDNEY FLIGHTS BY DC9 AIRCRAFT, 1977 VALUES

Stage	Trip Cost (DOC) ($)	-10% for Fuel Costs Avoided ($)	+15% Peak Period Adjustment ($)
CBR-MEL	1041	937	1077
CBR-SYD	678	610	702

Source: Gannon (1979:133).

It could be argued that the values used for aircraft delay time should be increased further to take account of the flow-on effects of aircraft delay through the system. In fact, however, disruption of this sort is relatively rare, and the cost in terms of aircraft delay is small. Airlines try to minimise the impact of delay at Canberra on other parts of their systems by not waiting for delayed connecting flights. Thus most of the cost of system disruption falls on those passengers who miss connecting flights rather than on the airlines (Personal Communication, Manager, TAA Canberra, 31 March 1981).

CHAPTER 4

EVALUATION OF COSTS OF DELAY DUE TO FOG

The objective of this chapter is to arrive at an approximate figure for the cost of delay due to fog at Canberra Airport. This cost can be divided into two parts:

(1) costs incurred by passengers departing from or arriving at Canberra who experience delay due to fog; and

(2) costs incurred by the two main airlines due to aircraft delay.

The first is evaluated using data collected for this study presented in Chapter 2 above, and estimates of the value of business travel time derived by Hensher (1977). The second is evaluated as the opportunity cost of the time lost by DC9 aircraft due to fog delay.

4.1 Estimation of Cost Incurred by Passengers

To estimate the cost to passengers the total number of passengers during fog-prone hours is dissected according to whether the passengers are business or non-business, arriving or departing, domestic or international, and each category multiplied by the probable average daily length of delay (by half-hourly intervals) in the appropriate month, and the appropriate cost of delay for each category. Since there is monthly variation in the number of passengers passing through Canberra Airport, and in the length of delay due to fog, the calculation is carried out on a monthly basis.

A simple model of the calculation is:

Cost incurred by passengers =

Number of business passengers (domestic and international, arriving and departing) during fog-prone hours × likely length of delay (minutes) × cost of delay ($/minute)	+	Number of non-business passengers (domestic and international, arriving and departing) during fog-prone hours × likely length of delay (minutes) × cost of delay ($/minute)

The estimation is based on 1978-79 data.

4.11 Estimation of Number of Passengers Affected

In this study business travellers are those travelling for work or business reasons, and non-business travellers are those travelling for recreational or non-work reasons. From Table 2.5 the total number of passenger movements through Canberra Airport in 1978-79 was 964 013. We assume that this number was equally divided between inwards and outwards passengers. We assume that 43.5 per cent of outwards movements and 33.1 per cent of inwards movements occur during fog-prone hours (Section 2.24), and that 54.7 per cent were business travellers, and 5 per cent were international travellers (Section 2.25). Using the monthly distribution for 1978-79 of main airline passengers given in Table 2.6, the following allocation of total passengers in fog-prone hours by business and non-business, domestic and international travel is made (Tables 4.1, 4.2 and 4.3).

It is not enough, however, to know only the total number of passengers arriving or departing during fog-prone hours (7.00 a.m. to 12.30 p.m.). It is necessary also to determine the daily (morning) profile of the numbers of passengers according to the actual times they are scheduled to arrive or depart, so that the likely length of delay at given

TABLE 4.1: NUMBER OF PASSENGERS DURING FOG-PRONE HOURS, BY DIRECTION

Month	Total	Half of Total	Number during Fog-prone Hours Arriving (33.1% of Half)	Number during Fog-prone Hours Departing (43.5% of Half)
July	78 953	39 476	13 067	17 172
August	82 327	41 164	13 625	17 906
September	96 690	48 345	16 002	21 030
October	78 856	39 428	13 051	17 151
November	80 784	40 392	13 370	17 571
December	73 458	36 729	12 157	15 977
January	64 396	32 198	10 658	14 006
February	73 072	36 536	12 093	15 893
March	91 003	45 501	15 061	19 793
April	78 278	39 139	12 955	17 025
May	88 593	44 297	14 662	19 269
June	77 603	38 801	12 843	16 878
Total	964 013	482 006	159 544	209 671

TABLE 4.2: NUMBER OF *ARRIVING* PASSENGERS (DURING FOG-PRONE HOURS) BY BUSINESS OR NON-BUSINESS, DOMESTIC OR INTERNATIONAL

Month	Business Travellers (54.7%) Domestic (95%)	Business Travellers (54.7%) International (5%)	Non-business Travellers (45.3%) Domestic (95%)	Non-business Travellers (45.3%) International (5%)	Total Arriving Passengers
July	6791	357	5623	296	13 067
August	7080	372	5864	309	13 625
September	8316	438	6886	362	16 002
October	6782	357	5616	296	13 051
November	6948	365	5754	303	13 370
December	6317	333	5232	275	12 157
January	5538	292	4587	241	10 648
February	6284	331	5204	274	12 093
March	7826	412	6482	341	15 061
April	6732	354	5575	294	12 955
May	7619	401	6310	332	14 662
June	6674	351	5527	291	12 843
Total	82 907	4363	68 660	3614	159 544

TABLE 4.3: NUMBER OF *DEPARTING* PASSENGERS (DURING FOG-PRONE HOURS) BY BUSINESS OR NON-BUSINESS, DOMESTIC OR INTERNATIONAL

Month	Business Travellers (54.7%) Domestic (95%)	Business Travellers (54.7%) International (5%)	Non-business Travellers (45.3%) Domestic (95%)	Non-business Travellers (45.3%) International (5%)	Total Departing Passengers
July	8923	470	7390	389	17 172
August	9304	490	7706	406	17 906
September	10928	575	9051	476	21 030
October	8913	469	7381	388	17 151
November	9131	481	7561	398	17 571
December	8302	437	6876	362	15 977
January	7278	383	6028	317	14 006
February	8258	435	6840	360	15 893
March	10285	541	8519	448	19 793
April	8847	466	7327	385	17 025
May	10013	527	8292	437	19 269
June	8771	462	7263	382	16 878
Total	108 953	5736	90 234	4748	209 671

times of day during the fog-prone months can be applied to each group of passengers. To achieve this the assumption is made that the number of passengers arriving or departing is proportional to the number of flights scheduled to arrive or depart at given times.(Table 2.7).

The percentage figures from Table 2.7 are applied to the monthly numbers of arriving and departing passengers, by the categories business and non-business, and domestic and international. The resulting profile of number of passengers by various categories, arriving and departing, is presented in Table 4.4.

4.12 Estimation of Likely Length of Delay

To estimate the likely average length of delay at various times throughout the morning it is necessary to establish a relationship between two sets of disparate data, namely: the length of time the airport was closed due to fog in each month in 1978 and 1979 (Table 2.4), and the probability of fog occurring at various hours through the day in each month (Table 2.3).

Although it is recognised that two years is an unduly short period on which to base the argument, in the absence of any further data the information on duration of airport closure in 1978 and 1979 is used here as an approximate measure of the likely length of delay by month.[4] Table 4.5 gives the total time the airport was closed for arrivals and departures by month, and converts this information into the average length of closure on days on which fog occurred.

4 The curves of likely occurrence of fog at 7 a.m. at Canberra Airport over 32 years (Table 2.2) and total duration of closure for arrivals and departures over two years (Table 4.5) are very similar, with means and medians occurring in late June in all cases.

TABLE 4.4: NUMBER OF PASSENGERS ARRIVING OR DEPARTING PER MONTH, BY HALF-HOURLY INTERVALS, BY CATEGORY

Month	Time Period (a.m.)	ARRIVING				DEPARTING			
		Business Travellers		Non-business Travellers		Business Travellers		Non-business travellers	
		D	I	D	I	D	I	D	I
March	7.00- 7.30	-	-	-	-	2303	121	1907	100
	7.30- 8.00	460	24	381	20	922	48	763	40
	8.00- 8.30	-	-	-	-	922	48	763	40
	8.30- 9.00	-	-	-	-	-	-	-	-
April	7.00- 7.30	-	-	-	-	1981	104	1641	86
	7.30- 8.00	396	21	328	17	793	42	657	35
	8.00- 8.30	-	-	-	-	793	42	657	35
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	1980	104	1640	86	-	-	-	-
May	7.00- 7.30	-	-	-	-	2242	118	1857	98
	7.30- 8.00	448	24	371	20	897	47	743	39
	8.00- 8.30	-	-	-	-	897	47	743	39
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	2241	118	1856	98	-	-	-	-
	9.30-10.00	1942	102	1608	85	3138	165	2599	137
	10.00-10.30	896	47	742	39	149	8	124	7
	10.30-11.00	-	-	-	-	1644	87	1362	72
June	7.00- 7.30	-	-	-	-	1964	103	1626	86
	7.30- 8.00	392	21	325	17	786	41	651	34
	8.00- 8.30	-	-	-	-	786	41	651	34
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	1963	103	1625	86	-	-	-	-
	9.30-10.00	1701	89	1409	74	2749	145	2276	120
	10.00-10.30	785	41	650	34	131	7	108	6
	10.30-11.00	-	-	-	-	1440	76	1193	63
	11.00-11.30	-	-	-	-	-	-	-	-

Note: D = Domestic, I = International.

(contd. over)

TABLE 4.4 CONTD.

Month	Time Period (a.m.)	ARRIVING Business Travellers D	I	Non-business Travellers D	I	DEPARTING Business Travellers D	I	Non-business travellers D	I
July	7.00- 7.30	-	-	-	-	1998	105	1655	87
	7.30- 8.00	399	21	331	17	800	42	662	35
	8.00- 8.30	-	-	-	-	800	42	662	35
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	1997	105	1654	87	-	-	-	-
	9.30-10.00	1731	91	1433	75	2796	147	2316	122
	10.00-10.30	799	44	661	35	133	7	110	6
August	7.00- 7.30	-	-	-	-	2083	110	1725	91
	7.30- 8.00	416	22	345	18	834	44	690	36
	8.00- 8.30	-	-	-	-	834	44	690	36
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	2082	109	1725	91	-	-	-	-
	9.30-10.00	1805	95	1495	79	2916	154	2415	127
	10.00-10.30	833	44	690	36	139	7	115	6
September	7.00- 7.30	-	-	-	-	2247	129	2027	107
	7.30- 8.00	489	26	405	21	979	52	811	43
	8.00- 8.30	-	-	-	-	979	52	811	43
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	2446	129	2025	106	-	-	-	-
October	7.00- 7.30	-	-	-	-	1996	105	1653	87
	7.30- 8.00	399	21	330	17	799	42	661	35
	8.00- 8.30	-	-	-	-	799	42	661	35

Source: Calculated from Tables 4.2, 4.3 and 2.7.

TABLE 4.5: AVERAGE DURATION OF CANBERRA AIRPORT CLOSURE ON FOG-DAYS, 1978 AND 1979

Month	Total Time Closed		Number of Days Closed		Average Length of Closure/Day	
	Arrivals	Departures	Arrivals	Departures	Arrivals	Departures
	(minutes)		(no.)		(minutes)	
March	235	70	2	1	118	70
April	343	35	3	1	114	35
May	1356	709	7	5	194	142
June	2878	1150	15	9	192	128
July	3008	1172	14	8	215	147
August	1104	393	9	6	123	66
September	235	103	2	2	118	52
October	129	-	1	-	129	-

Source: Calculated from Table 2.4.

It is assumed that the period of closure always begins at 7.00 a.m., and the following table of duration of closure by half-hourly intervals on days on which fog occurs is deduced (Table 4.6).

But fog does not occur on every day in each month. Table 2.3 gives the probability of fog being present at half-hourly intervals through the morning in each month. By combining this probability with the estimated duration of fog on fog-days a table of probable average duration of delay due to fog at half-hourly intervals for each month is obtained (Table 4.7).

4.13 Estimation of Cost of Delay

The values of business travel time adopted here are those found by the Second Sydney Airport Study, adjusted to 1979 values. Hensher (1977:104) reports that "the mean value of business travel time for domestic and international business air travel when the productivity effect is

TABLE 4.6: ESTIMATED AVERAGE DURATION OF CLOSURE ON FOG-DAYS, BY HALF-HOURLY INTERVALS, BY MONTH

Time	March		April		May		June		July		August		September		October	
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
	(minutes)															
7.00- 7.30	118	70	114	35	194	142	192	128	215	147	123	66	118	52	129	-
7.30- 8.00	88	40	84	5	164	112	162	98	185	117	93	36	88	22	99	
8.00- 8.30	58	10	54		134	82	132	68	155	87	63	6	58		69	
8.30- 9.00	28		24		104	52	102	38	125	57	33		28		39	
9.00- 9.30					74	22	72	8	95	27	3				9	
9.30-10.00					44		42		65							
10.00-10.30					14		12		35							
10.30-11.00									5							
11.00-11.30																

Note: A = Arrivals, D = Departures.

TABLE 4.7: ESTIMATION OF PROBABLE AVERAGE DAILY LENGTH OF DELAY, AT HALF-HOURLY INTERVALS, FOR ARRIVALS AND DEPARTURES

Time	March		April		May		June		July		August		September		October	
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
	(minutes)															
7.00- 7.30	2.36	1.40	5.70	1.75	19.40	14.20	23.04	15.36	23.65	16.17	7.38	3.96	3.54	1.56	2.58	-
7.30- 8.00	1.76	0.80	3.36	0.20	11.48	7.84	16.20	9.80	18.50	11.70	4.65	1.80	1.76	0.44	0.99	
8.00- 8.30	0.58	0.10	1.08		8.04	4.92	9.24	4.76	13.95	7.83	2.52	0.24	0.58		0.69	
8.30- 9.00	0.28		0.24		4.16	2.08	6.12	2.28	10.00	4.56	0.99		0.28			
9.00- 9.30					2.22	0.66	3.60	0.40	5.70	1.62	0.06					
9.30-10.00					0.88		1.68		3.25							
10.00-10.30					0.14		0.36		1.05							
10.30-11.00																
11.00-11.30																

Note: A = Arrivals, D = Departures.

assumed to apply, are respectively $3.50 per hour per person and $2.01 per hour per person" (1973 values). To relate these values to 1979 values they are transformed by application of the implicit price deflators (1974-75 = 100.0) provided in the Australian National Accounts (ABS, 1979). They then become $7.10 per hour per person and $4.08 per hour per person, or $0.12 per minute per person and $0.07 per minute per person respectively.

For passengers travelling for non-business reasons, an arbitrary value of *half* that given above for business travel time is used, since it appears to be a reasonable assumption that delay has some cost to leisure travellers (Section 3.7). The values used are therefore $0.06 per minute per domestic traveller and $0.04 per minute per international traveller.

4.14 Evaluation of Cost of Delay to Passengers

Table 4.8 gives the cost of delay to business and non-business passengers (domestic and international), arriving or departing at specified half-hourly intervals. The costs of delay shown in this table total $35,493. The cost to all arriving passengers is $10,311, to all departing passengers $25,182; to all business passengers $24,599, and to all non-business passengers $10,894.

4.2 Estimation of Cost to Airlines through Fog Delay

There appear to be at least four possible ways in which delay due to fog at Canberra Airport could impose costs on the operating airlines. These are:

(1) the situation where incoming and/or outgoing flights are delayed but not cancelled and flow-on effects cause system disruption;

TABLE 4.8: COST OF DELAY TO PASSENGERS

Month	Time	COST TO ARRIVING PASSENGERS ($) Business Travellers D	I	Non-business Travellers D	I	COST TO DEPARTING PASSENGERS ($) Business Travellers D	I	Non-business Travellers D	I
March	7.00- 7.30	-	-	-	-	387	12	160	6
	7.30- 8.00	97	3	80	2	89	3	37	1
	8.00- 8.30	-	-	-	-	11	-	5	-
	8.30- 9.00	-	-	-	-	-	-	-	-
April	7.00- 7.30	-	-	-	-	416	13	172	6
	7.30- 8.00	271	8	112	5	19	1	8	-
	8.00- 8.30	-	-	-	-	-	-	-	-
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	-	-	-	-	-	-	-	-
May	7.00- 7.30	-	-	-	-	1946	117	1582	56
	7.30- 8.00	617	19	256	9	844	26	350	12
	8.00- 8.30	-	-	-	-	530	16	219	8
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	597	18	247	9	-	-	-	-
	9.30-10.00	205	6	85	3	-	-	-	-
	10.00-10.30	15	-	6	-	-	-	-	-
	10.30-11.00	-	-	-	-	-	-	-	-
June	7.00- 7.30	-	-	-	-	3620	111	1499	53
	7.30- 8.00	762	24	316	11	924	28	383	13
	8.00- 8.30	-	-	-	-	449	14	186	6
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	848	26	351	12	-	-	-	-
	9.30-10.00	284	10	142	5	-	-	-	-
	10.00-10.30	34	1	14	1	-	-	-	-
	10.30-11.00	-	-	-	-	-	-	-	-
	11.00-11.30	-	-	-	-	-	-	-	-

Note: D = Domestic, I = International

(contd. over)

TABLE 4.8 CONTD.

Month	Time	COST TO ARRIVING PASSENGERS ($)				COST TO DEPARTING PASSENGERS ($)			
		Business Travellers		Non-business Travellers		Business Travellers		Non-business Travellers	
		D	I	D	I	D	I	D	I
July	7.00- 7.30	-	-	-	-	3877	119	1606	56
	7.30- 8.00	886	27	169	13	1123	34	465	16
	8.00- 8.30	-	-	-	-	752	23	311	11
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	1366	42	566	20	-	-	-	-
	9.30-10.00	675	21	279	10	-	-	-	-
	10.00-10.30	101	3	42	1	-	-	-	-
August	7.00- 7.30	-	-	-	-	990	30	410	14
	7.30- 8.00	232	7	96	3	180	6	75	3
	8.00- 8.30	-	-	-	-	24	1	10	-
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	15	1	6	-	-	-	-	-
	9.30-10.00	-	-	-	-	-	-	-	-
	10.00-10.30	-	-	-	-	-	-	-	-
September	7.00- 7.30	-	-	-	-	421	14	190	7
	7.30- 8.00	103	3	43	1	52	2	21	1
	8.00- 8.30	-	-	-	-	-	-	-	-
	8.30- 9.00	-	-	-	-	-	-	-	-
	9.00- 9.30	-	-	-	-	-	-	-	-
October	7.00- 7.30	-	-	-	-	-	-	-	-
	7.30- 8.00	47	1	20	1	-	-	-	-
	8.00- 8.30	-	-	-	-	-	-	-	-
Total		7155	220	2830	106	16 654	570	7689	269

Source: Calculated from Tables 4.4 and 4.7.

(2) the situation where incoming and/or outgoing flights are cancelled;

(3) loss of revenue from reservations cancelled by passengers;

(4) loss of potential revenue from people who would fly if there were no risk of fog, but who choose to travel by alternative modes.

The first two cases could also have further ramifications in that delay or cancellations in the movement of aircraft to and from Canberra could generate delay in other flight sectors. In practice, however, the airlines tend to keep the same aircraft in use between Sydney, Canberra and Melbourne thus helping to minimise the risk of delay to other flight sectors. If fog delays are relatively short, time can sometimes be made up by compressing turn-around time, so that system effects are kept to a minimum.

4.21 Estimation of Costs to Airlines of Aircraft Delay and System Disruption

In Section 3.8 it was argued that the direct operating costs per trip, adjusted for fuel costs avoided and a peak hour factor, could be used as a measure of the value of delay to aircraft. This value must be expressed as a cost per minute (Table 4.9).

TABLE 4.9: COST PER MINUTE VALUE OF AIRCRAFT DELAY, YEAR ENDING 30 JUNE 1977

Stage	Adjusted DOC/Trip	Duration of Trip	Average Delay Cost per Minute
	($)	(minutes)	($/minute)
CBR-MEL	1077	55.0	19.58
CBR-SYD	702	37.5	18.72

<u>Source</u>: Table 3.2 and airline timetables.

The model used is:

Cost of aircraft delay =

Average delay cost per minute (Canberra-Melbourne) × average number of affected trips by half-hour interval per day × number of days in month × probable average daily length of delay (in minutes) by half-hour interval	+	Average delay cost per minute (Canberra-Sydney) × average number of affected trips by half-hour interval per day × number of days in month × probable average daily length of delay (in minutes) by half-hour interval

Table 4.10 gives the actual number of arrivals and departures between Canberra-Melbourne and Canberra-Sydney per week, and converts these to average number per day. Table 4.11 gives the results of the calculation.

TABLE 4.10: WEEKLY AND AVERAGE DAILY NUMBER OF ARRIVALS AND DEPARTURES AT CANBERRA AIRPORT FROM AND TO MELBOURNE AND SYDNEY, 1979, BY HALF-HOURLY INTERVALS DURING FOG-PRONE HOURS

Time	ARRIVALS		DEPARTURES	
	Per Week	Average per Day	Per Week	Average per Day
7.00- 7.30	-	-	15(S)	2.14(S)
7.30- 8.00	3(S)	0.43(S)	6(M)	0.86(M)
8.00- 8.30	-	-	6(M)	0.86(M)
8.30- 9.00	-	-	-	-
9.00- 9.30	14(S); 1(M)	2(S); 0.14(M)	-	-
9.30-10.00	13(M)	1.86(M)	17(S); 4(M)	2.43(S); 0.57(M)
10.00-10.30	4(S); 2(M)	0.57(S); 0.29(M)	1(S)	0.14(S)

Note: S = Sydney, M = Melbourne.

Source: TAA and Ansett timetables.

TABLE 4.11: COST OF DELAY TO AIRCRAFT AND SYSTEM DISRUPTION

Month (No. of Days)	Time (a.m.)	Cost to Arrivals CBR-MEL	Cost to Arrivals CBR-SYD	Cost to Departures CBR-MEL	Cost to Departures CBR-SYD
		($)	($)	($)	($)
March (31)	7.00- 7.30	-	-	-	1 739
	7.30- 8.00	-	200	418	-
	8.00- 8.30	-	-	52	-
April (30)	7.00- 7.30	-	-	-	2 103
	7.30- 8.00	-	811	101	-
May (31)	7.00- 7.30	-	-	-	17 635
	7.30- 8.00	-	2 865	4 093	-
	8.00- 8.30	-	-	2 568	-
	8.30- 9.00	-	-	-	-
	9.00- 9.30	189	2 577	-	-
	9.30-10.00	994	-	-	-
	10.00-10.30	25	46	-	-
June (30)	7.00- 7.30	-	-	-	27 690
	7.30- 8.00	-	3 912	4 951	-
	8.00- 8.30	-	-	2 405	-
	8.30- 9.00	-	-	-	-
	9.00- 9.30	296	4 044	-	-
	9.30-10.00	1 836	-	-	-
	10.00-10.30	61	115	-	-
July (31)	7.00- 7.30	-	-	-	20 081
	7.30- 8.00	-	4 616	6 107	-
	8.00- 8.30	-	-	4 087	-
	8.30- 9.00	-	-	-	-
	9.00- 9.30	484	6 616	-	-
	9.30-10.00	3 669	-	-	-
	10.00-10.30	185	347	-	-
August (31)	7.00- 7.30	-	-	-	4 918
	7.30- 8.00	-	1 160	940	-
	8.00- 8.30	-	-	125	-
	8.30- 9.00	-	-	-	-
	9.00- 9.30	5	70	-	-
September (30)	7.00- 7.30	-	-	-	1 875
	7.30- 8.00	-	425	222	-
October (31)	7.00- 7.30	-	-	-	-
	7.30- 8.00	-	110	-	-
Sub-total		7 744	27 914	26 069	76 041
Total	$147 768				

Thus the cost to the airlines of delays (but not cancellations) to aircraft and flow-on effects causing system disruption is estimated to be $147 768 (1977 values). This figure is converted to $169 616 in 1979 values.

4.22 Cost of Flight Cancellation

The surveys carried out at Canberra Airport for part of the winter of 1979 indicated that about 20 flights were actually cancelled due to fog in that year. This would suggest that the net revenue from 20 flights should be counted as a cost due to fog. If it is assumed that the cancelled flights were equally divided between Sydney and Melbourne this cost would be $14 897 (1977 values) or $17 429 (1979 values). In practice, however, even though some flights are cancelled the passengers on them are usually accommodated on later flights, and only rarely are they diverted to bus or rail. In view of this, including this cost probably represents an element of double-counting, and to obtain a conservative result it is not included in the final figure.

4.23 Cost of Passenger Cancellation

Some passengers do cancel reservations when fog occurs at Canberra Airport. One of the two surveys carried out between 5 June and 7 August 1979 recorded 131 cancellations fairly clearly attributable to fog. It will be assumed that the total number of cancellations due to fog for both airlines for the whole winter is 300. It is assumed also that these are absolute cancellations: the travellers either choose alternative modes or do not travel. Revenue per passenger figures given by Gannon (1979:141) are given in Table 4.12.

TABLE 4.12: REVENUE PER PASSENGER CANBERRA-MELBOURNE AND CANBERRA-SYDNEY, 1977

Stage	TAA	Ansett	Average
	($)	($)	($)
CBR-MEL	32.82	32.70	32.76
CBR-SYD	20.68	20.61	20.65

Source: Gannon (1979:141) (1977 values).

If it is assumed that the cancellations are split equally between Sydney and Melbourne, the cost to the airlines is $26 705 (1977 values) which becomes $31 284 in 1979 values.

4.24 Loss of Potential Passengers

A further potential source of loss to the airlines is the loss of potential passengers who, knowing the risk of delay due to fog at Canberra, choose an alternative land transport mode. The airlines will have lost the revenue they would have gained from these potential passengers if there was no risk of fog delay.

But these potential passengers are also bearing a cost: that of a longer, possibly less comfortable and less convenient, but possibly cheaper journey which they have traded off against the cost, comfort and convenience of the journey by air, plus the cost of the possible delay due to fog.

There is no way of determining the numbers of potential passengers who decide not to fly because of fog risk. Monthly figures for passengers at Canberra (Table 2.6) do not show any marked decrease in the winter months. On this evidence we conclude that the number of 'non-passengers' in the sense described above is small, and hence the loss of revenue from them is ignored.

In addition there are passengers who knowing the risk of fog is highest in the early morning, choose to fly in the afternoon or evening. They do not represent a loss to the airlines but for some there will be an additional cost of overnight accommodation to be borne. Again there is no evidence to suggest a significant increase in evening travellers in the winter months, and again we conclude that the cost is small enough to be ignored.

4.25 Total Cost to Airlines

The total cost of fog delay to the airlines is as follows:

Costs of aircraft delay and system disruption	:	$169 616
Cost of flight cancellation	:	not included
Cost of passenger cancellation	:	$31 284
Loss of potential passenger revenue	:	not included
Total Cost to Airlines	:	$200 900

4.3 Total Cost due to Fog Delays at Canberra Airport

To the above is added the cost of delay to passengers (Section 4.12) of $35 493, making a total cost in 1979 values of $236 393.

CHAPTER 5

POSSIBLE COUNTERMEASURES AND THEIR COST

The preceding chapters were concerned with evaluating the cost of delays due to fog at Canberra Airport. A logical extension is to examine the costs of possible ways of overcoming the problem. This chapter therefore examines some possible technical and other ways of lessening the problem of fog delays at Canberra.

5.1 Interscan[1]

Canberra Airport, like most airports handling significant commercial traffic, is already equipped with Instrument Landing System (ILS), which is capable of landing aircraft in conditions of low visibility. The existing ILS does not help with take-off in fog. ILS permits an aircraft to descend along a single defined line (the runway centreline) at a fixed angle, usually 3°. Although the system has been very effective it has certain shortcomings which motivated ICAO (International Civil Aeronautics Organisation) to recommend the development of a new system.

In 1978 a system named Interscan (from INTERval SCANning) was announced by Australia where it had been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of Transport, and Amalgamated Wireless of Australia (AWA), a private firm which manufactured the necessary electronic components. Briefly, Interscan provides precision guidance in a large part of the terminal airspace. Three subsystems provide azimuth angle, elevation angle, and distance

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1 Technical information in subsequent paragraphs is drawn from Stern (1978).

from a reference point on the airport, thus defining three space co-ordinates which fix the approaching aircraft's position over about 30 nautical miles. A flare subsystem gives guidance in the final landing stage, and a missed-approach azimuth subsystem provides guidance for missed approach manoeuvres.

The Interscan system depends on sweeping fan-shaped microwave beams, through $\pm 40^{0}$ sideways and 15^{0} vertically. Airborne equipment receives signal pulses as the beams intercept the aircraft, and the precise time intervals between pulses define the aircraft's angular position in both azimuth and elevation. The Distance Measuring Equipment (DME) is a precision version of existing DME, which measures the slant distance between the aircraft and the ground beacon. Interscan covers a wider area of approach than existing ILS, and is a considerable improvement on earlier systems. It has been adopted by ICAO as the future standard precision approach and landing system for international civil aviation.

The cost of the ground equipment needed is relatively low. It has been suggested that the existing system at Canberra Airport could be improved at a cost of the order of only $10 000 (Personal Communication, Mr B. O'Keefe, Department of Transport, Melbourne, 24 November 1980). The much larger cost lies in the equipping of aircraft with the appropriate receiving equipment. It is not simply a matter of installing devices into existing aircraft, but more an incorporation in the total design of new aircraft, and as such seems unlikely to be brought about immediately. In Australia it would seem that the whole fleets of the internal airlines would, in due course, be routinely equipped with the appropriate equipment.

Other airports in the world, particularly those in Western Europe, suffer from adverse weather conditions much more than do Australian airports. Within Australia only Canberra (which has only a small share of the total traffic) has a significant fog problem. Other major airports are only occasionally affected by adverse weather, such as heavy tropical rain in Brisbane, and occasional severe electrical storms elsewhere. Hence there is much greater interest in improved landing systems elsewhere in the world, for example at London Airport. British Air has invested heavily in improved landing systems which permit landing in the adverse conditions which prevail much more frequently than they do in Canberra.

It is therefore not possible at this stage to attribute a specific cost figure to the installation of the Interscan system at Canberra Airport and in the aircraft which would use it. It is more likely that over a fairly long time period the Interscan system or a similar one will be introduced into new generations of aircraft and to all major airports. This will also involve aspects of pilot training, flight simulators, etc.

5.2 Alternative Solutions to the Fog Problem at Canberra Airport

Alternative solutions which do not involve the installation of particular equipment should also be considered. One of these has already been adopted for Canberra, namely the scheduling of aircraft so that at least two DC9s overnight on the ground at Canberra, and are therefore available for the first morning flights to Sydney and Melbourne. This has been a regular procedure for many years. It is often the case that these two aircraft can leave Canberra in conditions of fog occurrence with relatively short delays, while incoming flights experience longer delays.

Another possibility is the relocation of Canberra Airport to some less fog-affected location. This has been frequently considered, but the nearest possible site is some 40 kilometres distant, and could itself be fog-bound under the same meteorological conditions which cause fog at Canberra Airport. The present size of the city of Canberra and the potential air traffic demand which it generates, together with the relatively low number of days when fog creates serious disruption to air services do not warrant the major expenditure of a move to a new airport site, considering the additional inconvenience of a more distant location.

A third possibility is the use of fog-dispersal techniques such as ground-based liquid propane dispensers or cloud-seeding techniques. These were developed in the Northern Hemisphere and have never been used in Australia. None of these techniques have been outstandingly successful and the cost is understood to be prohibitive for not particularly good results.

CHAPTER 6

CONCLUSION

The objective of this study was to examine the cost of fog at Canberra Airport, to obtain if possible an indicative cost for the delays caused, and to examine possible ameliorative measures and compare their cost with the costs of delay to passengers and disruption to the two main airlines.

The meteorological information presented in Chapter 2 shows that fog occurs at Canberra Airport on a significant number of days each winter, but that their number is highly variable from year to year. Technological advances in Instrument Landing Systems mean that the duration of airport closure has lessened over the years, and appropriate airline scheduling usually permits the first two flights to leave Canberra each morning. Later incoming flights frequently experience longer delays. Even so, it is likely that each year there will be some days with fog severe enough to cause irritating delays to passengers on morning flights and disruption to airline schedules.

The evaluation of the cost of fog delays hinges on the value given to passengers' time. The literature regarding the value of time in transportation studies was examined in Chapter 3, and the method developed by Hensher adopted. His method, based on empirical research into the costs of business travel in Australia, follows a production-cost approach but includes employer and employee related costs in employer's and employee's time, the extent of compensation, and a productivity effect for work done in the course of travel.

The cost to the airlines of delay due to fog was estimated by using the marginal costs of operation adjusted for fuel costs avoided and a peak hour factor as a measure of the opportunity costs of aircraft and crews, and the estimated loss of revenue from passenger cancellations.

The analysis showed that of an estimated total annual cost in 1979 of $236 393, 15 per cent was attributable to the costs of passengers' time (including non-business passengers' time valued at half that of business travel time). The largest element of cost was in delays to aircraft, particularly in early morning departures to Sydney.

The airlines face a predicament in that the later they schedule their arrivals and departures from Canberra the less will be the threat of fog delay (and hence less potential cost), but there is a passenger demand for early morning flights to and from Sydney and Melbourne which must be met. In addition the airlines must maintain regular schedules over wide route networks. The compromise is to have at least two aircraft overnight at Canberra.

The investigation of the Australian-developed improved approach and landing guidance system Interscan found that while the cost of installing the necessary ground equipment was quite low at approximately $10 000, its use would require total incorporation of the system into aircraft and into crew training, the cost of which cannot at this stage be separately identified, but which would of course be relatively very large. Other methods of fog dispersal do not appear to be very promising for Canberra Airport.

The conclusion must be reached that although fog at Canberra Airport does, and will continue to, cause inconvenience to passengers and disruption to airline operations on a few days each year, the costs, both to passengers and airlines are relatively small. On average they are about 4 cents per year per passenger, and about $100 000 to each of the two main airlines annually. It seems likely that technical developments in landing systems, such as Interscan, will be routinely incorporated in future generations of large passenger aircraft, and at major airports, thus permitting safe landings under all but the most adverse weather conditions.

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