Forecasting Aircraft Movements at Major Australian Airports

Occasional Paper

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ABSTRACT

Forecasts of aircraft movements play an integral part in the assessment of the needs for future runway and terminal infrastructure. The time-series and simulation analyses undertaken in this Paper provide useful tools for transforming passenger demand into aircraft movements.

Forecasts for both domestic and international aircraft movements are generated for the years 1990, 1995 and 2000. From these forecasts growth rates in aircraft traffic have been calculated for the major international airports and for the major sectors in the Australian domestic aviation network. The time-series model produces annual aircraft movements whereas the simulation model produces movements for a standard business day divided into morning, midday and evening periods.

Both streams of analysis assume that there will be moderate growth in the Australian economy in the period to 2000. The analyses estimate a growth rate of 1 per cent per annum in domestic aircraft movements and 5 per cent per annum in international aviation movements for the period to 2000.

FOREWORD

In discussions between the Bureau of Transport and Communications Economics and the then Department of Aviation it became apparent that a model to forecast aircraft movements at major airports would assist planning of airport facilities. The study that the Bureau subsequently undertook used both time-series equations and a simulation model to explore the problem.

The work for the time-series modelling was conducted by Dr D. Gargett and the simulation modelling by Ms L. Douglas. Assistance was provided by Mr G. Lockwood. The project was supervised at various times by Dr H. Milloy, Mr G. Piko and Mr K. Hassall who also compiled the Paper. The assistance of staff of the Department of Aviation in providing data and advice is gratefully acknowledged.

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Canberra
September 1988

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SUMMARY

Aircraft movements' forecasts play a vital role in assessing the future needs and requirements of airport infrastructure. The two models which have been constructed in this analysis project to the year 2000:

- future passenger demand at major international and domestic airports; and
- future aircraft fleet sizes into aircraft movements.

Neither model specifically examines general or commuter aviation but instead examines activity on major domestic and international trunk routes. The airports considered in the analysis are:

- Sydney, Melbourne, Brisbane, Adelaide, Perth and Canberra

as well as the combined ports of:

- North Queensland, the Northern Territory and Tasmania.

The modelling approaches used

Two approaches to modelling have been used in this study, a time-series approach and a simulation approach.

The first model is based on time-series modelling of future passenger demand and aircraft load factor, combined with estimates of average aircraft capacity. The annual number of aircraft movements at an airport is determined by dividing the annual passenger movements at an airport by the average aircraft capacity and the aircraft load factor.

Passenger movement forecasts are derived using time-series relationships from previous research done by the Bureau (BTE 1985c and BTE 1986). These relationships are themselves dependent upon forecasts of various explanatory variables, for example, air fares, national income and population. Another set of time-series equations has been developed as part of this study to relate aircraft load factor to the change in passenger movements, change in average

aircraft capacity, change in aviation fuel price and a range of trend variables. Forecasts of average aircraft seating capacity were based on the known equipment acquisition of the airlines and consideration of likely changes in aircraft technology.

The time-series model provides forecasts of annual trunk and regional aircraft movements for Australia's six major domestic airports, and annual international aircraft movements for the four major international airports.

The second method of analysis involves using forecasts of daily passenger demand and of fleet composition in a simulation model. This model uses simple allocation rules for assigning aircraft to major routes on the air network. It thus produces a trace of aircraft movements by time of day at the major domestic airports. Total aircraft movements per day as well as approximations per year can also be derived.

The simulation model is structured to allocate aircraft to specific flight sectors in each of three periods of the day. Daily passenger movement forecasts for each of the morning, midday and evening periods for each flight sector are used in the model. These passenger forecasts were derived from BTE (1986). The other major input to the simulation model is a specification of the jet aircraft fleet. This involves specifying the seating capacity and the minimum and maximum acceptable load factors for each jet in the Australian fleet.

The simulation model provides forecasts of jet aircraft movements for each of the three periods in the day at seven major domestic airports and three pseudo-airports covering a region containing more than one airport. Validation of the simulation model shows that it can accurately predict total daily aircraft movements and the variation in aircraft movements between the three periods of the day.

Forecasts from the analysis

A summary of forecast movements derived from both models is presented in the following tables to illustrate how the models are applied and to compare the two sets of estimates. Results are in the form of forecasts to the year 2000 of scheduled aircraft movements at major Australian domestic and international airports.

Although the domestic time-series forecasts relate to trunk and regional flights and the simulation forecasts relate only to flights by jet aircraft, the two sets of forecasts can be compared for broad agreement. The forecast growth rates for aircraft movements at domestic airports are estimated at -1.1 to 0.8 per cent per annum according to the time-series approach and at 1.7 to 3.9 per cent per annum by the simulation model. Over the period 1985 to 2000, these rates of increase would see domestic aircraft movements increase by 15 to 35 per cent.

International aircraft movements have been estimated using the time-series approach and are expected to grow by about 5 per cent per annum. This would result in a doubling of such movements over the period 1985 to 2000.

All the forecasts presented in this Paper are based on the assumption that there will be a fairly constant, moderate growth in the Australian economy in the period to 2000. Based on this assumption, the two models broadly agree that the resulting average rate of growth in domestic aircraft movements will be approximately 1 per cent per annum. This rate of growth is significantly below the 5 to 6 per cent annual growth in aircraft movements that typified the 1950s to the 1970s. This is partly a reflection of expected continuing developments in aircraft technology, and partly a reflection of the growing maturity of the Australian air network and of air travel as a transport mode.

ANNUAL INTERNATIONAL AIRCRAFT MOVEMENTS FORECASTS BY AIRPORT: 1990-2000

(number of aircraft movements)[a]

		Forecast Year			*Annual growth rate (per cent)*
Airport	*1985*	*1990*	*1995*	*2000*	
Sydney	20 000	25 000	33 000	43 000	5.2
Melbourne	11 000	15 000	19 000	24 000	5.3
Brisbane	4 400	6 000	7 700	10 000	5.6
Perth	3 400	5 200	6 600	8 600	6.4

a. Average growth rate scenario.

Source BTCE estimates.

DOMESTIC AIRCRAFT MOVEMENTS FORECASTS[a] BY MAJOR AIRPORT: 1990-2000

		Forecast Year			Annual growth rate
Airport	*1985*	*1990*	*1995*	*2000*	*(per cent)*
Sydney					
Time-series	75 000	71 000	78 000	84 000	0.8
Simulation[b]	124	146	148	160	1.7
Melbourne					
Time-series	58 000	57 000	60 000	63 000	0.8
Simulation	124	142	156	162	1.8
Brisbane					
Time-series	33 000	32 000	36 000	38 000	0.9
Simulation	68	80	88	102	2.7
Adelaide					
Time-series	22 000	20 000	22 000	23 000	0.3
Simulation	50	58	54	64	1.7
Perth					
Time-series	16 000	16 000	17 000	18 000	0.6
Simulation	18	22	28	32	3.9
Canberra					
Time-series	13 000	11 000	11 000	11 000	-1.1
Simulation	32	38	36	42	1.8

a. Average growth rate scenario.
b. Simulation model forecasts are based on movements for a standard business day for trunk-domestic-jets only.

Source BTCE estimates.

Of course the forecasts presented in this Paper are based on a particular set of assumptions. A major benefit of the two methods of forecasting aircraft movements is that they each provide an explanation of the links between the general economy, the aviation industry and aircraft movements. The two models are, therefore, useful tools for examining the likely effect on aircraft movements of possible changes to the economy or the aviation industry.

CHAPTER 1 INTRODUCTION

Forecasts of aircraft movements are a necessary part of any assessment of future airport capacity needs. Airport capacity encompasses both runway capacity (involving aircraft movements) and terminal capacity (involving both aircraft movements and passenger movements).

The planning of airport facilities requires information on both the future levels of aircraft movements and the variation in those movements by time of day. It was therefore decided to pursue two methods of forecasting aircraft movements: time-series analysis and simulation. In general terms, the time-series analysis provides an understanding of a relationship between aircraft movements and factors influencing those movements. The major benefit of the simulation method is that it is a flexible tool for examining the variation in aircraft movements with real or hypothetical aircraft fleet mixes across real or constructed networks by time of day.

Earlier forecasting studies undertaken by the Bureau included the use of a linear programming model of aircraft routing (BTE 1984a) and time-series forecasting of passenger demand for air travel (BTE 1986). The latter work forms one of the bases for the present Paper.

The aim of this study was to develop reliable methodologies that would be useful in forecasting aircraft movements. The different methods developed were designed to be complementary in their approaches to forecasting total aircraft movements. These forecasts could then be broadly compared. Both models would also incorporate unique elements that would prove useful in examining different aspects of the aircraft movements' problem. It was felt that a combination of such different, yet complementary, models would thus produce both a greater understanding of the subject, and a greater confidence in the explanatory power of each of the individual models.

Parameters of particular interest which are inputs to either or both models are:

- passenger demand to and from the major domestic airports of Sydney, Melbourne, Brisbane, Perth, Adelaide and Canberra;
- passenger demand to and from the major international airports of Sydney, Melbourne, Brisbane and Perth;
- the domestic and international jet aircraft fleets serving Australia; and
- estimates of the sector passenger demand.

The two models are described separately in Chapters 2 and 3, and are compared in Chapter 4. In Chapter 5, the models are applied to forecast aircraft movements at major airports. The final chapter presents concluding remarks.

CHAPTER 2 TIME-SERIES MODELLING OF AIRCRAFT MOVEMENTS

OVERVIEW

This chapter shows how time-series analysis can be used to estimate annual trunk and regional aircraft movements at Australia's six major domestic airports. The chapter also illustrates the application of the technique to estimate annual international aircraft movements at Australia's four major international airports.

The number of aircraft movements at an airport (a movement being defined as a landing or take-off) depends on passenger movements, aircraft capacities, load factors and re-positioning activities. This chapter presents equations designed to predict passenger movements and load factors and then shows how these relationships can be combined with information on aircraft capacity to generate estimates of aircraft movements.

The basic identity underlying the analysis is:

$$PSMOV = ACMOV \cdot PSCAP \cdot LF \qquad (2.1)$$

where: PSMOV = passenger movements
ACMOV = aircraft movements
PSCAP = average passenger capacity per aircraft in the fleet

$$LF = \text{load factor} = \frac{PSMOV/ACMOV}{PSCAP} \qquad (2.1a)$$

Rearranging the identity allows one to isolate aircraft movements:

$$ACMOV = PSMOV/(PSCAP.LF) \qquad (2.2)$$

Time-series analysis was undertaken on the identity presented in Equation (2.1a) in order to provide a basis for predicting aircraft movements.

In previous work related to the present subject, the Bureau has developed time-series equations to explain passenger movements as a function of airfares, income levels, and so on (BTE 1985c and BTE 1986).[1] These relationships have been utilised in this study to generate forecasts of passenger movements under 'high' and 'low' scenarios (the 'high' scenario reflecting increased passenger movements).

It has been necessary to prepare forecasts of aircraft capacities by considering the likely changes in aircraft technology in the next 15 years. Both domestic and international aircraft sizes have been considered.

Time-series equations to explain load factor variation over time were developed in the present project. These have been used to forecast load factor in Equation (2.2).

The time-series equations developed for passenger movements and load factors enable the explanation of these particular variables in terms of more basic concepts (for example airfares, incomes) which in principle are more amenable to long-term projection. These equations can then be utilised to translate forecasts of the basic variables into forecasts of aircraft movements (see Chapter 5).

ADVANTAGES OF THE METHOD

There are a number of advantages of the time-series method of forecasting aircraft movements. First, it is *convenient,* in that data to support the models are easily obtained from regularly published sources. Second, it is *simple,* in that models are quickly and easily estimated and updated. Another value of simplicity is that the models can be easily understood and utilised by those having a need to apply the models. Third, the method is *extendable* to cover more airports in the network, and/or to take in commuter aviation if required. Fourth, the method is *behavioural* as opposed to normative. For forecasting, behavioural approaches have some advantages over normative methods in that they focus more closely on actual as opposed to optimising behaviour and take account of lags in adjustment present within the system.

1. The domestic time-series model relied on data and estimates produced in BTE 1986. This publication examined data for the period 1977-1984. Data for the international time-series model was drawn from BTCE 1988.

DISADVANTAGES OF THE METHOD

There are however some disadvantages associated with the method. First, the method ignores the possibility of network development. An example of such development occurred in 1981-82 with the introduction of the Airbus direct flights between Perth and Sydney. These flights replaced (at least in part) the previous combined Perth-Adelaide, Adelaide-Sydney routes. In the current modelling, this has been handled by the inclusion of a dummy variable. However, the basic problem is that, because the modelling is based on sectoral rather than *origin-destination* demand, the sudden pattern-shifting effects of significant future network development would not be captured. The method thus relies on the assumption that, as the Australian inter-capital network is relatively developed, such major changes are less likely to occur in the future.

Second, there are some characteristics of the pattern of aircraft movements which are not modelled. For example, the models provide estimates of annual aircraft movements at an airport, but do not provide information on the actual daily schedules, fleet utilisation and so on. Being behaviourial and not normative, the models do not include cost minimisation as a criterion in their predictions. However, the price of aviation fuel is taken into account in both the passenger movement and load factor models, and so one major element of aircraft operating cost does influence the results.

Finally, fleet composition does not emerge as an output of the model, but rather forms an implicit input to the model (in the form of average aircraft size).

Thus the models ignore the possibility of network development and several variables of interest are not addressed. However the simulation model addresses some of these problems as will be seen in Chapter 3.

TIME-SERIES EQUATIONS FOR PASSENGER MOVEMENTS

A full explanation of the analysis of passenger movements is given in BTE (1985c) and more particularly in BTE (1986). Only a brief summary of that work will be presented in this Paper.

In both of these studies the assumption was made that the supply of air services was completely elastic in the short run, and that the market structure would therefore reduce to a single equation relating the quantity demanded to price and to other variables affecting demand.

The demand for aviation passenger services on a route was seen as a function of the cost of air travel, the cost of alternative modes of travel (car, coach, and even sea transport in the case of Tasmania), income, population and other factors. Individual demand relationships were estimated for 30 trunk routes in all, representing over 94 per cent of total trunk airline travel. For international air travel four separate equations were estimated. These equations covered Australian international business, non-business travel, non-Australian business and non-business travel affecting the major international terminals considered.

The general form of the passenger movement equations was:

$$PSMOV = k.X_1{}^{a}.X_2{}^{b}....X_n{}^{p} \qquad (2.3)$$

where: PSMOV = airport passenger movements (domestic or international uplifts and discharges)

k = constant
$X_1,X_2,....,X_n$ = explanatory variables (airfares, etc)
$a,b,....p$ = coefficients

This equation was then linearised by taking natural logs and was estimated by ordinary least squares using quarterly data from March 1977 to December 1983. This period witnessed a major recession in air passenger movements and so provided ample variation with which to estimate the relationships. All of the estimated elasticities for airfares and incomes were of the expected signs and most were statistically significant. Further, the demand elasticities appeared to have a consistent pattern when routes were grouped into sub-markets (for example, short haul, medium haul, long haul, summer and winter holiday routes). Detailed specifications of the equations are presented in Appendix VI of BTE (1986). They are not reviewed here.

TIME-SERIES EQUATIONS FOR LOAD FACTORS

The load factor for an aircraft is defined as the percentage of its seat capacity that is filled with passengers on a journey. For an individual airport an overall load factor can be estimated from the average of the load factors of aircraft arriving and departing. The behaviour of this airport-specific average over time has been modelled and model results are presented in this section.

An important distinction in terminology must be made between the term 'load factor' as it applies to the simulation and the time-series models. 'Load factor' means actual load factor with respect to the simulation model, that is, the actual percentage or fraction of allowable capacity utilised per aircraft by passengers. For the time-series model, however, load factor refers to a 'proxy load factor'. This proxy load factor refers to how an aircraft with 'average' capacity (derived from the fleet servicing the airport) is utilised by passenger demand. Because aircraft capacity is set for this average value, the proxy load factors may reach values greater than 1.0 when demand is large enough (for example, see Figure 2.4).

It was hypothesised that for each Australian airport the load factor would have a constant long-term average but also vary in the short run according to a number of other factors. For example, if airlines were in the process of expanding the average size of their aircraft, then this would exert a temporary downward influence on load factor. Similarly, if passenger demand jumped in any one year, this would exert a temporary upward influence on load factor. If fuel prices rose in any one year, the airlines were hypothesised to cut down on scheduled flights. This would exert a temporary positive influence on load factor. All these influences were seen as causing only temporary deviation of load factor from its constant value. Other influences could, however, cause and maintain a trend in load factor, resulting in a general upward or downward movement relative to the long-term average.

Based on this hypothetical model, the load factor relationship can be expressed as follows:

$$LF = a - b.CHPSCAP + c.CHPSMOV + d.CHFUEL + e.Z + U \qquad (2.4)$$

where:

where:	LF	= load factor
	CHPSCAP	= biennial percentage change in average aircraft capacity
	CHPSMOV	= annual percentage change in total passenger movements
	CHFUEL	= annual change in the real price of aviation turbine fuel
	Z	= trend variables representing long-term influences affecting flights to particular airports
	a	= constant
	b,c,d,e	= coefficients
	U	= random error term

Equations of this type were fitted to the data for the six major domestic airports (Sydney, Melbourne, Brisbane, Adelaide, Perth and Canberra) and for the four major international airports (Sydney, Melbourne, Brisbane and Perth). The data used in the regressions are shown in Appendix I.

A typical domestic load factor equation

A typical time-series equation of the form given in Equation (2.4) is the one for Sydney domestic airport, presented in Table 2.1. The actual load factor and the predicted load factor, over a period of 17 years, are shown in Figure 2.1.

The equation giving predicted load factor contains a constant term and three variables. The value of the constant (0.86) gives the value of the 'constant element' in load factor. As there are no trend terms, this is also close to the long-term average load factor. The signs on the coefficients of the three variables are as predicted by the theoretical model of Equation (2.4). The t-statistics on the coefficients show that they are all statistically significant. The fit of the equation (R^2=0.87) is satisfactory. The Durbin-Watson statistic of 2.8 indicates that negative auto correlation in the residuals is possibly but not conclusively indicated, so that some misspecification in this particular model may exist.

Load factor equations for the other major domestic airports

The coefficients for equations for the remaining major capital city airports are also presented in Table 2.1. The equations generally seem well-behaved, with most coefficients reaching significance (those variables whose coefficients were not significant have been excluded from the analysis).

Plots of actual versus predicted load factors are shown in Figures 2.1 to 2.6. All models capture the declines in load factor in the mid 1970s and early 1980s, as well as the rise in load factors that occurred between these two periods. Load factors in most domestic airports were relatively trendless. However, two airports, Canberra and Perth, required trend variables. The upward trend (to 1976) in the number of Federal public servants per capita successfully explained a similar upward trend in load factor at Canberra airport, after the adoption of a three-year lagged variable. This upward trend per capita ceased in 1976. Movements through Perth airport had been affected by a rapid expansion after 1980 in the number of flights of smaller aircraft to the North-West Shelf. The additional activity of the smaller aircraft is reflected by an increase in aircraft movements at Perth. The actual annual load factor estimate, Equation (2.1a), is derived from the annual domestic aircraft capacity (which is constant) and the passenger to aircraft movements ratio. Any significant increase in aircraft movements reduces the value of this ratio lowering the estimated actual airport load factor estimate. To therefore account for this diluting effect, a variable was introduced that measured passenger uplift and discharge at Karratha, the airport for Dampier.

TABLE 2.1 LOAD FACTOR EQUATIONS[a] FOR MAJOR DOMESTIC AIRPORTS, 1966-67 TO 1982-83

		Coefficients								
Airport	*Constant*	*One-year percentage change in passenger movements*	*Two-year percentage change in average aircraft capacity*	*One-year percentage change in real aviation turbine fuel price*	*Foreign fleet dummy*[b]	*North-West Shelf activity*[c]	*Dummy variable*[d]	*Commonwealth public servants as a percentage of population*	*Adjusted R^2*	*Durbin Watson statistic*
Sydney	0.856	0.00387	-0.00216	0.00354					0.87	2.8
	(87.8)	(5.1)	(-3.5)	(7.2)						
Melbourne	0.888	0.00315	-0.00257	0.00332					0.72	1.9
	(51.0)	(2.5)	(-2.4)	(2.5)						
Brisbane	0.806	0.00188	-0.00393	0.00311	0.00720		0.09446		0.80	2.0
	(31.0)	(1.7)	(-4.1)	(3.0)	(3.2)		(3.1)			
Adelaide	0.919	0.00667	-0.00269	0.00466					0.81	1.7
	(45.6)	(4.1)	(-2.1)	(5.1)						

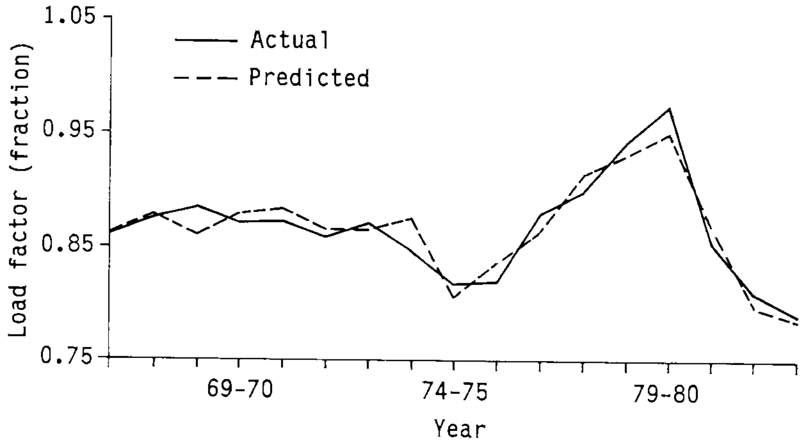
TABLE 2.1 (Cont.) LOAD FACTOR EQUATIONS[a] FOR MAJOR DOMESTIC AIRPORTS, 1966-67 TO 1982-83

	Coefficients									
Airport	*Constant*	*One-year percentage change in passenger movements*	*Two-year percentage change in average aircraft capacity*	*One-year percentage change in real aviation turbine fuel price*	*Foreign fleet dummy*[b]	*North-West Shelf activity*[c]	*Dummy variable*[d]	*Commonwealth public servants as a percentage of population*	*Adjusted* R^2	*Durbin Watson statistic*
Perth	0.946		-0.00489	0.00332		-0.00107	0.08007		0.80	2.1
	(40.9)		(-4.1)	(3.7)		(-2.3)	(4.1)			
Canberra	-0.705		-0.00211	0.00164				0.542	0.90	1.7
	(4.9)		(-1.7)	(1.4)				(9.9)		

a. See Equation 2.5 for the form of the relationship.
b. Three-year average of aircraft movements to or from Pacific Island nations (including Papua New Guinea and New Caledonia) as a percentage of aircraft movements at Sydney international airport.
c. Passenger uplift and discharge at Karratha Airport.
d. The dummy variables are as follows:
Brisbane = 1 in 1974-75 to account for Papua New Guinea independence and new international airport.
Perth = -1 in 1966-67 and 1967-68 to account for inability of airport to handle larger aircraft.
= 1 in 1972-73 to account for re-sheeting of main runway.

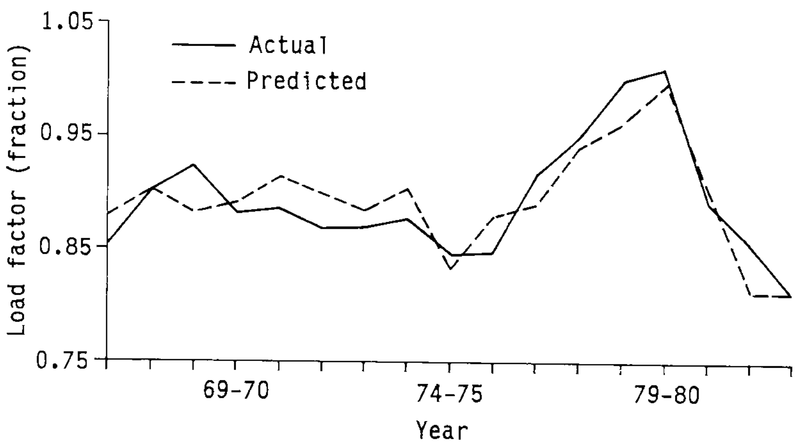
Note Figures in parenthesis are t-statistics.

Source BTCE estimates.



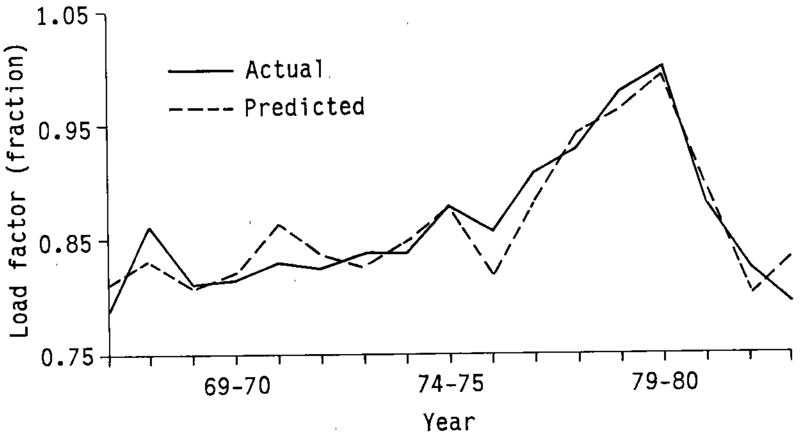
Source Prepared by BTCE.

Figure 2.1 Domestic load factor, Sydney



Source Prepared by BTCE.

Figure 2.2 Domestic load factor, Melbourne



Source Prepared by BTCE.

Figure 2.3 Domestic load factor, Brisbane

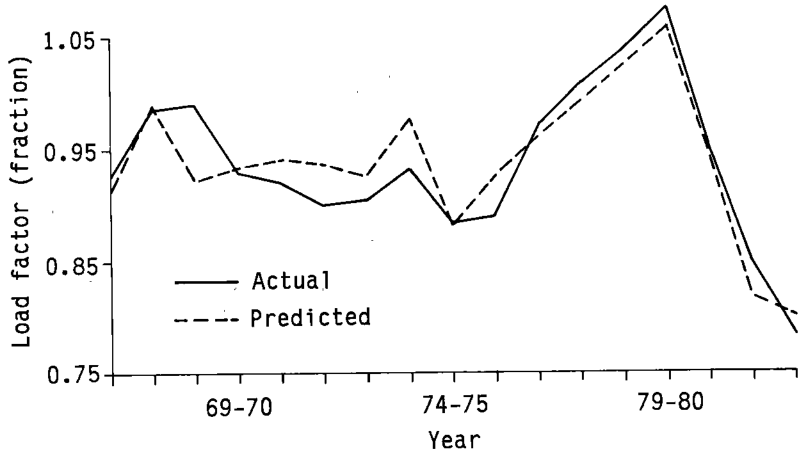


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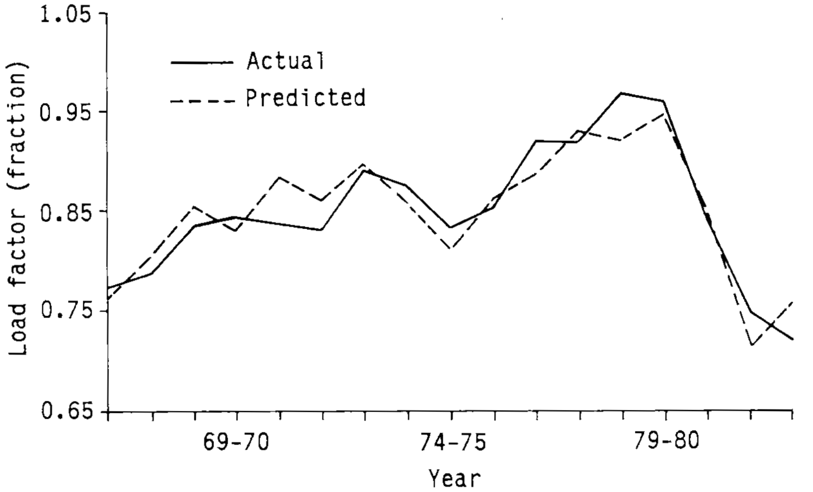
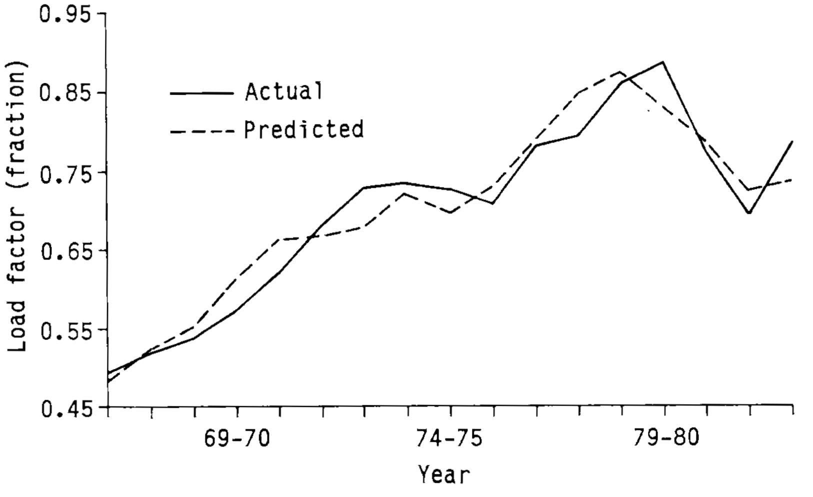
Figure 2.4 Domestic load factor, Adelaide



Source Prepared by BTCE.

Figure 2.5 Domestic load factor, Perth



Source Prepared by BTCE.

Figure 2.6 Domestic load factor, Canberra

Load factor equations for major international airports

The variables used to explain load factors for international aircraft at major airports are parallel to the domestic case after the inclusion of some further variables. In the equations fitted, 'average aircraft size' refers to the QANTAS fleet only. Variations in this variable have been used to approximate the average size of aircraft of all airlines flying into Australia. However, with regard to the growing airline network serving the Pacific Island nations to Australia, a compensatory approximation was included into the 'QANTAS average aircraft size' variable to adjust for the fact that these aircraft were smaller.

This was done by introducing a foreign fleet dummy variable that measured the three-year average of aircraft movements to and from Pacific Island nations (including Papua New Guinea and New Caledonia) as a percentage of total Sydney International aircraft movements. The foreign fleets dummy variable is a general proxy for the entry of smaller, foreign airlines into the market for travel to and from Australia. As such it is included as a variable in the equations for all four major international airports.

Also necessary to estimate load factors for international airports were dummy variables representing the phasing-in period following the opening of new international airports in the network. Before the opening of a major airport there is a crowding of passengers into the available facilities. After the opening the reverse is the case, and there is a dilution effect from the larger number of scheduled flights available to passengers. These effects are transient, lasting only while flight schedules remain relatively fixed in anticipation of increasing passenger demand. In the case of the largest international airport opened during the period under analysis, Tullamarine at Melbourne, the crowding and then dilution effect was felt not only at Melbourne but also at other international airports in Australia. Accordingly a dummy variable for the opening of Tullamarine was included in the equations for Sydney, Melbourne and Perth. This variable was set to 1 for 1966-67 to 1969-70, to -1 for 1970-71 to 1971-72 and 0 for other years for Sydney, Perth and Melbourne. A dummy variable was also necessary for the opening of the Brisbane international airport and was set to 1 in 1972-73, 2 in 1973-74 and -1 in 1974-75 and 1975-76 to account for the lead up to and opening of Brisbane's new international airport.

The dummy variable values reflect the intensity of congestion at airports. Values of 1 and 2 indicate mild and high congestion respectively whilst values of -1 and 0 reflect airport under-utilisation and normal airport operating conditions respectively.

The international load factor equations are shown in Table 2.2. Again the signs of the coefficients are consistent with the basic form postulated in Equation 2.4. Only those variables exhibiting statistical significance are shown.

The plots of actual versus predicted international load factors for the four airports are shown in Figures 2.7 to 2.10. It can be seen that the equations model the dips in load factor in the early and late 1970s and the recovery in the mid 1970s. The declining trend evident in three of the four airports is also captured, as is the upsurge in load factor at Perth in the early 1980s.

ESTIMATION OF AIRCRAFT MOVEMENTS

In order to generate estimates of aircraft movements, the various model parameters need to be combined. For example, trunk and regional passenger movements for Sydney domestic airport for 1982-83 totalled 5 338 944. The average capacity for domestic aircraft using the airport was 94 passengers. The load factor as conceptualised in this chapter was 0.79. Given this information, Equation (2.2) can be used to estimate the number of aircraft movements required to transport the specified number of passengers. The calculation yields an estimate of 71 900 aircraft movements.

$$
\begin{aligned}
\text{ACMOV} &= 5\ 338\ 944/(94 \times 0.79) \\
&= 71\ 900
\end{aligned}
$$

Estimates of 1984-85 aircraft movements were made for Sydney and Melbourne (using the component models). These were then compared with the Department of Aviation estimates of 1984-85 aircraft movements at Sydney and Melbourne (both domestic and international airports). The results for the domestic airports, presented in Figures 2.11 and 2.12, show that the models accurately predicted the Melbourne movements and correctly predicted the ending of the decline in aircraft movements at Sydney. At the international airports the predicted aircraft movements closely matched the estimates (see Figures 2.13 and 2.14).

The time-series models that have been developed and employed would, therefore, seem to have demonstrated an acceptable level of reliability as aircraft movement predictors. These models will again be applied in Chapter 5 in the task of forecasting aircraft movements at the turn of the century.

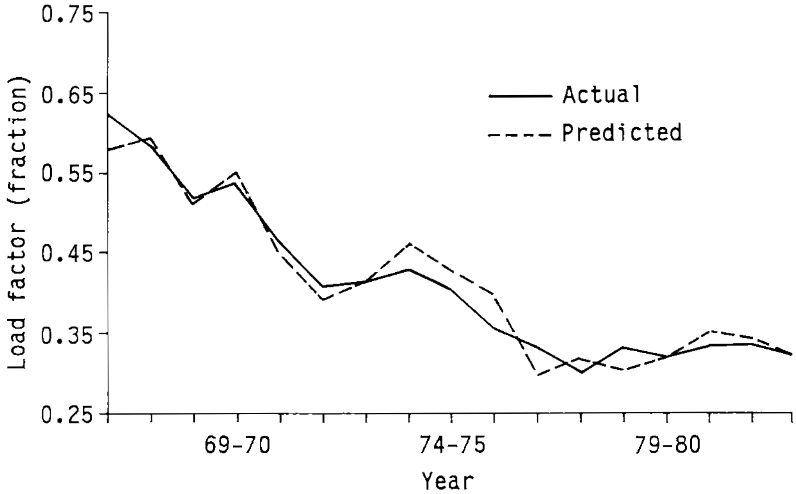
TABLE 2.2 LOAD FACTOR EQUATIONS[a] FOR MAJOR INTERNATIONAL AIPORTS, 1966-67 TO 1982-83

		Coefficients							
Airport	*Constant*	*One-year percentage change in passenger movements*	*Two-year percentage change in average Qantas fleet size*[b]	*One-year percentage change in real aviation turbine fuel price*	*North-West Shelf activity*[b]	*Dummy variables*[c]	*Foreign fleets dummy*[d]	*Adjusted R^2*	*Durbin Watson statistic*
Sydney	0.581	0.00217	-0.00233	0.00215		0.0691	-0.01764	0.93	2.1
	(19.6)	(1.7)	(-4.0)	(2.1)		(5.3)	(-7.1)		
Melbourne	0.489	0.00056	-0.00035	0.00114		0.0957	-0.01747	0.98	2.5
	(28.0)	(3.6)	(-1.3)	(4.0)		(11.2)	(-12.7)		
Brisbane	0.317	0.00097				0.0237	-0.00455	0.84	2.6
	(25.9)	(3.3)				(4.5)	(-5.0)		
Perth	0.184			0.00214	0.00199	0.0313	-0.00555	0.80	2.1
	(14.7)			(4.0)	(6.4)	(4.3)	(-3.6)		

a. See Equation 2.5 for the form of the relationships.
b. Passenger uplift and discharge at Karratha Airport.
c. Equal to 1 for 1966-67 to 1969-70 and -1 for 1970-71 and 1971-72 for Sydney, Melbourne and Perth to account for the opening of Tullarmarine international airport; for Brisbane, equal to 1 in 1972-73, 2 in 1973-74, and -1 in 1974-75 and 1975-76 to account for the opening of Brisbane international airport.
d. Three-year average of aircraft movements to or from Pacific Island nations (including Papua New Guinea and New Caledonia) as a percentage of aircraft movements at Sydney international airport.

Note Figures in parenthesis are t-statistics.

Source BTCE estimates.



Source Prepared by BTCE.

Figure 2.7 International load factor, Sydney

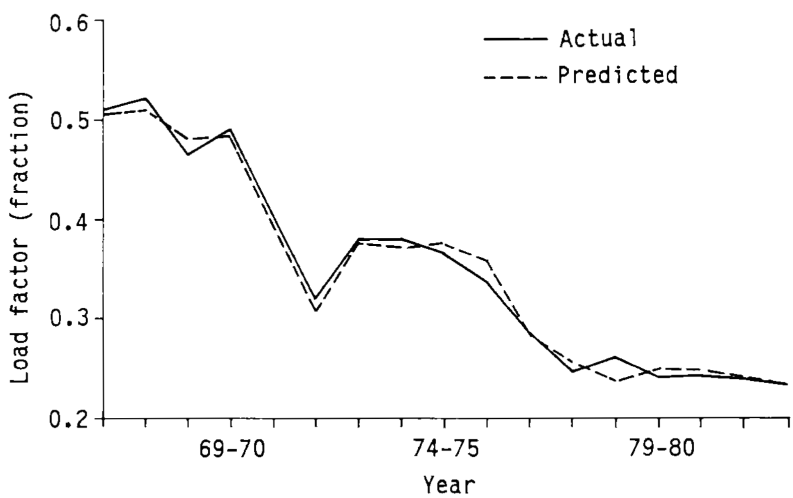


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Figure 2.8 International load factor, Melbourne

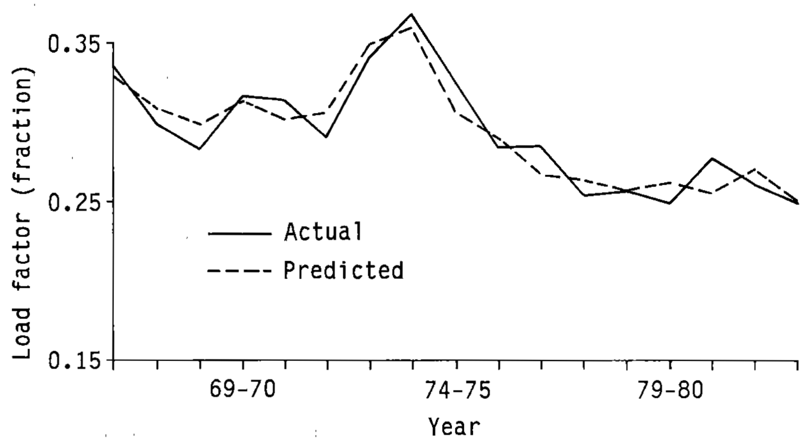

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Figure 2.9 International load factor, Brisbane

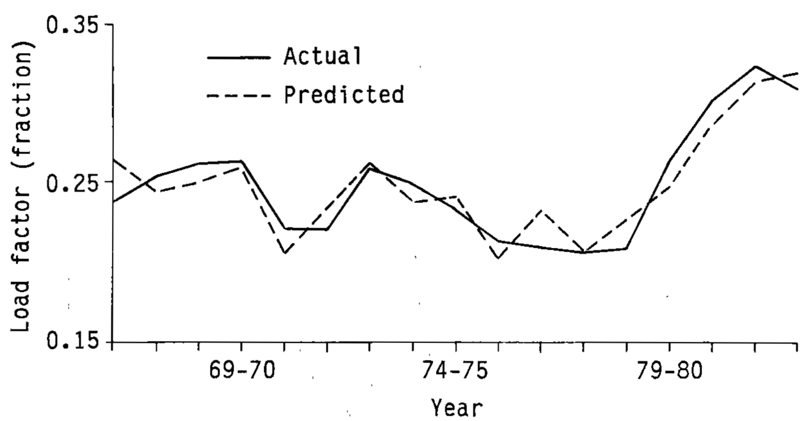

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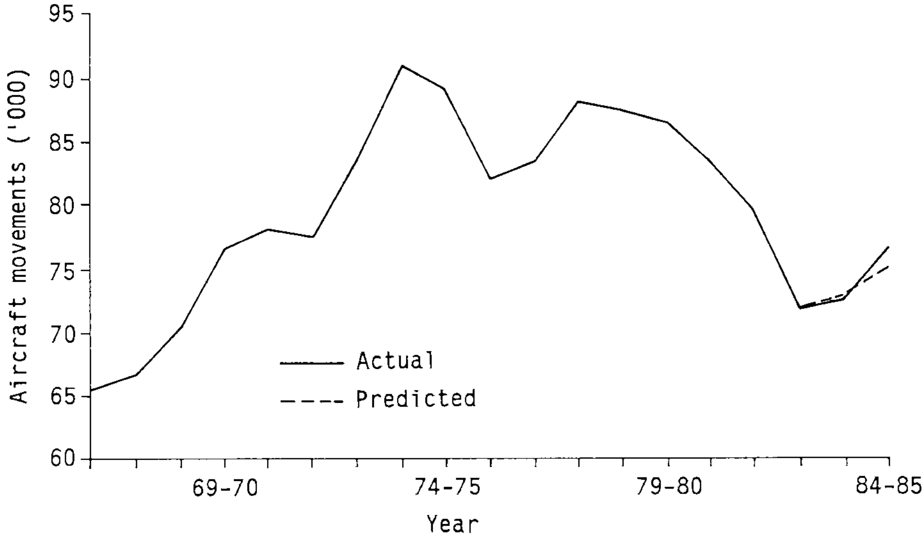
Figure 2.10 International load factor, Perth



Source Prepared by BTCE.

Figure 2.11 Domestic aircraft movements, Sydney: 1982-83 onwards predicted

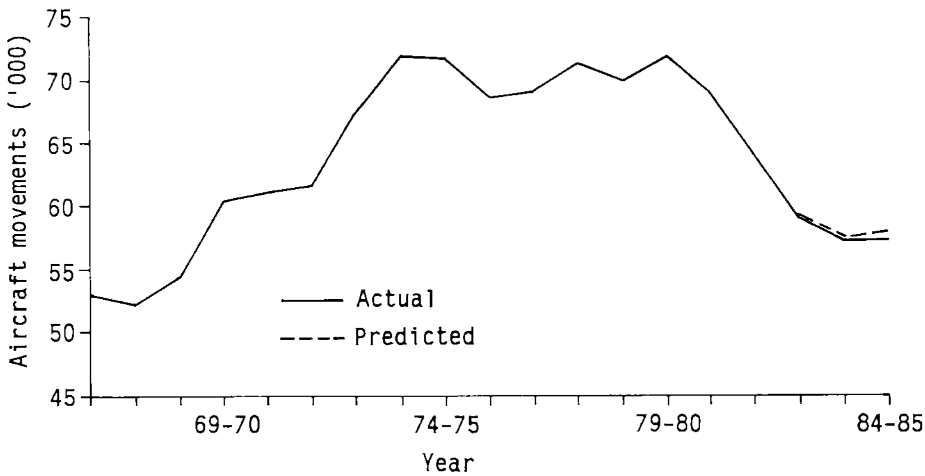


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Figure 2.12 Domestic aircraft movements, Melbourne: 1982-83 onwards predicted

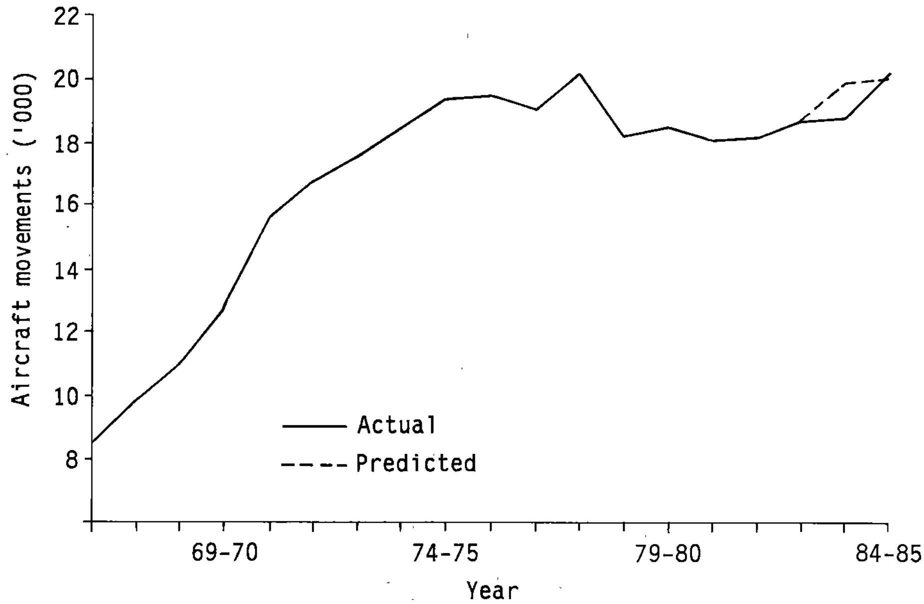

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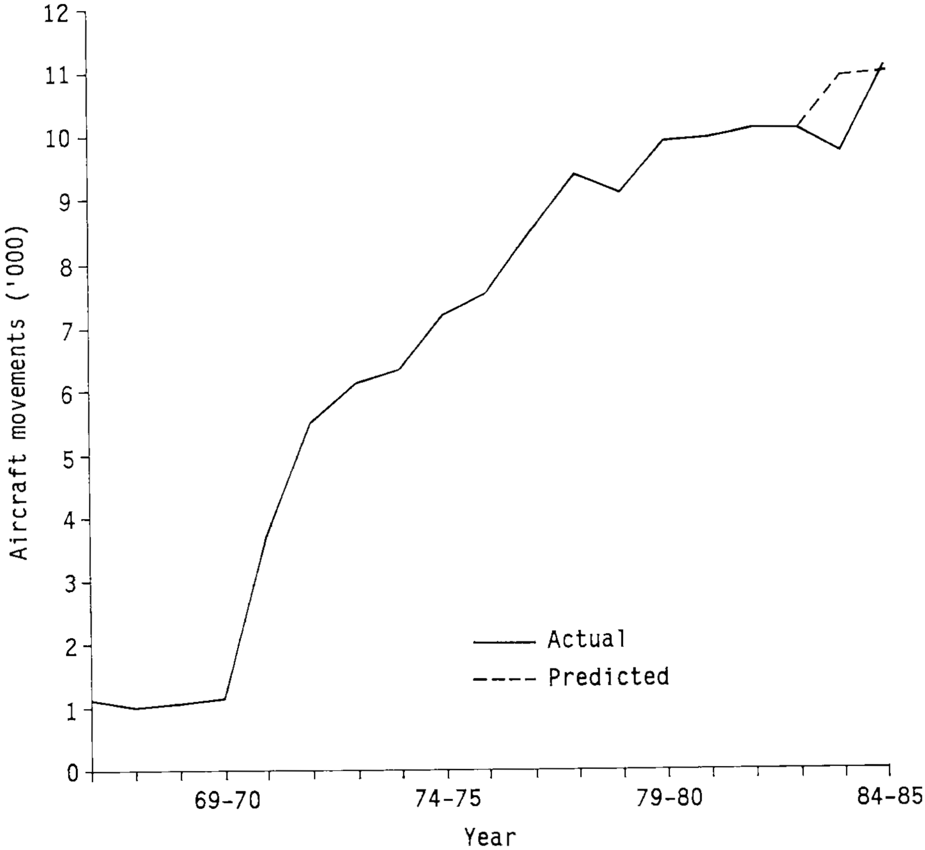
Figure 2.13 International aircraft movements, Sydney: 1982-83 onwards predicted



Source Prepared by BTCE.

Figure 2.14 International aircraft movements, Melbourne: 1982-83 onwards predicted

CHAPTER 3 SIMULATION MODELLING OF AIRCRAFT MOVEMENTS

OVERVIEW

Simulation involves the construction of a computer model of a system with certain operating conditions that will reproduce and explain the behaviour of the system consistent with reality. If this is achieved, the computer model can then be used to predict the behaviour of the real system under different operating conditions.

The system modelled in this study involves the daily allocation of an aircraft fleet on specific routes of an airport network. The aircraft are assigned in each of three periods (morning, midday and evening) given the passenger demand in each of these periods.

Specifically, the computer model representing the system has been designed and tested on the daily allocation of the Australian jet aircraft fleet on a simplified version of the current Australian domestic trunk route network. Primarily this is so the model can be used to translate forecasts of passenger demand and fleet composition into forecasts of aircraft movements at the major Australian airports. It can also be used to examine the possible effects of changes in passenger demand and fleet composition on aircraft movements at the major Australian airports. Examples of such changes are:

- passenger demand on certain routes either increasing or decreasing;
- changes in the aircraft fleet; and
- new network routes became operational.

Theoretically, the model could also be used to simulate other situations, for example, the behaviour of a regional fleet operating on a regional network. However, the model has not as yet been tested in such a regional or commuter context.

The aim of the model is to approximate the actual aircraft utilisation of the airlines. It uses practical, if simple, allocation rules to approximate the aircraft assignment methods of the airlines. It is not designed to minimise aircraft operating costs or overall passenger delays, but rather to produce schedules of aircraft movements consistent with the actual aircraft utilisation of the airlines.

BACKGROUND AND DEVELOPMENT OF THE SIMULATION MODEL

Previous methods which attempted to convert passenger movements into aircraft movements include the model DAFCARAM which is presently used by the Department of Transport and Communications' Aviation Group. DAFCARAM is a linear programming algorithm which produces an allocation of aircraft types to a given route structure over a network, such that demand is satisfied, operating costs minimised and other restrictions fulfilled (BTE 1984a). DAFCARAM's main limitations include the fact that demand is assumed to be independent of time of day and day of week. There is no account taken of peak versus off-peak periods and weekday versus weekend differences. In addition, there is no guarantee that aircraft allocations produced by DAFCARAM could actually be scheduled as the program makes no allowances for timetabling, coordination or placement of aircraft within the network. The simulation model attempts to overcome these limitations. It can be run on any particular day's passenger demand using the actual aircraft fleet to produce flight schedules that are realistic and coordinated within that day.

As mentioned in Chapter 2, the time-series approach does not directly account for network effects, fleet composition, peak versus off-peak distributions or cost considerations. The simulation model complements the time-series models by directly including the first three of these factors in its structure. It includes network effects in terms of consistency of aircraft movements. It is sensitive to changes in fleet size and structure and it incorporates peak versus off-peak differences in daily passenger demand. It indirectly considers cost factors via a minimum acceptable passenger load for each aircraft which must be achieved before the aircraft can be assigned to a route.

The main difficulty in developing a simulation model is striking the right balance between simplicity and realism. The model can become so complex that it is impossible to program or even understand. Hence, the model developed in this study is based on very simple allocation rules and many practical scheduling constraints are not included. These approximation rules give rise to some anomalies, especially on long distance routes or routes sustaining lower traffic. Thus the model has some limitations if the focus is on smaller airports in the network. However, for the major airports the model recreates quite well the existing airport scheduling patterns. For example, the simulation model assigns Airbus A300s primarily to the more heavily trafficked Sydney-Melbourne and Sydney-Brisbane routes.

In addition, the model does not attempt to schedule individual passengers who might be going 'through' an airport on their way to another. This, however, is not likely to significantly detract from the validity of the overall model, focused as it is on total aircraft movements at airports.

NATURE OF THE INPUTS

There are four primary inputs that drive the simulation model:

- the definition of the route network;
- the aircraft fleet available to service the network;
- the passenger demand on given routes of the network; and
- the proportion of the passenger demand that occurs in each period of the day.

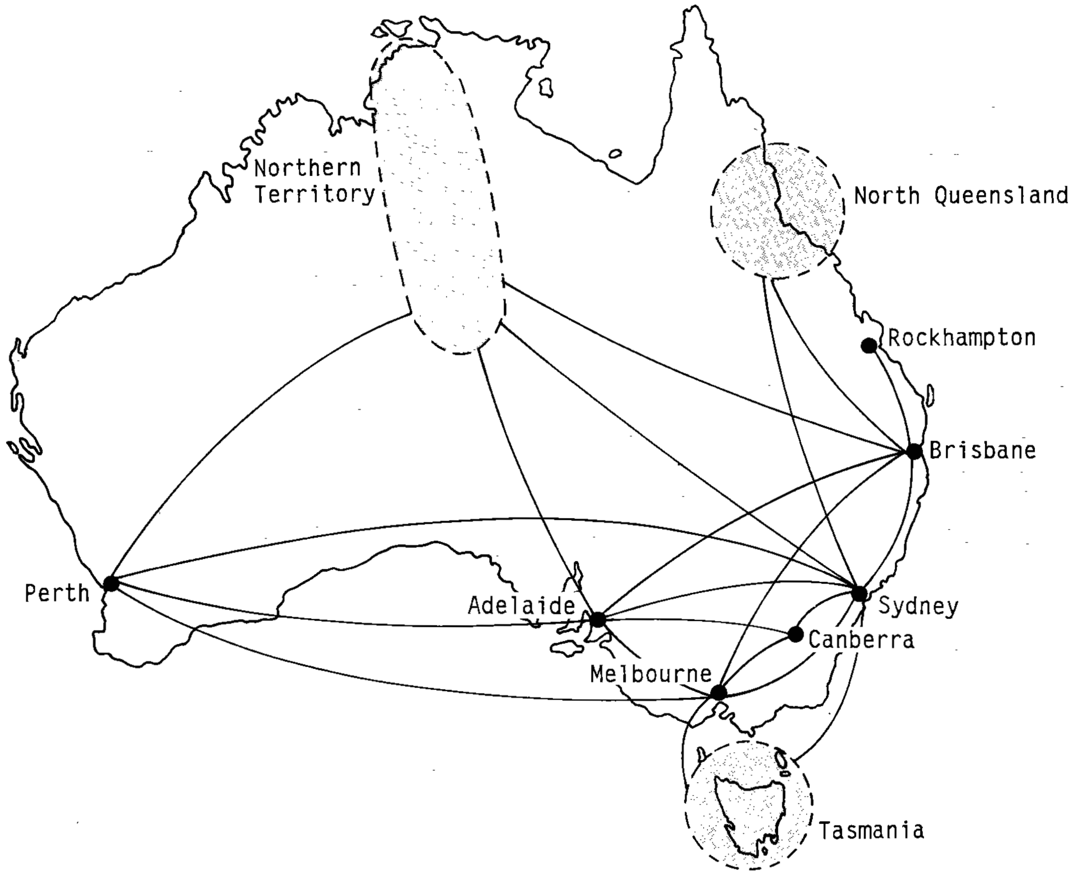
Each of these inputs is discussed in the following paragraphs.

Network definition

The model as currently developed allows for up to ten nodes in the network. In this study, all ten have been used to represent a simplified version of the current Australian domestic trunk route network. Included in these are seven nodes representing the individual airports Sydney, Melbourne, Brisbane, Adelaide, Perth, Canberra and Rockhampton and three nodes each covering a region containing more than one airport. These pseudo-nodes are North Queensland representing Cairns and Townsville, Tasmania representing Hobart and Launceston and the Northern Territory representing Darwin and Alice Springs airports.

These nodes were chosen as they represent points on most of the routes serviced by jet aircraft. Several of the possible routes between the ten nodes do not in fact have scheduled flights. The routes between the nine airports and regional aggregations that have scheduled flights are illustrated in Figure 3.1. These routes form the network to which the model is applied.

Routes in the network are defined to be 'long' if they are more than 1200 kilometres in distance, otherwise they are defined to be 'short' routes. This cut-off point is part of the model input. The actual distances between each node in the network must also be specified.



Note Northern Territory comprises Darwin and Alice Springs, Tasmania comprises Hobart and Launceston, North Queensland comprises Cairns and Townsville.

Source Prepared by BTCE.

Figure 3.1 Simplified Australian domestic trunk route network

Aircraft fleet

The model allows for up to 100 aircraft in the total fleet servicing the airports and associated route network. For each aircraft, the aircraft type, total seating capacity and minimum and maximum acceptable passenger loads must be specified. The minimum and maximum passenger load of an aircraft is defined as a percentage of the total seating capacity and is variable by period. The minimum acceptable passenger load represents an indirect consideration of the cost factors associated with operating the aircraft. It must be achieved before an aircraft can be assigned to provide a particular service on a route. The maximum 'acceptable' passenger load is the maximum number of passengers allowed on an aircraft. (This is different from the maximum possible load which is the aircraft capacity.) It represents the average load factor that occurs in the operation of the fleet under consideration. In practice, not every aircraft flies full. The term 'load factor' refers to the average occupancy of the available seats in the aircraft fleet calculated over an operational period. Incorporating load factor in the model ensures that the flight frequencies produced by the model match more closely the airlines' actual flight frequencies. As mentioned before, the aim of the model is to approximate the airlines' existing aircraft utilisation, not to optimise airline aircraft utilisation.

The model has been tested using the combined Ansett Airlines of Australia and Australian Airlines jet aircraft fleet in the years 1979-80 to 1984-85. As an illustration, details of the 1984-85 aircraft fleet are shown in Table 3.1.

TABLE 3.1 AUSTRALIAN JET AIRCRAFT FLEET, 1984-85
(number of aircraft)

Aircraft	*Seating Capacity*	*Ansett Airlines*	*Australian Airlines*	*Total Fleet*
Airbus A300	230	0	4	4
Boeing 767-200	211	5	0	5
Boeing 727-200	144	14	12	26
Boeing 737-200	102	12	0	12
McDonnell Douglas DC9	92	0	9	9
Total	..	31	25	56

.. Not applicable.

Source Department of Aviation (1987a).

Passenger demand

Passenger demand is defined to be flight sector demand. The term flight sector is used by the aviation industry to describe a single aircraft journey between take-off and landing. Thus, flight sector demand represents the demand for direct flights from one airport to another. The model does not attempt to schedule individual passengers who might be travelling through one airport on their way to another; that is, it is not considering origin-destination (O-D) demand.

The model uses flight sector demand in preference to O-D demand as it is readily available and forecasts of it can be derived relatively easily (see Appendix III). O-D data, on the other hand, is not readily available, and, in any case, its use would have greatly increased the complexity of the model. As mentioned before, the model is focused on total aircraft movements at airports and so, using flight sector demand in preference to O-D demand should not greatly affect those results.

Use of flight sector data in forecasting assumes that no new flight sectors will open up in response to growth in passenger demand. The route structure assumed for any particular application of the model is fixed. The model itself cannot determine when and if direct flights should become viable on any new routes. However, it is possible to examine the effect of changes to the route network by respecifying the routes and passenger demand.

It is important to note that the term flight sector encompasses direction. Thus, the sector Sydney-Melbourne is distinguished from the sector Melbourne-Sydney. Flight sectors are also referred to throughout this chapter as either sectors or the forward and return journeys of a specific route, where the term route does not encompass direction. The Department of Transport and Communications' Aviation group publishes data on 'traffic on-board by stages' (TOBs), which detail the aggregated movement of revenue traffic (passenger numbers) on each sector (Department of Aviation 1987b). These annual figures are referred to as sector demand.

Passenger demand proportions by time of day

The time frame of the model is one day. The day is split into three periods corresponding to the peaked pattern of passenger demand that occurs on an average business day. That is, a busy morning and evening period and slower midday period.

Lacking other sources of data on passenger demand by time of day, both past and future annual sector demand were converted into an average business day's peaked demand by using factors derived from Ansett and Australian Airlines flight timetables. Note this assumes that the pattern of aircraft flights by time of day reflects the pattern of passenger demand by time of day.

The three periods chosen for the model as representing the peaked pattern of aircraft flights that occurred on an average business day, were:

- Morning period - departures up to and including 11.00am;
- Midday or off-peak period - departures after 11.00am to before 3.30pm; and
- Evening period - departures after and including 3.30pm.

For each of the network sectors which had scheduled flights, the number of regular jet aircraft flights occurring in the business week morning, midday and evening periods and on the weekend were recorded. These data allowed estimation of the factors used to split the annual sector demand into weekend versus business week demand, and the business week demand into an average business day's morning, midday and evening period demand. For example, total business week demand may have been 70 per cent of total weekly demand, 30 per cent of which occurs in the morning period, 10 per cent in the midday period and 30 per cent in the evening period.

This business day's passenger demand averages out the seasonal demand for Christmas, Easter, school holidays, and so on. Hence, it reflects a level of passenger demand greater than would occur on a normal business day in a non-holiday period. Also, the simple application of the number of flights to derive the proportions ignores the seating capacity of the aircraft used and any variation in aircraft load factors throughout the day. This would probably increase the proportion of passenger demand occurring in the morning and evening periods because the load factors for those two periods are higher than for the midday period on most sectors.

When calculating these proportions it was apparent that certain sectors did not display a peaked pattern of flights throughout the day. These invariably were the longer sectors (where the actual flight time would prohibit peaked demand) or the very low demand sectors.[1] In the model these sectors are treated as having only a daily demand figure, the demand being satisfied primarily in the morning and evening periods, depending on the aircraft allocation.

Appendix II contains a table of the factors used to apportion an average week's demand into a morning, midday and evening period business week's demand for each network sector. Note these factors do not add to unity as they do not include weekend demand.

LOGIC OF THE MODEL

As stated previously, the model examines passenger demand spread over three periods in a day, on the given routes of a defined network and then assigns aircraft to satisfy that demand. The model does not attempt to produce the optimal allocation of aircraft to routes, but instead produces a viable allocation that approximates the operational practice of the airlines.

The model is divided into three main sections corresponding to the morning, midday and evening periods. Aircraft assignment is considered separately in each period and is dependent on the associated demand in that period. With a 'trip' being defined as either a forward and return flight on a short route or a one-way forward flight on a long route, an aircraft is assumed to complete a single trip in both the morning and midday periods. In the evening period, however, the model allows the option of specifying whether an aircraft can complete one or two trips. Hence the user of the model has the choice of specifying how intensively the aircraft fleet is utilised. Unsatisfied demand in the morning period is added to the demand in the midday period and the aggregate demand considered for assignment in that period. Similarly unsatisfied demand in the midday period is added to the demand in the evening period.

The model is structured to ensure that, at the end of the day, there are aircraft at each of the starting points of that day's assignment ready to satisfy the next day's demand. This is achieved by matching each flight on a forward journey of a route with a flight on the return journey. The following description, in conjunction with Figure 3.2, indicates how the model is structured to produce this situation.

---

1. If the model was used to determine aircraft assignment on a 'typical' day as opposed to an average day, demand on those sectors exhibiting a very low average demand could be set to either a zero or a value commensurate with the demand occurring on a day on which flights take place. This would reflect the fact these sectors would not warrant a daily service.

In the morning period, aircraft 'x' can undertake either

- a forward and return flight on a short route (for example, from airport A to B and back to A), or
- a one-way forward flight on a long route (for example, from airport A to G).

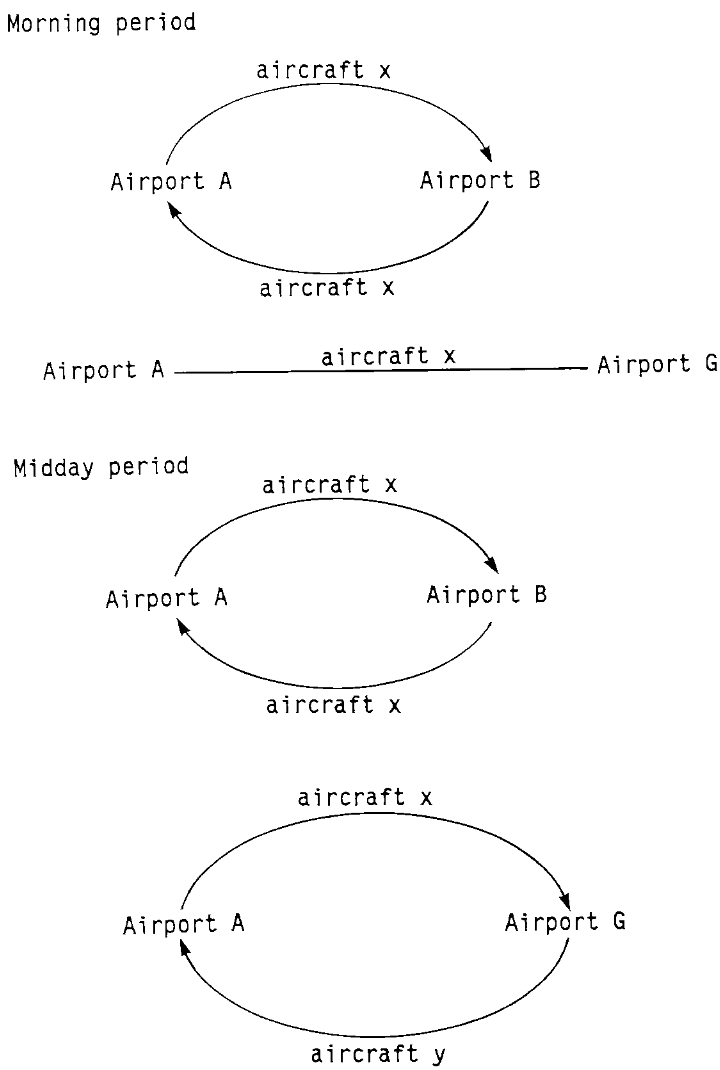


Figure 3.2 Basic logic of aircraft assignment

In the midday period, again aircraft 'x' can complete either a short return flight or a long one-way flight. However, the long one-way flight requires that another aircraft, 'y' say, is available to simultaneously undertake the return leg of the long journey. That is, the two aircraft 'swap' positions. Hence, aircraft 'x' can only fly from airport A to G in the midday period if there is an aircraft 'y' available at G to simultaneously fly from airport G to A.

Assignment of aircraft 'x' in the evening period is dependent on the combination of morning and midday period assignment. The various possibilities are illustrated in Figure 3.3.

1. Aircraft 'x' completes a short return flight in the morning period and in the midday period.

In this case, aircraft 'x' will complete the same short return flight in the evening period as it completed in the morning period.

2. Aircraft 'x' completes a short return flight in the morning period and a long one-way flight in the midday period, swapping with aircraft 'y'.

In this case, assignment of aircraft 'x' in the evening period is dependent on assignment of aircraft 'y' in the morning period. There are three possibilities:

- If aircraft 'y' completed a short return flight in the morning period, aircraft 'x' will repeat this same short return journey in the evening period.
- If aircraft 'y' completed a long one-way flight in the morning period, aircraft 'x' will complete the return of this long one-way flight in the evening period.
- If aircraft 'y' was not assigned to complete a flight in the morning period, aircraft 'x' will not be assigned to complete a flight in the evening period.

In all three cases, in the evening period aircraft 'y' is assigned to complete the same short return flight that aircraft 'x' completed in the morning period.

3. Aircraft 'x' completes a long one-way flight in the morning period and a short return flight in the midday period.

In this case, aircraft 'x' will complete the return of the long one-way flight in the evening period that it completed in the morning period.

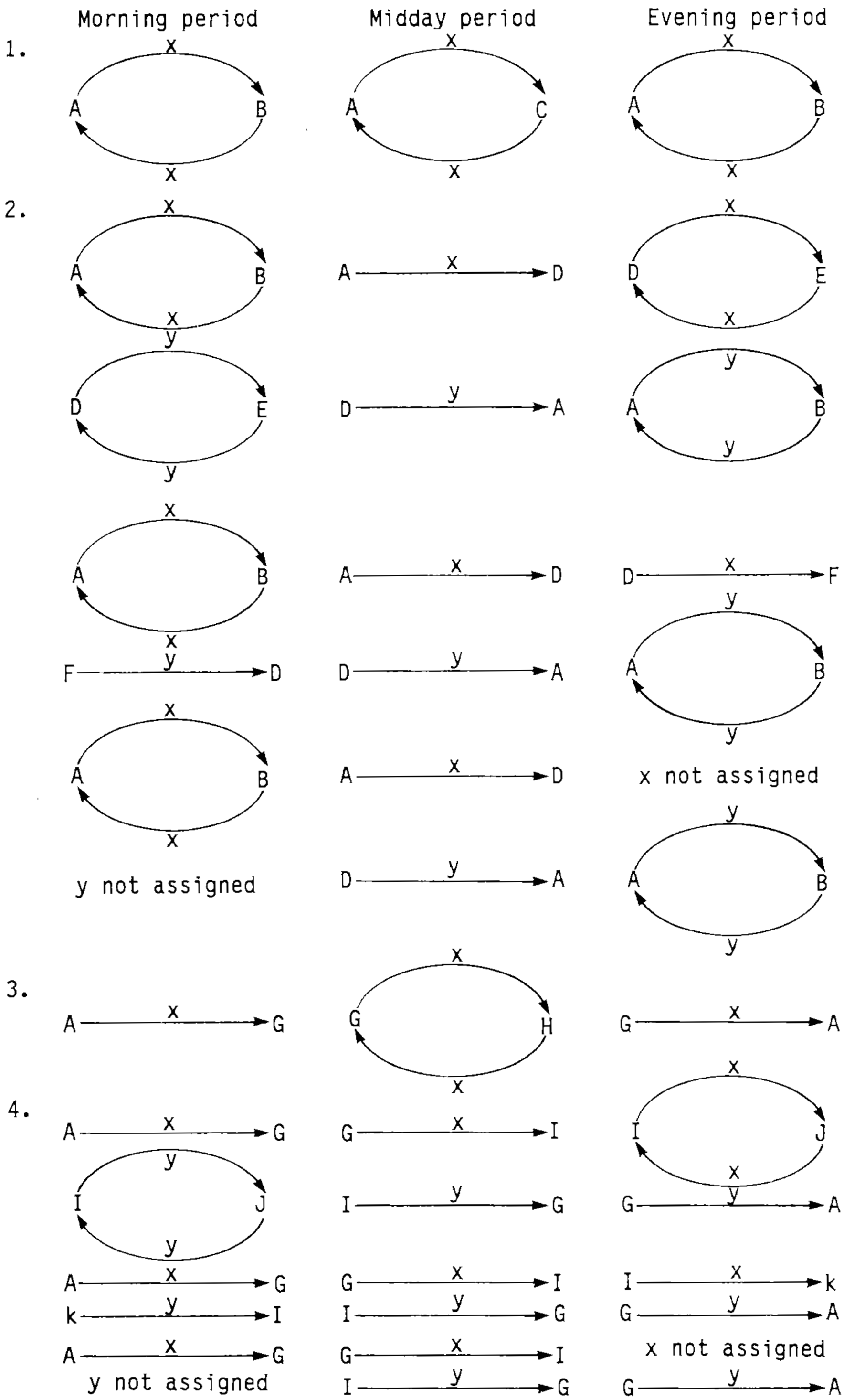


Figure 3.3 Allowable flight sequences by period of day

4. Aircraft 'x' completes a long one-way flight in the morning period and in the midday period. In the midday period, aircraft 'x' swaps with aircraft 'y'.

In this case, assignment of aircraft 'x' in the evening period is the same as when aircraft 'x' completed a short return journey in the morning period (Case 1). That is, it is dependent on the assignment of aircraft 'y' in the morning period. Aircraft 'y' in the evening period is assigned to complete the return of the long one-way flight that aircraft 'x' completed in the morning period.

In summary, in the evening period aircraft 'x' must repeat the same short return flight or the return of the long one-way flight it completed in the morning period unless it was involved in a swap in the midday period. In this case, the aircraft it swapped with, aircraft 'y' say, repeats the same short return flight or the return of the long one-way flight aircraft 'x' completed in the morning period. Aircraft 'x' undertakes the corresponding aircraft 'y' trip.

At this point, the same number of aircraft are located at each of the airports as was the case at the start of the morning period.

If only one evening trip per aircraft has been specified and there are aircraft remaining that have not yet been assigned to sectors in the evening period, these aircraft can be assigned to routes under the same rules that applied for the midday period. That is, they can complete either a short return flight or a long one-way flight if and only if there is an aircraft to simultaneously undertake the return of the long one-way flight.

If two evening trips per aircraft have been specified, all the aircraft are available for assignment on the second trip under the same rules that applied for the midday period.

At the end of the evening period, aircraft numbers and locations match those at the start of the morning period and are ready for the next day's assignments.

The following sections set out the logic of the actual aircraft assignment to sectors in each period.

Morning period

For the purpose of initial assignment of aircraft to their starting points in the morning period, all aircraft in the fleet are considered to constitute a pool.

Passenger demand on each of the network sectors is set equal to the morning period demand. For those routes for which only a daily demand figure exists, one leg is arbitrarily chosen for assignment in the morning period and the return leg in the evening period. For example, let I-J be a route for which only a daily demand figure is specified. Then if the sector I to J is selected for assignment in the morning period, the sector J to I will be considered in the evening period. In this case, the morning period demand of the sector I to J is set to the full daily demand and for the sector J to I to zero. The reverse is set in the evening period, that is, the evening period demand of the sector I to J is set to zero and for J to I to the full daily demand. This is consistent with the model logic of returning long one-way morning flights in the evening period as most routes for which only a daily demand is specified are long routes.

Sectors on the network are then sorted in order of the passenger demand attributed to them. The sector with the highest demand is considered for assignment first. The largest available aircraft for which the sector demand equals or exceeds its minimum acceptable passenger load is assigned to this sector. The assigned aircraft is then assumed to be at the sector origin ready to commence the flight.

If the sector distance is short, the aircraft completes both the forward and return journeys of the route. Otherwise the aircraft completes the long one-way forward journey only. After this assignment, the sectors are resorted on the basis of the remaining unsatisfied demand and the process continues until all aircraft in the fleet are assigned or the demand on any of the remaining sectors does not cover the minimum acceptable passenger load of any unassigned aircraft.

Midday period

The aircraft are either at a particular airport as a result of a morning period flight, or still in the aircraft pool awaiting assignment. Sector demand is set equal to the midday period demand plus unsatisfied morning period demand. No routes for which only a daily demand is specified are considered in this period except for those with carried over unsatisfied morning period demand.

The sectors are sorted by passenger demand and the highest demand sector considered for assignment first. The largest available aircraft either at the sector origin, in the aircraft pool or, if the route is short, at the sector destination, for which the sector demand equals or exceeds its minimum acceptable passenger load is considered for assignment to the sector. If such an aircraft exists and the route is short, the aircraft is assigned to complete both the forward and return journey. If the route is long, the aircraft is only assigned to complete the forward journey if there is an aircraft already at the sector destination or remaining in the aircraft pool which can undertake the simultaneous return journey. As mentioned before, the two aircraft 'swap' positions.

On such a return journey, there is no minimum acceptable passenger load condition and the aircraft can, in fact, fly empty in what may essentially be a repositioning flight. The preferential selection procedure for the aircraft that is assigned to complete the return journey is:

1. An aircraft of the same type as that completing the forward journey if available at the sector destination.

2. An aircraft of the same type as that completing the forward journey from the aircraft pool (assumed to be at the sector destination).

3. The largest available aircraft at the sector destination for which the return sector demand equals or exceeds its minimum acceptable passenger load.

4. The largest available aircraft from the aircraft pool for which the return sector demand equals or exceeds its minimum acceptable passenger load (assumed to be at the sector destination).

5. The smallest available aircraft at the sector destination.

6. The smallest aircraft from the aircraft pool (assumed to be at the sector destination).

If such an aircraft exists, both aircraft are assigned to complete their respective journeys.

After assignment, the routes are re-sorted on the basis of the remaining unsatisfied demand and the process continues until all aircraft in the fleet are assigned to sectors or the demand on any of the remaining sectors does not cover the minimum acceptable passenger load of any unassigned aircraft or there are no available aircraft at appropriate positions.

Evening period

The aircraft are either at a particular airport as a result of a morning or midday period flight or still in the aircraft pool awaiting assignment. Demand on each of the network sectors is set equal to the evening period demand or the daily demand for those sectors which comprise the return journeys of the daily demand sectors considered in the morning period. Unsatisfied midday period demand is also included.

There are two assignment phases in the evening period. Initially, all aircraft that flew in the morning period are assigned to complete the same forward and return short journey or the return of the one-way forward long journey they completed in the morning, except if the aircraft were involved in a 'swap' in the midday period. In this case, the aircraft undertakes the journey that would have been undertaken by the aircraft with which it swapped, had that swap not occurred. This repeating of journeys is based on the assumption that as peaked demand comprises mainly business travel, the morning period demand on a sector is approximately equal to the evening period demand on the return sector. Again, there is no minimum acceptable passenger load condition on these flights. Hence, all the morning period trips are repeated in the evening period and usually by the same aircraft.

In the second assignment phase of the evening period, any remaining passenger demand is satisfied by assignment of aircraft under the same rules that applied for the midday period. That is, an aircraft can undertake a short return flight or a long one-way flight if there is an aircraft available to undertake the return journey. As mentioned before, the aircraft available to undertake a trip in the second assignment phase is dependent on whether an aircraft can complete one or two trips in the evening period. If the user of the model has specified one trip in the evening period, only aircraft that have not been assigned in the first assignment phase are available. If the user has specified two trips, all fleet aircraft are available for assignment to satisfy the remaining passenger demand.

SIMULATION MODEL OUTPUT

For each period of the day, the model produces an ordered table of passenger demand by sector, a set of aircraft schedules to satisfy this demand, tables of total aircraft movements for each airport by aircraft type and the demand not satisfied on each sector. It also gives each aircraft's movements during the day and the number of passengers carried on each movement.

As an example, the model involving two trips per aircraft in the evening period was applied using the 1984-85 commercial jet aircraft fleet and sector demand. Maximum acceptable passenger load was set at 75 per cent and minimum acceptable passenger load at 30 per cent for each aircraft in the fleet for each period. All abbreviations used to describe the simulation model output are expanded in the abbreviations table following the appendixes.

Table 3.2 shows the ordered morning period passenger demand by sector. Sectors exhibiting the highest demand are those between Sydney, Melbourne and Brisbane. Total network demand is for 8708 sector passenger trips in the morning period. Table 3.3 shows how the model scheduled aircraft in the fleet to satisfy this morning period demand. As would be expected, the larger aircraft are primarily used to satisfy demand on the largest demand sectors, that is, those between Sydney, Melbourne and Brisbane. Aircraft undertaking only one flight in the morning period are flying on long routes, aircraft undertaking two flights are flying on short routes. On the return of a short route there is no minimum acceptable passenger load condition and the planes can, in fact, fly empty in what may essentially be a repositioning flight. From these tables it can be seen that 97.7 per cent of total morning period sector demand was satisfied in that period. The unsatisfied morning period demand is added to the midday period demand.

Table 3.4 presents both the total and the unsatisfied passenger demand by sector (as estimated by the model) for the morning, midday and evening periods. Note that unsatisfied morning period demand is added to the midday period demand and the unsatisfied midday period demand to the evening period demand. Sectors with very low passenger demand, for example Brisbane-Northern Territory, have not had aircraft assigned to them as they did not cover the 30 per cent minimum acceptable passenger load condition of any of the aircraft in the fleet. In practice, these sectors would have a few flights scheduled per week rather than daily flights. Otherwise, the model was able to assign aircraft to satisfy most of the passenger demand. Exceptions occurred when the remaining passenger demand did not justify allocating aircraft to the appropriate sector or aircraft were not in appropriate positions to fly certain journeys. As in the case of the evening period Adelaide-Perth sector, there was not an available aircraft at Perth to undertake the required simultaneous return journey.

Table 3.5 presents total aircraft movements, both arrivals and departures, by aircraft type for each of the network nodes. The total

TABLE 3.2 PASSENGER DEMAND ON SECTORS IN THE MORNING PERIOD, 1984-85

Origin	*Destination*	*Demand (passengers)*
Sydney	Melbourne	1 140
Melbourne	Sydney	1 084
Sydney	Brisbane	623
Brisbane	Sydney	520
Tasmania	Melbourne	480
Perth	Melbourne	449
Melbourne	Adelaide	377
Adelaide	Melbourne	371
Canberra	Sydney	346
Melbourne	Tasmania	292
Northern Territory	Adelaide	257
Perth	Sydney	252
Perth	Adelaide	249
Brisbane	North Queensland	226
Sydney	Adelaide	214
Canberra	Melbourne	195
North Queensland	Brisbane	190
Adelaide	Sydney	190
Sydney	Canberra	187
Melbourne	Brisbane	175
Brisbane	Melbourne	167
Melbourne	Canberra	155
Rockhampton	Brisbane	126
Brisbane	Rockhampton	124
Tasmania	Sydney	107
Sydney	North Queensland	75
Northern Territory	Sydney	52
Adelaide	Brisbane	27
Northern Territory	Brisbane	22
Perth	Northern Territory	19
Adelaide	Canberra	17
Total		8 708

Source BTCE estimates.

TABLE 3.3 MORNING PERIOD FLEET SCHEDULE, 1984-85

Aircraft identi-fication number	*Aircraft type*	*Origin*	*Destination*	*Total passengers*
1	A300	Sydney	Melbourne	173
		Melbourne	Sydney	173
2	A300	Sydney	Melbourne	173
		Melbourne	Sydney	173
3	A300	Sydney	Melbourne	173
		Melbourne	Sydney	173
4	A300	Sydney	Brisbane	173
		Brisbane	Sydney	173
5	B767	Sydney	Melbourne	158
		Melbourne	Sydney	158
6	B767	Tasmania	Melbourne	158
		Melbourne	Tasmania	158
7	B767	Sydney	Melbourne	158
		Melbourne	Sydney	158
8	B767	Sydney	Brisbane	158
		Brisbane	Sydney	158
9	B767	Perth	Melbourne	158
10	B727	Melbourne	Adelaide	108
		Adelaide	Melbourne	108
11	B727	Canberra	Sydney	108
		Sydney	Canberra	108
12	B727	Tasmania	Melbourne	108
		Melbourne	Tasmania	108
13	B727	Sydney	Melbourne	108
		Melbourne	Sydney	108
14	B727	Sydney	Brisbane	108
		Brisbane	Sydney	108
15	B727	Perth	Melbourne	108
16	B727	Melbourne	Adelaide	108
		Adelaide	Melbourne	108
17	B727	Northern Territory	Adelaide	108
18	B727	Perth	Sydney	108
19	B727	Perth	Adelaide	108
20	B727	Canberra	Sydney	108
		Sydney	Canberra	79

TABLE 3.3 (Cont.) MORNING PERIOD FLEET SCHEDULE, 1984-85

Aircraft identi-fication number	*Aircraft type*	*Origin*	*Destination*	*Total passengers*
21	B727	Brisbane	North Queensland	108
22	B727	Tasmania	Melbourne	108
		Melbourne	Tasmania	26
23	B727	Sydney	Adelaide	108
		Adelaide	Sydney	108
24	B727	Sydney	Melbourne	108
		Melbourne	Sydney	108
25	B727	Canberra	Melbourne	108
		Melbourne	Canberra	108
26	B727	North Queensland	Brisbane	108
27	B727	Sydney	Brisbane	108
		Brisbane	Sydney	81
28	B727	Perth	Melbourne	108
29	B727	Melbourne	Brisbane	108
30	B727	Brisbane	Melbourne	108
31	B727	Melbourne	Adelaide	108
		Adelaide	Melbourne	108
32	B727	Northern Territory	Adelaide	108
33	B727	Perth	Sydney	108
34	B727	Perth	Adelaide	108
35	B727	Canberra	Sydney	108
		Sydney	Canberra	0
36	B737	Rockhampton	Brisbane	77
		Brisbane	Rockhampton	77
37	B737	Brisbane	North Queensland	77
38	B737	Tasmania	Sydney	77
		Sydney	Tasmania	0
39	B737	Tasmania	Melbourne	77
		Melbourne	Tasmania	0
40	B737	Sydney	Adelaide	77
		Adelaide	Sydney	77

TABLE 3.3 (Cont.) MORNING PERIOD FLEET SCHEDULE, 1984-85

Aircraft identi-fication number	*Aircraft type*	*Origin*	*Destination*	*Total passengers*
41	B737	Sydney	Melbourne	77
		Melbourne	Sydney	33
42	B737	Canberra	Melbourne	77
		Melbourne	Canberra	47
43	B737	North Queensland	Brisbane	77
44	B737	Sydney	Brisbane	76
		Brisbane	Sydney	0
45	B737	Sydney	North Queensland	75
46	B737	Perth	Melbourne	75
47	B737	Melbourne	Brisbane	67
48	DC9	Brisbane	Melbourne	59
49	DC9	Melbourne	Adelaide	53
		Adelaide	Melbourne	47
50	DC9	Northern Territory	Sydney	52
51	DC9	Rockhampton	Brisbane	49
		Brisbane	Rockhampton	47
52	DC9	Brisbane	North Queensland	41
53	DC9	Northern Territory	Adelaide	41
54	DC9	Tasmania	Sydney	30
		Sydney	Tasmania	0
55	DC9	Tasmania	Melbourne	29
		Melbourne	Tasmania	0
56	DC9	Sydney	Adelaide	29
		Adelaide	Sydney	5
Total morning passengers flown				8 505

Source BTCE estimates.

TABLE 3.4 SIMULATED TOTAL AND UNSATISFIED SECTOR PASSENGER DEMAND BY PERIOD, 1984-85

(number of passengers)

	Morning period		Midday period		Evening period		Daily	
Sector	*Total*	*Unsatisfied*	*Total*	*Unsatisfied*	*Total*	*Unsatisfied*[a]	*Total*	*Per cent unsatisfied*
Sydney-Melbourne	1 140	12	536	-	1 389	-	3 053	-
Melbourne-Sydney	1 084	-	497	-	1 376	-	2 957	-
Sydney-Brisbane	623	-	374	-	686	-	1 683	-
Brisbane-Sydney	520	-	341	-	816	19	1 677	1.1
Melbourne-Adelaide	377	-	189	-	433	-	999	-
Adelaide-Melbourne	371	-	203	-	389	-	963	-
Melbourne-Tasmania	292	-	292	-	385	-	969	-
Tasmania-Melbourne	480	-	170	-	326	-	976	-
Sydney-Canberra	187	-	203	-	459	-	849	-
Canberra-Sydney	346	22	145	-	328	-	797	-
Brisbane-North Queensland	226	-	188	-	188	-	602	-
North Queensland-Brisbane	190	5	234	-	172	-	591	-
Sydney-Adelaide	214	-	194	-	194	-	602	-
Adelaide-Sydney	190	-	171	-	210	-	571	-

TABLE 3.4 (Cont.) SIMULATED TOTAL AND UNSATISFIED SECTOR PASSENGER DEMAND BY PERIOD, 1984-85
(number of passengers)

	Morning period		*Midday period*		*Evening period*		*Daily*	
Sector	*Total*	*Un-satisfied*	*Total*	*Un-satisfied*	*Total*	*Un-satisfied*[a]	*Total*	*Per cent un-satisfied*
Melbourne-Canberra	155	-	62	-	310	17	527	3.2
Canberra-Melbourne	195	10	100	-	255	-	540	-
Melbourne-Brisbane	175	-	245	-	70	-	490	-
Brisbane-Melbourne	167	-	67	-	234	-	468	-
Melbourne-Perth	-	-	-	-	430	10	430	2.3
Perth-Melbourne	449	-	-	-	-	-	449	-
Brisbane-Rockhampton	124	-	96	-	138	-	358	-
Rockhampton-Brisbane	126	-	126	-	126	-	378	-
Adelaide-Perth	-	-	-	-	330	114	330	34.5
Perth Adelaide	249	33	33	33	33	33	249	13.3
Adelaide-Northern Territory	-	-	-	-	276	-	276	-
Northern Territory-Adelaide	257	-	-	-	-	-	257	-
Sydney-Perth	-	-	-	-	215	-	215	-
Perth-Sydney	252	36	36	36	36	-	252	-

TABLE 3.4 (Cont.) SIMULATED TOTAL AND UNSATISFIED SECTOR PASSENGER DEMAND BY PERIOD, 1984-85
(number of passengers)

	Morning period		*Midday period*		*Evening period*		*Daily*	
Sector	*Total*	*Un-satisfied*	*Total*	*Un-satisfied*	*Total*	*Un-satisfied*[a]	*Total*	*Per cent un-satisfied*
Sydney-Tasmania	-	-	-	-	129	-	129	-
Tasmania-Sydney	107	-	-	-	-	-	107	-
Sydney-North Queensland	75	-	-	-	-	-	75	-
North Queensland-Sydney	-	-	-	-	86	17	86	19.8
Sydney-Northern Territory	-	-	-	-	33	-	33	-
Northern Territory-Sydney	52	-	-	-	-	-	52	-
Adelaide-Brisbane	27	27	27	27	27	27	27	100.0
Brisbane-Adelaide	-	-	-	-	44	44	44	100.0
Brisbane-Northern Territory	-	-	-	-	23	23	23	100.0
Northern Territory-Brisbane	22	22	22	22	22	22	22	100.0
Adelaide-Canberra	17	17	17	17	17	-	17	-
Canberra-Adelaide	-	-	-	-	35	-	35	-

TABLE 3.4 (Cont.) SIMULATED TOTAL AND UNSATISFIED SECTOR PASSENGER DEMAND BY PERIOD, 1984-85

(number of passengers)

	Morning period		*Midday period*		*Evening period*		*Daily*	
Sector	*Total*	*Unsatisfied*	*Total*	*Unsatisfied*	*Total*	*Unsatisfied*[a]	*Total*	*Per cent unsatisfied*
Perth-Northern Territory	19	19	19	19	19	19	19	100.0
Northern Territory-Perth	-	-	-	-	18	18	18	100.0
Total	8 708	203	4 587	154	10 257	363	23 552	1.5

a. This is equal to total unsatisfied demand.
\- Rounded to zero.

Note Unsatisfied demand in the morning period is added to the demand in the midday period and unsatisfied demand in the midday period is added to the demand in the evening period. Hence, morning, midday and evening period demand may not add to total demand.

Source BTCE estimates.

TABLE 3.5 SIMULATED DAILY AIRCRAFT MOVEMENTS BY AIRPORT, 1984-85

	A300	*B767*	*B727*	*B737*	*DC9*	*Total*
Sydney	32	18	38	24	12	124
Melbourne	20	20	52	22	10	124
Brisbane	8	6	26	18	10	68
Adelaide	0	2	28	10	10	50
Perth	0	2	11	5	0	18
Canberra	4	0	20	6	2	32
Tasmania	0	8	8	8	8	32
North Queensland	0	0	7	7	2	16
Northern Territory	0	0	4	0	4	8
Rockhampton	0	0	0	6	6	12
Total	64	56	194	106	64	484

Source BTCE estimates.

summary of aircraft movements at each airport provides the statistics of interest when the model is used for forecasting purposes. The distributions across airports by aircraft type show where each aircraft type is used. The total movements by aircraft type, when compared with the number of each aircraft type in the fleet, shows the degree to which the model utilises each aircraft type available.

The simulated daily movements of some individual aircraft determined by the model are presented in Table 3.6. The Airbus A300s generally ferry up to the present maximum load factor threshold between Sydney, Melbourne and Brisbane. The Boeing 767s are used on the large to medium sized routes and the smaller aircraft generally serve smaller demand routes. Note that aircraft numbers 37 and 47 were involved in a 'swap' in the midday period and hence in the evening period have completed each other's required morning period trip in the first assignment phase of the evening period allocation. Aircraft 37 has also completed a Melbourne to Adelaide return trip in the second assignment phase of the evening period.

VALIDATION OF THE MODEL

The model's ability to reproduce the pattern of aircraft movements at each airport by time of day is illustrated in Table 3.7 and Figure 3.4. The actual number of jet aircraft movements between the nodes in

TABLE 3.6 EXAMPLES OF SIMULATED DAILY MOVEMENTS GENERATED BY THE MODEL, 1984-85

		Daily movements			
				Evening	
Aircraft identi-fication number	*Aircraft type*	*Morning*	*Midday*	*First assignment*	*Second assignment*
1	A300	Sydney-Melbourne-Sydney	-Melbourne-Sydney	-Melbourne-Sydney	-Melbourne-Sydney
2	A300	Sydney-Melbourne-Sydney	-Brisbane-Sydney	-Melbourne-Sydney	-Brisbane-Sydney
5	B767	Sydney-Melbourne-Sydney	-Brisbane-Sydney	-Melbourne-Sydney	a
6	B767	Tasmania-Melbourne-Tasmania	-Melbourne-Tasmania	-Melbourne-Tasmania	a
18	B727	Perth-Sydney	a	-Perth	a
19	B727	Perth-Adelaide	-Melbourne-Adelaide	-Perth	a
20	B727	Canberra-Sydeny-Canberra	a	-Sydney-Canberra	a
37	B737	Brisbane-North Queensland	-Brisbane	-Melbourne	-Adelaide-Melbourne
47	B737	Melbourne-Brisbane	-North Queensland	-Brisbane	a
52	DC9	Brisbane-North Queensland	a	-Brisbane	a
56	DC9	Sydney-Adelaide-Sydney	a	-Adelaide-Sydney	a

a. No flights.

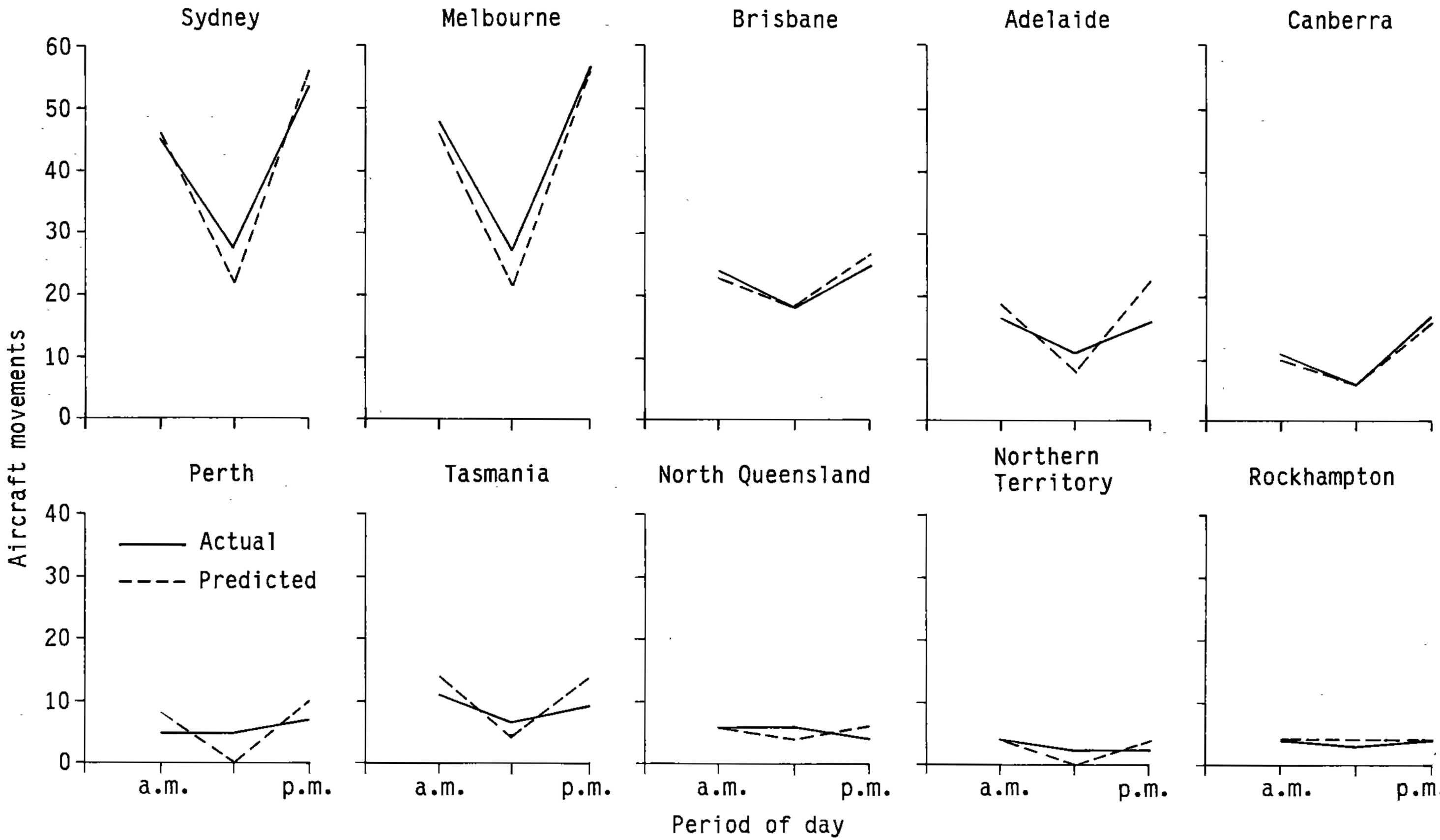
Source BTCE estimates.

TABLE 3.7 ACTUAL AND PREDICTED JET AIRCRAFT MOVEMENTS BY TIME OF DAY, 1984-85

(number of jet aircraft movements)

Airport	*Morning period*	*Midday period*	*Evening period*	*Total*	*Per cent of actual*
Sydney					
Actual	45	27	54	126	
Predicted	46	22	56	124	98
Melbourne					
Actual	48	27	57	132	
Predicted	46	22	56	124	94
Brisbane					
Actual	24	18	25	67	
Predicted	23	18	27	68	101
Adelaide					
Actual	17	11	16	44	
Predicted	19	8	23	50	114
Canberra					
Actual	11	6	17	34	
Predicted	10	6	16	32	94
Perth					
Actual	5	5	7	17	
Predicted	8	0	10	18	106
Tasmania					
Actual	11	7	9	27	
Predicted	14	4	14	32	119
North Queensland					
Actual	6	6	4	16	
Predicted	6	4	6	16	100
Northern Territory					
Actual	4	2	2	8	
Predicted	4	0	4	8	100
Rockhampton					
Actual	4	3	4	11	
Predicted	4	4	4	12	109
Total					
Actual	175	112	195	482	
Predicted	180	88	216	484	100

Sources Ansett and Australian Airlines timetables (1985). BTCE estimates.



Sources Ansett and Australian Airlines timetables (1985). BTCE estimates.

Figure 3.4 Actual and predicted jet aircraft movements by time of day, 1984-85

the network were derived from Ansett and Australian Airlines 1985 flight timetables. The predicted number of jet aircraft movements were obtained from the model allowing for two trips per aircraft in the evening period and using 1984-85 demand and fleet data. The minimum and maximum acceptable passenger loads were set at 30 and 75 per cent respectively for each aircraft in the fleet for each period. Although airlines may not use a 30 per cent minimum acceptable passenger load, this value was used as it produced schedules consistent with current practice. Advice from the Department of Transport and Communications' Aviation group suggested that 75 per cent is roughly equivalent to the present airline load factor of 70+ per cent.

On inspection, the model predicts to a reasonable level of acceptance both the peaked pattern of aircraft movements by time of day and the total number of jet aircraft movements at each airport. There are some problems in the pattern of movements for airports serving mainly sectors for which only a daily demand is specified, the Northern Territory, Perth and, to a lesser extent, Adelaide and Tasmania. This is because the model forces aircraft on these sectors to be assigned in the morning and evening periods. The predicted number of jet aircraft movements, for the total of the ten airports, is 100 per cent of the actual numbers observed.

The model's ability to predict the behaviour of the historical aircraft allocation process was tested using sector and aircraft fleet input data for the years 1979-80 to 1984-85. Again the model was applied allowing two trips per aircraft in the evening period to derive the predicted jet aircraft movement figures. The minimum acceptable passenger load was set at 30 per cent for each aircraft for each period whilst the maximum acceptable passenger load at 80 per cent for the first three years of this period and then at 75 per cent for the last three years. This was found to give a good fit between predicted and actual aircraft movements and was consistent with the airlines being required to run their fleets more intensively with higher load factors in those earlier years. This was because daily demand over the network remained fairly constant over the six-year period but total fleet seating capacity was much smaller in the first three years than for the latter three, as shown in Table 3.8. The airlines were then awaiting the delivery of new, larger, more fuel efficient aircraft that would replace the older jets. When these new aircraft became operational, the utilisation of each aircraft declined as did the respective aircraft load factors. This situation was captured in the model in that the proportion of aircraft being required to complete four trips per day in order to satisfy sector

TABLE 3.8 COMPARISON OF DAILY SECTOR DEMAND AND TOTAL FLEET SEATING CAPACITY, 1979-80 TO 1984-85

		Jet aircraft fleet		
Year	*Daily sector demand*	*Number of aircraft*	*Total seating capacity*	*Average aircraft seating capacity*
1979-80	23 679	46	5337	116
1980-81	22 984	48	5664	118
1981-82	23 924	53	6668	126
1982-83	21 705	53	7004	132
1983-84	21 997	55	7560	137
1984-85	23 195	56	7771	139

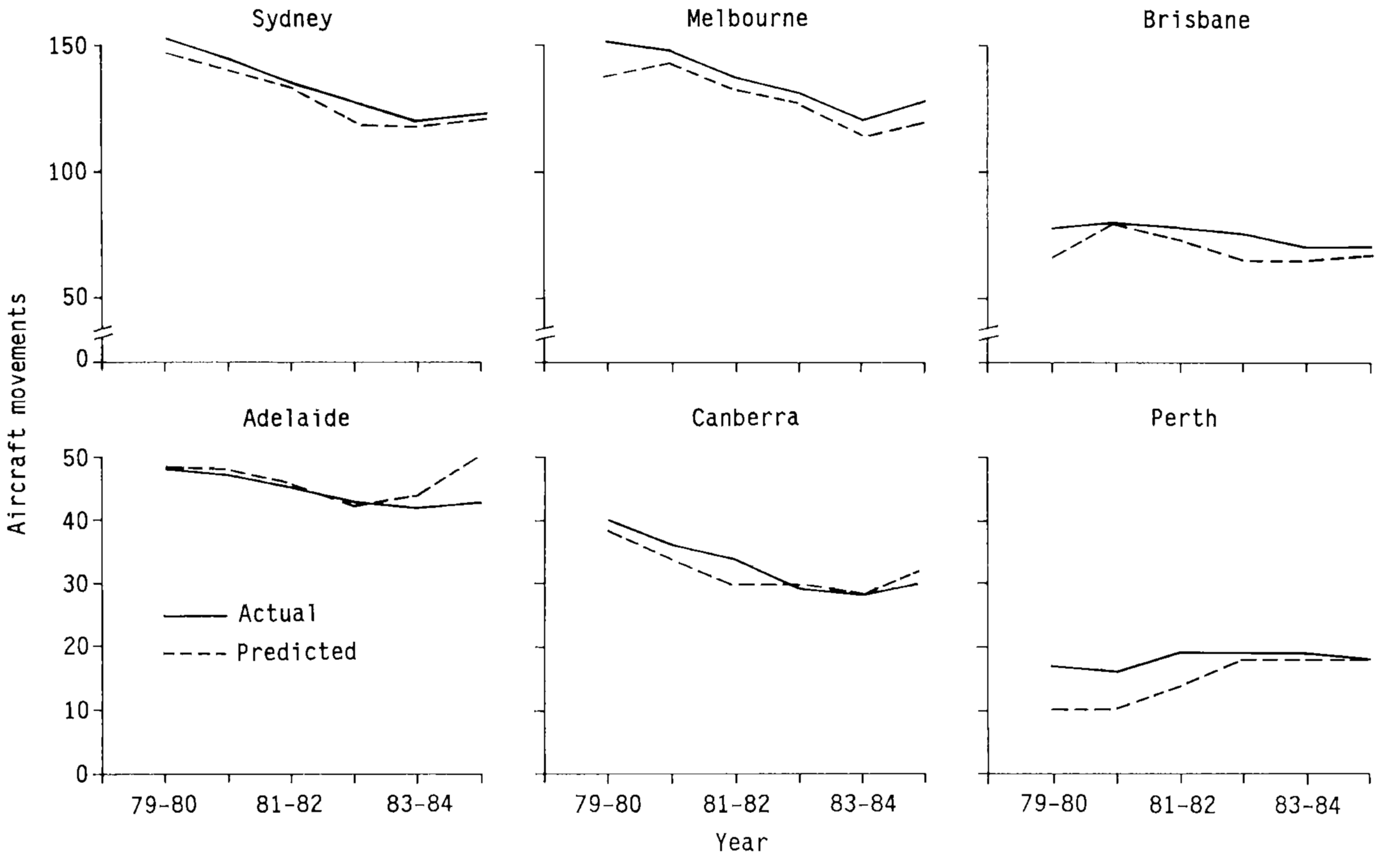
Sources Department of Aviation (1987a). BTCE estimates.

demand was much higher in the earlier years than in the later years under investigation.

The actual number of jet aircraft movements over the six-year period under consideration was obtained from the Department of Transport and Communications' Aviation group. Annual aircraft movements by aircraft type were available for the six major airports - Sydney, Melbourne, Brisbane, Adelaide, Canberra and Perth. A daily average of movements for domestic jet aircraft was used to compare with the predicted values. Comparing the 1984-85 actual aircraft movement figures derived this way with those derived from the Ansett and Australian Airlines timetables (Table 3.7), shows that both sets of figures are approximately equal.

Table 3.9 and Figure 3.5 present the actual versus predicted daily jet aircraft movements at each of the major airports. During the six-year period, the model predicted the decline in aircraft movements for Sydney, Melbourne, Brisbane and Canberra. It also simulated a rising trend for Adelaide and Perth.

The model predicted the total number of jet aircraft movements at each airport reasonably well for the six-year period under consideration. Across all six airports, the predicted number of jet aircraft movements was about 97 per cent of the actual number observed for each year.



Source BTCE estimates.

Figure 3.5 Actual and predicted daily jet aircraft movements, 1979-80 to 1984-85

TABLE 3.9 ACTUAL AND PREDICTED DAILY JET AIRCRAFT MOVEMENTS, 1979-80 TO 1984-85

(number of jet aircraft movements)

Airport	*1979-80*	*1980-81*	*1981-82*	*1982-83*	*1983-84*	*1984-85*[a]
Sydney						
Actual	152	145	139	129	119	124
Predicted	146	142	138	122	118	124
Melbourne						
Actual	152	149	140	129	123	130
Predicted	140	146	136	134	116	124
Brisbane						
Actual	77	78	77	75	71	72
Predicted	66	78	74	66	66	68
Adelaide						
Actual	48	47	45	43	42	43
Predicted	48	48	46	42	44	50
Canberra						
Actual	40	36	34	29	28	30
Predicted	38	34	30	30	28	32
Perth						
Actual	17	16	19	19	19	18
Predicted	10	10	14	18	18	18
Total						
Actual	486	471	454	424	402	417
Predicted	448	458	438	412	390	416
Predicted as a percentage of total	92	97	96	97	97	100

a. 1984-85 actual jet aircraft movements do not equal those in Table 3.7 as they come from different sources. Here the figures are derived from Aviation annual figures (Department of Aviation 1987b); in Table 3.7 they are from Ansett and Australian Airlines timetables since figures on a daily period basis are not available from DoTC's Aviation group.

Source BTCE estimates.

In summary, the model predicts, to a reasonable level of acceptance, the pattern and total number of aircraft movements over the six-year investigation period.

However, the model treats all aircraft as part of a single fleet. Table 3.10 contains the results of halving the 1984-85 sector demand and using the Ansett and Australian Airlines fleets separately to service the demand. It can be seen from this table that splitting the fleet did not make a great difference to the overall number of aircraft movements using 1984-85 input data.

TABLE 3.10 ACTUAL AND PREDICTED DAILY JET AIRCRAFT MOVEMENTS, 1984-85
(number of aircraft movements)

	Predicted		
Airport	*Separate fleets*	*Combined fleet*[a]	*Actual*[b]
Sydney	124	124	126
Melbourne	124	124	132
Brisbane	68	68	67
Adelaide	46	50	44
Canberra	40	32	34
Perth	18	18	17
Tasmania	28	32	27
North Queensland	16	16	16
Northern Territory	4	8	8
Rockhampton	12	12	11
Total	480	484	482

a. From Table 3.7.
b. Actual jet aircraft movements from Ansett and Australian Airlines timetables as in Table 3.7.

Sources Ansett and Australian Airlines timetables (1985). BTCE estimates.

CHAPTER 4 A COMPARISON OF THE MODELS

Following the discussions of the time-series and simulation models in Chapters 2 and 3, a brief comparison of the two models is presented in this chapter. Each of the models possesses unique as well as common features and they can be compared in four broad areas: inputs, conceptual basis, outputs and use in forecasting. These comparisons are set out in Table 4.1.

INPUTS

Of the two models, the time-series model relies most heavily on historical data. However, for historical data, both models use information from regular aviation publications which are publicly available.

The time-series model easily incorporates airport-specific factors (such as the opening of new facilities) into its estimates. The simulation model has no requirement to do this since it effectively assumes the airports are capable of handling the flights the model generates.

CONCEPTUAL BASIS

There are two major differences in the conceptual bases of the models. First, they are different types of models, and second, they operate at different levels of aggregation and detail. Differences in these two areas are reflected in differences in the models' outputs and in their uses for forecasting.

The time-series models are behavioural, that is, they seek ways to emulate the actual behaviour of the airline systems. For example, time-series equations often include lagged variables in an attempt to emulate adjustment lags in the system modelled. However, the basic assumption in the simulation model is that the adoption of very simple allocation rules for aircraft will result in a simulated system which emulates a modified real world environment. Thus the simulation model is a normative model (although not an optimising one). Both of the aircraft movement models are similar in making use of behavioural models of passenger demand. These models are based on observations and projections of actual passenger movements.

Variations in the level of aggregation represent the other major difference between the two models. Differences in level of aggregation are apparent in the units of time employed, in the units of analysis, in the level of simplicity involved, and in the scope of the models. In particular, the simulation model as developed currently has only been used to investigate trunk domestic jet travel, whereas the time-series model has been used to cover domestic trunk and regional as well as international travel. Both models, however, can be extended in scope.

TABLE 4.1 A COMPARISON OF THE MODELS

Item	*Time-Series*	*Simulation*
Inputs		
needs historical data	yes	no, except for validation
uses published data	yes	yes
includes airport-specific factors	yes	no, except time of day pattern on routes
Conceptual basis		
type of model	behavioural	behavioural (passengers) normative (aircraft)
lags in adjustment	yes	no
unit of time	year	day
unit of analysis	airport	flight sector
level of simplicity	could be done on a calculator	computer required
cost considerations	minimally, through the price of fuel	indirectly, through minimum acceptable load factor
fleet mix	no	yes
network effects	no	yes
network development effects	no	could be built in, but not generated automatically

TABLE 4.1 (Cont.) A COMPARISON OF THE MODELS

Item	*Time-Series*	*Simulation*
Outputs		
load factor	yes	yes
aircraft movements	by airport (trunk and regional, international)	by sector, by airport (domestic jet)
scheduling of aircraft	no	yes
time of day	no	yes
Use in forecasting		
passenger demand	based on BTE (1986) forecasts by route, aggregated	based on BTE (1986) forecasts by route dynamic capability
scope of forecasts	6 major domestic, 4 major international airports	10 domestic airport equivalents (extension possible)
load factor forecasts	yes	estimated load factor is input
time frame	short to long	short to long
composition of fleet	average size forecast	actual fleet size

Source Prepared by BTCE.

The greater detail afforded by the simulation model is apparent in the inclusion of several parameters that the time-series does not address: fleet mixes, maximum and minimum passenger loads, network effects, and network development effects.

OUTPUTS

Differences in conceptual basis also show up in the outputs of the models. 'Load factor' is an explicit output from the time-series approach whereas for the simulation model 'load factor' is an input with a preset upper limit.

Differences in the scope of the models show up in the types of aircraft movements that are produced. The time-series model produces load factor, and domestic or international movements by airport. In comparison, the simulation model produces movements by sector, by airport providing approximate schedules by period of day.

USE IN FORECASTING

Both models are designed primarily to be used in conjunction with the passenger demand forecasting models developed in BTE (1986). However, again the scope of these predictions varies. The time-series model provides forecasts for six domestic and four international airports, with the simulation model forecasting ten domestic airports and 'pseudo-airports'. In addition, both models can provide forecasts for the short, medium and long-terms.

The level of detail also varies between the models. For example, the simulation model uses a forecast of the actual composition of the fleet (that is, real and estimated fleet mixes are specified), whereas the time-series model merely applies a simple estimate of average aircraft capacity.

Both models, however, allow forecasting of growth rates for annual aircraft movements at the six major domestic airports (see Chapter 5). The time-series method provides information on annual aircraft movements at these airports, while the simulation method satisfies an allocation procedure interpretable as daily aircraft movements. Thus, the models can be viewed as being complementary though stemming from two seemingly different approaches.

CHAPTER 5 FORECASTS OF AIRCRAFT MOVEMENTS

FORECASTS OF INPUT PARAMETERS

In order to generate forecasts of aircraft movements, a number of factors used for input to the models must be specified. Rather than provide a specific forecast, the examples in this chapter use a range for these estimates. High and low estimates of the input factors thus generate high and low values of forecasts for aircraft movements.

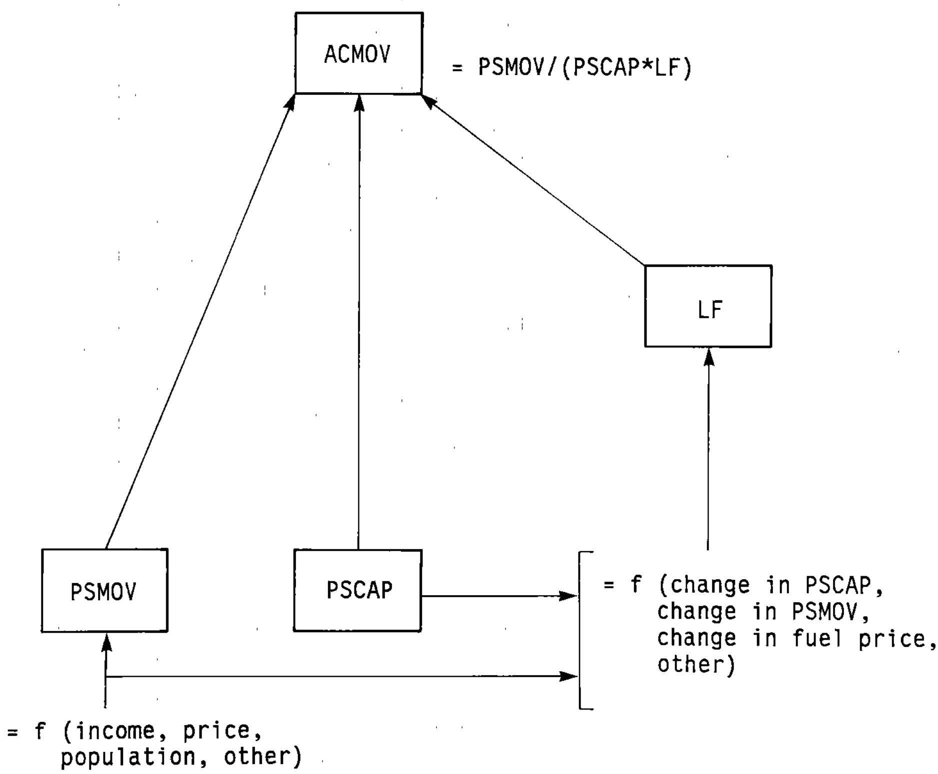
There are two sets of input factors from which forecasts are generated. First, at an aggregated level there are parameters such as passenger movements, aircraft capacity and load factor. Second, on a broader constituent variable level there are input factors such as gross domestic product and air fares which determine the values of the aggregated variables. The basic structure of this approach is illustrated by the flow chart for time-series forecasting model set out in Figure 5.1. From Figure 5.1 it can be seen that various constituent models determine the aggregate level forecasts of passenger movements, aircraft capacity, load factor and finally aircraft movements. This section discusses the scenario assumptions for constituent variables under the three headings of passenger movements, aircraft capacity and load factor.

Passenger movement forecasts

For the aggregate passenger forecasts required for this analysis, reliance is placed on work performed by Bureau as an extension to previous research (see BTE 1986 and BTE 1985c). That work used time-series analysis to predict uplift and discharge passenger movements on a sector basis. Explanatory variables included air fares, national income, exchange rates, population, exports, imports, migration, cost of alternative travel and so on. Two scenarios (high and low) specified the values of the constituent variables used to generate passenger movement forecasts. In Table 5.1, the scenario values of these variables are outlined. The reader is referred to BTE (1985c) and BTE (1986) for a more detailed discussion of the rationale for these forecasts.

Use of these parameters as the constituent variables generated forecasts for passenger movements by uplift and discharge sector (see BTE 1986). These individual uplift and discharge sector forecasts formed an input to the simulation model. (Appendix III presents the method used to derive flight sector passenger demand from uplift and discharge sector passenger demand.)

Examples of passenger demand forecasts on selected flight sectors are shown in Table 5.2. It can be seen that the forecasts for these routes vary considerably. Routes such as Canberra to Sydney have extremely low rates of growth forecast for passenger demand. At the other end of the scale are routes, such as, Adelaide to the Northern Territory where high rates of increase in passenger demand are forecast. On the large inter-capital city routes, the average growth rate in passenger demand is of the order of 2 per cent per annum.



ACMOV Aircraft movements identity
PSMOV Passenger movements model
PSCAP Aircraft capacity estimate
LF Load factor model

Figure 5.1 Flow chart for Time-Series Forecasting

TABLE 5.1 PROJECTED AVERAGE ANNUAL GROWTH RATES IN PASSENGER MOVEMENT CONSTITUENT VARIABLES UNDER THE HIGH AND LOW SCENARIOS TO THE YEAR 2000

(per cent)

		Year			
Item	*Scenario*[a]	*1985*	*1985-90*	*1990-95*	*1995-2000*
International					
fares (real)	High	0.0	-1.3	-1.3	-1.3
	Low	2.0	1.0	0.0	0.0
GDP (real)					
Australia	High	4.5	3.5	3.5	3.5
	Low	4.0	1.5	1.5	1.5
Overseas	High	3.0	3.5	3.5	3.5
	Low	2.0	1.5	1.5	1.5
Exchange rate	High	-6.0	-2.0	0.5	1.0
	Low	-8.0	-4.6	0.0	0.0
Population					
Australia	High	1.2	1.3	1.3	1.2
	Low	1.2	1.2	1.2	1.1
Overseas (OECD)	High	1.0	1.0	0.9	0.9
	Low	0.7	0.7	0.6	0.6
Australian value of					
trade (real)	High	12.0	4.0	4.0	4.0
	Low	8.0	2.0	2.0	2.0
Migrants as a proportion					
of the population	High	0.5	0.5	0.5	0.5
	Low	0.0	0.0	0.0	0.0
Trunk and secondary trunk					
fares (real)	High	1.0	1.0	1.0	1.0
	Low	1.9	1.6	1.3	1.3
Expenditure on tourism					
(real)	High	1.0	1.5	1.2	1.2
	Low	0.0	0.5	0.9	0.9
Car Cost (real)	High	2.0	1.0	1.0	1.0
	Low	1.0	0.0	0.0	0.0
Coach fares (real)	High	1.0	1.0	1.0	1.0
	Low	-3.0	-2.0	0.0	0.0
Sea fares to Tasmania					
(real)	High	1.0	1.0	1.0	1.0
	Low	-3.0	-2.0	0.0	0.0

a. The 'high' scenario implies a high growth rate in aircraft movements.
Source BTE (1986).

However, for the time-series analysis, uplift and discharge passenger activity on sectors leading into a major airport were aggregated, resulting in forecast passenger movements at that airport for each scenario. These aggregate airport forecasts are set out in Table 5.3.

It is apparent from Table 5.3, that the average forecast for domestic passenger movements results in an increase in the order of about 2.5 per cent per annum at most airports. For example, Sydney has an average growth rate of 2.5 per cent per annum, which leads to passenger movements increasing by 45 per cent over the 15 years to 2000. Comparing this 2.5 per cent annual growth in passenger demand at Sydney, with the 1.8 per cent growth in passenger demand forecast for the Melbourne to Sydney route (see Table 5.2), it can be inferred that traffic at Sydney will increasingly be affected by demand from high-growth routes. These are routes linking Sydney with such places as Cairns, Townsville, Darwin, Perth, Hobart and Coolangatta.

International passenger movements by airport are forecast to grow by 4.5 to 9.2 per cent per annum in the years to the end of the century depending on the scenario adopted (see BTCE 1988). International passenger traffic was forecast in aggregate, not by individual airport. This is the reason for the uniform growth rates attributed to all four airports. As can be seen from Table 5.3, the average forecast passenger growth rate for the four international airports is 6.8 per cent per annum.

Aircraft capacity forecasts

For the time-series forecasting approach, forecasts of the average capacity of domestic trunk aircraft are needed. In the 'high' aircraft movements scenario it is assumed that the current average aircraft size will remain relatively constant until the year 2000, experiencing a growth rate of 0.3 per cent per annum (see Table 5.4).

In the 'low' scenario the long-term upward trend for aircraft capacity was estimated as being half that experienced from 1966-67 to 1982-83. This was estimated to be 2.3 per cent per annum. A bias towards slower growth in size is apparent in both scenarios as shown in Figure 5.2. Current aircraft capacities, as borne out in evidence, from the simulation model especially, seem well suited to handling the present levels of demand on the domestic trunk routes. This situation has occurred following recent major new equipment investments by the two largest domestic operators.

For the simulation model it was necessary to obtain forecasts of the trunk-domestic-jet fleet capacity and composition. This was achieved

TABLE 5.2 FORECAST DAILY PASSENGER MOVEMENTS ON SELECTED FLIGHT SECTORS, 1990 TO 2000

(number of passengers)

Flight sector[a]	*1985*[b]	*Scenario*	*Year 1990*	*Year 1995*	*Year 2000*	*Per cent annual growth*
Sydney-Melbourne	3 053	High	3 493	3 902	4 258	2.2
		Average	3 405	3 740	4 015	1.8
		Low	3 315	3 577	3 771	1.4
Melbourne-Sydney	2 957	High	3 382	3 777	4 122	2.2
		Average	3 297	3 621	3 888	1.8
		Low	3 120	3 464	3 651	1.4
Brisbane-Sydney	1 677	High	1 950	2 211	2 443	2.5
		Average	1 886	2 078	2 234	1.9
		Low	1 821	1 944	2 022	1.3
Melbourne-Adelaide	999	High	1 298	1 551	1 853	4.2
		Average	1 128	1 276	1 450	2.5
		Low	956	999	1 045	0.3
Brisbane-North Queensland	602	High	743	894	1 041	3.7
		Average	727	855	977	3.3
		Low	708	816	910	2.8
Adelaide-Perth	330	High	368	403	430	1.8
		Average	361	389	409	1.4
		Low	353	374	388	1.1
Adelaide-Northern Territory	276	High	386	525	684	6.2
		Average	368	480	601	5.3
		Low	349	435	518	4.3

a. Growth of passenger movements from A to B is assumed equivalent to growth of passenger movements from B to A.
b. Actual demand derived from Department of Aviation statistics.

Sources BTE (1986). BTCE estimates.

TABLE 5.3 FORECAST ANNUAL PASSENGER MOVEMENTS BY AIRPORT, 1985 TO 2000

(passengers '000)

Air travel market and airport	*Scenario*[a]	*Year 1985*	*1990*	*1995*	*2000*	*Per cent annual growth*
International						
Sydney	High	2 600	4 000	6 300	9 700	9.2
	Average	2 600	3 600	5 000	7 000	6.8
	Low	2 600	3 200	4 000	5 000	4.5
Melbourne	High	1 100	1 700	2 700	4 100	9.2
	Average	1 100	1 500	2 100	3 000	6.8
	Low	1 100	1 400	1 700	2 100	4.5
Brisbane	High	480	750	1 160	1 800	9.2
	Average	480	670	930	1 290	6.8
	Low	480	600	750	930	4.5
Perth	High	480	750	1 160	1 800	9.2
	Average	480	670	930	1 290	6.8
	Low	480	600	750	930	4.5
Domestic trunk						
Sydney	High	5 900	6 900	8 100	9 400	3.2
	Average	5 900	6 600	7 600	8 600	2.5
	Low	5 900	6 300	7 100	7 800	1.9
Melbourne	High	4 800	5 700	6 700	7 500	3.0
	Average	4 800	5 400	6 100	6 650	2.2
	Low	4 800	5 100	5 500	5 800	1.3
Brisbane	High	2 700	3 300	3 900	4 500	3.5
	Average	2 700	3 150	3 650	4 100	2.8
	Low	2 700	3 000	3 400	3 700	2.1
Adelaide	High	1 800	2 200	2 600	3 000	3.5
	Average	1 800	2 000	2 250	2 500	2.2
	Low	1 800	1 800	1 900	2 000	0.7
Perth	High	1 100	1 500	1 800	2 000	4.1
	Average	1 100	1 350	1 600	1 700	2.9
	Low	1 100	1 200	1 400	1 400	1.6
Canberra	High	930	930	1 000	1 050	0.8
	Average	930	915	965	1 000	0.5
	Low	930	900	930	950	0.1

a. The 'high' scenario implies a high growth in aircraft movements.

Source BTE (1986).

TABLE 5.4 FORECAST AVERAGE AIRCRAFT CAPACITY, 1985 TO 2000
(seats per aircraft)

Variable	*Scenario*[a]	*1985*	*1990*	*1995*	*2000*
International aircraft capacity	High	400	400	400	400
	Low	400	465	540	611
Domestic aircraft capacity[b]	High	100	105	105	105
	Low	100	110	125	140

a. The 'high' scenario implies a high growth in aircraft movements.
b. Estimated with Fokker F27 and Fokker F28 aircraft considered.

Source BTCE estimates.

TABLE 5.5 FORECAST DOMESTIC TRUNK JET AIRCRAFT FLEET USED IN SIMULATION MODEL
(Number of aircraft)

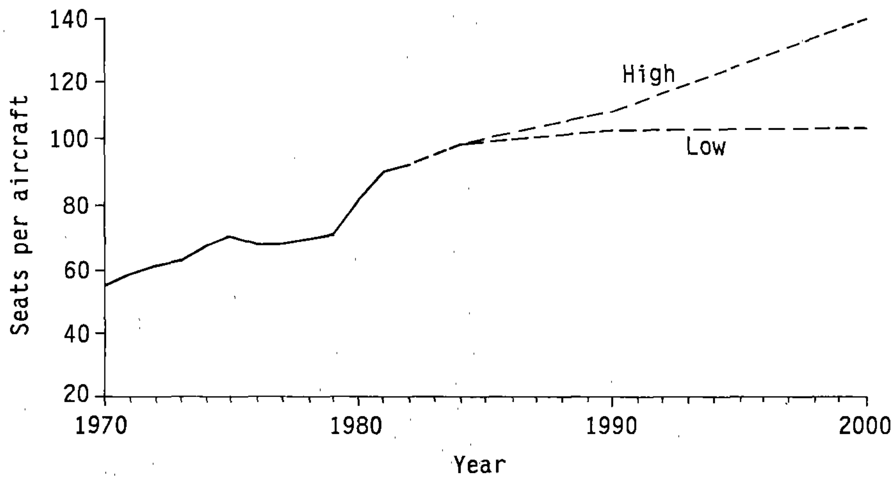
Aircraft seating capacity	*Year*			
	1985[a]	*1990*	*1995*	*2000*
200-230[b]	9	7	8	14
140-160[c]	26	26	38	39
95-115[d]	21	34	32	32
Total fleet number	56	67	78	85
Average aircraft seating capacity	144	134	138	144

a. See Table 3.1 for detailed fleet composition.
b. Includes Airbus A300, Boeing 767-200.
c. Includes Airbus A320, Boeing 727-200.
d. Includes Boeing 737-200, Boeing 737-300, McDonnell Douglas DC9.

Sources Department of Transport and Communications' Aviation group (pers. comm. 1987) BTCE estimates.

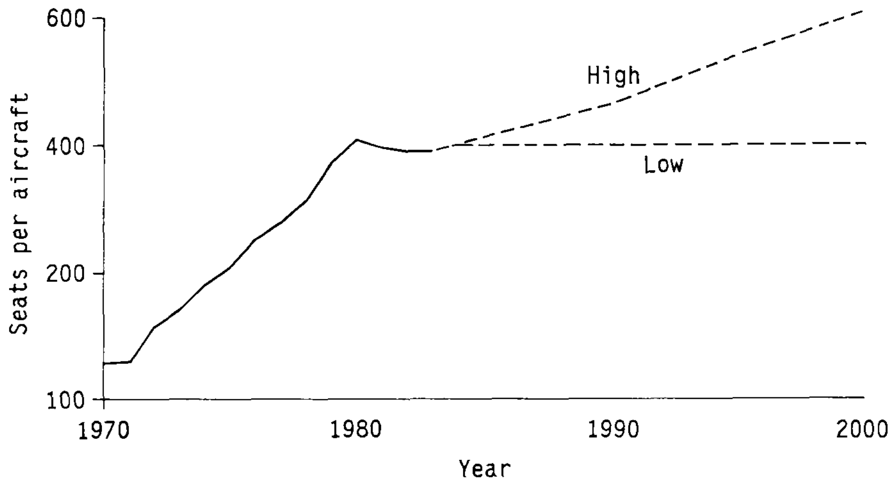
by drawing on DoTC's Aviation group estimates of the Australian Airlines fleet composition predicted for the years 1990, 1995 and 2000. From these an annual capacity growth rate for each five-year period was calculated. The growth rates were applied to the current Ansett domestic jet fleet capacity for these years. (No adjustment was attempted for the future effects of deregulation.) Specific aircraft fleet mixes were produced such that the average jet aircraft capacity of the Ansett fleet equalled that of the predicted Australian Airlines fleet. The combined estimated fleet is presented in Table 5.5.

The forecast growth in international aircraft capacity under a 'high' aircraft movements scenario is 0 per cent. That is, average future fleet capacities will be comparable to the average current capacities. Under a 'low' movements scenario average aircraft capacity could be expected to increase resulting in smaller fleets of larger aircraft. This growth rate of 2.9 per cent per annum is one third that experienced in the 1966-67 to 1982-83 period. For example, specially configured Boeing 747-400 aircraft, with a passenger capacity of 450, are expected to be in operation by 1988. Also should radical new technologies (Marchetti, 1980) be developed near the end of the century, such capacities, as predicted in Table 5.4, might be realised. Such a scenario is graphically presented in Figure 5.3.



Sources Department of Aviation (1984a, 1984b). BTCE.

Figure 5.2 Historical and forecast domestic aircraft capacity, 1970 to 2000



Sources Department of Aviation (1984a, 1984c). BTCE.

Figure 5.3 Historical and forecast international aircraft capacity, 1970 to 2000

Load factor forecasts

The time-series load factor models developed in Chapter 2, besides drawing on the scenarios for passenger movements and aircraft capacity, also require scenarios for several additional constituent variables. Scenarios for these variables, which are only needed for the time-series analysis, are shown in Table 5.6.

Fuel price scenarios are based on work done for the Independent Review of Economic Regulation of Domestic Aviation (BTE 1985a). The 'high' scenario assumes no real increase in fuel prices. The 'low' scenario assumes fuel prices increase by 1 per cent per annum to 2000.

The 'high 'scenario for North-West shelf activity is for a continuation of the present high level of passenger uplifts and discharges from Karratha airport (the proxy for this concept). The 'low' scenario is for a 25 per cent decrease in North-west shelf activity over 15 years. These scenarios apply to domestic aircraft movements at Perth airport. For international aircraft movements at Perth, there is a positive influence on the international load factor exerted from Karratha. This influence is negative in the domestic situation (see Table 2.1 and Table 2.2).

TABLE 5.6 VALUES FOR CONSTITUENT VARIABLES APPEARING IN THE LOAD FACTOR EQUATIONS, HIGH AND LOW SCENARIOS, 1985 TO 2000

Variable	*Scenario*[a]	*Units*	*1985*	*1990*	*1995*	*2000*
Real price of aviation turbine fuel	High	BTE index 1977 = 100	185.00	185.00	185.00	185.00
	Low	BTE index 1977 = 100	185.00	195.00	205.00	215.00
North-west shelf activity[b]	High	'000 passengers at Karratha	110.00	110.00	110.00	110.00
	Low	'000 passengers at Karratha	110.00	101.00	93.00	85.00
Foreign fleet dummy	High	per cent of Sydney movements	15.00	15.00	15.00	15.00
	Low	per cent of Sydney movements	15.00	15.00	15.00	15.00
Commonwealth public servants	High	per cent of population	2.70	2.66	2.63	2.60
	Low	per cent of population	2.70	2.77	2.83	2.90

a. The 'high' scenario implies a high growth in aircraft movements.
b. For Perth domestic airport the scenarios are as shown. For Perth international airport the scenarios are reversed because of the change sign for the Karratha load factor influence. (Refer Table 2.1, Table 2.2 and Figure 2.5 and 2.10.)

Source BTCE estimates.

The 'high' and 'low' scenarios for Pacific Island flights both assume that these flights will represent 15 per cent of Sydney international movements. Such flights seem to have stabilised at that level over the last five years.

The percentage of Commonwealth public servants in the population is hypothesised to rise to 2.9 per cent or fall to 2.6 per cent by 2000. These assumptions give the 'high' and 'low' scenario respectively.

FORECASTS OF AIRCRAFT MOVEMENTS

Time-series method

From the forecasts for passenger movements, aircraft capacities and load factors, and the equation to estimate aircraft movements (Equation 2.2), high and low forecasts of aircraft movements can be calculated. These are shown in Table 5.7. The 'high' and 'low' scenarios perhaps represent undue extremes. For example, the 'low' scenario combines a 'low' passenger movement scenario with a scenario where airlines increase the average size of their aircraft. In practice, such an increase is only likely to occur under conditions of rising passenger demand. In other words the scenarios for passenger movements and aircraft capacity have been treated as independent, and thus extreme values of each have been multiplied by the other. In reality, the effects of changes in passenger demand on aircraft movements would be dampened by a countervailing change in aircraft capacity. Thus while the 'high' and 'low' scenarios show the extremes of the range, it is more likely that actual values for aircraft movements in the future would be much closer to the average figure. High, low and average values for forecast aircraft movements are shown in Table 5.7.

As can be seen, annual average growth rates in aircraft movements at international airports are of the order of 0.5 to 1.5 per cent per year. Annual growth rates vary from a decline of about 2 per cent under the 'low' scenario, to an increase of around 2.5 per cent under the 'high' scenario. Perth airport has airport-specific factors in its load factor equation that account for its higher growth rate.

TABLE 5.7 ANNUAL AIRCRAFT MOVEMENT FORECASTS BY AIRPORT, 1985 TO 2000: TIME-SERIES METHOD
(number of aircraft movements)

		Year				*Annual growth rate*
Airport	*Scenario*[a]	*1985*[b]	*1990*	*1995*	*2000*	*(per cent)*
International						
Sydney	High	20 000	32 000	50 000	77 000	9.4
	Average[c]	20 000	25 000	33 000	43 000	5.2
	Low	20 000	21 000	22 000	24 000	1.2
Melbourne	High	11 000	19 000	29 000	45 000	9.8
	Average	11 000	15 000	19 000	24 000	5.3
	Low	11 000	12 000	13 000	14 000	1.6
Brisbane	High	4 400	7 400	11 400	17 800	9.8
	Average	4 400	6 000	7 700	10 000	5.6
	Low	4 400	5 000	5 400	5 900	2.0

TABLE 5.7 (Cont.) ANNUAL AIRCRAFT MOVEMENT FORECASTS BY AIRPORT, 1985 TO 2000: TIME-SERIES METHOD
(number of aircraft movements)

		Year				*Annual growth rate*
Airport	*Scenario*[a]	*1985*[b]	*1990*	*1995*	*2000*	*(per cent)*
Perth	High	3 400	6 900	10 700	16 600	11.1
	Average	3 400	5 200	6 600	8 600	6.4
	Low	3 400	4 000	4 300	4 700	2.2
Domestic						
Sydney	High	75 000	75 000	89 000	103 000	2.1
	Average	75 000	71 000	78 000	84 000	0.8
	Low	75 000	66 000	66 000	65 000	-0.9
Melbourne	High	58 000	61 000	70 000	79 000	2.1
	Average	58 000	57 000	60 000	63 000	0.6
	Low	58 000	52 000	50 000	47 000	-1.3
Brisbane	High	33 000	34 000	41 000	47 000	2.4
	Average	33 000	32 000	36 000	38 000	0.9
	Low	33 000	30 000	30 000	29 000	-0.9
Adelaide	High	22 000	22 000	26 000	30 000	2.1
	Average	22 000	20 000	22 000	23 000	0.3
	Low	22 000	18 000	17 000	16 000	-2.1
Perth	High	16 000	17 000	20 000	23 000	2.4
	Average	16 000	16 000	17 000	18 000	0.6
	Low	16 000	14 000	13 000	12 000	-1.9
Canberra	High	13 000	12 000	13 000	14 000	0.5
	Average	13 000	11 000	11 000	11 000	-1.1
	Low	13 000	10 000	9 000	8 000	-3.2

a. The 'high' scenario implies a high growth in aircraft movements.
b. Preliminary Department of Aviation estimates.
c. Average aircraft movements and hence average growth rates in aircraft movements, 1985 to 2000, are calculated using average passenger movements, average aircraft capacity and load factors as inputs into Equation 2.2. 'Average' is not a mean of the 'high' and 'low' values.

Sources Department of Aviation (1985b, 1985c). BTCE forecasts.

For domestic airports, the average rate of growth in trunk and regional aircraft movements is forecast to average around 0.5 to 1.0 per cent per year. The exception is Canberra, where a decline in traffic is forecast by the time-series method. The rates of growth in aircraft movements for the domestic airports are generally similar to those for the corresponding international airports. The forecasts for domestic aircraft movements vary from about 2 to 2.5 per cent under the 'high' scenario to a decrease of 1 per cent to 2 per cent per year under the 'low' scenario.

The following examples illustrate the situation in the year 2000 relative to 1985. Melbourne international airport, with a growth rate of 5.3 per cent per year under the 'average' scenario, would experience about 24 000 aircraft movements in the year 2000, as compared to approximately 11 000 in 1985. Thus over the 15-year period aircraft movements would more than double. Under the 'low' scenario there would be a lesser increase in annual international aircraft movements at Melbourne, from 11 000 to about 14 000. The 'high' scenario results in annual aircraft movements rising from 11 000 to 45 000 which is a quadrupling of international aircraft movements. This is unlikely.

Using Sydney as an example of a major domestic airport, an 'average' growth rate of 0.8 per cent per year would increase the number of aircraft movements from 75 000 in 1985 to 84 000 in the year 2000. This is an increase of about 10 per cent over the 15-year period. Under the 'low' scenario domestic aircraft movements are forecast to decline by 10 per cent. The 'high' scenario results in aircraft movements rising about 40 per cent by the year 2000.

Simulation method

The aircraft movements investigated by the simulation model were domestic-trunk-jet movements. (Domestic-trunk-jet movements excluded Fokker F28, Fokker F27 and smaller domestic aircraft which predominantly service regional routes.) Forecasts of domestic-trunk-jet movements were obtained by using average passenger sector demand (derived from the high and low demand estimates, Table 5.2) in conjunction with the forecast domestic-trunk-jet fleets, for 1990, 1995 and 2000 (Table 5.5), as inputs to the model. The resultant aircraft movement forecasts for each airport are presented in Table 5.8. Movement forecasts are also split into a morning, midday and evening period. The growth rates over the 15 years to 2000 are given with the airport's total daily traffic figures. Further aircraft movements forecasts were made for the simulation model network using various demand scenarios at the year 2000. These forecasts are presented in Appendix IV.

TABLE 5.8 DAILY DOMESTIC TRUNK JET AIRCRAFT MOVEMENT FORECASTS[a] BY AIRPORT, 1990 TO 2000: SIMULATION METHOD

(number of jet aircraft movements)

Airport	*Period*	*1985*	*1990[a]*	*1995[a]*	*2000[a]*	*Annual per cent growth rate*
Sydney	Morning	46	57	53	62	
	Midday	22	22	26	24	
	Evening	56	67	69	74	
	Total	124	146	148	160	1.7
Melbourne	Morning	46	53	55	60	
	Midday	22	24	30	28	
	Evening	56	65	71	74	
	Total	124	142	156	162	1.8
Brisbane	Morning	23	28	27	35	
	Midday	18	20	24	26	
	Evening	27	32	37	41	
	Total	68	80	88	102	2.7
Adelaide	Morning	19	23	19	25	
	Midday	8	8	10	8	
	Evening	23	27	25	31	
	Total	50	58	54	64	1.7
Perth	Morning	8	11	13	14	
	Midday	0	0	0	0	
	Evening	10	11	15	18	
	Total	18	22	28	32	3.9
Canberra	Morning	10	12	10	14	
	Midday	6	6	8	6	
	Evening	16	20	18	22	
	Total	32	38	36	42	1.8

TABLE 5.8 (Cont.) DAILY DOMESTIC TRUNK JET AIRCRAFT MOVEMENT FORECASTS[a] BY AIRPORT, 1990 TO 2000: SIMULATION METHOD
(number of jet aircraft movements)

Airport	*Period*	*1985*	*1990[a]*	*1995[a]*	*2000[a]*	*Annual per cent growth rate*
Tasmania	Morning	14	14	16	14	
	Midday	4	6	6	6	
	Evening	14	14	18	16	
	Total	32	34	40	36	0.8
North Queensland	Morning	6	7	8	9	
	Midday	4	6	6	8	
	Evening	6	9	8	9	
	Total	16	22	22	26	3.3
Northern Territory	Morning	4	5	5	9	
	Midday	0	0	0	0	
	Evening	4	5	7	9	
	Total	8	10	12	18	5.6
Rockhampton	Morning	4	4	4	6	
	Midday	4	4	6	6	
	Evening	4	4	6	6	
	Total	12	12	16	18	2.7

a. Passenger demand used as input to the simulation model is the average of the high and low scenario passenger demand.

Source BTCE estimates.

For most of the major airports, the average rates of growth in jet aircraft movements are generally of the order of 1 to 2 per cent per annum. Perth and the Northern Territory seem to be exceptions to the general trend among the airports, though the observed high growth rates are somewhat balanced by the fact that these airports are two of the least active in comparative terms.

FORECAST GROWTH RATE COMPARISONS

From the time-series model, growth rates in domestic (trunk and regional) aircraft movements can be calculated. The simulation model examines only a subset of domestic movements, namely trunk-jet movements. The growth rates of aircraft movements produced by the two models cannot be directly compared as they reflect growth in two different sets of aircraft movements (namely only jet aircraft services investigated in the simulation approach, with the time-series approach including non-jet services). These growth rates, however, are presented in Table 5.9.

Growth rates, calculated from the simulation model, operating in a 'best-scheduling' mode, tend to be higher than the growth rates obtained from the time-series model. Average predicted growth rates for both models are generally modest and positive. They are also below the 5 to 6 per cent growth rates which occurred during the 1950s and 1960s. This result is partly a reflection of the maturity of the Australian air network, the suitability of current technology (that is, the size of aircraft) and the acceptance of air travel as a transport mode.

TABLE 5.9 FORECAST GROWTH IN ANNUAL DOMESTIC AIRCRAFT MOVEMENTS: TIME-SERIES AND SIMULATION METHODS
(per cent)

Airport	*Model*	*High*	*Average*	*Low*
Sydney	Simulation	2.4	1.7	0.5
	Time Series	2.1	0.8	-0.9
Melbourne	Simulation	2.3	1.8	0.8
	Time Series	2.1	0.6	-1.3
Brisbane	Simulation	3.0	2.7	1.7
	Time Series	2.4	0.9	-0.9

TABLE 5.9 (Cont.) FORECAST GROWTH IN ANNUAL DOMESTIC AIRCRAFT MOVEMENTS: TIME-SERIES AND SIMULATION METHODS
(per cent)

Airport	*Model*	*High*	*Average*	*Low*
Adelaide	Simulation	2.1	1.7	0.8
	Time Series	2.1	0.3	-2.1
Perth	Simulation	5.1	3.9	1.9
	Time Series	2.4	0.6	-1.9
Canberra	Simulation	1.5	1.8	0.4
	Time Series	0.5	-1.1	-3.2

Note The simulation model results refer only to jet aircraft on trunk routes, while the time-series model results include non-jet commercial aircraft movements as well.

Source BTCE estimates.

CHAPTER 6 CONCLUDING REMARKS

This Paper describes two techniques that have been developed for use in forecasting aircraft movements at major Australian airports. The time-series analysis provides forecasts of the overall growth in aircraft movements and indicates the factors that contribute to that growth. The simulation method provides a tool which generates a hypothetical allocation of aircraft throughout the air network and also provides forecasts of aircraft movements by time of day.

Economic forecasts for any industry are always subject to error. However, retrospective reviews of forecasting errors in industries, as diverse as base metals and chemicals, have usually concluded that the source of the errors lay less in the industry-specific elements than in the assumptions about general economic forces impinging on the industries from the outside world (see for example Caudle, 1981 and Rush & Page, 1979). This is also likely to be the case when forecasting aircraft movements. Both of the methods described in this paper are dependent on forecasts of passenger demand which in turn are heavily dependent on the assumption for future growth in GDP, growth in prices and so on.

A major benefit of the models of aircraft movements developed in this Paper is the explicit specification of the links between air travel and the general economy. Once explicitly formulated, the models can be used to explore the sensitivity of aircraft movements to differences in general economic conditions.

The major use to which the models of aircraft movements are likely to be put, is in the area of assessing future airport congestion. Aircraft movements are the cause of runway congestion directly and of terminal congestion indirectly (in conjunction with passenger movements). Of course the demand for airport capacity arises not only from international, trunk and regional flights but also from commuter and general aviation aircraft movements which can form a significant proportion of traffic at major airports.

The models presented are not intended for use in forecasting commuter or general aviation aircraft movements. These classes of flights will be dependent on factors which are not of major significance for international or trunk flights. For example, commuter and general aviation aircraft movements can be very sensitive to changes in airport charges. Both the time-series and simulation methods should, however, provide valuable assistance in forecasting the likely demand for airport capacity.

The two models were designed to be useful tools in forecasting aircraft movements. Each method estimates aircraft movements from its own independent set of premises reflected by the input parameters. The parameters emphasize different approaches taken in attempting to produce an insight into the aircraft movements forecasting problem.

APPENDIX I TIME-SERIES MODEL DATA

The data sets used in the time-series analysis are given in the tables below. Sources are given at the bottom of each table and refer the reader to published sources listed in the 'References' section. Earlier data are given for the variable relating to Commonwealth public servants since the regression equation using this variable requires its value three years previously.

TABLE I.1 DOMESTIC AIRCRAFT MOVEMENTS[a] BY AIRPORT, 1966-67 TO 1982-83
(number of aircraft)

Year	*Sydney*	*Melbourne*	*Brisbane*	*Adelaide*	*Perth*	*Canberra*
1966-67	65 564	53 112	27 160	19 957	8 708	16 338
1967-68	66 932	52 396	25 957	20 130	9 267	17 835
1968-69	70 593	54 659	28 563	20 675	9 506	18 573
1969-70	76 847	60 724	30 852	22 327	10 262	18 986
1970-71	78 020	61 149	33 817	22 176	12 333	18 865
1971-72	77 751	61 984	34 158	22 083	12 410	18 029
1972-73	83 538	67 517	37 178	23 004	10 965	19 821
1973-74	91 108	72 037	40 534	24 225	12 141	20 682
1974-75	89 458	71 993	37 652	25 020	12 069	19 857
1975-76	82 256	68 600	34 104	24 248	10 885	17 357
1976-77	83 791	69 339	34 726	25 200	11 964	17 239
1977-78	88 187	71 527	35 525	25 618	13 043	17 801
1978-79	87 682	70 065	34 939	25 716	13 013	15 796
1979-80	86 748	72 028	37 027	25 719	13 654	15 106
1980-81	83 638	69 066	36 581	24 853	13 546	13 772
1981-82	79 570	64 098	36 411	23 822	14 860	12 904
1982-83	71 945	59 250	33 807	22 237	14 813	10 657

a. Trunk and regional.

Source Department of Aviation (1984b).

TABLE I.2 INTERNATIONAL AIRCRAFT MOVEMENTS BY AIRPORT, 1966-67 TO 1982-83

(number of aircraft)

Year	*Sydney*	*Melbourne*	*Brisbane*	*Perth*
1966-67	8 474	1 129	1 304	1 408
1967-68	9 990	1 049	1 466	1 666
1968-69	11 061	1 075	1 411	1 655
1969-70	12 750	1 160	1 510	1 904
1970-71	15 653	3 713	1 629	2 801
1971-72	16 844	5 541	1 707	2 909
1972-73	17 536	6 127	1 814	2 569
1973-74	18 528	6 389	1 906	2 907
1974-75	19 439	7 278	2 856	3 423
1975-76	19 484	7 528	3 500	3 598
1976-77	19 066	8 578	3 149	3 466
1977-78	20 207	9 485	3 375	3 433
1978-79	18 238	9 131	3 129	3 309
1979-80	18 543	9 907	3 379	2 977
1980-81	18 010	9 921	3 237	2 857
1981-82	18 154	10 162	4 140	3 239
1982-83	18 744	10 155	4 329	3 391

Source Department of Aviation (1984c).

TABLE I.3 DOMESTIC PASSENGER MOVEMENTS[a] BY AIRPORT, 1966-67 TO 1982-83

(number of passengers)

Year	*Sydney*	*Melbourne*	*Brisbane*	*Adelaide*	*Perth*	*Canberra*
1966-67	2 595 618	2 088 320	979 142	848 774	309 671	370 247
1967-68	2 815 034	2 268 946	1 074 596	951 503	350 879	445 850
1968-69	3 122 307	2 529 301	1 156 423	1 024 828	396 988	501 418
1969-70	3 613 533	2 890 468	1 357 881	1 120 107	467 407	588 159
1970-71	3 745 653	2 982 709	1 543 851	1 123 005	567 116	647 193
1971-72	3 937 735	3 177 566	1 660 521	1 173 156	606 635	728 001
1972-73	4 436 719	3 582 157	1 900 184	1 271 808	595 708	883 352
1973-74	4 860 508	3 990 847	2 142 407	1 425 860	667 684	961 375
1974-75	4 970 858	4 137 338	2 251 302	1 506 317	681 264	981 888
1975-76	4 793 006	4 135 874	2 072 363	1 535 232	658 332	872 353
1976-77	5 002 640	4 330 575	2 149 886	1 663 457	746 240	917 090
1977-78	5 401 223	4 628 254	2 250 540	1 757 635	812 396	961 963
1978-79	5 783 282	4 908 893	2 396 845	1 868 795	879 113	951 166
1979-80	5 999 925	5 173 483	2 632 639	1 962 462	928 095	951 157
1980-81	5 858 143	5 046 031	2 636 552	1 930 219	929 949	872 223
1981-82	5 917 874	5 038 634	2 758 922	1 852 906	1 017 173	820 943
1982-83	5 338 944	4 500 234	2 518 841	1 635 544	995 987	786 449

a. Trunk and regional.

Source Department of Aviation (1984b).

TABLE I.4 INTERNATIONAL PASSENGER MOVEMENTS BY AIRPORT, 1966-67 TO 1982-83

(number of passengers)

Year	*Sydney*	*Melbourne*	*Brisbane*	*Perth*
1966-67	517 268	56 479	42 912	32 828
1967-68	633 895	59 650	47 753	46 041
1968-69	727 382	63 537	50 644	55 257
1969-70	880 864	72 935	61 144	64 481
1970-71	938 931	190 399	66 293	80 346
1971-72	1 069 563	276 795	77 195	100 148
1972-73	1 263 708	407 050	107 046	116 705
1973-74	1 524 270	465 642	133 917	138 636
1974-75	1 618 539	551 626	190 443	165 498
1975-76	1 763 945	653 529	254 530	196 550
1976-77	1 758 177	685 219	250 855	204 012
1977-78	1 919 631	739 271	272 188	225 341
1978-79	2 260 102	843 210	301 112	261 182
1979-80	2 412 152	971 376	342 260	324 977
1980-81	2 361 857	960 583	358 033	348 963
1981-82	2 385 292	956 760	421 451	414 231
1982-83	2 336 456	923 692	421 247	413 146

Source Department of Aviation (1984c).

TABLE I.5 VALUES OF OTHER INDEPENDENT VARIABLES, 1966-67 TO 1982-83

Year	*Nominal price of aviation turbine fuel index (1976-77 = 100)*	*Consumer price index (1976-77 = 1.00)*	*Flights as percentage of total Sydney international flights*[a]	*Average domestic aircraft size (passengers per aircraft)*	*Average international aircraft size (passengers per aircraft)*	*North-West Shelf activity ('000 passengers at Karratha)*[b]	*Commonwealth public servants (percentage of population)*
1966-67	49.53	0.46	4.4	46	98	28	2.23
1967-68	51.21	0.47	4.2	48	109	30	2.29
1968-69	50.26	0.49	5.2	50	127	31	2.37
1969-70	49.96	0.50	5.6	54	128	34	2.49
1970-71	56.32	0.51	5.4	55	130	45	2.53
1971-72	63.55	0.56	6.0	59	156	47	2.56
1972-73	63.55	0.59	6.8	61	174	56	2.61
1973-74	71.59	0.67	6.6	63	191	50	2.67
1974-75	74.95	0.77	6.0	68	206	47	2.66
1975-76	91.38	0.89	7.8	71	256	42	2.68
1976-77	100.00	1.00	11.0	68	280	49	2.77
1977-78	115.05	1.10	13.6	68	317	53	2.83
1978-79	143.39	1.19	15.4	70	374	60	2.88
1979-80	196.35	1.30	15.0	71	407	59	2.77
1980-81	251.42	1.43	14.6	82	399	68	2.76
1981-82	275.53	1.57	14.2	92	392	88	2.75
1982-83	307.96	1.76	14.6	94	392	110	2.72

a. Pacific Island flights used as a proxy variable for foreign fleets activity.
b. Figures before 1972-73 based on Broome.

Sources ABS (1984, 1985). BTE (1985d). Department of Aviation (1984a, 1984b, 1984c).

APPENDIX II CONVERSION FACTORS FOR DERIVING PEAKED DEMANDS

In order to convert annual sector passenger demand into the average demand variation during a week day, the pattern of jet aircraft flights by time of day was used. This was obtained from Ansett and Australian Airlines timetables for 1985. Table II.1 shows the derived factors used to split an average week's total passenger demand into the demand experienced in the morning, midday and evening period of a business day for each network sector. To convert annual passenger sector data to weekday peak demand, the following formula is used in connection with the conversion factors (fractions) given in Table II.1:

Weekday Peak Demand (morning, midday or evening period)
= (yearly sector demand/260) x (morning, midday or evening period fraction)

where 260 is the number of weekdays in a year, public holidays included.

TABLE II.1 PERCENTAGE OF TOTAL WEEK'S AIRCRAFT FLIGHTS FALLING IN EACH WEEKDAY PERIOD: BY SECTOR, 1985

	Arrival									
Departure	*North Queensland*	*Brisbane*	*Sydney*	*Melbourne*	*Canberra*	*Adelaide*	*Tasmania*	*Northern Territory*	*Perth*	*Rock-hampton*
North Queensland	..			..	..	..	..	..	..	..
Morning		22.7	0.0							
Midday		27.3	66.7							
Evening		20.5	0.0							
Brisbane					..		..		..	
Morning	26.7	0.0	23.2	24.4		0.0		0.0		25.7
Midday	22.2		15.2	9.8		60.0		50.0		20.0
Evening	22.2	0.0	36.4	34.1		0.0		0.0		28.6
Sydney			..							..
Morning	0.0	27.8		29.8	17.5	25.6	0.0	0.0	0.0	
Midday	63.6	16.7		13.7	19.0	23.3	60.0	57.1	62.5	
Evening	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	
Melbourne	..			..						
Morning		25.0	28.6		22.7	27.8	21.8	..	0.0	..
Midday		35.0	13.1		9.1	13.9	21.8		73.1	
Evening		10.0	36.3		45.5	31.9	28.7		0.0	
Canberra	..	..			..		..	..	..	..
Morning			32.8	28.3		0.0		..	..	..
Midday			11.5	13.0		100.0				
Evening			31.1	37.0		0.0				

TABLE II.1 (Cont.) PERCENTAGE OF TOTAL WEEK'S AIRCRAFT FLIGHTS FALLING IN EACH WEEKDAY PERIOD: BY SECTOR, 1985

	Arrival									
Departure	*North Queensland*	*Brisbane*	*Sydney*	*Melbourne*	*Canberra*	*Adelaide*	*Tasmania*	*Northern Territory*	*Perth*	*Rock-hampton*
Adelaide	..					..	..			..
Morning		0.0	23.8	29.0	0.0			0.0	0.0	
Midday		40.0	21.4	15.9	50.0			75.0	76.5	
Evening		0.0	26.2	30.4	0.0			0.0	0.0	
Tasmania	..	..			..	..	..	..	..	..
Morning			0.0	35.2						
Midday			55.6	12.5						
Evening			0.0	23.9						
Northern Territory	..			..	..		..			..
Morning		0.0	0.0			0.0			0.0	
Midday		40.0	66.7			75.0			25.0	
Evening		0.0	0.0			0.0			0.0	
Perth	..	..			..		..		..	..
Morning			0.0	0.0		0.0		0.0		
Midday			68.9	71.4		71.4		25.0		
Evening			0.0	0.0		0.0		0.0		

TABLE II.1 (Cont.) PERCENTAGE OF TOTAL WEEK'S AIRCRAFT FLIGHTS FALLING IN EACH WEEKDAY PERIOD: BY SECTOR, 1985

	Arrival									
Departure	*North Queensland*	*Brisbane*	*Sydney*	*Melbourne*	*Canberra*	*Adelaide*	*Tasmania*	*Northern Territory*	*Perth*	*Rock-hampton*
Rockhampton	..		..	..	..	..	..	..	..	..
Morning		25.7								
Midday		25.7								
Evening		25.7								

.. Not applicable.

Note Where the proportions for a particular sector do not sum to unity, the remainder represents the proportion of flights taking place at weekends.

Source Ansett and Australian Airlines timetables (1985).

APPENDIX III DERIVATION OF SECTOR PASSENGER FORECASTS

This appendix explains the procedure adopted for converting passenger demand forecasts from an uplift discharge basis to a sector basis.

There are three standard methods used in the recording of passenger demand data. Forecasts, therefore, can reflect demand modelled on any of these data standards. Origin-destination data reflect the most detailed level. These data consist of records of passenger trips from an origin in one city, through perhaps one or more intermediate stops to a final destination. At a less comprehensive level of detail are data on 'uplifts and discharges within flight' (U/D). These data relate to trips between two airports connected by the same flight number. An uplift and discharge unit may therefore involve more than one flight sector. However, all flights are considered to change flight numbers when passing through any of the following airports: Adelaide, Brisbane, Cairns, Canberra, Darwin, Gove, Hobart, Melbourne, Perth and Sydney. There is also 'traffic on-board by stages' (TOB) data which record passenger movements on each sector (city to city). This is what has been referred to as sector demand.

The passenger demand models which form the basis for both the simulation and time-series models are described in BTE (1986) and summarised in Chapter 2. They are based on U/D data and the forecasts derived from them are thus similarly based. For the time-series forecasting method all the routes leading into airports are aggregated, and as only major domestic airports are considered, each of these would naturally be the terminus of a flight number. Thus the use of U/D data is as satisfactory as the use of sector data for the time-series model. However, a problem arises with the simulation model, which requires TOB data.

The problem is already partly solved, in that the sectors considered between the major capital cities are predominantly serviced by direct flights and hence comprise one flight number, plus flight numbers terminate at each of the major capital cities. Hence most major U/D routes (for example Melbourne-Sydney) are already true flight sectors.

Comparing the TOB and U/D demand on the major flight sectors between the airports Adelaide, Brisbane, Canberra, Melbourne, Perth and Sydney, the TOB demand yields a better than 95 per cent approximation to the U/D demand (Department of Aviation 1987a). Hence the growth in U/D demand has been used as an estimate of the growth in TOB demand for forecasting purposes on these sectors. The U/D routes on the network that are not identical to flight sectors are the following: Brisbane to North Queensland, Sydney to North Queensland, Melbourne to Tasmania, Sydney to Tasmania, Adelaide to the Northern Territory, Sydney to the Northern Territory, Perth to the Northern Territory and Brisbane to Rockhampton. This appendix deals with the method adopted for deriving passenger demand forecasts by sector from the constituent U/D forecasts available from BTE (1986).

The Brisbane to Rockhampton route is distinct from the others and will be dealt with later. Taking the Brisbane to North Queensland route as an example, the details of the method used on routes with a regional combined node can be described. The two ports considered as comprising North Queensland in the model are Townsville and Cairns. Figure III.1 shows how traffic is classified under the two traffic definitions.

Let X equal the number of passengers travelling from Brisbane to Townsville and no further; Y equal the number of passengers travelling from Brisbane to Cairns with a stop in Townsville; and Z equal the number of passengers travelling from Brisbane to Cairns directly. Then the definition of U/D demand classifies those passengers stopping at Townsville on their way to Cairns as part of the Brisbane-Cairns U/D demand with those passengers travelling directly from Brisbane to Cairns. That is, Brisbane-Cairns U/D demand equals Y plus Z. The Brisbane-Townsville U/D demand only includes passengers travelling from Brisbane to Townsville and no further. That is, Brisbane-Townsville U/D demand equals X.

The definition of TOB, or sector, demand classifies those passengers stopping at Townsville on their way to Cairns as part of the Brisbane-Townsville TOB demand with those travelling from Brisbane to Townsville and no further. That is, Brisbane-Townsville TOB demand equals X plus Y. The Brisbane-Cairns TOB demand only includes passengers travelling from Brisbane to Cairns directly. That is, Brisbane-Cairns TOB demand equals Z. Summarising,

Brisbane to Townsville TOB demand = X + Y

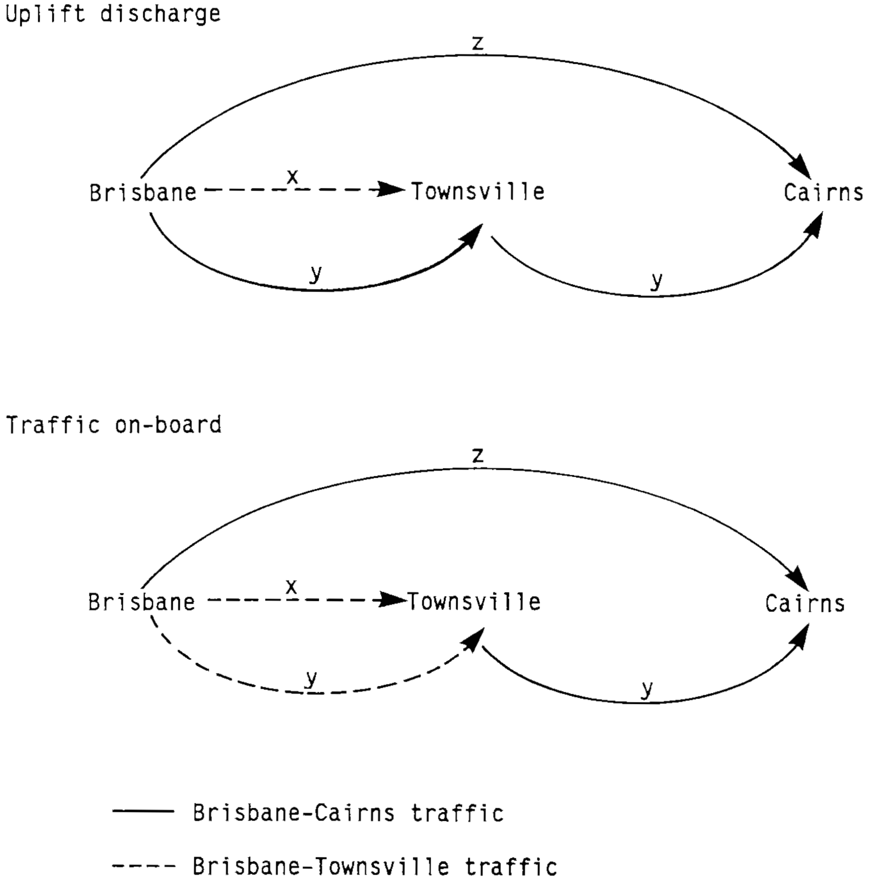
Brisbane to Cairns TOB demand = Z

whereas,

Brisbane to Townsville U/D demand = X

Brisbane to Cairns U/D demand = Z + Y.

Thus the difference between the two definitions involves only the passengers stopping at Townsville on their way to Cairns. The Brisbane to Cairns TOB growth rate is assumed to be equal to the Brisbane to Cairns U/D growth rate. The Brisbane to Townsville TOB growth rate however includes the Brisbane to Townsville U/D growth rate for those passengers only travelling from Brisbane to Townsville and the Brisbane-Cairns U/D growth rate for those passengers stopping at Townsville on their way to Cairns.



x = Number of passengers travelling from Brisbane to Townsivlle and no further
y = Number of passengers travelling from Brisbane to Cairns with a stop in Townsville
z = Number of passengers travelling from Brisbane to Cairns directly.

Figure III.1 Uplift discharge and traffic on-board traffic definitions

The formula for the growth rates is as follows:

Brisbane to Cairns TOB growth rate
= Brisbane to Cairns U/D rate

Brisbane to Townsville TOB growth rate

$$= \frac{X}{X+Y} \text{(Brisbane to Townsville U/D rate)} + \frac{Y}{X+Y} \text{(Brisbane to Cairns U/D rate)}$$

This method was used for the rest of the routes involving a regional combined route. For the Brisbane to Rockhampton route, the U/D growth rate has been used as an approximation to the TOB rate. A certain proportion of passengers travelling on this route would be continuing on to Mackay or Great Keppel Island, for which growth rates from Brisbane are not available. For this reason, the Brisbane to Rockhampton flight sector was defined and treated as a route with both independent or non-combined nodes.

Notwithstanding the above process, the simulation model's demand data matrix is adaptable to any user input data change. More refined TOB demand estimates, if developed, can be easily re-run.

APPENDIX IV SIMULATION MODEL SENSITIVITY ANALYSIS

Sensitivity analysis was undertaken using the simulation model to assess a broader range of passenger demand scenarios than those presented in Chapter 5. The analysis conducted and presented here examined the simulation model forecasts using variations in the average and high passenger demand scenarios at the year 2000. Table IV.1 presents the aircraft movements associated with five different demand scenarios. The 'average' forecast passenger demand, derived from passenger growth rates used in Chapter 5, was used as the base case in Table IV.1. The other scenarios investigated are derived by incrementing this base case demand by a flat 25 per cent, 50 per cent and 100 per cent respectively across all routes and using a 0.75 and/or a 1.0 maximum aircraft load factor.

Table IV.2 presents the aircraft movements produced by using a similar incremental passenger demand approach to that pursued in the average demand case above. However the base case used for the analysis presented in Table IV.2 is the high scenario estimate of passenger demand at the year 2000.

TABLE IV.1 SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING AVERAGE GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Sydney	Morning	62	68	68	69	67
	Midday	24	38	52	30	54
	Evening	76	94	106	85	107
	Total	162	200	226	184	228
Melbourne	Morning	60	69	74	65	76
	Midday	28	40	54	34	52
	Evening	74	93	104	83	108
	Total	162	202	232	182	236
Brisbane	Morning	35	35	35	36	35
	Midday	26	28	30	28	30
	Evening	41	55	61	46	61
	Total	102	118	126	110	126
Adelaide	Morning	25	27	26	25	28
	Midday	8	14	20	10	20
	Evening	31	35	34	33	38
	Total	64	76	80	68	86
Perth	Morning	14	15	15	15	15
	Midday	0	0	0	0	0
	Evening	18	21	25	21	25
	Evening	18	21	25	21	25
	Total	32	36	40	36	40

TABLE IV.1 (Cont.) SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING AVERAGE GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Canberra	Morning	14	14	12	14	12
	Midday	6	8	14	8	16
	Evening	22	24	26	22	26
	Total	42	46	52	44	54
Tasmania	Morning	14	16	16	18	16
	Midday	6	10	14	6	14
	Evening	16	18	20	20	20
	Total	36	44	50	44	50
North Queensland	Morning	9	9	9	9	8
	Midday	8	8	8	10	10
	Evening	11	15	15	11	14
	Total	28	32	32	30	32
Northern Territory	Morning	9	7	7	7	7
	Midday	0	0	0	0	0
	Evening	9	13	13	11	13
	Total	18	20	20	18	20
Rock-hampton	Morning	6	6	4	6	4
	Midday	6	6	4	6	4
	Evening	6	10	14	8	12
	Total	18	22	22	20	20

TABLE IV.1 (Cont.) SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING AVERAGE GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Total	Morning	248	266	266	264	268
	Midday	112	152	196	132	200
	Evening	304	3789	418	340	424
	Total	664	796	880	736	892
Unsatisfied demand (per cent)		0.2	1.7	5.3	0.6	4.8

a. D = Forecast daily passenger movements derived from average growth scenario in Chapter 5.
b. MLF = Maximum allowable load factor.

Source Derived by BTCE.

TABLE IV.2 SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING HIGH GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Sydney	Morning	66	65	67	67	67
	Midday	26	48	66	36	68
	Evening	84	95	115	95	115
	Total	176	208	248	198	250
Melbourne	Morning	65	72	76	69	76
	Midday	30	46	60	36	60
	Evening	79	98	114	89	114
	Total	174	216	250	194	250
Brisbane	Morning	35	34	35	35	35
	Midday	26	30	34	28	34
	Evening	45	60	63	53	63
	Total	106	124	132	116	132
Adelaide	Morning	27	27	27	27	27
	Midday	10	18	26	16	28
	Evening	31	35	41	35	41
	Total	68	80	94	78	96
Perth	Morning	16	16	17	15	17
	Midday	0	0	0	0	0
	Evening	22	24	27	21	27
	Total	38	40	44	36	44

TABLE IV.2 (Cont.) SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING HIGH GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Canberra	Morning	14	10	10	12	10
	Midday	6	12	18	10	18
	Evening	20	22	28	22	28
	Total	40	44	56	44	56
Tasmania	Morning	16	18	16	16	16
	Midday	6	10	18	8	18
	Evening	18	20	24	18	24
	Total	40	48	58	42	58
North Queensland	Morning	10	9	8	9	8
	Midday	6	12	10	8	10
	Evening	12	15	14	15	14
	Total	28	36	32	32	32
Northern Territory	Morning	7	7	6	8	6
	Midday	0	0	0	0	0
	Evening	11	11	14	14	14
	Total	18	18	20	22	20
Rock-hampton	Morning	6	4	4	6	4
	Midday	6	4	4	6	4
	Evening	8	14	14	10	14
	Total	20	22	22	22	22

TABLE IV.2 (Cont.) SENSITIVITY ANALYSIS: FORECAST DAILY AIRCRAFT MOVEMENTS BY AIRPORT, USING HIGH GROWTH RATE SCENARIOS AT THE YEAR 2000

		Incremented daily passenger demand				
		D[a]x1.0	*Dx1.25*	*Dx1.5*		*Dx2.0*
Airport	*Period*	*MLF[b] = 0.75*	*MLF = 0.75*	*MLF = 0.75*	*MLF = 1.0*	*MLF = 1.0*
Total	Morning	262	262	266	264	266
	Midday	116	180	236	148	240
	Evening	330	394	454	372	454
	Total	708	836	956	784	960
Unsatisfied demand (per cent)		1.2	3.2	8.3	1.6	8.1

a. D = Forecast daily passenger movements derived from high growth scenario in BTE 1986.
b. MLF = Maximum allowable load factor.

Source Derived by BTCE.

REFERENCES

Abbreviations

ABS	Australian Bureau of Statistics
AGPS	Australian Government Publishing Service
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics

Australian Bureau of Statistics (1984), *Employed Wage and Salary Earners*, Australia, 1983-84, Cat. No. 6248.0, (and previous issues), Canberra.

__ (1985), *Consumer Price Index*, Cat. No. 6401.0, (and previous issues), Canberra

Bureau of Transport and Communications Economics (1988), *Trends and Prospects for Australian International Air Transport,* Occasional Paper 88, AGPS, Canberra.

Bureau of Transport Economics (1984a), The Domestic Airlines Fleet Composition and Route Allocation Model, Reference Paper 69, Canberra.

__ (1984b), *Transport Outlook Conference 1984: Transport Outlook to the Year 2000*, AGPS, Canberra.

__ (1985a), *Competition and Regulation in Domestic Aviation*, Occasional Paper 72, AGPS, Canberra.

__ (1985b), *Market Response to Discount Air Fares,* Occasional Paper 66, AGPS, Canberra.

__ (1985c), *National Aerodrome Plan*, Report 59, AGPS, Canberra.

__ (1985d), *Transport Indicators, Bulletin 9, March 1985*, (and previous issues), Canberra.

__ (1986), *Demand for Domestic Aviation Services: Forecasts by Market Segment*, Occasional Paper 79, AGPS, Canberra.

Caudle, P. (1981), Trends in the Chemical Industry, *Futures*, October, 413-16.

Department of Aviation (1984a), *Air Transport Statistics: Airline Aircraft Utilisation, 1983-84,* (and previous issues), Canberra.

__ (1984b), *Air Transport Statistics: Domestic Air Transport, 1983-84*, (and previous issues), Canberra.

__ (1984c), *Air Transport Statistics: International Air Transport, 1983-84*, (and previous issues), Canberra.

__ (1985a), *Air Transport Statistics: Australian Air Distances*, Canberra.

__ (1985b), *Monthly Provisional Statistics of International Scheduled Air Transport, June 1985*, Canberra.

__ (1985c), *Provisional Statistics of Domestic Scheduled Airline Performance*, June quarter, 1985, Canberra.

__ (1985d), Yearly Airport Traffic Statistics, 1983-84, (and previous years), unpublished computer output.

__ (1987a), *Air Transport Statistics: Airline Aircraft Utilisation, 1984-85*, (and previous issues), Canberra.

__ (1987b), *Air Transport Statistics: Domestic Air Transport, 1984-85*, (and previous issues), Canberra.

Marchetti, C. (1980), The Evolution of the Energy System and the Aircraft Industry, *Chemical Economy and Engineering Review*, vol. 12, no. 5, pp 7-13.

Naylor, T. H. et al (1966), *Computer Simulation Techniques,* John Wiley and Sons, New York.

Rush, H. and Page, W. (1979), Long-term Metals Forecasting, *Futures*, August, 321-25.

ABBREVIATIONS

A300	Airbus A300
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
B727	Boeing 727-200
B737	Boeing 737-200
B767	Boeing 767-200
DC9	McDonnell Douglas DC9
DofA	Department of Aviation
DoTC	Department of Transport and Communications
F27	Fokker F27
F28	Fokker F28
GDP	Gross Domestic Product
O-D	Origin - destination
OECD	Organisation for Economic Co-Operation and Development
TOB	Traffic on-board by stages
U/D	Uplifts and discharges within flight