AIRPORT CONGESTION IN NEW ZEALAND

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Gwyneth MacInnes MacLeod

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ABSTRACT

OF A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

M.Appl.Sc.

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By G.M. MacLeod

The phenomenom of airport congestion at New Zealand's major airports is the subject of this research thesis. A growing problem in New Zealand, the importance of understanding this problem and identifying options for solution is high. The intention of this research was to identify the extent of congestion at New Zealand airports; to estimate the industry cost of congestion; to identify the causes of congestion; to estimate future levels of congestion; and to offer suggestions for solution of this problem.

Actual levels of airborne delay for flights arriving at these airports have been measured, and the industry cost of this delay in terms of time and fuel burn is estimated. Airport capacity for Auckland, Wellington and Christchurch airports is established and compared with the levels of demand for service. The level of delay attributable to excess demand is thus established. Comparison of differing airports' capacity levels indicates some level of delay attributable to air traffic control procedures. The majority of current delay is directly attributable to demand schedules which are characterised by grouping of demand - i.e. the scheduling of several aircraft at the same time, followed by periods of little or no demand. At Auckland and Christchurch airports, the current levels of airborne delay is due exclusively to scheduling patterns. Demand exceeds available capacity for many short periods throughout the course of the day, but is interspersed by a greater number of periods where capacity exceeds current demand. The delays experienced at these airports is also low – averaging approximately three minutes per aircraft.

Similar levels of delay are experienced at Wellington airport during weather conditions which meet visual or instrument above circling minima criteria, but delays rise markedly when weather conditions fall below this criteria. This is due to the differing air traffic control procedures which must (for safety reasons) be invoked during these conditions, and result in

a decrease in airport capacity. Instrument conditions below circling minima occur approximately 11% of the time at Wellington, compared with approximately 3% for Auckland and Christchurch. Moreover, weather conditions below circling minima do not necessarily reduce the capacity of Auckland or Christchurch airports.

Forecast increases in demand over the next twelve years, when compared with available airport capacity indicate future levels of delay at extremely high rates for Auckland and Wellington airports which are currently operating at levels close to capacity. At Auckland, management of aircraft schedules is sufficient to provide a solution until 2005. Forecast levels of demand beyond this indicate that a greater level of solution will be required. These issues are likely to be addressed by the addition of a second runway.

At Wellington airport the problem of congestion is more severe. Capacity is well exceeded by present levels of demand during weather conditions below circling minima, and is reached during instrument conditions for significant periods. There is little available capacity for future growth. Terrain and cost issues make additional runways for Wellington airport unfeasible options. It is essential then, that the available capacity of Wellington airport be managed with regard to available capacity. This must take the form of schedule management, and restrictions on aircraft types during busy periods.

The primary cause of capacity degradation during weather conditions below circling minima is increased separation provided by air traffic control to keep aircraft safely separated in the event of a missed approach. Where the performance characteristics of the aircraft using an airport are similar, and minimal wake turbulence separation applies, then it is not necessary to increase separation between aircraft to provide this protection. In other words, if all aircraft using Wellington airport are restricted to a similar size and have similar speed and climb performance, then capacity will not be degraded during weather conditions below circling minima. As well as providing a constant capacity, standardisation of aircraft types will provide a small increase in that capacity.

This is the only feasible solution to a growing problem at Wellington airport. It should be implemented immediately to both relieve current congestion and to prevent future levels of delay which are forecast to reach 1 hour duration by 2000 and exceed 6 hours by 2005.

TABLE OF CONTENTS

LIST OF FIGURES

Introduction

Airport and airspace congestion is the direct result of too many aircraft trying to use airport resources – primarily the runway – than can be accommodated. In other words, congestion occurs when demand exceeds available capacity – the level of congestion being directly proportional to the level of excess demand. A new phenomena to the New Zealand industry in 1991, congestion has since risen to a level where the economic considerations of high levels of delay dictate the attendance to, and resolution of this problem.

Accordingly, the focus of this research is an investigation of the levels of delay at New Zealand's major airports and the level of resolution which is required to solve the problem.

Specifically, the objectives of this research are:

1. To define the levels of delay currently experienced at New Zealand airports
2. To indicate the effects of this delay in terms of disruption and fuel costs
3. To describe the level of demand for service experienced at New Zealand airports
4. To identify the current capacity of New Zealand's major airports
5. To identify and describe the causes of delay
6. To estimate future levels of delay
7. To devise possible options for solution

Literature Review

Airport Congestion – a New Zealand Problem: A review

The study of airport congestion – historically a world wide problem and, increasingly a New Zealand problem – is examined. Whilst congestion of airports and airspace has long been an issue in the U.S. and in parts of Europe, smaller countries such as New Zealand have largely remained immune to such inconveniences to airline scheduling. In 1991, the New Zealand industry first faced the realities of delays at Wellington airport – due to excess demand and fluctuating capacity levels with weather conditions. In the years since, delays have grown more frequent, lengthier and have spread to encompass Auckland and even Christchurch airports. As well as schedule disruptions, the economic effects of these delays have been sufficient to engender a response from the industry in the form of increasing complaints levelled at Airways Corporation, the air traffic control service provider and at the Wellington Airport Company, the owner of Wellington airport. The New Zealand industry is fast approaching a time where increasing regulation and management of air traffic levels is becoming a reality.

Airport congestion is often related to the after-effects of industry de-regulation where competition encourages the close attention of airlines to consumer demand issues. Unfortunately this often results in too many small aircraft congesting airport systems. This is a problem which has affected many air transport industries, and is one of the primary causes of airport congestion within New Zealand.

Congestion:

Airport and airspace congestion is the result of too many aircraft trying to use airport resources – primarily the runway – than can be accommodated. In other words, congestion occurs when demand exceeds available capacity; the level of congestion being directly proportional to the level of excess demand. An increasingly world wide phenomenon, airport congestion has primarily been the problem of the U.S. and European industries.

Deregulatory Effects:

In the U.S. particularly, the years following deregulation were characterised by smaller aircraft being operated on a more frequent basis. A direct response to competition and consumer demand, this trend caused significant increases in congestion levels (O'Lone, 1988). By 1988, the U.S. Federal Aviation Administration (FAA) was using its administrative powers to limit flight numbers into busy airports, largely in response to requests by airlines feeling the economic effects of soaring levels of delay (Fotos, 1988). A duplication of this trend has been seen in the New Zealand industry, with smaller and more frequent flights accelerating a growing capacity problem at both Auckland and Wellington airports (MacLeod & Webb, 1997).

U.S. solutions:

Other attempts by the U.S. administration to overcome the capacity problem experienced by their industry have included pricing structures designed to favour the use of larger aircraft. O'Lone (1988) describes the introduction of PACE – Program for Airport Capacity Efficiency – at Boston's Logan airport. Imposing substantial fee penalties for smaller aircraft types, this program was successful in its discouragement of general aviation aircraft at the airport, and in prompting moves towards larger aircraft by some commuter airlines. The program failed, however, when airlines passed fee increases to the consumer rather than implementing the desired shift toward larger aircraft types.

The U.S. industry has continued to address its congestion problems through pricing / incentive structures. Fotos (1989) describes a peak-pricing program designed to reduce inconvenience to large aircraft while offering subsidies to commuter airlines in order to attract them to off-peak scheduling.

Congestion in Europe:

Congestion within the European industries has been equally problematic. Substantial growth of air traffic over the past twenty years has seen steadily increasing pressure applied to a system with limited capacity for growth (Ott, 1988).

The very nature of Europe, with a multitude of countries bound together, has dictated a co-operative approach to alleviating the congestion problem. Recognising the interrelation of airspace and airport congestion throughout Europe, the need for a centralised air traffic control system was similarly apparent. The establishment of Eurocontrol thus laid the groundwork for a truly European industry (Ott, 1988). Deregulation in Europe has not been without problems, however, with some countries maintaining some form of protectionism over their industries citing efficient utilisation and employment protection as cause (Reed, 1996).

The European approach toward battling congestion problems has been two-fold. In contrast to the U.S., the European industry has applied an optimisation approach to traffic flow through air traffic management and has largely achieved a co-operative approach to management of scheduling (National Air traffic Service (U.K.) (NATS), 1993). The exception to this being the Federal Republic of Germany which has taken legislative measures to control traffic levels at its international airports (Deutsche Flugsicherung GmbH (DFS), 1996).

The efficiency of the optimisation approach to congestion has been reflected in the higher utilisation rates and enhanced capacity achieved at European airports, notably London Gatwick and London Heathrow (NATS, 1996). Indeed, the superiority of this approach is evident in the attempts of the U.S. industry to effect similar methods. Phillips (1996) describes a dynamic air traffic management system known as Free Flight, which is currently under development in the U.S. Simpson (1993) andCoogal

(1996) support this with descriptions of other U.S. initiated plans for global air traffic management systems.

European Deregulation:

True deregulation of the European industry has been a gradual process which is not yet at its completion. Reed (1996) has described fears that the U.S. trend toward smaller aircraft on a more frequent basis would be an outcome of complete European deregulation. This has not been the case, however. Extreme levels of demand combined with capped capacity levels have engendered a consistent trend toward larger aircraft types – precisely the opposite of the U.S. experience. Reed (1996) reports a trend by airlines to transfer landing rights to medium and long haul flights (which are operated by large aircraft), and attributes this greatly to short haul competition from high speed rail networks. Passengers are finding it more convenient to utilise other forms of transport for short trips, rather than coping with the inconveniences associated with air travel amongst congestion.

The fact of larger aircraft being more prevalent in Europe is reflected in the technical investigations of European aircraft manufacturers. Sparaco (1995) describes French manufacturer Aerospatiale's studies into the merits of very high capacity, flying wing commercial transport. "Aerospatiale expects that steady traffic growth will eventually necessitate higher capacity transports and greatly reduced operating costs. The flying wing transport would carry 800 –1000 passengers and prevent airspace and airport congestion."

Congestion in Asia:

Growing traffic levels throughout Asia has led also to pressure on capacity constraints. Carlos Chua, President of the Orient Airlines Association says that airlines are facing greater airport constraints than ever in 1995, with airport congestion and noise curfews impeding aircraft utilisation rates (Meecham, 1995).

While conceding that a European style centralised air traffic control system is becoming a necessity in the battle against delays, Meecham suggests that Asian countries would be slow to embrace the concept. This he attributes to sovereignty issues, with nations hesitant about giving up their own enroute radar controls in favour of a satellite based navigation system.

Whilst Asia has avoided the U.S. problem of small aircraft encrescence, the use of large aircraft has its own problems arising from airport congestion and the slow turn-arounds associated with large passenger loads. The most significant is the pressure applied to profitability through low aircraft utilisation rates (Meecham, 1995).

Deregulation in New Zealand:

Deregulation in New Zealand in 1987 saw the immediate introduction of a competitor for the National carrier, Air New Zealand in the form of Ansett New Zealand. Since its inception, Ansett has quickly duplicated Air New Zealand's schedules and attracted a 45% market share (Air New Zealand Annual Report, 1995).

While this competition benefits the consumer in that more frequent flights options are available, competition has created serious congestion problems at New Zealand's major airports – particularly Auckland and Wellington (McLean, 1991). Competition in any industry results in increased response to consumer demand. In the case of air transport this means more frequent flight availability. Wellington airport, for example, has experienced a 30% rise in traffic levels since 1991 (MacLeod & Webb, 1997). Of more concern, however, is changes in the type of aircraft using Wellington airport.

MacLeod & Webb (1997) detail the changes as a 5% decrease in mainstream transport such as the Boeing 737 and Bae 146 (Whisper Jet), and a 27% decrease in medium range aircraft such as the ATR72. This is countered by a 32% rise in the number of light commuter transports. These figures represent the proportions of each group in the total mix of aircraft using Wellington airport. Both passenger numbers and aircraft numbers have increased, but the growth rate of aircraft numbers is by far the higher. This is a direct indication of the trend toward smaller aircraft.

The result of this down-sizing of aircraft types, of course, is that more flights are required to carry the same number of passengers. This causes severe congestion at Wellington given that, as the 'business capital' of New Zealand, most people wish to travel at the same time. Consequently, Wellington experiences extreme morning and evening peak demand periods where delays commonly exceed 45 minutes (MacLeod & Webb, 1997).

The costs associated with airborne delay are significant. Cost, in this case is limited to fuel – fuel burned by aircraft flying holding patterns and fuel burned as aircraft carry extra fuel to enable them to hold. Given that fuel costs are one of the major economic considerations of airline operators, the cost to the industry becomes apparent.

Also to be considered is the possibility of diversions caused by excessive delay – that is, when aircraft cannot wait any longer to land and must go elsewhere. The fuel cost in this case may not be limited to holding and diversions, but may include additional flights as passengers must be on-flown. Safety considerations and customer relations cannot be improved by this eventuality.

Asia / Pacific Region Forecast

A regional forecast entitled "Asia Pacific Air Traffic Growth and Constraints" (1997), published by the Air Transport Action Group (ATAG) predicts a high rate of growth throughout the Asia / Pacific region. ATAG is an "independent coalition of organisations from throughout the air transport industry which have united to press for economically beneficial aviation capacity improvements in an environmentally responsible manner"; the report is based on an International Air Transport Association (IATA) traffic forecast covering this region of the world and published in 1997.

Domestic passenger numbers within New Zealand are shown to have increased from 2.7 million in 1985 to 4 million in 1995 a rise of 48%. Similarly, international passenger traffic has grown 109% from 2.2 million to 4.6 million. Growth between

1995 and 2010 is forecast as 105% domestic passenger growth to 8.6 million in 2010 and 137% international passenger growth to 10.9 million.

The average annual rate of growth for the period 1985–1995 is 5.7%. The forecasted average annual rate of growth 1995–2010 is 5.4%. As the major international as well as domestic New Zealand ports, this level of forecasted growth has significant ramifications for particularly for Wellington and Auckland airports.

Notable conclusions of this report are:

1. Demand for air travel in the Asia/Pacific region is growing faster than in any other world region. It is forecast to grow by an average of 7.4% per annum between 1995 and 2010.
2. The ability of airlines to respond to this increase in demand by increasing load factors, seat densities and aircraft size will be limited. Most of the capacity growth will come from an increased number of flights.

Discussion

Airport and airspace congestion is a problem fast reaching global proportions. Although technological solutions may help ease the difficulties experienced in airspace congestion, the final limiting factor on air travel must be the number of aircraft that can be accommodated by the world's airports. With noise curfews and space limitations constraining airport capacity, it is essential that the most efficient usage of available capacity be achieved. The most efficient solutions appear to have been found by the European industries who adopt a centralised air traffic control system and manage demand through co-operative methods.

Deregulation of air transport industries often encourages the use of smaller aircraft so as to provide frequent flight options for the consumer. Particularly at Wellington airport, extreme levels of delay are apparent during peak times. Because the majority of traffic at Wellington is business oriented, it is unlikely that attempting to shift demand through pricing structures will be an effective solution. An air traffic management system similar to that employed in Europe is likely to be a far more effective solution. By limiting the number of aircraft which may use an airport within a

given time frame, airlines are forced to utilise larger aircraft in order to meet consumer demand.

It is evident that the New Zealand air transport industry is experiencing similar outcomes of deregulation as those of the U.S. industry. It is also apparent that attempting to solve congestion problems via pricing structures which endeavour to spread demand will have no greater success than in the U.S. industry. However, the economic and safety considerations of the current levels of delay dictate that the industry address this problem now. The required outcome is a reversal of the current trend and forecasts of smaller more frequent services so that larger aircraft are utilised to meet consumer demand. Only by these means may demand be satisfied without resultant congestion.

Methodology

Data Collection

The information presented in this research is drawn from five main sources.

1. Airways Corporation Aeronautical Fixed Telecommunications Network (AFTN) has been the source of both airport traffic schedules, and of flight plan information. Traffic schedules have been utilised in the determination of distribution and level of demand at each of Auckland, Wellington, Christchurch, Nelson and Palmerston North airports. It has also been used in the determination of aircraft type mix using these airports.

   Flight plan information is the planned route and duration of individual flights. This information has been used, in conjunction with actual flight duration data, to determine levels of delay.

2. Airways Corporation Aviation Traffic Database (ATDb) is the source of arrival and departure times of individual aircraft movements. Data has been drawn corresponding to the peak demand periods at Auckland, Wellington, Christchurch and Nelson airports (identified from traffic schedules). This information has been used in the determination of airport throughput, growth, type mix changes and individual airborne delays. The periods monitored have been:

Wellington Airport: Morning and evening peaks, 0730 – 1000 and 1630 – 2000. Data has been collected on a daily basis for the 10 month period April 1997 – January 1998 and encompasses some 43,713 individual aircraft movements.

Auckland / Christchurch / Nelson Airports: Owing to more evenly distributed demand the period reviewed at Auckland, Christchurch and Nelson airports has been 0700 – 2000 for the two month period October 1997 – November 1997. Arrival and

departure times of some 30,443 aircraft at Auckland, 17,193 at Christchurch, and 4,067 at Nelson have been recorded.

3. Weather information has been collected for Auckland and Wellington airports over a period of 14 and 19 months, respectively. This information is actual aerodrome reports, which are updated on an ongoing basis whenever some parameter - such as cloud or wind - alters.

4. Aircraft performance information, specifically fuel burn, has been drawn from a report entitled "Aircraft Performance Summary Tables for BADA Revision 2.3" and issued by Eurocontrol's Experimental Research Facility at Bretigny-sur-Orge in France. This report, contains a set of aircraft performance summary tables for the 65 aircraft types modeled by the Base of Aircraft Data (BADA) Revision 2.3. For each aircraft type, the performance tables specify the true air speed, rate of climb/descent and fuel flow for conditions of climb, cruise and descent at various flight levels. The performance figures contained within the tables are calculated based on a total-energy model and BADA 2.3 performance co-efficients.

5. Airport capacity for Auckland and Wellington airports is drawn from capacity studies undertaken by this author for the Airways Corporation of New Zealand Ltd. Shown are theoretical maximum capacity and realistic 'declared' capacity levels for both airports. A single runway capacity is calculated for Christchurch airport using the same methodology, and this is used for comparative purposes with Auckland and Wellington. Capacity for these models was calculated using the following method:

- Individual aircraft speed and performance was drawn initially from aircraft performance files held by Airways Corporations Aircat air traffic control system.
- Aircraft speeds and performance characteristics were then observed (via radar monitor) and actual performance compared with that given by the performance files. Some 10,000 takeoffs and landings were observed.
- The average of the above figures was used as a standard performance measure for individual aircraft types. This standard was represented as a distance and height measure at fifteen second intervals.

- The standard performance measure for each aircraft when incorporated with the minimum allowable air traffic control separation (which varies with weather conditions) gives a measure of capacity for various weather states. That is, a measure of how many aircraft may utilise a runway system within a given time frame (usually an hourly rate). The measure may be used to depict exact situations and aircraft movements, or used to estimate a more 'general' case.

Interpretation of Data

Delay

Delay, as described by this research, refers to the airborne delay experienced by individual aircraft in flight to Auckland, Wellington, Christchurch and Nelson airports. Cause of delay is not described here, being one of the intended findings of this investigation. The focus of this thesis is congestion and its effects. Unavoidable delay caused by such things as runway closure due to fog or accident is outside the scope of this research. Days on which this has occurred have therefore been excluded.

Drawing on information collected from Airways Corporations ATDb, duration of flight has been calculated as the difference between departure and arrival time. Intended duration has been provided by aircraft flight plans, collected from Airways Corporations AFTN. Delay to individual aircraft has then been calculated as the difference between the planned duration of a flight, and its actual duration.

Delay is then presented for each airport as:

1. Total minutes of delay incurred over period of investigation
2. Total minutes of delay by aircraft type over period of investigation
3. Average delay during peak demand periods
4. Average delay during peak periods for various weather conditions

Cost of Delay

The cost of delay is restricted to estimates in terms of fuel burnt during airborne delay. Associated costs such as crews, schedule disruption, passenger inconvenience and the cost of aircraft carrying fuel to enable airborne holding is not included. As such, this is a limited indication of the true cost of delays, but is nevertheless indicative of the economic effects of airport congestion in New Zealand.

Fuel burn is estimated for each aircraft type from aircraft performance summary tables issued by Eurocontrol. Fuel consumed in flight varies with altitude and with aircraft weight. Airborne delay, for the purposes of this estimation is calculated as having occurred at the standard descent levels of 7,000 feet for aircraft arriving from relatively close airports such as Nelson, and 13,000 feet from airports further afield. Light aircraft and E110 Bandierante traffic is calculated at 4,000 feet.

Information is presented as:

- Fuel cost estimated for each aircraft type in airborne delay
- Fuel burn matched to total minutes of delay by aircraft type, to estimate the cost of airborne delay over the period investigated.

Annual delay is estimated from average delay during stated weather conditions, and proportions of each weather condition which have occurred during the past year. This data is available for Auckland and Wellington airports.

Information is presented as:

1. Estimated annual delay
2. Estimated annual fuel cost

Demand

Demand for airport services, as presented by this research, is scheduled air transport operations. It does not include private or training operations. Daily schedules have been drawn from Airways Corporations AFTN over the following periods:

Auckland: 4 months
Wellington: 14 months
Christchurch: 1 month
Nelson: 1 month

Comparison of daily schedules has revealed small variations, particularly with international aircraft movements. Schedule information shown in this research is not average scheduled demand, but rather is actual data which conforms closely to average weekday schedules.

As expected, weekend and holiday scheduled demand has been found to be distributed differently to 'normal' weekday schedules, and substantially lower. Weekend days and holidays have been excluded from this data.

Schedule information has been presented as hourly demand, allowing easy identification of peak demand periods. Peak periods are then shown in greater detail, as ten minute intervals incorporating arrival and departure proportions.

Airport Capacity

Airport capacity is calculated through the use of capacity models developed for the Airways Corporation by this author, and released as the Wellington Air Traffic Management Study (1997), Wellington Air Traffic Management Study (1998), and the Auckland Capacity Study (1997). The same methodology is used to present a single runway capacity for Christchurch airport.

These capacity models utilise aircraft performance data, which was determined from performance files held by Airways Corporation and through observation of arriving and departing aircraft. Also utilised by these models is runway occupancy data, which was determined through the observation of some 1100 take-offs and landings at Wellington airport, and 500 at Auckland.

Descriptions of the factors which affect capacity are made, and capacity statements for Auckland and Wellington airports are provided. Single runway capacity for Christchurch airport is modelled, and a comparison between Auckland and Christchurch capacity is drawn.

Causes of Delay

Explicit causes of delay are identified through a comparison of airport capacity and levels of demand. The effects of various factors which combine to determine capacity are examined and a comparison between airports is used to determine the extent to which each is a cause of delay.

Limitations of Research

The main limitations of this research arise from limitations of data accuracy. The primary sources of data are Airways Corporations AFTN and ATDb. The limitations on this data are as follows:

1. Schedule information gathered from the AFTN does not include itinerant traffic or schedule alterations. The positive aspect of this is that scheduled operations are isolated from 'one-off' or infrequent traffic. Also, it provides an explicit account of normally planned air transport operations. The negative aspect is that, by excluding itinerant traffic, total planned demand is not shown. This may include IFR traffic which is airline additions or air transport charter operations. Further, traffic schedules do not take into account the deviation from scheduled time, which occurs on a daily basis.

2. Flight plan information, which provides the planned duration of flights from which delay duration is derived may not contain time for approach. The effect of this is variable but, using Wellington as an example, will approximate the following:

Flight plans for flights to Wellington from Nelson and Blenheim normally include the instrument approach point. The effect of this is accurate planned duration during instrument conditions, and possible underestimation of delay during visual conditions – due to the flight planned route being slightly abbreviated .

Flight plans for flights which originate from the Auckland and Hamilton direction usually include Tory VOR as an enroute point to Wellington. If Runway 16 is in use at Wellington, flights are likely (but not certain) to short cut the planned route by flying direct to Titahi Bay to commence approach. This would cause an under-estimate of any delay. If Tory VOR is not circumvented, delay will be over-estimated because the instrument approach is not included in the planned duration of flight. If Runway 34 is in use, aircraft must fly further south than is included in the flight plan – resulting in overestimate of delay during instrument conditions, but will be accurate for visual conditions.

The opposite occurs for flights originating from a southern direction. These plans are direct to Wellington and will be accurate for Runway 34, but may lead to overestimate of delay for Runway 16 where aircraft must proceed further North to commence an instrument approach. These are necessary and integral parts of flight and are not an effect of congestion. These details, however, are not included in the standard plan data which is filed with Airways AFTN.

The effects of this are similar at Christchurch airport. Auckland is also affected, but due to runway orientation, the effect is smaller.

In all cases, some flight planned durations will be shorter than actual duration and some will exceed it. This will be balanced, to some extent by opposite direction traffic, and by use on other days of the opposite runway vector. It is considered, however, that delays of less than six minutes duration (which is the approximate time taken by an aircraft for one lap of a holding pattern) is due to data limitations, rather than actual airborne delay.

3. Arrival times in ATDb. While information held in ATDb is extremely accurate for departures which is radar information from an aircraft on the runway during its take-off roll, it is not as accurate for aircraft arrival times. Aircraft arrival times are recorded manually by airport tower personnel. The accuracy required is –5 or +10 minutes. Comparison with timed arrivals indicates that these times are usually accurate to within 2 minutes.

Delay, as presented by this research, deals only with airborne delays. No attempt has been made to produce data on ground based delay. This is primarily due to the difficulty of accurate data collection, and the limitations of time andresources which a single person could devote.

Ground based delay (due to congestion) cannot be measured as the time differential between planned departure time and actual. This is because of the many possible causes which are unrelated to airport congestion – E.g. Aircraft engineering problems, late passengers, late arrival of aircraft, etc. Rather, delay due to congestion must be air traffic control instructed delay.

When an IFR aircraft is nearing readiness for departure, start and enroute clearances are requested from air traffic control. If a queue of departures already exists, start clearance will not be given. This avoids large numbers of aircraft queuing with engines running (and hence burning fuel) at a holding point. This queue is generally restricted to four or five aircraft. Ground based delay, therefore must be considered as time spent waiting at a holding point plus start delay incurred. Measurement of this delay would be very time consuming and would require the co-operation of airport tower personnel.

In addition, there is some question over the accuracy of any measurement of this data. In a survey of runway occupancy times undertaken by this author, and encompassing some 1200 aircraft movements at Wellington airport, the time taken for aircraft to reach the holding point after start clearance delivery was also recorded. During busy or congested periods, this time was noticeably longer in some cases than during non-congested periods. In the absence of any other reason, it is concluded that in some cases pilots will call for start clearance prior to readiness in order to avoid being placed in a queue, or to minimise time spent in that queue. The

accuracy of departure delay recording, especially during peak demand periods, is therefore questionable.

In the absence of any solution to this dilemma, and accepting the restraints of time and resources, departure delays are not presented by this research.

It is not considered, however, that absence of ground based data significantly detracts from the value of this research. This is for the following reasons:

- Ground based delay prior to engine start uses no fuel, and minimal fuel after start. The vast majority of the cost of delay in terms of fuel burn occurs during airborne delay. It is cost due to fuel burn that this research seeks to estimate.
- In a system (such as Wellington and Christchurch airports) where equal priority is given to arriving and departing flights, ground based delay will be equal to, or more likely, less than airborne delay.
- At airports such as Auckland, where departures are given priority over arrivals or at Christchurch, where demand is well below airport capacity, any ground based departure delay will be very small

Airport Capacity. The capacity scenarios utilised in this research are the result of average 'normal' airport capacity. Any deviation in terms of aircraft type mix, arrival / departure mix, or any of the other factors which influence capacity will cause slight changes in actual capacity.

Weather Conditions. Any given time period will be generally classified as visual conditions, instrument, etc. This does not guarantee equal conditions, however. For example, one day which is classified as visual may be turbulent with strong gusty winds while another is calm. Similarly, one instrument conditions day may have a cloud base low enough to require an instrument approach to be flown for only a short distance before conditions allow the remainder to be flown by visual reference.

Aircraft Fuel Burn. Fuel consumption by aircraft is directly related to aircraft weight and condition of flight. The performance summary tables presented in the BADA report specify fuel consumption for low, nominal and high mass levels. Fuel consumption at nominal weight has been utilised in this research, but it is recognised that actual aircraft weight (and hence fuel flow) may differ. Further, this fuel consumption data is specified for aircraft in the cruise phase of flight. Particularly in

the case of jet aircraft, the speed at which they fly in a holding pattern may differ from that at which the same aircraft would cruise at that level. Any difference in speed will affect fuel consumption. Because cruising speeds are generally calculated to produce the most efficient combination of speed and fuel consumption, it is likely that fuel flow in a hold will be higher.

Flight Levels. The flight levels at which aircraft are delayed are variable. Aircraft use differing amounts of fuel at low altitudes than high, thus any deviation from the levels assumed in this research will produce differing results. The flight levels assumed by this research are: F130 (13,000') for jet aircraft; 7,000' for medium category turbo-prop aircraft; and 4,000' for all others. Observation indicates that these levels accurately reflect a general case scenario, but it is acknowledged that deviation from these levels will occur frequently.

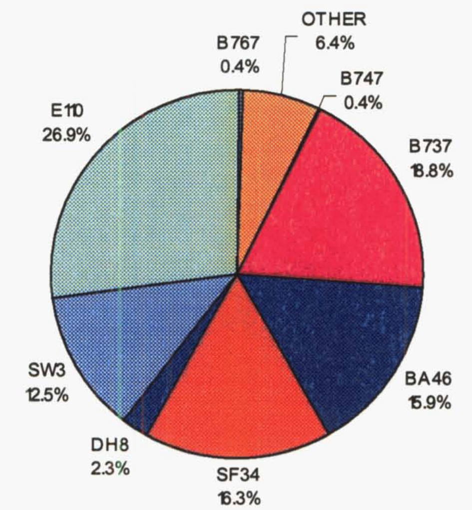
. Delay to international aircraft. It has not been possible to measure the delay incurred by international aircraft because of limitation of data sources. Airways Corporation's AFTN system does not hold information on flight duration or departure times for flights which originate outside the New Zealand flight data processing system. In order to gain this information, it would be necessary to access the systems of other countries. Because no system of allocating priority to these flights exists within New Zealand, however, it is reasonable to assume the incursion of average delay. This method has been chosen in calculation of the cost of delay.

Airborne Delay

AUCKLAND AIRPORT

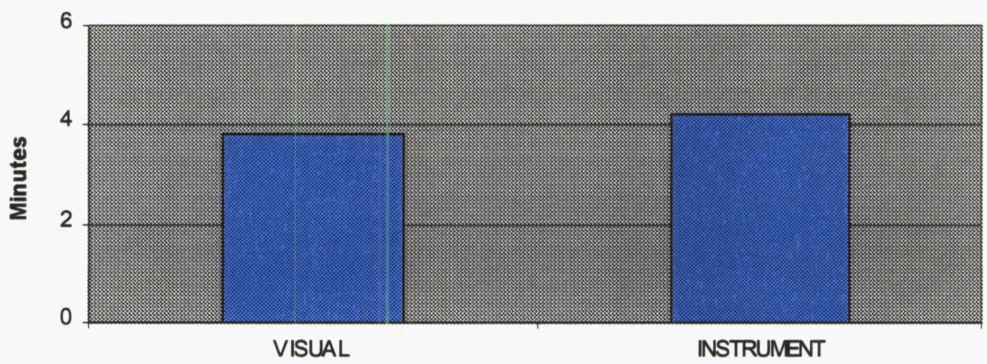
Airborne delay has been measured at Auckland airport on weekdays over the two month period October / November 1997. The period monitored is 0700 – 2000 local time. Peak period runway throughput is also measured. Delay has been determined for a total of 15,206 arriving aircraft. Aircraft mix over this measured period does not include international traffic. Figure 4.1 shows distribution of aircraft types for which delay has been determined.

Figure 4.1: Auckland Measured traffic Mix



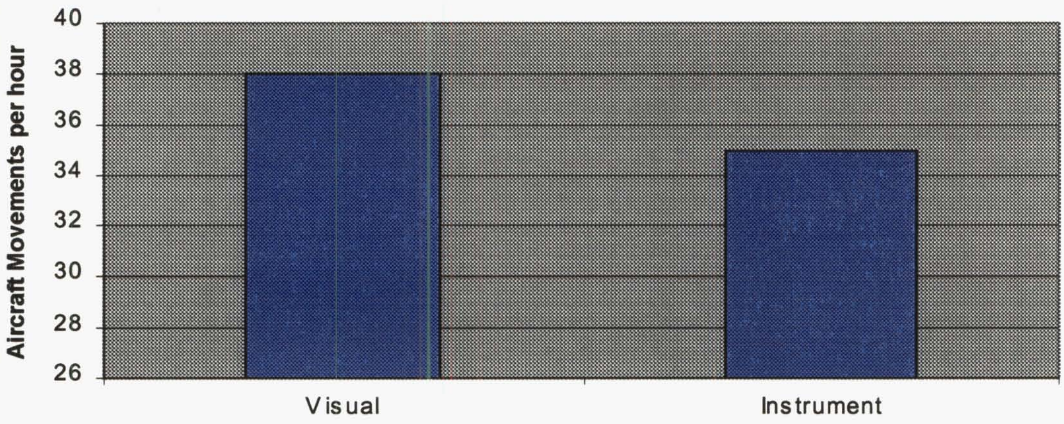
No significant difference is seen in the amount of delay incurred by each aircraft type, nor does weather condition appear to significantly affect the level of delay.

Figure 4.2: Average Delay by Weather Condition



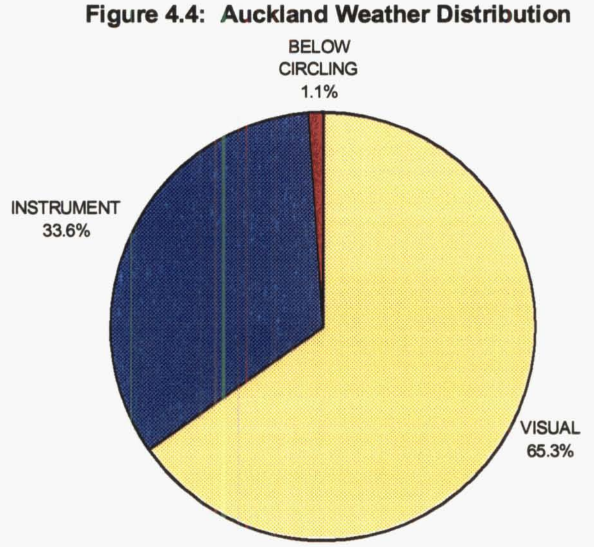
Total delay measured over 15,206 aircraft was 57,782 minutes, at an average of 3.8 minutes per aircraft. Delay during instrument conditions is higher than during visual conditions, but the difference is only 0.8 minutes. Average delay during the peak hours 0800-0900 and 1800-1900 is higher at 6 and 5 minutes, respectively. Throughput differs slightly, averaging 35 aircraft per hour during instrument conditions and 38 on visual days.

Figure 4.3: Average Throughput by Weather Condition

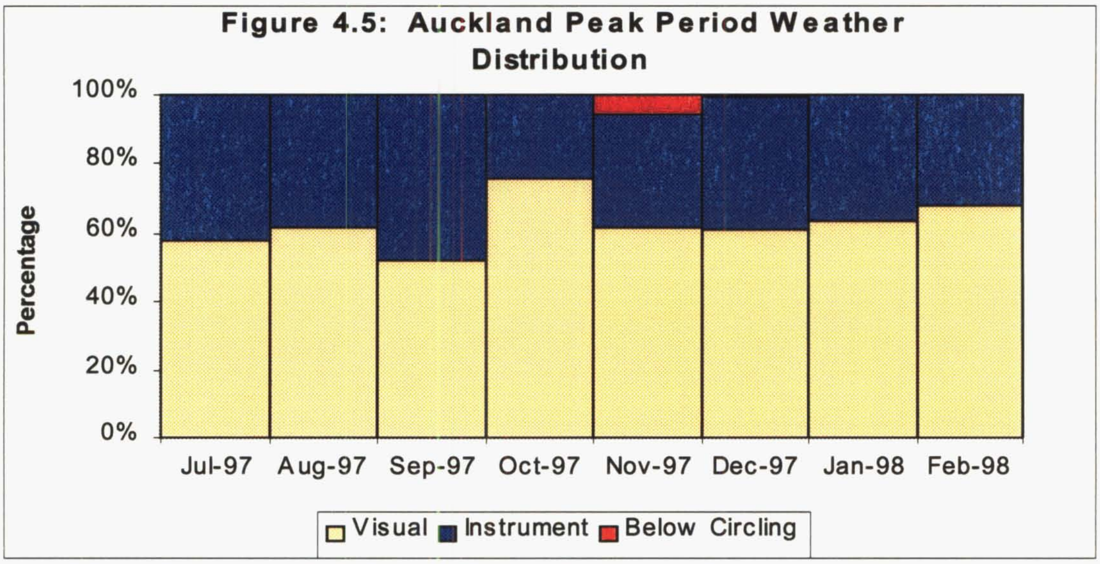


Weather conditions at Auckland have been recorded over the8 month period July 1997 – February 1998. Data recording is for the peak period 0700 – 2000. Figure 4.4 shows weather conditions distribution.

Figure 4.4: Auckland Weather Distribution

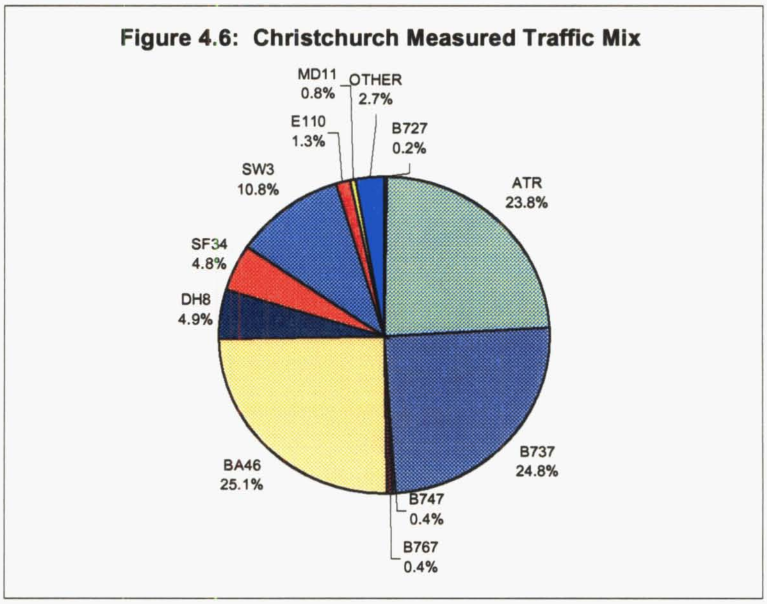


Visual conditions predominate at Auckland, and conditions that are below circling minima occur only 1.1% of the time. These conditions include occurrence of fog.



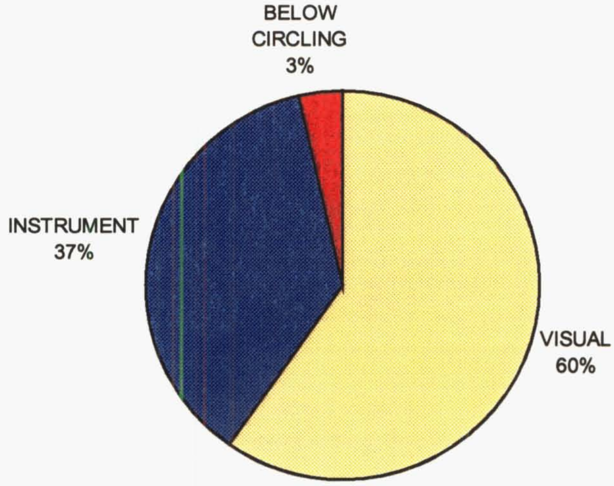
CHRISTCHURCH AIRPORT

Airborne delay at Christchurch has been monitored over the same period as Auckland – October / November 1997 and also January / February 1998 0700-2000 local time. Delay was determined for 8,570 aircraft. Figure 4.6 shows aircraft type distribution.



Like Auckland, no difference was discernible in allocation of delay between aircraft types. Weather data is not available for the entire period, monitored only January / February 1998. Figure 4.7 shows distribution of weather conditions over thistwo month period.

Figure 4.7: Christchurch Weather distribution Jan / Feb 1998



No difference is evident in delay level on various days. Average delay during visual conditions was 3.2 minutes and during instrument conditions was 3.4 minutes. It is unlikely that weather significantly affects delay at Christchurch airport (runway closure / fog excepted).

Total delay measured over 8,570 aircraft was 27,446 minutes. Throughput at Christchurch is also low, averaging 20 aircraft movements per hour with little variation throughout the day.

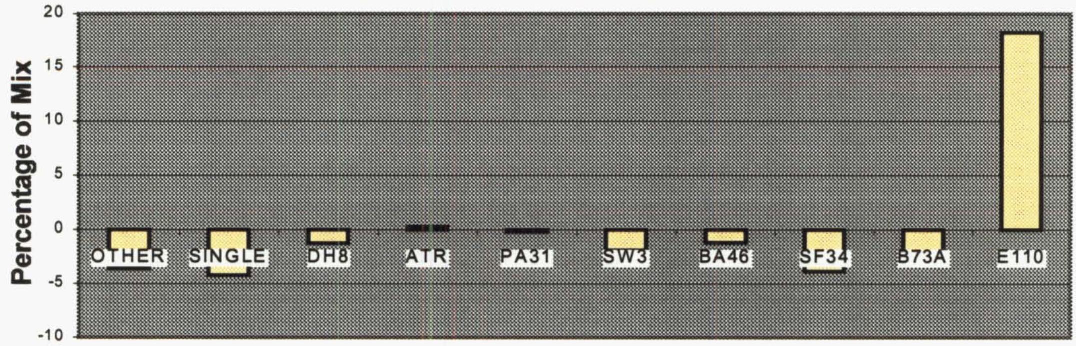
WELLINGTON AIRPORT

Airborne delay at Wellington has been measured on weekdays over the10 month period April 1997 – January 1998, inclusive. The periods monitored have been 0730 – 1000 and 1630 – 2000 local time. Peak hour runway throughput (number of aircraft movements which have taken place) has also been measured over the same period.

A total of some 43,713 aircraft movements have been recorded. 21,815 of these are arriving aircraft for which level of delay has been determined.

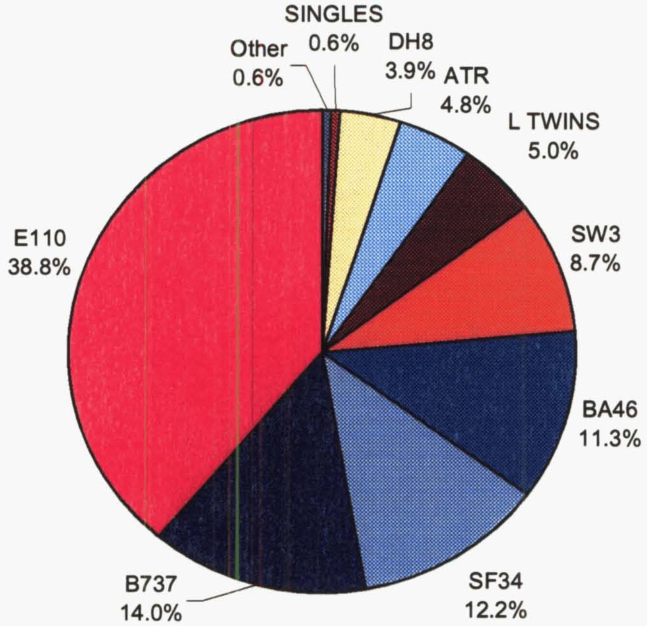
It is notable that the aircraft type mix during these peaks differs slightly from the overall mix of scheduled aircraft. Figure 4.8 below shows how type mix differs.

Figure 4.8: Percentage Change - Peak Period Aircraft Type Mix vs Total Type Mix



E110 Bandierante aircraft make up a much higher proportion of peak period traffic mix than total traffic mix. ATR 72 aircraft are also slightly more prolific, while all other type proportions are diminished. Figure 4.9 shows traffic mix during peak periods.

Figure 4.9: Wellington Peak Period Traffic Mix



The total amount of airborne delay measured over this period was 85,427 minutes – equating to an average of 3.92 minutes per aircraft. Delay is not apportioned evenly, however. Figures 4.10 and 4.11 show this disproportion.

Figure 4.10: Percentage of Airborne Delay

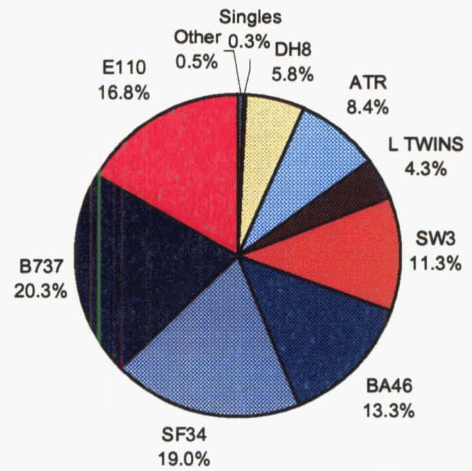
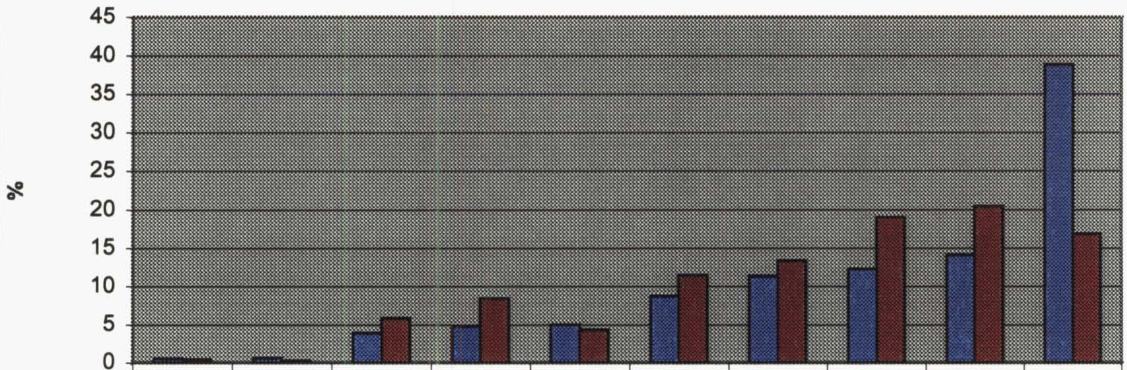


Figure 4.11: Percentage of Aircraft Mix and Delay



	Other	Singles	DH8	ATR	L TWINS	SW3	BA46	SF34	B737	E110
% of Aircraft	0.57	0.59	3.87	4.83	4.96	8.72	11.34	12.23	14.05	38.84
% of delay	0.49	0.30	5.79	8.35	4.33	11.35	13.31	18.96	20.35	16.77

The total number of minutes delay incurred by each aircraft type and its average delay is shown by Figure 4.12 and Table 1 below.

Figure 4.12: Average Delay by Aircraft Type

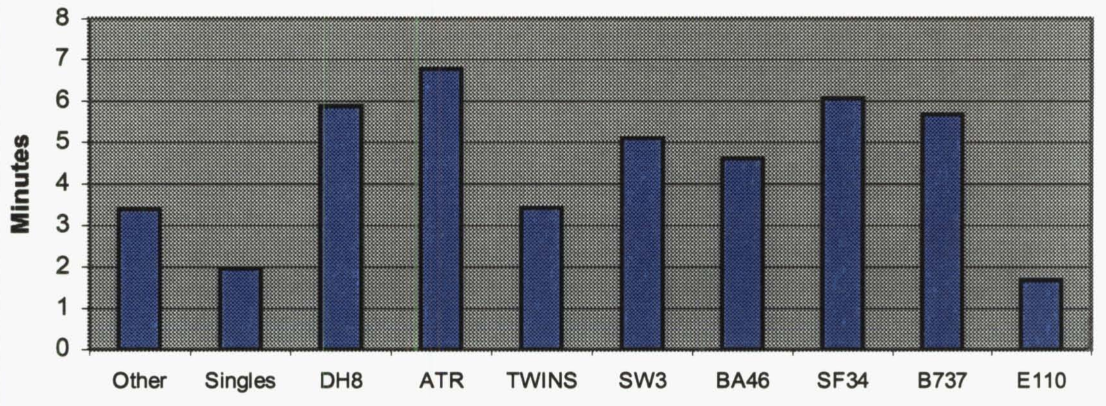
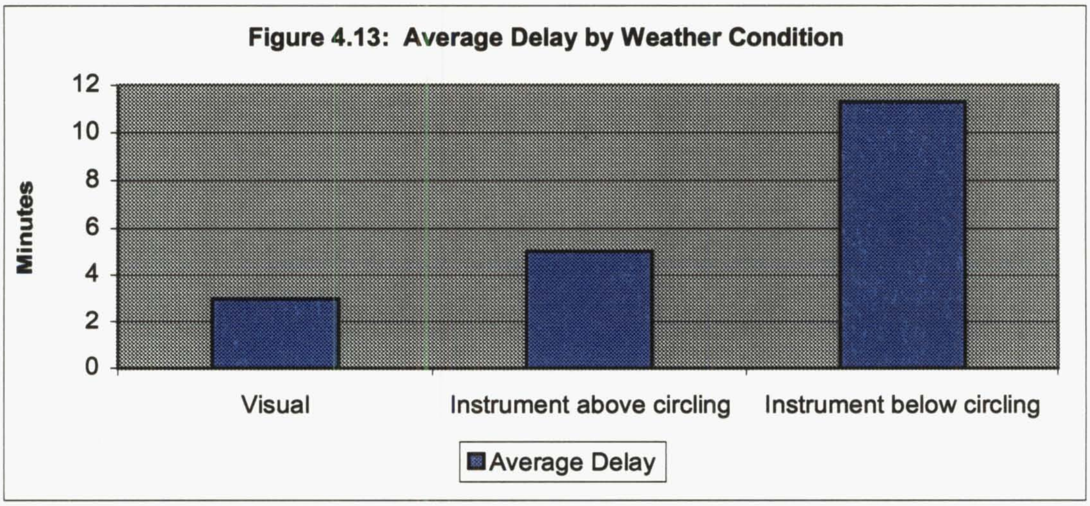


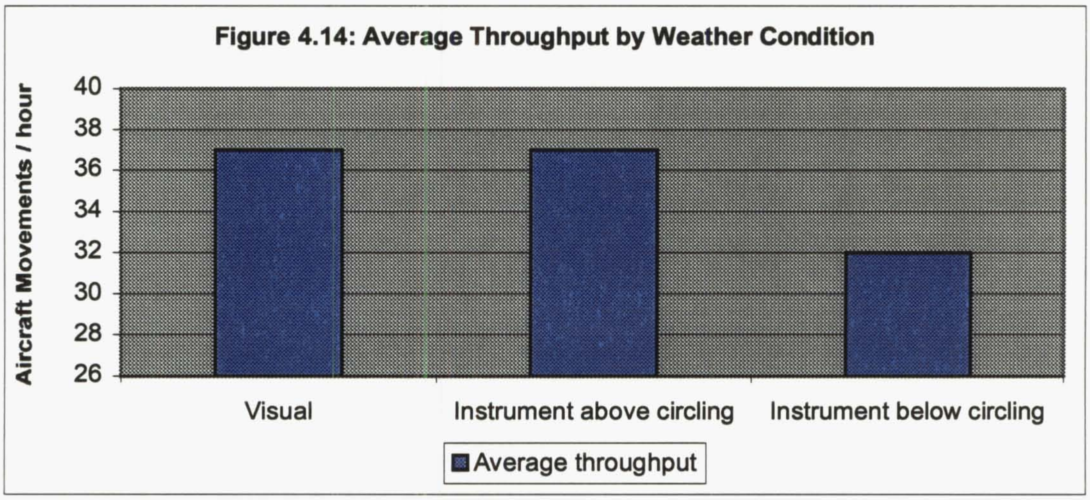
Table 1:
Minutes and Average Delay by Aircraft Type

Aircraft Type	Number of Aircraft	Minutes Delay	Average Delay
Other	124	420	3.39
Singles	129	254	1.97
DH8	844	4949	5.86
ATR	1053	7137	6.78
L TWINS	1082	3697	3.42
SW3	1903	9694	5.09
BA46	2474	11370	4.60
SF34	2668	16196	6.07
B737	3064	17383	5.67
E110	8474	14327	1.69
TOTAL	**21815**	**85427**	**3.92**

Delays incurred are not equal over all weather conditions. Figure 4.13 below depicts average delay incurred during the weather conditions of Visual, Instrument above circling minima, and Instrument below circling minima.



It can be seen from this that delay increases as weather conditions deteriorate - the greatest levels of delay occur when the weather is below circling minima. Achieved runway throughput – the number of movements which take place in a given time – is not constant either. Figure 4.14 below shows average hourly peak period runway throughput.



Average runway throughput remains constant through visual and instrument above circling minima conditions, but is significantly lower during instrument conditions below circling minima.

Throughput is lowest, and delays highest during conditions below circling. Because demand from IFR air transport aircraft is unchanged by weather condition, this suggests that airport capacity is exceeded during below circling conditions. Average throughput during visual and above circling conditions is constant. Delay, however, is higher during above circling conditions. Given the limitations of ATDb data, it is not immediately clear whether delay is due to excess demand for either condition. An investigation of demand and airport capacity is required to determine this.

Weather conditions at Wellington have been recorded over the past 19 months, between the hours of 0500 and 2400. Figures 4.15 and 4.16 show variation of weather conditions over the course of the day and during peak demand periods.

Figure 4.15: Wellington Total Weather Distribution

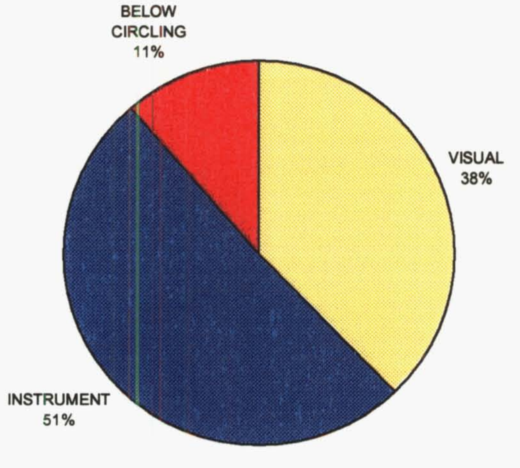
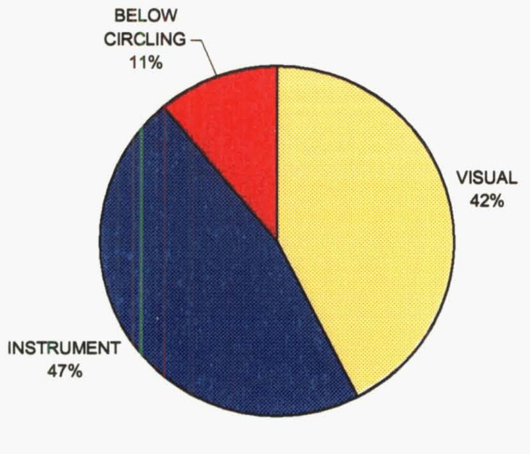


Figure 4.16: Wellington Peak Period Weather Distribution



There is little difference between peak periods and total weather distribution. The slight increase of visual conditions in favour of instrument conditions is due to less darkness hours during peak periods.

Some seasonal variation is indicated, also largely due to hours of darkness with respect to visual versus instrument conditions. During below circling conditions, no seasonal variation is apparent, but data collection over a greater time period is required to confirm this.

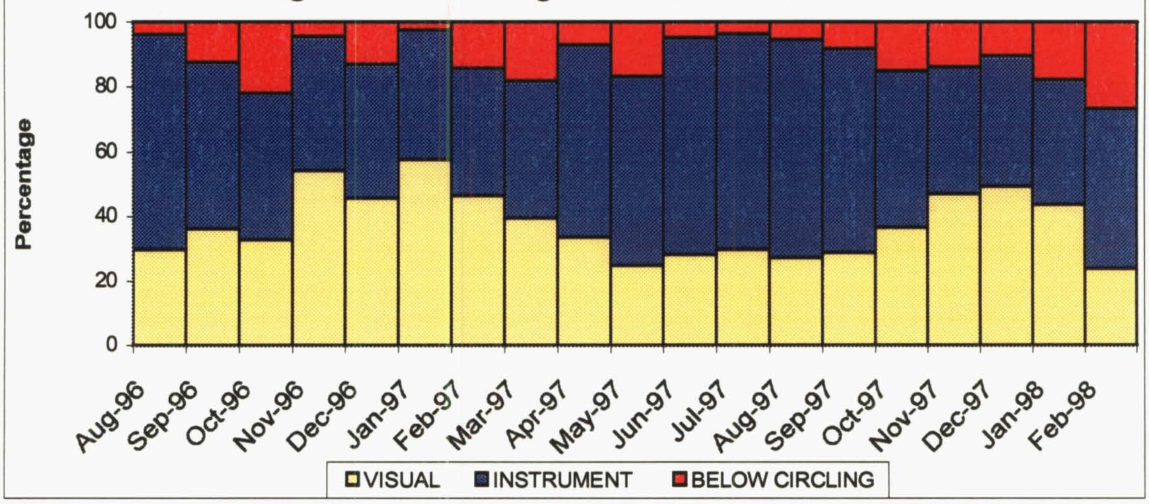


Figure 4.17: Wellington Weather Distibution

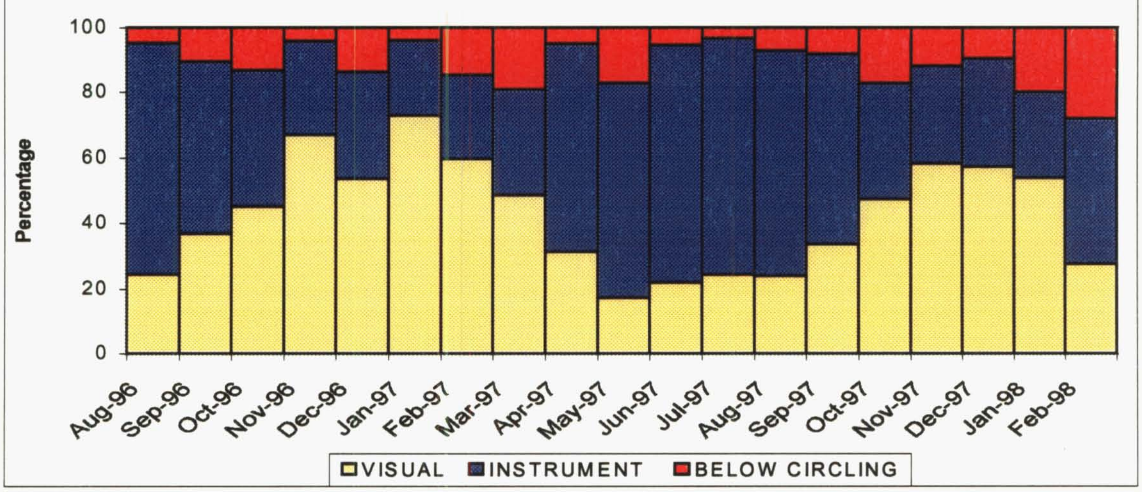


Figure 4.18: Wellington Peak Period Weather Distribution

Closer examination of occurrence of below circling minima conditions is given by figures 4.19 and 4.20.

Figure 4.19: Wellington Below Circling Occurence

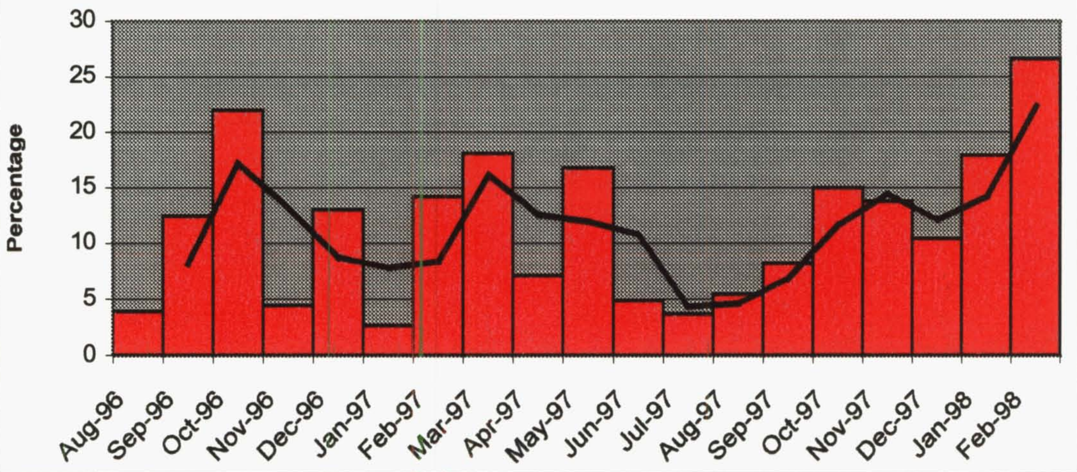
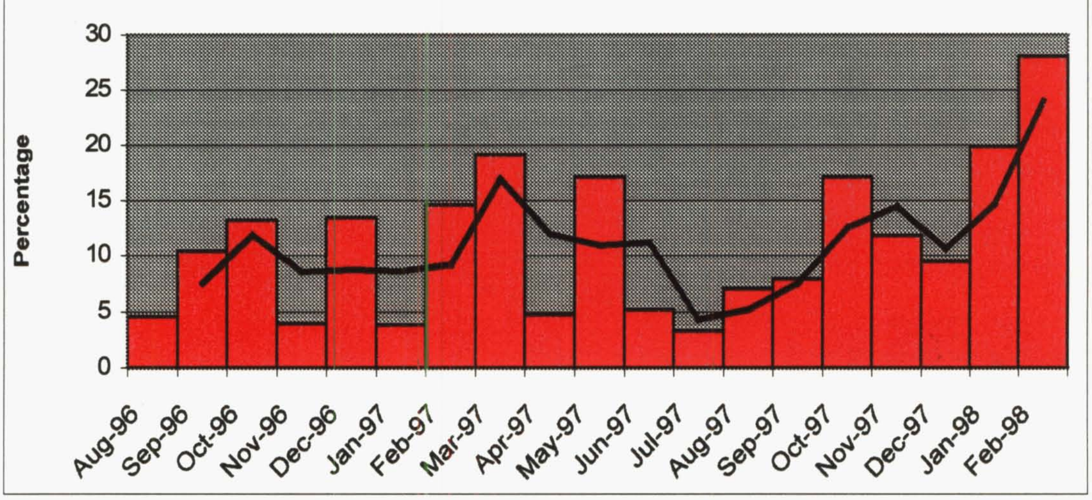


Figure 4.20: Wellington Peak Period Below Circling Occurence



Similar distribution is seen during both peak demand periods and throughout the day. This suggests consistency of weather state. In other words, weather conditions – good or bad – are unlikely to be brief.

Ongoing Effects of Delays

Delays at any of New Zealand's major airports are likely to have substantial on-going effects. These occur in two ways:

Networking: An aircraft that incurs delay may cause similar delays to other aircraft if it is carrying passengers who are connecting to other flights. For example, an aircraft flying from Nelson to Wellington is likely to carry passengers whose final destination is Auckland, Christchurch, or some other place. In this case, the aircraft departing Wellington for these destinations will be delayed awaiting their passengers.

Schedule disruption: Any aircraft that incurs delay at one airport is likely to be late at its next destination. Although it may be possible for some time to be made up in faster turn-around on the ground, or increased speed in the air, the amount of time that may be saved in this way is small. For example, the maximum possible time a Boeing 737 could save flying between Auckland and Wellington would be approximately five minutes, although it would need favourable flying conditions to do so. On shorter routes, the possible time aircraft can save in the air is lower. A fifteen minute delay, then, will take several flights to recoup.

It can be seen then, that the effects of congestion can be wide ranging and will affect operations at other airports, whether those airports suffer congestion or not. A substantial delay, say 45 minutes, will probably disrupt airline operations throughout the course of the day.

While total demand at Nelson is not high, the level of Wellington-Nelson traffic amongst total traffic at Nelson is significant. Although situated on the opposite side of Cook Strait, Nelson falls within domain of the Wellington business district. A great deal of commuting between these centres, therefore is done by both Public and Private sector business people, as well as by the general public. Unlike most of New Zealand's other provincial towns, which have easy access by either road or rail to the region's major city, access to Wellington from Nelson is more difficult. The alternative option to air transport is travel by road to Picton, followed by a 3.5 hour ferry crossing of Cook Strait.

As a consequence, demand for air travel between Nelson and Wellington on a frequent basis is higher than experienced at other provincial townships which experience a greater level of choice in convenient forms of travel. This high frequency of flights is a substantial contributor to congestion at Wellington, and can cause a similar problem at Nelson airport.

The close vicinity of Nelson to Wellington creates a situation where the flight time on this route differs little between aircraft. Aircraft departing Wellington in quick succession will arrive at Nelson at similar close time intervals. Nelson does not have the benefit of radar assistance – rather, during instrument conditions aircraft are separated by time intervals. The rate at which aeroplanes can depart Wellington during instrument conditions is greater than the rate at which they may arrive at Nelson.

This becomes a problem when weather conditions at both Wellington and Nelson are poor. When congestion occurs at Wellington, departing jets often gain priority from their operators. As a result, light and medium turboprop aircraft tend to depart Wellington within a smaller time frame than would otherwise be the case. This can result in a succession of aircraft departing Wellington bound for Nelson. If the weather at Nelson is fine, this presents no problems. If, however, the weather at Nelson is also poor then substantial delays can result, despite the relatively low level of scheduled demand at this airport.

The Cost of Delay

The purpose of this thesis is not to provide a detailed scrutiny of the monetary cost of delays. It seeks, rather, to provide a detailed investigation of airport congestion. No attempt, therefore, is made to provide an account of the true economic cost to the air transport industry – cost which must include fuel burn, the cost of carrying extra fuel, air and ground crews, maintenance and wear – or an account of the cost in terms of passenger dissatisfaction and inconvenience. The economic cost of airport congestion is, however, a consequence of this problem which must be considered as the primary incentive to effect a solution.

The cost of delay is therefore presented here as total annual time lost in airborne delay, and as an estimate of the fuel burnt by aircraft as a result of this delay.

Fuel usage data for each aircraft type has been drawn from a 1995 Eurocontrol report, entitled 'Aircraft Performance Summary Tables for BADA revision 2.3'. Fuel usage at nominal weight has been utilised here.

It should be noted that actual fuel usage may be higher than this rate because aircraft fly at a slower speed than normal cruise during holding. Further, fuel usage is dependent upon the height at which an aircraft flies. In general, the higher an aircraft is, the lower its rate of fuel burn. For the purposes of estimating fuel used, aircraft have been assumed to be held at the following levels:

FL130 (13,000')	All heavy and medium jets (includes B767, B737, BA46)
7,000'	All medium turboprop aircraft and SW3 Metroliner
4,000'	E110 Bandierante, all piston-engine aircraft

Estimated fuel burn for each aircraft type at these levels is as follows:

B747	220.3	Kg/min	**DH8**	7.6	Kg/min
MD11	134.4		**SF34**	11.7	
B767	82		**SW3**	4.1	
B737	32.6		**E110**	4.0	
BA46	23.7		**Twins**	2.8	
ATR	9.2		**Singles**	0.5	

Delay incurred by international aircraft has not been ascertained. For the purpose of estimating the cost of delay, international aircraft are assumed to incur the average delay. Refer data limitations, (4) pg. 27.

AUCKLAND AIRPORT

In 1997, 127,412 IFR movements took place. This equates to an average of 349 movements per day, of which approximately 175 will be arriving aircraft. Average delay during visual conditions is 3.6 minutes; during instrument conditions it is 4.1 minutes.

Total daily delay therefore is:

175 x 3.6 = 630 minutes in visual conditions
175 x 4.1 = 718 minutes in instrument conditions

Instrument conditions occur 33.6% of the time at Auckland; visual conditions 65.3%. The remaining 1.1% is below circling conditions, including fog. Delay is likely to be higher during these conditions if runway closure results. Delay due to fog and/or runway closure is not calculated here.

Instrument conditions = 33.6% of 365 days = 123 days per year
Visual conditions = 65.3% of 365 days = 238 days per year

Total Annual Delay = (123 x 630) + (238 x 718)
= 77,490 + 170,884
= 248,374 minutes per year

No significant difference is discernible in the amount of delay incurred by each type of aircraft at Auckland. Average delay is therefore assumed for all types. Estimated fuel cost is given by the following calculation.

Auckland Aircraft Mix:	**B747**	7%	of	248,374	=	17,386	minutes
	MD11	1%	of	248,374	=	2,484	minutes
	B767	6%	of	248,374	=	14,902	minutes
	B737	18%	of	248,374	=	44,707	minutes
	BA46	14%	of	248,374	=	34,772	minutes
	DH8	2%	of	248,374	=	4,967	minutes
	SF34	12%	of	248,374	=	29,805	minutes
	SW3	13%	of	248,374	=	32,289	minutes
	E110	19%	of	248,374	=	47,191	minutes
	Other	3%	of	248,374	=	7,451	minutes
	Twins	5%	of	248,374	=	12,419	minutes

B747	17,386	minutes	@	220.3 Kg/min	=	3,830,136 Kg
MD11	2,484	minutes	@	134.4 Kg/min	=	333,850
B767	14,902	minutes	@	82 Kg/min	=	1,221,964
B737	44,707	minutes	@	32.6 Kg/min	=	1,437,888
BA46	34,772	minutes	@	23.7 Kg/min	=	824,096
DH8	4,967	minutes	@	7.6 Kg/min	=	37,749
SF34	29,805	minutes	@	11.7 Kg/min	=	348,719
SW3	32,289	minutes	@	4.1 Kg/min	=	132,385
E110	47,191	minutes	@	4 Kg/min	=	188,764
Other	7,451	minutes	@	20 Kg/min	=	149,020
Twins	12,419	minutes	@	2.8 Kg/min	=	34,773

The annual cost of delay at Auckland airport, in terms of fuel burn is therefore some 7,101,456 Kg of fuel. This is made up of 5,385,950 Kg burned by international aircraft, and a 1,725,506 Kg cost to the domestic transport market.

CHRISTCHURCH AIRPORT

In 1997, Christchurch airport handled 86,430 IFR aircraft movements. This equates to an average of 237 movements per day, of which approximately 118 will be arriving aircraft. Average delay during visual conditions is 3.2 minutes; during instrument conditions it is 3.4 minutes.

Total daily delay therefore is:

118 x 3.2 = 378 minutes in visual conditions
118 x 3.4 = 401 minutes in instrument conditions

Instrument conditions occur 37% of the time; visual conditions 60%. The remaining 3% is below circling conditions, including fog. Delay is likely to be higher during these conditions if runway closure results. Delay due to fog and/or runway closure is not calculated here.

Instrument conditions	= 37% of 365 days	= 135 days per year
Visual conditions	= 60% of 365 days	= 219 days per year

Total Annual Delay = (135 x 378) + (219 x 401)
= 51,030 + 87,819
= 138,849 minutes per year

Like Auckland, no significant difference is discernible in the amount of delay incurred by each type of aircraft at Christchurch airport. Average delay is therefore assumed for all types. Estimated fuel cost is given by the following calculation.

Auckland Aircraft Mix:	**B747**	4%	of	138,849	=	5,554 minutes
	MD11	1%	of	138,849	=	1,388 minutes
	B767	1%	of	138,849	=	1,388 minutes
	B737	23%	of	138,8494	=	31,935 minutes
	BA46	22%	of	138,849	=	30,546 minutes
	ATR	18%	of	138,849	=	24,993 minutes
	DH8	5%	of	138,849	=	6,942 minutes
	SF34	2%	of	138,849	=	2,777 minutes

SW3	16%	of	138,849	=	22,216	minutes
E110	0%	of	138,849	=	0	minutes
Other	4%	of	138,849	=	5,554	minutes
Twins	4%	of	138,849	=	5,554	minutes

B747	5,554	minutes @	220.3 Kg/min	=	1,223,546 Kg
MD11	1,388	minutes @	134.4 Kg/min	=	186,547
B767	1,388	minutes @	82 Kg/min	=	113,816
B737	31,935	minutes @	32.6 Kg/min	=	1,041,081
BA46	30,546	minutes @	23.7 Kg/min	=	723,940
ATR	24,993	minutes @	9.2 Kg/min	=	229,936
DH8	6,942	minutes @	7.6 Kg/min	=	52,759
SF34	2,777	minutes @	11.7 Kg/min	=	32,491
SW3	22,216	minutes @	4.1 Kg/min	=	91,086
E110	0	minutes @	4 Kg/min	=	0
Other	5,554	minutes @	20 Kg/min	=	111,080
Twins	5,554	minutes @	2.8 Kg/min	=	15,551

The annual cost of delay at Christchurch airport, in terms of fuel burn is therefore some 3,821,833 Kg of fuel. This is made up of 1,523,909 Kg burned by international aircraft, and a 2,297,924 Kg cost to the domestic transport market.

WELLINGTON AIRPORT

Wellington airport is more complex than either Auckland or Christchurch. Three main weather conditions, for which vastly different levels of delay exist, must be considered. As well as this, it has been shown that the delay incurred at Wellington is not apportioned evenly amongst the aircraft types using the airport.

In general, larger aircraft receive a larger portion of the airborne delay than smaller aircraft. This is predominately due to ground delays directed by air traffic control. That is to say, when queues of aircraft exist at Wellington, ATC will issue ground holding instructions to aircraft which are not already enroute. This occurs first at close airports such as Blenheim and Nelson, only occurring at airports further afield such as Auckland when delays are extreme. For this reason, aircraft departing for Wellington from nearby airports (which are usually small aircraft types) will incur greater ground delay but lesser airborne delay.

In 1997, Wellington airport handled 115,414 IFR aircraft movements. This equates to 316 movements per day, of which approximately 158 will be arriving aircraft. Average delay in visual conditions is 3.2 minutes, during instrument conditions it is 5.1 minutes, and during below circling minima conditions, this rises to 11.3 minutes average delay.

Total daily delay therefore is:

158	x 3.2	=	507	minutes in visual conditions
158	x 5.1	=	806	minutes in instrument conditions
158	x 11.3	=	1785	minutes in below circling conditions

Visual conditions occur 38% of the time at Wellington; instrument conditions 51%; and below circling minima conditions 11%. Delays due to fog or runway closure is excluded from this calculation.

Visual conditions	= 38% of 365 days	=	139 days per year
Instrument conditions	= 51% of 365 days	=	186 days per year
Below circling conditions	= 11% of 365 days	=	40 days per year

Total Annual Delay = (139 x 507) + (186 x 806) + (40 x 1785)
= 70,334 + 149,916 + 71,400
= 291,650 minutes per year

It has not been possible to determine the delay incurred by international aircraft. Calculation of the cost of delay therefore assumes average delay for international

traffic, but is more specific for other types. The annual cost of delay is estimated by the following calculations:

Total annual delay = 291,650 minutes

International traffic (B767) = 2% of traffic = 2% of 291,650 = 5,833 minutes

Remainder of delay = 285,817 minutes.

Delay allocation by aircraft type:

B737	20.3%	of	285,817	=	58,021	minutes
BA46	13.3%	of	285,817	=	38,014	minutes
ATR	8.4%	of	285,817	=	24,008	minutes
DH8	5.8%	of	285,817	=	16,577	minutes
SF34	19%	of	285,817	=	54,305	minutes
SW3	11.3%	of	285,817	=	32,297	minutes
E110	16.8%	of	285,817	=	48,017	minutes
Other	0.5%	of	285,817	=	1,429	minutes
Twins	4.3%	of	285,817	=	12,290	minutes
Singles	0.3%	of	285,817	=	857	minutes

B767	5,833 minutes	@	82 Kg/min	=	478,306 Kg
B737	58,021 minutes	@	32.6 Kg/min	=	1,891,485
BA46	30,014 minutes	@	23.7 Kg/min	=	711,332
ATR	24,008 minutes	@	9.2 Kg/min	=	220,874
DH8	16,577 minutes	@	7.6 Kg/min	=	125,985
SF34	54,305 minutes	@	11.7 Kg/min	=	635,368
SW3	32,297 minutes	@	4.1 Kg/min	=	132,418
E110	48,017 minutes	@	4 Kg/min	=	192,068
Other	1,429 minutes	@	20 Kg/min	=	28,580
Twins	12,290 minutes	@	2.8 Kg/min	=	34,412
Singles	857 minutes	@	0.5 Kg/min	=	429

The annual cost of delay at Wellington airport, in terms of fuel burn is therefore some 4,451,257 Kg of fuel. This is made up of 478,306 Kg burned by international aircraft, and a 3,972,951 Kg cost to the domestic transport market.

The total minutes of delay at Wellington airport is higher than either Auckland or Christchurch. Auckland airport, however, accommodates 11,988 extra movements with total delay 43,276 minutes less. Delay recorded during visual and instrument conditions is similar, but delay at Wellington during below circling conditions rises steeply. Weather conditions below circling minima at Wellingtonoccur only 11% of the time. Yet these days account for 24% of the total delay recorded.

Below circling conditions at Wellington are also the only occasion where delays exceed the limitations of data gathering. Delays during all other conditions are within the limitations of flight plan and ATDb accuracy. Physical observation of traffic flow suggests that small delays may exist at Auckland and Wellington during instrument conditions, but that the majority of delay recorded here is due to limitations of data, rather than to congestion. No delay has been observed at Christchurch airport, also suggesting that recorded delay is due to data limitations.

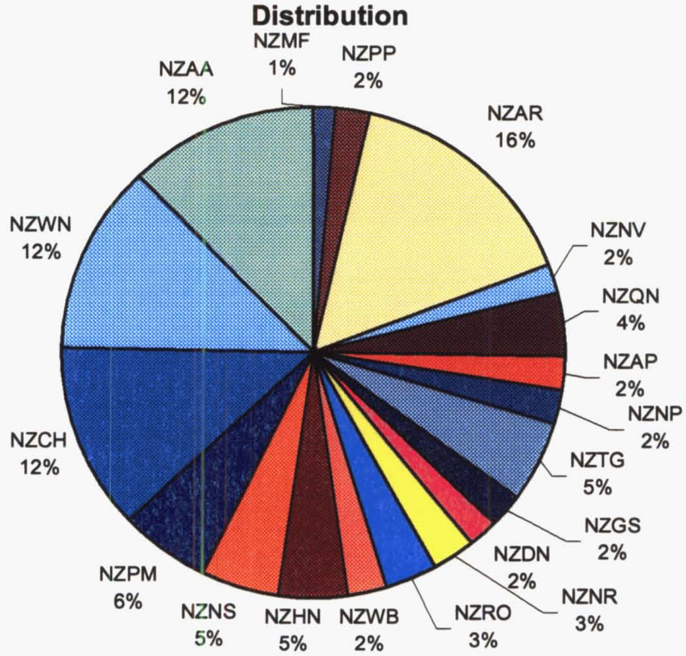
During weather conditions below circling minima at Wellington, large delays are known to result. Delays recorded during these conditions are most likely the result of system overload and congestion.

Demand for Service

Distribution of Demand

Amongst New Zealand's many airports, demand from commercial air transport services is overwhelmingly centred on Auckland, Wellington and Christchurch airports. Total aircraft movements within this country are somewhat more evenly spread – Ardmore airport rating as the busiest in the country. However, demand in these cases is predominantly made up of General Aviation and training aircraft rather than commercial passenger flights. Figure 7.1 below shows total New Zealand traffic distribution (exclusive military aerodromes - E.g. Ohakea - are excluded).

Figure 7.1: New Zealand Airports Total Traffic Distribution

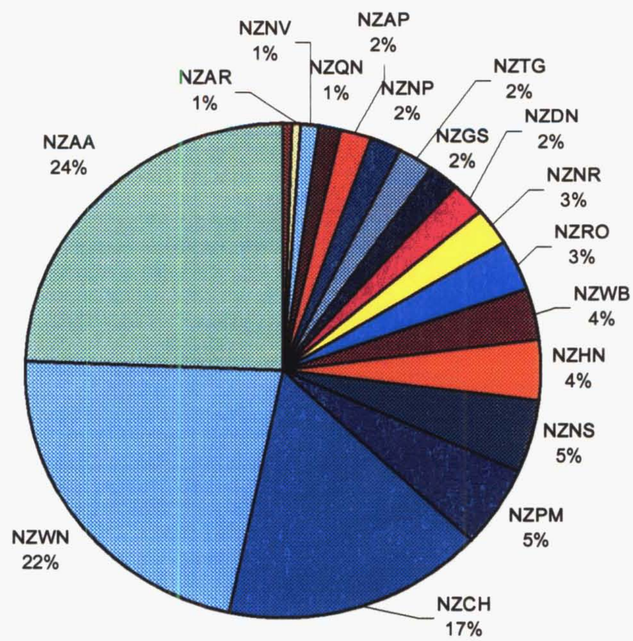


Refer glossary pg. 120 for aerodrome full name and location.

This is not indicative of air transport demand, however. The vast majority of air transport flights are operated by Instrument Flight Rules (IFR), while a similar majority of General Aviation and training flights are operated by visual flight rules

(VFR). This research is not concerned with scenic air transport operations, rather with commuter passenger transport. A more accurate indication of the distribution of air transport demand at New Zealand airports is thus provided by IFR traffic distribution. Figure 7.2 depicts this.

Figure 7.2: New Zealand Airports IFR traffic Distribution



Refer glossary pg. 120 for aerodrome full name and location.

It is clear from this that the vast majority of commuter air traffic is between Auckland, Wellington and Christchurch airports. Indeed, these airports make up 63% of all IFR traffic movements in New Zealand and are the main international, as well as domestic ports. It is for this reason that these three airports are the main focus of this research.

Growth of Demand

Growth of traffic movements throughout New Zealand over the past decade has been substantial. This has been in the wake of deregulation and competition. In the past three years IFR traffic has increased from 453,542 movements in 1995 to 521,759 in 1997 – an increase of 68,217 movements or 15%. Auckland, Wellington and Christchurch airports account for 40% of this growth, accommodating 329,256 IFR movements in 1997, up 26,889 from 1995. Figure 7.3 below shows total IFR traffic growth 1995 –1997 and Figure 7.4 growth at Auckland, Wellington and Christchurch.

Figure 7.3: New Zealand Airports IFR Traffic Growth

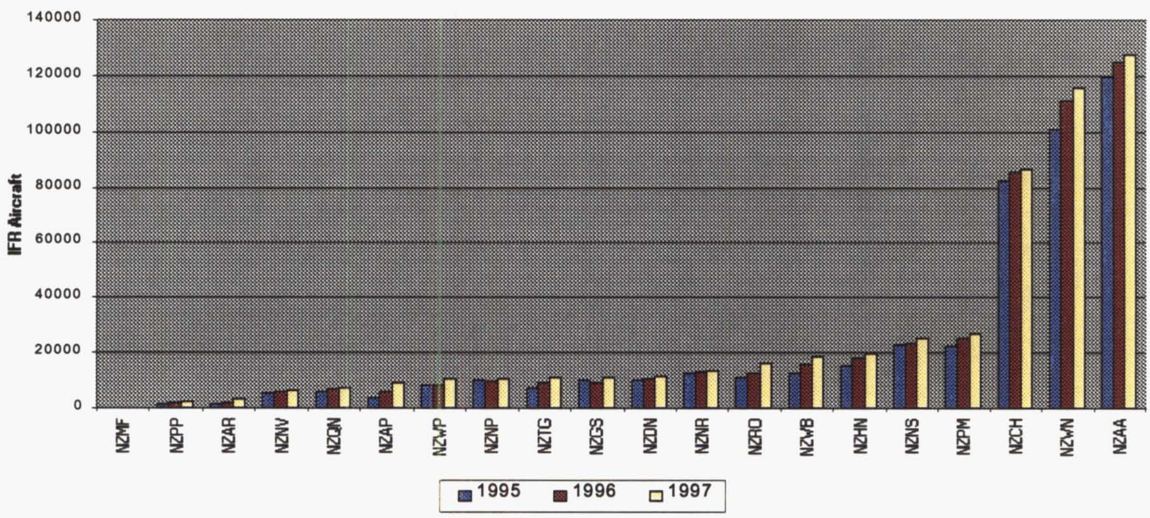
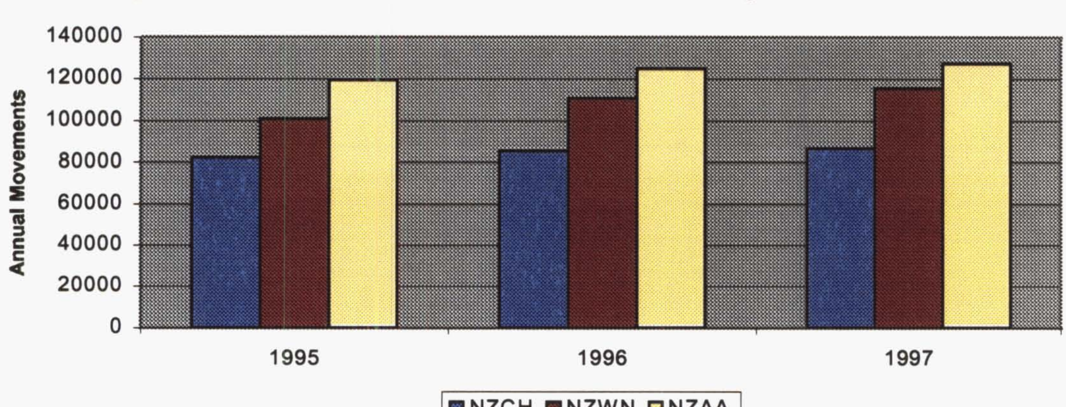
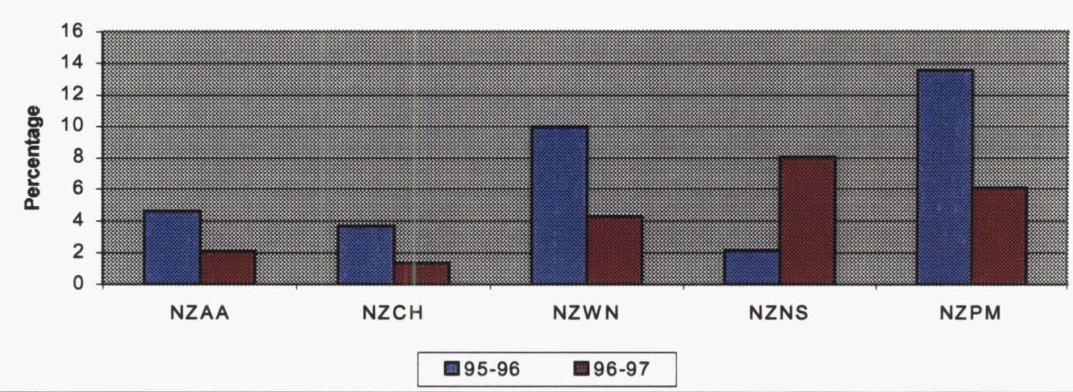


Figure 7.4: Traffic Growth 1995-1997 - Auckland, Wellington, Christchurch



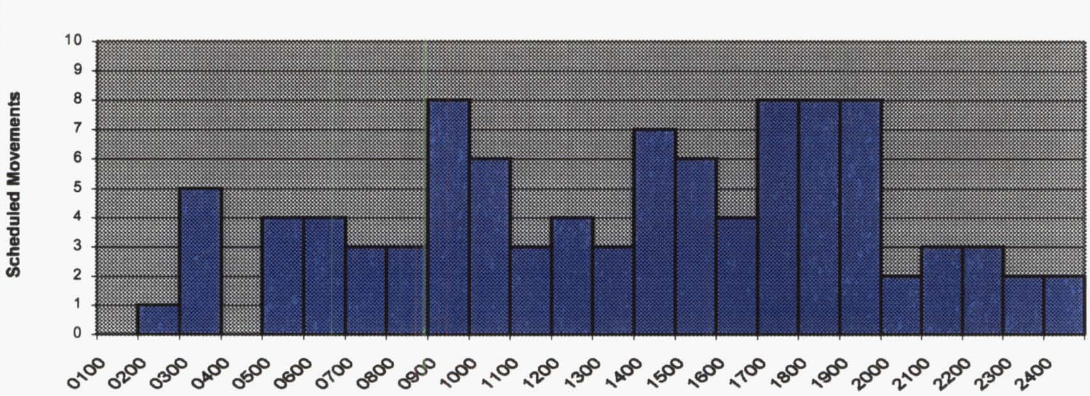
Two other airports – Nelson and Palmerston North - have experienced significant growth in IFR traffic during this period. They are the only other airports to accommodate more than 20,000 annual IFR movements. Figure 7.5 below indicates percentage growth.

Figure 7.5: Percentage Growth 1995-1997

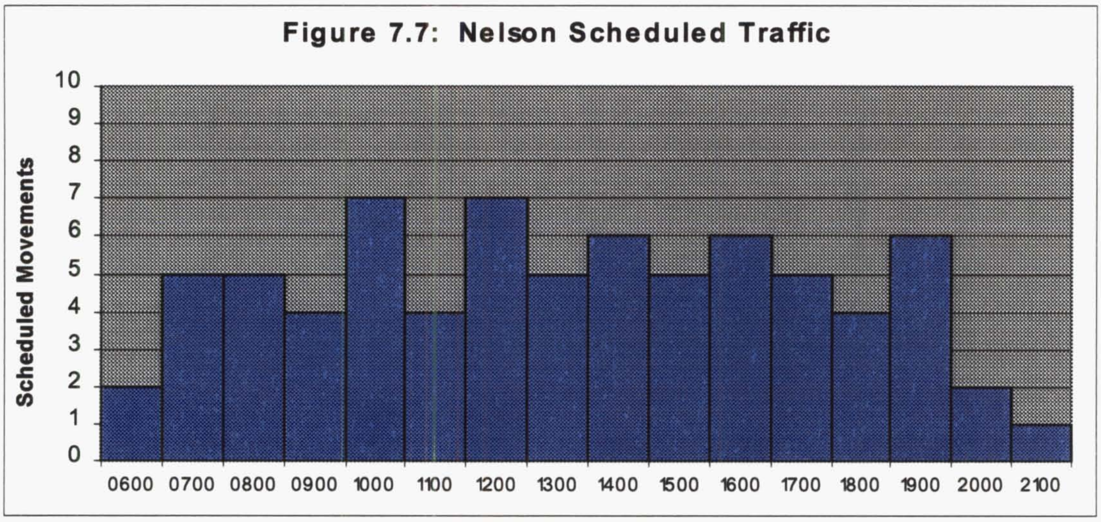


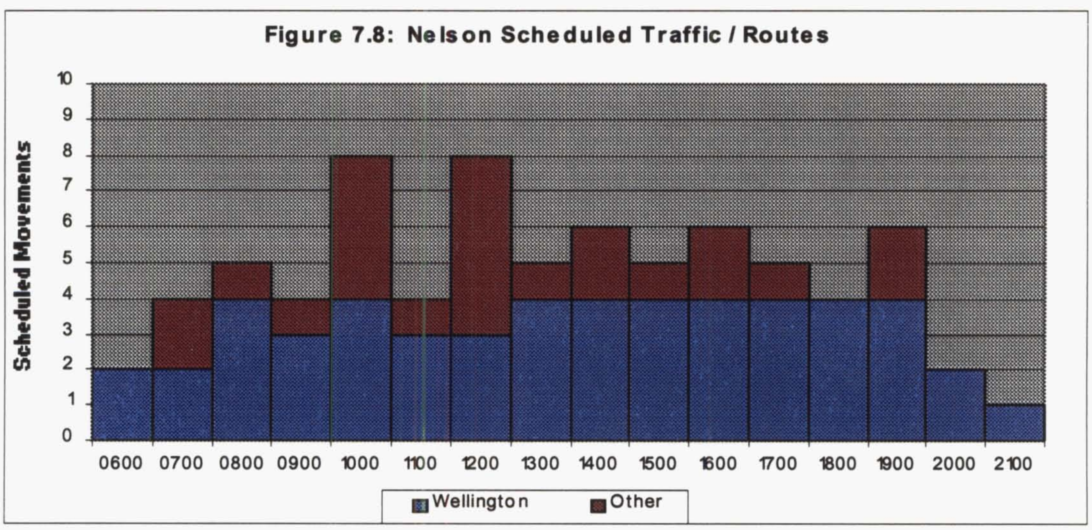
Palmerston North stands out immediately as having experienced a large amount of growth, some 3,000 movements or 13.5% in 1996 over 1995. This is largely attributable, however, to the curfew which was placed on Wellington airport late in 1995. Wellington is only able to operate between the hours of 0600 – 2300. As a result, a large amount of freight is flown via Palmerston North outside these hours, then transferred to Wellington by road. This traffic accounts for the majority of the growth at Palmerston North, rather than passenger air transport.

Figure 7.6: Palmerston North Scheduled traffic



Nelson has also experienced significant growth in the past year. But this growth is also largely attributable to Wellington – a full 72% of all IFR aircraft movements at Nelson airport are to or from Wellington. Figure 7.7 shows Nelson scheduled traffic, Figure 7.8 shows Nelson/Wellington route profusion.



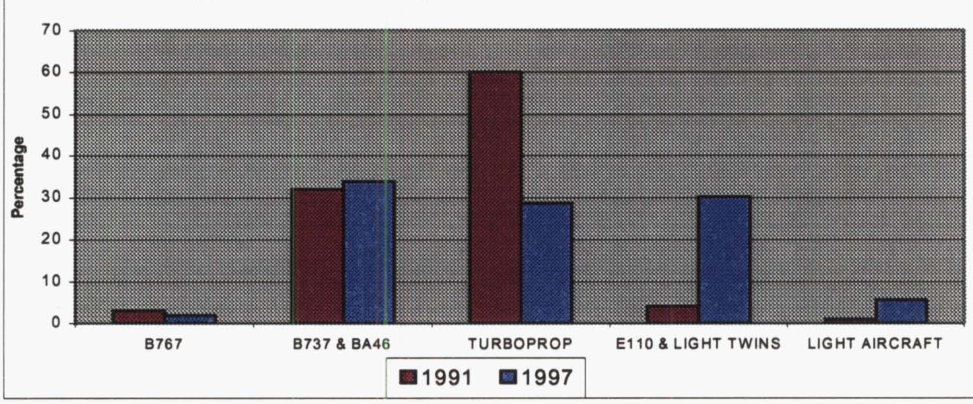


Neither of these airports experience significant levels of demand – hourly IFR scheduled demand does not exceed 10 aircraft per hour.

Wellington airport stands out as having experienced the most significant growth in air traffic numbers. IFR aircraft movements increased some 10,000, or nearly 10% in 1996, despite the restriction placed on operating hours. This growth has continued in 1997, with a further 4,800 extra aircraft.

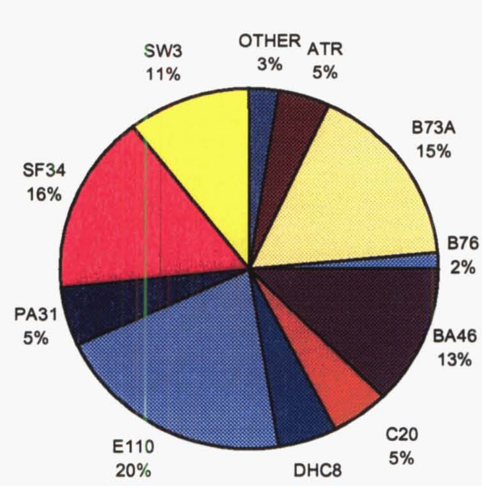
While some of this growth is directly attributable to increases in passenger numbers, the rate at which aircraft numbers has increased is greater. The Wellington International Airport Company Annual Report 1996 gives passenger growth at 5% per annum, and forecasts this rate of growth to continue over the next fifteen years. Growth of aircraft numbers is well in excess of this. The answer lies in changes of aircraft types. Figure 7.9 below shows a comparison of the mix of aircraft types in 1991 vs. 1997.

Figure 7.9: Wellington IFR Traffic Mix 1991-1997



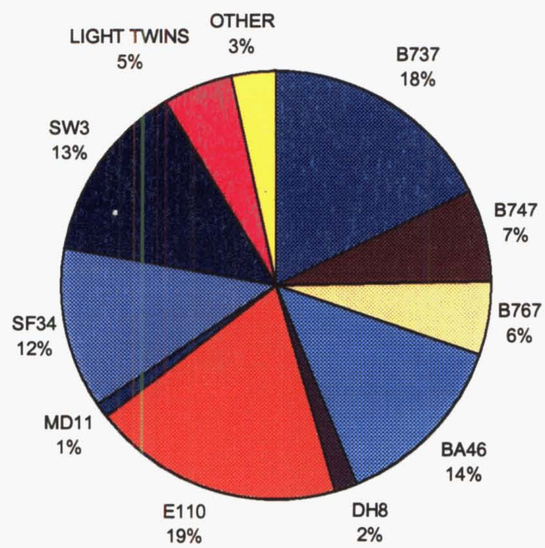
Most significant is a decrease in the number of 20-50 seat turboprop aircraft, from 60% in 1991 to 28.6% in 1997. This has been in favour of a rise from 4% to 31% of the 6 – 18 seat light twin engine commuter aircraft. Clearly more frequent flights are being offered to consumers by smaller aircraft. This is almost certainly a result of deregulation, competition and the need to satisfy consumer demand for convenience, yet must surely be a major cause of the level of congestion now seen at Wellington airport. Figure 7.10 shows a current aircraft mix in greater detail.

Figure 7.10: Wellington Traffic Mix 1997



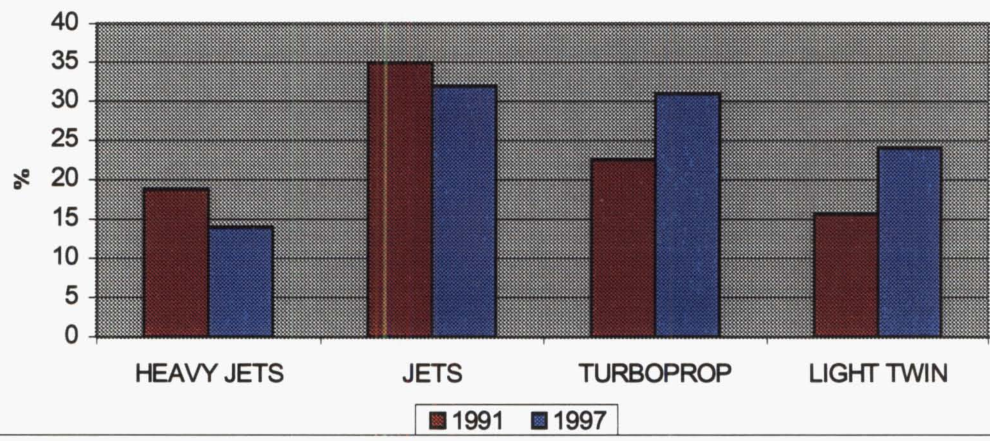
A similar distribution is seen at Auckland airport. A full 24% of aircraft at Auckland fall into the 6-15 seat light aircraft category, with only 27% in the 20-50 seat turboprop class.

Figure 7.11: Auckland IFR Traffic Mix 1997



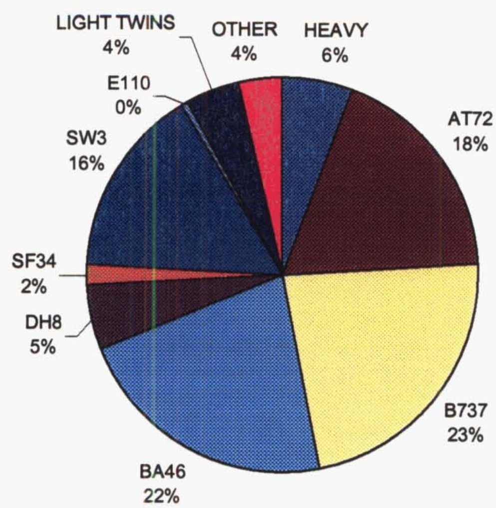
Change since 1991 at Auckland is similar to Wellington, with a greater number of light commuter aircraft, but at the expense of medium category jets, rather than turboprops.

Figure 7.12: Auckland IFR Traffic Mix 1991-97



Christchurch airport is entirely different. This is partially due to geographical factors. Christchurch is, by comparison with Auckland and Wellington, isolated by distance from other centres. Closer towns are easily accessible by road, thus rendering short haul air transport infrequent. Resultantly, Christchurch has largely escaped the trend toward small aircraft on frequent services, as shown by its traffic mix.

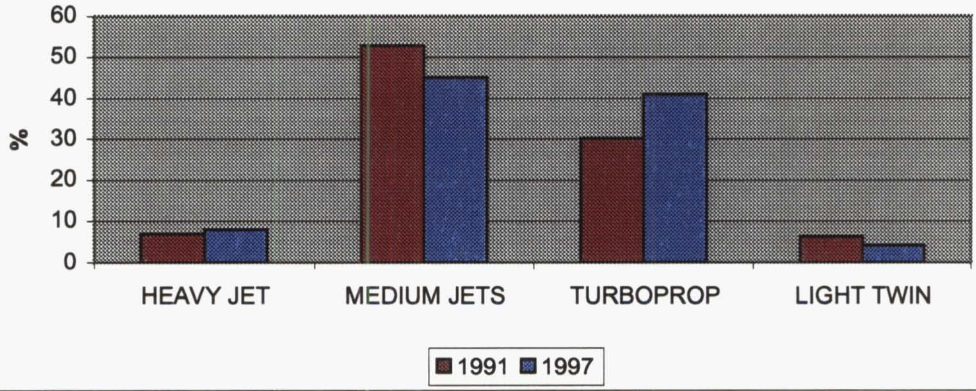
Figure 7.13: Christchurch IFR Traffic Mix 1997



At Christchurch, light commuter aircraft make up only 4 % of traffic while a full 41% is 20-35 seat turboprop category. Notable also is 45% of traffic is made up of Boeing 737 and Bae 146 aircraft. The significance of this is that 70% of all traffic fall into the medium wake turbulence category. Further, 96% of these aircraft have a great similarity of performance capability. As well as avoiding congestion caused by frequent flights by small aeroplanes, continuity of aircraft size and performance assists airport capacity maximization. This is through both continuity and minimization of required separations between aircraft.

Since 1991 it can be seen that some change has occurred, mostly an increase of turboprop aircraft in place of jets. While probably increasing frequency of flights with slightly smaller aircraft, this will not affect capacity as wake turbulence category and performance is largely similar.

Figure 7.14: Christchurch IFR Traffic Mix 1991-97

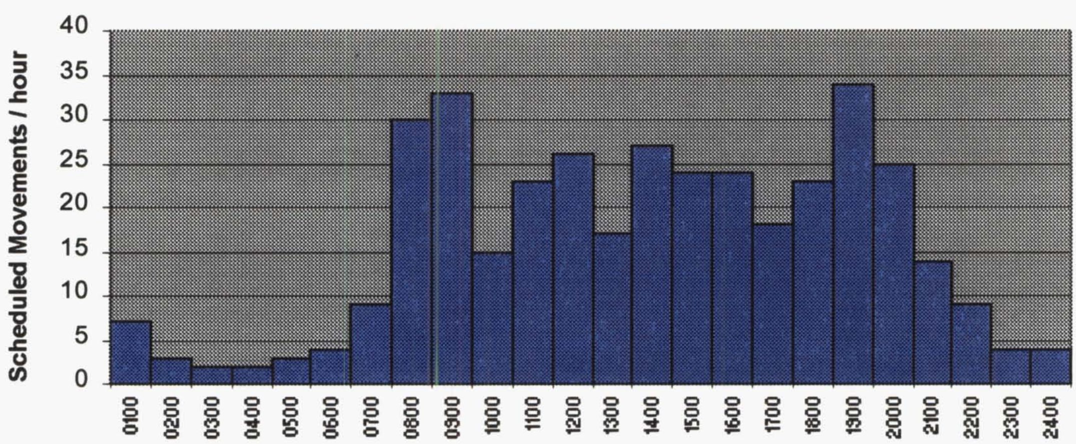


All three airports have experienced some movement to smaller aircraft types and greater frequency of flights. The greatest change by far has occurred at Wellington in terms of both size reduction and increased frequency.

AUCKLAND AIRPORT

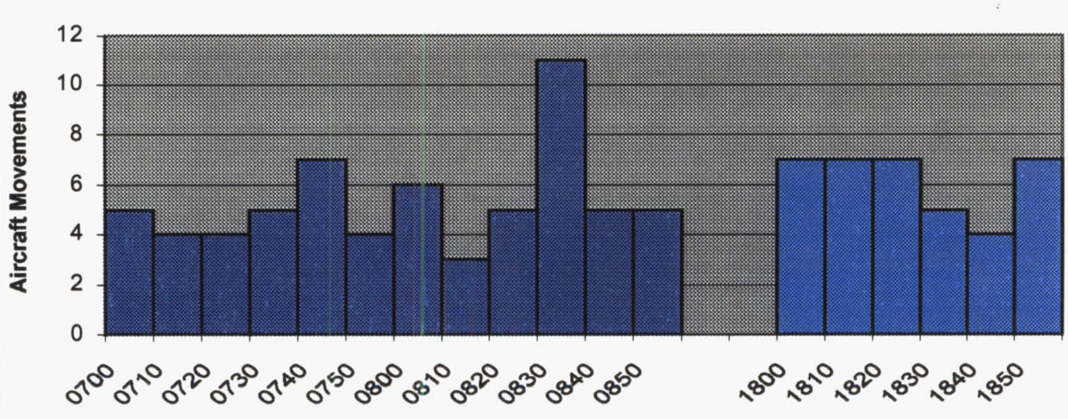
Scheduled demand at Auckland Airport is spread at a relatively even rate throughout the hours 0700 – 2100. Peaks in demand are seen in the morning period 0700 – 0900 and in the evening period 1800 – 1900. Typical daily demand by hourly rate is shown below.

Figure 8.1: Auckland Traffic Schedule



This does not mean, however, that demand is evenly spread throughout each hour. Closer examination of daily traffic schedules reveals some periods where there may be several aircraft scheduled to either arrive or depart at the same time. As only one aircraft may use the runway at a given time, it follows that only one of these aircraft may operate at its scheduled moment – in effect, this is scheduled delay. Providing that this occurs only for short period, this scheduled delay will be of similar short duration. Figure 8.2 depicts peak period traffic at a ten minute rate.

Figure 8.2: Auckland Peak Period Scheduled Demand

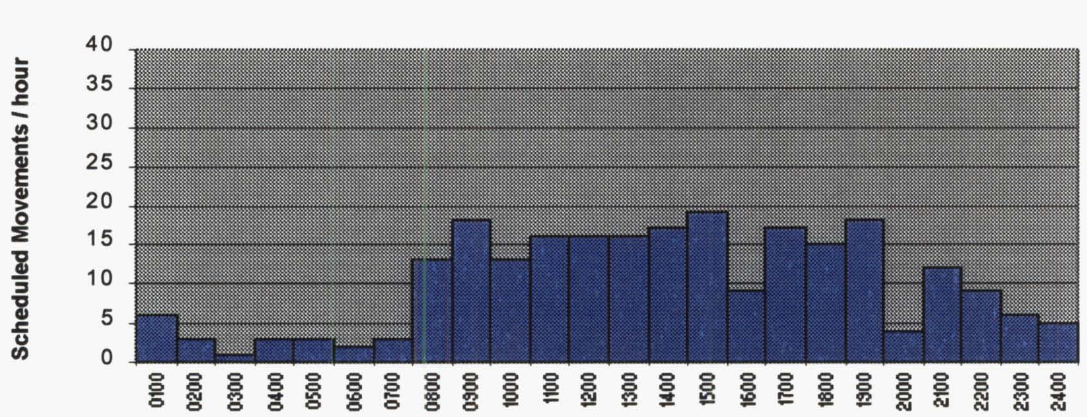


Again it can be seen that scheduled demand remains relatively constant. The ten-minute period 0830 – 0840 stands out as one where many aircraft are scheduled for a short period of time, but because demand surrounding this time period is much lower it is likely that any delays resulting from this will be cleared quickly.

CHRISTCHURCH AIRPORT

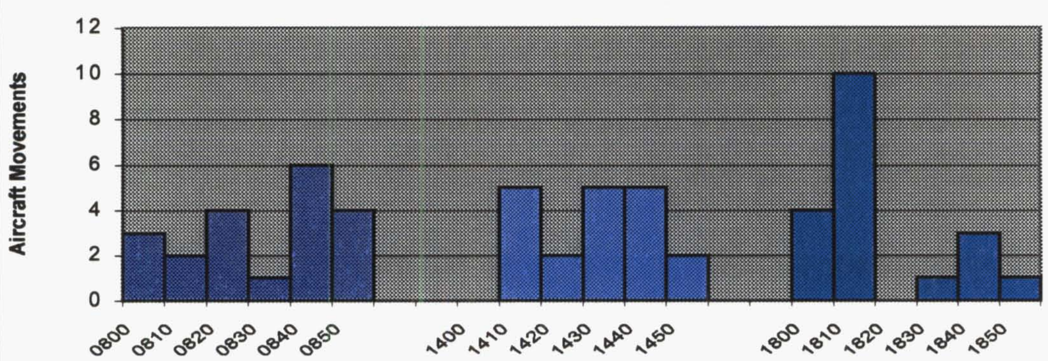
Scheduled demand at Christchurch follows a regular, even demand pattern similar to Auckland. Demand is far lower, however, and peaks are not strongly evident. Figure 8.3 shows typical scheduled demand at Christchurch.

Figure 8.3: Christchurch Traffic Schedule



Three periods – 0800-0900, 1400-1500 and 1800 – 1900 experience a slightly higher than normal demand. Figure 8.5 depicts these times as10 minute intervals. Only the period 1810 –1820 shows any large 'bunching' of scheduled movements and it is followed by a ten minute interval with no scheduled movements. Consequently, scheduled delay is likely to result only for a short period.

Figure 8.4: Christchurch Peak Period Scheduled Demand

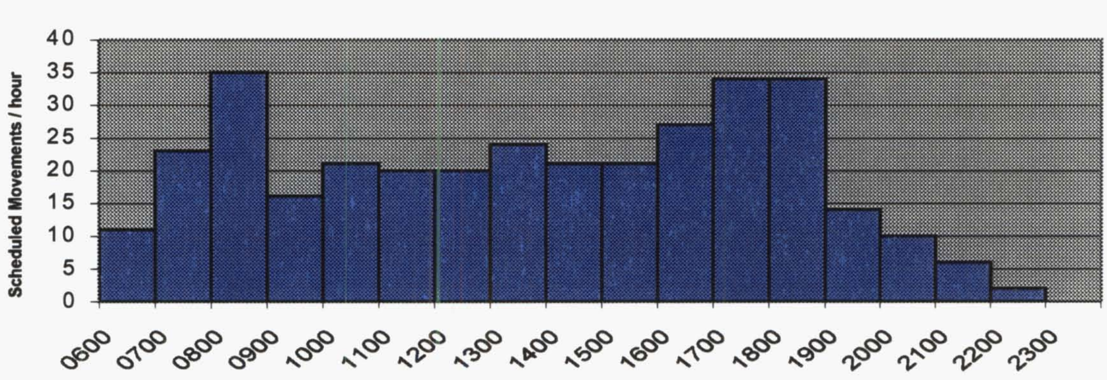


* Colour indicates non-continuous data only

WELLINGTON AIRPORT

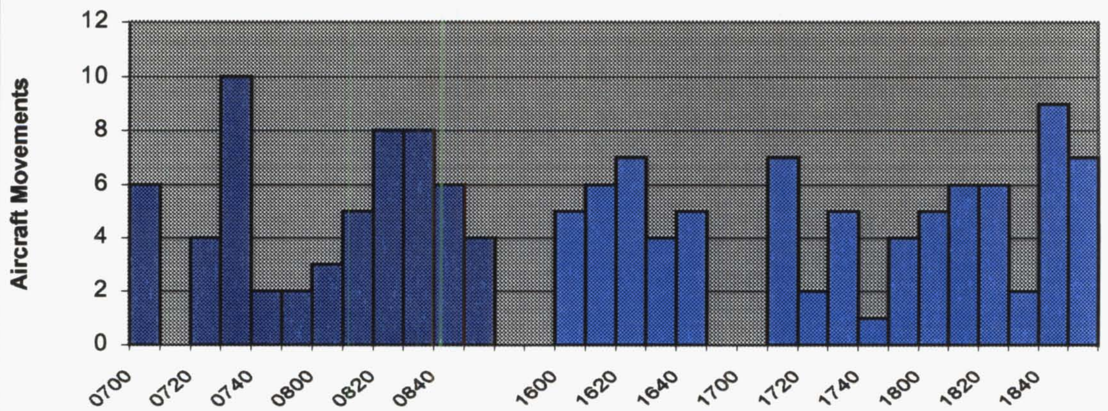
The traffic schedule at Wellington shows demand at a similar rate to Auckland. Peak periods are also evident at a similar rate of demand, but for a longer duration - 0700–0900 and 1600–1900. Because of the greater length of busy periods, it is likely that any scheduled delay will be in effect for a longer time – until an under utilised period occurs.

Figure 8.5: Wellington Scheduled Traffic



Examination of these peak periods indicates that scheduled delays at Wellington are likely to have ongoing effects, particularly during the evening peak.

Figure 8.6: Wellington Peak Period Scheduled Demand



In all cases traffic schedules are not regular – they contain periods of high and low demand. This in itself may not be a necessarily be a cause of delay – unless those high demand periods exceed available capacity. Where more than one aircraft is scheduled for the same time, unavoidable delay must result, but this delay may not be large. In the case of Christchurch, scheduled demand does not exceed 20 movements per hour. Despite periods of scheduled delay, following low demand periods enable this delay to be cleared quickly.

Schedule patterns at Auckland and Wellington, conversely, contain many more periods of scheduled delay with fewer low demand periods. Any delay resulting from overlapping schedules will take longer to clear. In all cases, the definitive factor must be airport capacity. Where capacity is met or exceeded, any scheduled delay cannot be cleared until demand falls below available capacity. An investigation of airport capacity is therefore crucial to the determination of causes of delay.

Airport Capacity

Airport Capacity is a complex issue. There are many factors which combine to determine an airport's capacity. The most significant of these are:

- Minimum separations between aircraft
- The proportions of each wake turbulence category in the traffic mix using the airport
- Aircraft performance mix
- The ratio of arriving aircraft to departures
- Weather conditions
- Runway occupancy times
- Runway size and geometry
- Air Traffic Control procedures

Capacity is affected to a great extent by all of these factors. It could be said that capacity is the result of the interactions between these factors, for capacity is dictated by time- the amount of time taken by each aircraft movement and the time which must be left between them. A more detailed explanation follows:

Separation

Separation refers to the distance – horizontal or vertical – which is required by CAA rules between aircraft in flight. In all cases, the rules of aviation require aircraft to be separated from each other – for the sound and quite obvious reason of collision avoidance. The way in which aircraft are required to be separated, however, is variable and dependant largely upon the conditions under which aircraft are flying. In the most simple case of VFR operations, aircraft are separated by visual means – in other words, by a pilot maintaining his own separation via sight. This is only possible, of course, when weather conditions are clear and is even then often unreliable when traffic density is high. For these reasons, the majority of air transport operations are conducted under Instrument Flight Rules.

Under this regime, separation between aircraft is provided by an Air Traffic Controller. This does not prevent pilots from maintaining visual separation, nor from making visual approaches at any airport if conditions permit. It does, however, facilitate aircraft operations in almost all conditions of weather. Exceptions may be extreme turbulence or fog.

Most of New Zealand is covered by radar based control. As well as enabling controllers to handle a higher volume of traffic, the accuracy of this system allows controllers to separate aircraft by distance. Non-radar separations must be time based. The minimum radar separation allowed between aircraft enroute is five nautical miles. This is reduced to three nautical miles within the terminal airspace surrounding Auckland, Wellington, Christchurch and Ohakea airports. These are the *minimum* allowable lateral separations which must never be infringed (negated if vertical separation of 1000 feet is attained).

Smaller separations between aircraft, especially on final approach raises the capacity of an airport. Obviously, if successive movements may take place in the time taken to fly three miles, a greater number of movements can occur than if, say five miles were required.

Wake Turbulence Separation

"Wake turbulence is the term used to describe the effects of the rotating air masses (wake vortices) generated behind the wing tips of aircraft in flight. These vortices are two counter-rotating cylindrical air masses trailing aft from the aircraft and are particularly severe when generated by large andwide bodied aircraft. The vortices are most dangerous to following aircraft during the take-off, initial climb, final approach and landing phases of flight. They tend to drift down, and when close to the ground move sideways from the track of the generating aircraft." (Instrument Flight Guide, ACNZ)

Wake turbulence separation is provided by Air Traffic Control to all aircraft in the approach or departure phases of flight, except in the case of an IFR aircraft making a visual approach or VFR arrivals.

Aircraft are divided into the following categories for the purpose of assessing required wake turbulence separation:

Heavy

All aircraft types of 136,000 kg or more maximum weight (includes B767, B747, MD11)

Medium

Aircraft types of less than 136,000 kg but more than 7,000 maximum weight (includes B737, B727, BA46, ATR, SF34)

Light

Aircraft types of less than 7,000 kg maximum weight (includes SW3, E110, PA31)

The following table provides the minimum radar wake turbulence separation for aircraft in the arrival or departure phases of flight:

LEADING AIRCRAFT	*AIRCRAFT CROSSING OR FOLLOWING BEHIND*	*MINIMUM DISTANCE*
HEAVY	*HEAVY* *MEDUIM* *LIGHT*	*4 NM* *5 NM* *6 NM*
MEDIUM	*HEAVY* *MEDUIM* *LIGHT*	*3 NM* *3 NM* *5 NM*
LIGHT	*HEAVY* *MEDUIM* *LIGHT*	*3 NM* *3 NM* *3 NM*

The only exception to this is light category aircraft following medium category aircraft below 25,000 kg maximum weight. In this case, wake turbulence separation may be reduced from 5 NM to 3 NM.

Practically, this means that light category aeroplanes such as the SW3 Metroliner or E110 Bandierante may follow 3 NM (rather than 5) behind ATR 72, DH8 or SF34 aircraft, but must be separated by five miles when following a B737 or BA46.

Tower wake turbulence separation is as follows:

Between Arriving Flights

LEADING AIRCRAFT	*FOLLOWING AIRCRAFT*	*MINIMUM TIME*
HEAVY	*MEDIUM*	*2 MIN*
	LIGHT	*3 MIN*
MEDIUM	*LIGHT*	*3 MIN*

Between Departing Flights

LEADING AIRCRAFT	*FOLLOWING AIRCRAFT*	*DEPARTING FROM SAME TAKE OFF POSITION*	*DEPARTING FROM INTERMEDIATE POSITION*
HEAVY	*MEDIUM*	*2 MIN*	*3 MIN*
	LIGHT	*2 MIN*	*3 MIN*
MEDIUM	*LIGHT*	*2 MIN*	*3 MIN*

Between Arriving and Departing Flights

LEADING AIRCRAFT	*FOLLOWING AIRCRAFT*	*MINIMUM SPACING AT TIME AIRCRAFT ARE AIRBORNE OR HAVE TOUCHED DOWN*
HEAVY ARRIVAL	*MEDIUM DEPARTURE*	*2 MIN*
	LIGHT DEPARTURE	*2 MIN*
MEDIUM ARRIVAL	*LIGHT DEPARTURE*	*2 MIN*
HEAVY DEPARTURE	*MEDIUM ARRIVAL*	*2 MIN*
	LIGHT ARRIVAL	*2 MIN*
MEDIUM DEPARTURE	*LIGHT ARRIVAL*	*2 MIN*

It is clear what effect wake turbulence separation can have upon capacity when there is a large diversity of aircraft types using an airport. For example, minimum separation will be 3 NM for any medium category aircraft following a Boeing 737 or Bae 146 aircraft – the same as minimum radar separation; but if the following aircraft is light then wake turbulence requirements dictate a larger five mile separation. Similarly, the required separation behind all heavy aircraft is larger than 3 NM. Capacity is greatest when all aircraft types fall into the same wake turbulence category, other than heavy.

Aircraft Performance Mix

Aircraft performance affects capacity through the need to take account of differing speeds and rates of climb amongst the aircraft type mix. Where performance of aircraft is similar, performance may be standardised. For example, if a Boeing 737 follows a Bae 146 or ATR 72 on approach, speed and descent rates can be dictated by Air Traffic Control and, consequently, minimum separation is easily achieved.

With great disparity in performance, however, the situation becomes more complex. A B737 will usually fly an approach at a speed between 170 and 200 Knots – a light twin usually around 140 Knots. If a fast aircraft follows a slow one, it is unlikely to be able to reduce its speed to that of the slower. An air traffic controller must therefore employ a larger gap than the minimum 3 NM so that this is not infringed as the leading aircraft approaches landing. Worse may be the situation of a slow aircraft following a fast one. In this scenario an initial three mile separation will continually widen as the slower aircraft cannot attain the speed of the faster.

A similar situation may arise with departures, especially under instrument conditions. If a fast aircraft is taking off behind a slower one, a greater time period may have to be used than that required by either radar or wake turbulence separations to avoid 'catch up' by the better performing type. In all cases, where performance is similar minimum separations may be used – this is not necessarily the case where differentials exist.

Air Traffic Controllers will attempt to minimise this effect by turning slow aircraft from the departure track at the earliest opportunity. Nevertheless, the time taken for a B737 departure, followed by a SF34, followed by a E110 is 4 min 15 sec. If the departure order were reversed, the time taken would be 6 min. 30 sec.

While efficient sequencing by air traffic control may combat the problem to some extent, in reality if a wide diversity of aircraft performance exists then capacity will be reduced.

Arrival / Departure Ratio

Not all aircraft movements take the same amount of time. It takes longer for an aircraft to fly an approach, land and vacate the runway than it does to line-up and take off. This is especially true in instrument conditions when aircraft fly a full10 mile approach to land. Under these conditions, wake turbulence separations and performance differentials take their full effect. Capacity is greatest when arrivals only sequences are avoided – that is, when each arriving aircraft is interspersed with a departure. Not only does this minimise the effect of performance differentials,but it is a sequence for which accuracy is most sustainable.

Weather Conditions

Weather conditions are the single biggest determinant of airport capacity. Separation and air traffic control procedures are both dictated primarily by weather conditions.

When conditions are visual, aircraft rarely fly a full 10 NM approach to landing. Rather, a final approach 2 – 5 NM is elected as pilots are able to navigate and descend by visual means. Speed differentials become less significant in this situation, as aircraft follow directly behind each other for only a short time. Additionally, wake turbulence separation is not required to be provided by air traffic control when an aircraft is flying a visual approach – rather the pilot is responsible for maintaining adequate separation. This may be less than theseparation which would be provided under instrument conditions. Finally, departing aircraft are often (although not always) able to be turned from the departure track at an earlier time. This allows performance related delay between successive departures to be reduced. Airport Capacity is greatest under visual conditions.

When instrument conditions exist – that is, when low cloud base and / or poor visibility exists to prevent pilots from navigating by visual means – all separations must be provided by air traffic control. Under these conditions, a full 10 NM final approach is flown by most aircraft and the factors of aircraft performance differentials and wake turbulence separation have their fullest effect.

Strong winds and turbulence also affect capacity. Where winds are strong and gusty, extra caution is required from pilots and air traffic controllers alike. Extra horizontal separation may be necessary if gusty conditions accelerate 'catch-up' between aircraft. Similarly, turbulence may necessitate an increase in vertical separations if aircraft experience difficulty in attaining or maintaining height.

Runway Occupancy

Runway occupancy time affects capacity because one aircraft must be clear of the runway before another aircraft can use it. Excessive runway occupancy has a surprisingly large effect on capacity. For example, a runway capacity of 36 movements per hour translates to one movement every 1 minute, 40 seconds. A saving of 5 seconds per aircraft would increase capacity by one movement per hour.

In order to achieve minimum separations between aircraft, air traffic controllers must be able to accurately predict the amount of time each aircraft will occupy the runway. For this reason, it is important that occupancy times be consistent as well as minimal. A survey of some 1700 aircraft movements at Auckland and Wellington airports shows that 55.6% of aircraft take longer than 10 seconds to respond to take-off clearance, and 15% take longer than 20 seconds.

Runway Geometry

Runway geometry affects capacity in two ways. For arrivals, geometry relates to runway occupancy time through runway exits. Arriving aircraft must slow to aspeed which allows them to turn prior to exiting the runway. Exit speed is related to the angle through which aircraft must turn – that is, a 30° degree turn may be executed at a faster speed than a larger turn. If runway exits are situated at a 90° angle to the runway, then aircraft must slow to a much greater extent prior to exiting. The taxiways at Auckland airport are situated so as to allow rapid exit, Wellington and Christchurch do not have this facility and require much sharper turns.

For departing aircraft, geometry also affects runway occupancy time but through availability of holding areas where aircraft can complete their pre take off checks. This helps to ensure that aircraft entering the runway are ready to commence take off immediately when instructed. Holding areas allow aircraft to pass one another, thus allow air traffic control to select the most efficient departure order, rather than 'first come, first served'. As explained earlier, the order in which aircraft depart can have large effects on capacity. New Zealand airports make little provision of holding bays, although Auckland and Christchurch airports circumvent this to a large extent by

virtue of their size. Few aircraft use the full length of the runway so can be lined up at varying points. Wellington does not have this luxury - a shorter runway, most aircraft use full length. In the absence of holding areas, aircraft can not normally be re-ordered and so departure order is largely determined by order of arrival at the holding point, even when a queue exists.

Calculation of Capacity

Capacity at any airport is the result of the interaction of all of the above factors. It is necessary, therefore, for any capacity model to incorporate these. Capacity for the purposes of this research draw upon capacity models developed by this author for the Airways Corporation of New Zealand Ltd, and released as the Wellington Air Traffic Management Study (1997) and Auckland Capacity Study (1997).

The methodology for development of these models is as follows. First aircraft performance by individual type was observed and recorded at fifteen second intervals, incorporating distance and height information (on arrival and departure). Runway occupancy times were recorded for each type, and at both airports. This information shows the time taken by each type of aircraft to fly an approach, land and vacate the runway, or alternatively to line up and take off. When incorporated with the appropriate separations and approach path, capacity is ascertained.

These models have been used to provide capacity statements for both Auckland and Wellington airports under varying weather conditions, and for arrival only, departure only, and 1 arrival / 1 departure sequence scenarios. These are general statements of capacity which incorporate normal aircraft type mix.

These models provide an explicit statement of the maximum possible number of aircraft movements which can be accommodated in a given time. They can be used to provide a general case, or to model a specific scenario with equal accuracy.

WELLINGTON AIRPORT

Capacity at Wellington airport is the most complex and variable. Three main discernible weather states exist at Wellington, for which capacity levels are distinct. This is because of differing separations which must be employed during the differing weather conditions.

When visual conditions exist at Wellington - that is, when the weather permits all aircraft to navigate by visual reference and to maintain their own separation from other aircraft – then the only separation requirement is tower wake turbulence. The time taken between aircraft is at its minimum, thus capacity is greatest.

Instrument conditions at Wellington fall into two broad categories – above circling minima, and below circling minima. All airports define a minimum visibility and height of cloud base under which aircraft may circle visually for a second approach to land if the first attempt is missed. These levels are defined in Table 2 below:

Table 2:

Circling Minima – ILS Approach

AIRCRAFT CATEGORY	*AUCKLAND*	*WELLINGTON*	*CHRISTCHURCH*
A	*470' (447') 1900m*	*1000' (958') 5000m*	*670' (547') 1900m*
B	*550' (527') 2800m*	*1000' (958') 5000m*	*670' (547') 2800m*
C	*770' (747') 3700m*	*1500' (1458') 5000m*	*800' (677') 3700m*
D	*910' (887') 4600m*	*NA*	*840' (717') 4600m*

The heights in this table refer to cloud base above mean sea level, the figure in brackets is cloud base above the ground – the third figure is visibility. Aircraft categories include the following:

Category	A	All singles, light twins, E110
	B	SW3, SF34, ATR, DH8
	C	B737, BA46, B767
	D	B747, MD11, DC10

It can be seen that the circling minima for Wellington is greater than for other airports. This is largely due to the terrain which surrounds Wellington airport – by contrast, Christchurch and Auckland are relatively flat. This is important to airport capacity for two reasons:

The height at which aircraft are unable to circle visually for a second attempt at landing should they miss on the first attempt is much higher. If an aircraft cannot circle visually, then it must return to radar based control (rather than tower) and the larger separations this entails.

More importantly, if an aircraft misses its landing at Wellington, it cannot be turned from the missed approach path until terrain clearance has been achieved. At Auckland or Christchurch airports, terrain is flat which allows aircraft to be turned early – this is not possible at Wellington.

The result of this is that the missed approach must be 'protected' for all arrivals at Wellington when weather conditions are below circling minima. In other words, much larger separations are required between arriving flights to ensure safe separation in the event of a missed approach. It is this which creates a third main weather category, and hence capacity level for Wellington airport.

The theoretical maximum capacity at Wellington airport is as follows:

Wellington Airport Capacity

	Arrivals	*Departures*	*1 Arr. / 1 Dep.*
Visual Conditions	*31*	*35*	*43*
Instrument Conditions Above Circling Minima	*28*	*31*	*38*
Instrument Conditions Below Circling Minima	*21*	*30*	*32/33*

What is most immediately significant about this is the level to which capacity is reduced during below circling conditions. During a 1 arrival / 1 departure sequence, capacity is always at its highest – during below circling minima conditions, however, this represents only 76% of capacity during visual conditions and 84% of instrument above circling minima capacity.

If the aircraft movements are 'bunched' – that is several arrivals followed by several departures, then capacity is reduced even further. As shown by aircraft schedules, demand during all peak periods exceeds this level of capacity. The outcome of this is unavoidably delay.

The requirement to protect the missed approach in this manner stems directly from differences in aircraft performance capabilities. If a high performance aircraft follows a poor performing one (in terms of speed and climb capability), then safe separation cannot be guaranteed by normal separation in the event of a missed approach. The faster aircraft will quickly catch up to the slower. This is equally applicable to a fast arrival following a slow arrival or departure. At Auckland or Christchurch, the slower aircraft would simply be turned under radar direction. For this reason, (unless landing or take-off minima is infringed) capacity is not significantly affected by below circling conditions.

This is the most serious effect of the variation of aircraft type mix at Wellington. If all aircraft using the airport were of similar performance characteristics then there would be little or no 'catch up' factor to contend with. In other words, the requirement to protect the missed approach would be removed. This, in turn, would eliminate the need for larger separations in below circling minima conditions. The final result – no reduction in airport capacity during below circling minima conditions.

AUCKLAND AIRPORT

The theoretical maximum capacity of Auckland airport is as follows:

Auckland Airport Capacity

	Arrivals	*Departures*	*1 Arr. / 1 Dep.*
Visual Conditions			
Runway 23	*34*	*36*	*40*
Runway 05	*32*	*36*	*39*
Instrument Conditions			
Runway 23	*28*	*36*	*37*
Runway 05	*26*	*36*	*36*

The differential between the two runways is due to a combination of runway geometry and to airspace avoidance requirements.

Airport layout at Auckland, specifically the siting of the runway exits causes longer runway occupancy times for the 05 vector than for its opposite 23. Additionally, aircraft which require the use of full runway length on take-off have to back-track to line up on runway 05. The additional time taken on the runway has a degrading effect on capacity.

As well as this, air traffic control procedures require that aircraft on departure from Runway 05 climb to sufficient height to avoid the Ardmore Training Area prior to commencing a right turn. Almost all aircraft departing Auckland are heading south, so this restriction affects most aircraft, particularly unpressurised aeroplaneswhich cannot maintain a steep rate of climb. In consequence, a differential is seen between the two runway vectors.

Capacity at Auckland airport is not affected by below circling minima conditions. As well as much lower minima, the relatively flat terrain surrounding the airport does not require the same protection of the missed approach as demanded at Wellington.

Consequently, the large reduction of capacity in below circling minima conditions experienced at Wellington does not occur at Auckland.

Capacity at Auckland is lower than Wellington. This may be due to differences in aircraft type mix. There is a much greater number of heavy aircraft at Auckland than Wellington, and the larger wake turbulence separation required by these aircraft is likely to adversely affect runway capacity. This is not the only difference between these two airports, however. Air traffic control procedures differ also.

At Auckland, a system of tower initiated departures (TIDs) is used. In basic terms this means that the arrivals radar controller at Auckland will position aircraft on approach with a set gap between them to allow a departure to take place. Tower controllers can therefore launch departing aircraft with no specific co-ordination with or requests for gaps from radar control.

At Wellington and Christchurch, conversely, gaps between arrivals are set according to the minimum separation required and increased for departures only on specific request from tower controllers.

In all cases, the capacity shown here is the theoretical maximum for that airport and weather condition. It incorporates aircraft performance, runway occupancy times, wind, separation and air traffic control procedures. There is no allowance, however, for variation of human performance or for weather conditions such as turbulence. Human performance – of both pilots and controllers – is thefactor which determines how close to theoretical maximum capacity achieved throughput will be.

As well as this, scheduled traffic does not follow a strict 1 arrival /1 departure sequence. Although this sequence of traffic movement generally yields the highest capacity and is also the most sustainable in terms of accuracy, actual traffic patterns rarely follow this pattern. Rather, traffic in New Zealand tends to be 'bunched'in groups of arrivals followed by groups of departures.

Both the Wellington Air Traffic Management Study and Auckland Capacity Study take account of this with the development of 'realistic' capacity levels. These capacity statements are the 'declared' capacity of Wellington and Auckland airports and are the average achieved throughput over periods where capacity is known to be

reached. By this method, variation of weather conditions, variations of human performance and aircraft movement patterns are embodied.

Auckland / Wellington Realistic Capacity levels

	Visual	*Instrument*	*Instrument Below Circling*
Auckland			
Runway 05	*37*	*34*	*N/A*
Runway 23	*38*	*35*	*N/A*
Wellington	*38*	*36*	*28*

CHRISTCHURCH AIRPORT

Delay measured at Christchurch is minimal and is clearly not the result of congestion. Examination of scheduled traffic confirms that demand is well below a level which could result in delay, other than that caused by schedules or runway closure. Because Christchurch is a multi-runway airport, its maximum capacity will be higher than either Auckland or Wellington, but will also be more variable and dependant upon weather conditions, especially wind strength and direction.

At best, both the main (02/20) and cross (11/29) runways will be available for use – at worst, only the cross vector. This is dictated in the main by wind, but is also by cloud. No instrument approach aid is available for runway 11 or 29. It is thus necessary for aircraft making an instrument approach for either of these runways to descend on the runway 02 or 20 approach to a point where they may circle by visual reference to land on 11 or 29.

Capacity at Christchurch is thus potentially a highly variable measure. In reality, the situation does not entail the risks suggested above. The weatherconditions which dictate the sole use of runway 11 or 29 will include strong easterly or westerly winds – this is not normally consistent with low level cloud. It is therefore extremely unlikely that runway closure would ever result from the lack of an approach aid for runways 11 and 29.

Examination of aircraft schedules at Christchurch reveals a level of demand well below that experienced at Auckland and Wellington airports – approximately 30% lower. Yet capacity at this airport will be approximately equal to Auckland and Wellington in the case of one useable runway, and significantly higher if two runways are useable. Not surprisingly, the level of delay recorded at Christchurch is very small. This is not attributable to congestion, but rather to limitations of data recording and to any unavoidable delay in aircraft schedules – that is, any periods where more than one aircraft is scheduled for the same time.

It is equally clear that Christchurch airport can sustain a high level of growth prior to facing issues of capacity and congestion. For this reason, it is not considered necessary in this research to develop a modelling technique to determine multi-runway airport capacity.

Capacity at Christchurch airport has been calculated here using the same modelling technique as for Auckland and Wellington airports. This is a single runway (02/20) capacity, and its purpose is to provide a comparison for Auckland and Wellington airports, rather than as a true indication of the capacity of Christchurch airport.

Christchurch Airport Single Runway Capacity

	Arrivals	*Departures*	*1 Arr. / 1 Dep.*
Visual Conditions	*36*	*44*	*43*
Instrument Conditions	*31*	*44*	*42*

Capacity at Christchurch is higher than at either Auckland or Wellington, most significantly in the instrument conditions case. This is most likely to be due to the similarity of aircraft in the type mix using Christchurch airport. As shown earlier, 70% of the aircraft using Christchurch airport are medium wake turbulence category aircraft. Just as significant as consistent weight category is aircraft performance capability. Of the remaining aircraft, 4% are other medium category aircraft,16% are SW3 Metroliners, and 6% are heavy jets. The Metroliner, while being a light category aircraft, has the performance capability of a much larger aircraft. It is a light commuter which is built to perform amongst jets.

Resultantly, 96% of the scheduled traffic using Christchurch airport are able to perform to a high and consistent standard. This avoids the difficulty of performance differentials seen at Auckland and Wellington airports, and is likely to be the major reason for the higher capacity levels at Christchurch airport.

Aircraft Type Mix

In order to determine the extent to which aircraft type mix affects capacity, the Auckland and Wellington capacity models have been executed with the aircraft type mix using Christchurch airport. The table below shows the result of this:

Auckland / Wellington Capacity – Christchurch Aircraft Type Mix

Instrument Conditions

	Arrivals	*Departures*	*1 Arr. / 1 Dep.*
Auckland	*31 (+3)*	*44 (+8)*	*39 (+2)*
Wellington	*31 (+3)*	*42 (+11)*	*40 (+2)*

It can be seen from this that capacity can be increased for both Auckland and Wellington by improving the aircraft type mix. This is particularly significant for Wellington airport which presently includes a high number of light category, low performance aircraft in its type mix. As well as increasing overall capacity, consistency of aircraft performance greatly removes the requirement for large separations in order to protect the missed approach. The benefits of improving type mix for Wellington are thus two-fold.

A note of caution though – increasing the number of heavy aircraft in the type mix at Wellington will reduce, rather than raise capacity. This is true to some extent at all airports – wake turbulence separation is larger behind heavy aircraft than any other, but at Wellington there is an additional problem during instrument conditions. The siting of the localiser portion of the ILS approach aid means that its signal is distorted by any aircraft the size of (or larger than) a Friendship which exits the runway by the

last taxiway. Most aircraft exit at a much earlier point – except for heavy types which use full runway length on landing. The result of this is that a 12 mile separation is required behind all heavy aircraft during all instrument conditions to ensure an accurate signal for following aircraft.

Despite the increase made by improved aircraft type mix, capacity at Auckland does not reach the level of Wellington or Christchurch. In the absence of any other factor, it is concluded that this differential is due to air traffic control procedures. The use of TIDs and its larger gaps between arriving aircraft, while possibly easing air traffic controller workload through reduced co-ordination between tower and radar controllers, has a detrimental effect on airport capacity. Capacity at Auckland could be enhanced by both aircraft type mix changes, and by air traffic control procedure changes.

It can be seen, then that aircraft type mix improvements could add an additional 2 movements per hour to both Auckland and Wellington runway capacities. This is for the 1 arrival / 1 departure sequence. Larger increases are evident for the arrivals only and departures only scenarios, but overall capacity is lower if these movement sequences are employed. Note that an approximately even number of arrivals and departures occur.

Movement Type Mix

Airline schedules do not follow this regime, however. Movements at all New Zealand airports tend to be bunched in groups of arrivals followed by groups of departures. Especially in the case of Wellington airport, this is a necessary industry response to demand. Traffic at Wellington is largely business orientated – hence the peak demand periods at the beginning and end of each day. This necessitates movement type bunching and is unlikely to alter. Aircraft movements are significantly bunched into groups of arrivals and departures – especially during the morning peak demand period at Wellington and at several times during the day at Auckland. Capacity cannot be maximized with this distribution.

Schedule Delay

The causes of delay identified so far all deal with capacity maximisation – or the lack of it. Airport congestion, however, is due to excess demand. This can take two forms. In the first case, congestion can be due to schedule delay – the scheduling of multiple aircraft movements for the same time. This type of delay is common in New Zealand – there is no method of management or control on aircraft flight planning. Delays due to schedules are unlikely to be severe, nor are they likely to have ongoing effects for any significant period of time. As shown earlier, schedules at Auckland, Wellington and Christchurch contain numerous periods where demand is high for short periods.

At Christchurch, this is a minor problem which results in very little delay. At Auckland and Wellington, the problem is more widespread. Aircraft planned movements are often concentrated on the hour and half hour. Where this is followed by low demand periods, delay is quickly dissipated. If no low demand periods occur immediately following this, however, then delay cannot be dispersed. The period 0830 – 0900 is a particular problem for both these airports. Auckland has 3 – 4 movements scheduled for 0830, followed by 7 at 0835. This cannot occur, so delay is created and cleared only when periods of low demand occur. At Wellington the problem is worse. 4 aircraft are regularly scheduled for 0820, 4 more for 0825 and 7 at 0830. There can be no other outcome from this but delay. Scheduled delay in the afternoon period occurs for the same reasons but it is longer before low demand periods occur to allow delay dispersal. Figures 10.1 and 10.2 below show scheduled delay at Auckland and Wellington airports.

Figure 10.6: Wellington Schedule Excess Demand Delay

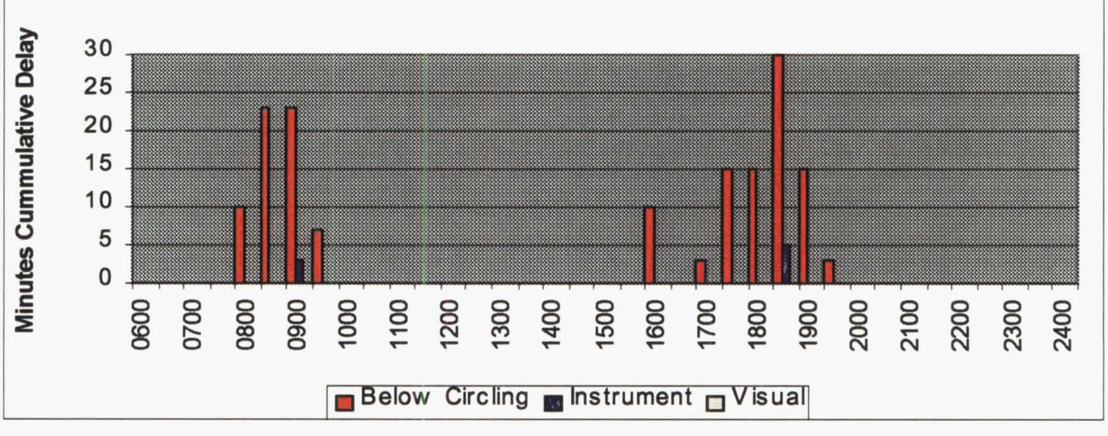
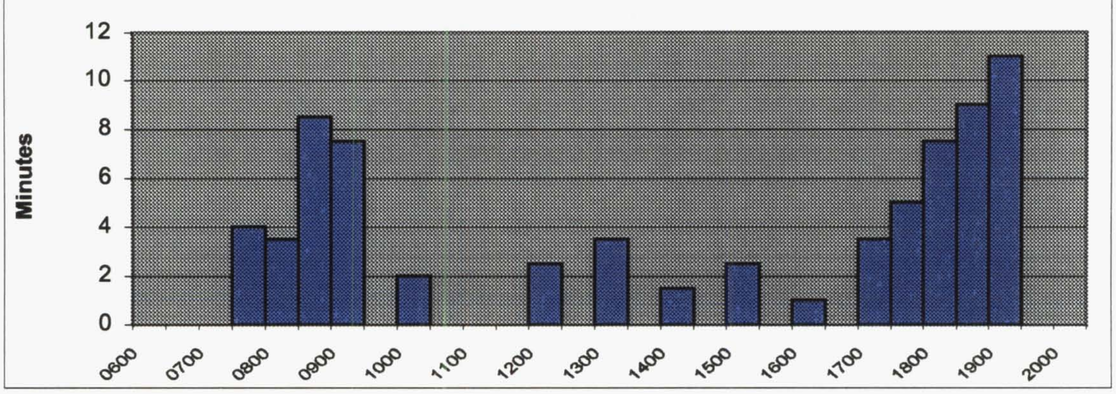


Figure 10.2: Wellington Schedule Delay



The second form of congestion is due to excess demand. The potential for ongoing delay is much higher in this case. In reality, schedule and congestion delay are symptoms of the same problem – excess demand over available capacity. The only difference between them is the extent of the problem and resulting delays.

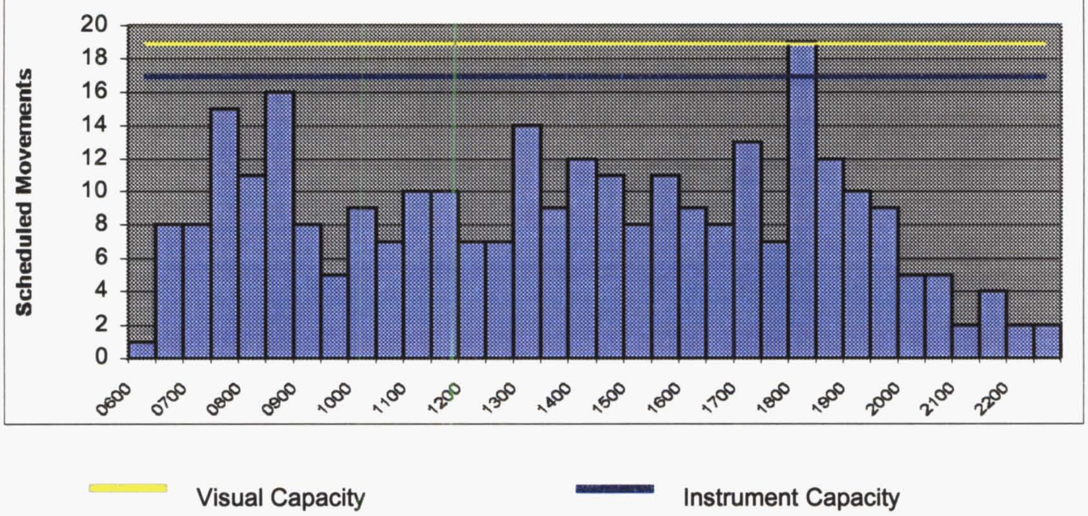
Schedule delay cannot be considered as true congestion, however. While the scheduling of multiple aircraft movements for the same period of time results in delay, these delays are quickly dispersed in periods of low demand. For example, if 6 aircraft are scheduled at say, 1300 then 5 of them must incur some delay. It is possible for only one of these aircraft to utilise the runway at 1300. There may, however, be no further movements scheduled for 10 or 15 minutes. Indeed, capacity over the period 1300-1330 or 1300-1400 may be well in excess of demand. This type of delay cannot be considered as true congestion.

Congestion must be considered to occur when demand exceeds the available capacity of an airport for significant periods of time. In this situation, delays are unable to be dispersed until demand lowers also for a significant period of time.

Excess Demand

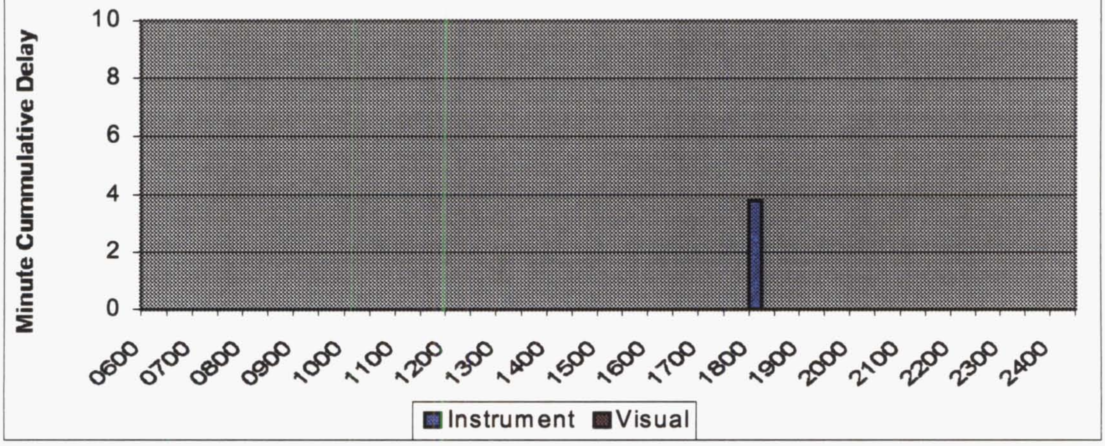
Demand and capacity for Auckland and Wellington airports has been identified. The extent to which delays are due to excess demand - airport congestion – may be established through a comparison of these two measures. Figure 10.3 shows scheduled demand at Auckland at half-hourly intervals and overlaid with theairport's 'declared' (realistic) capacity for that period.

Figure 10.3: Auckland Scheduled Traffic and Capacity

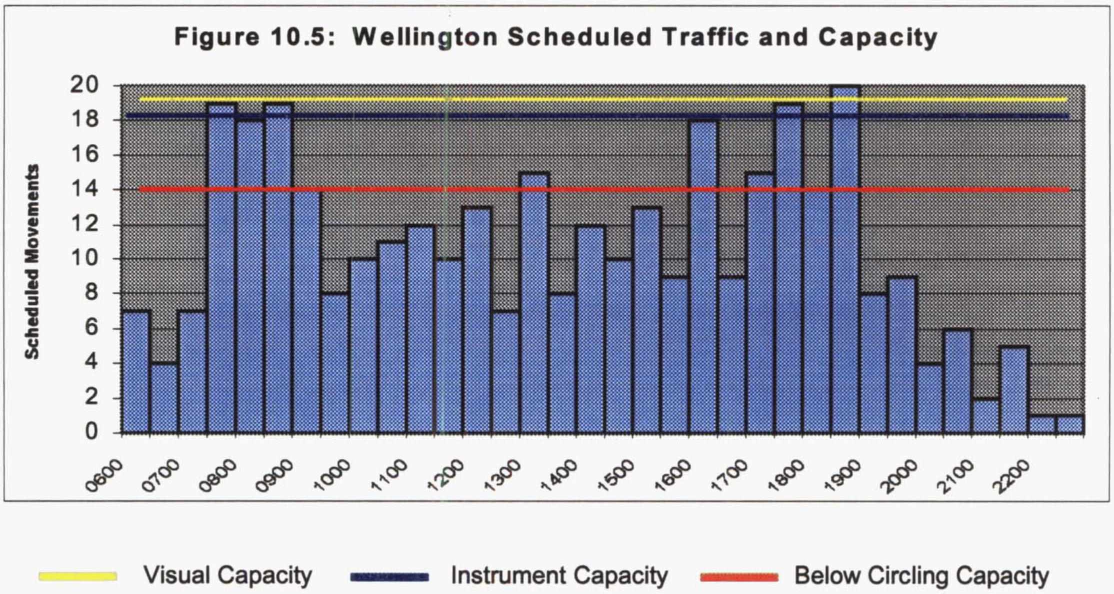


Auckland capacity is well in excess of the level of demand during both visual and instrument conditions. There is only one period at 1800 where demand exceeds available capacity. Figure 10.4 shows excess demand at Auckland, and the level of delay which is attributable to this.

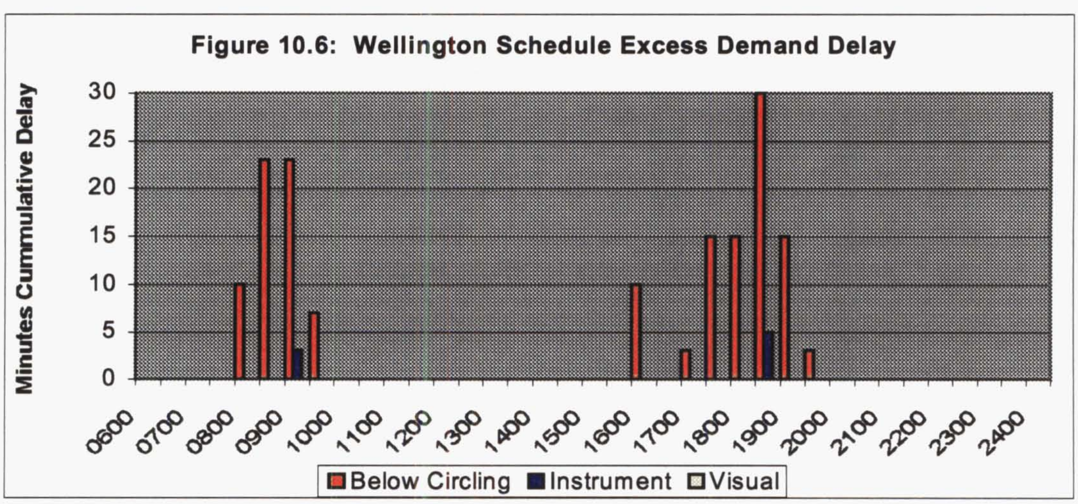
Figure 10.4: Auckland Schedule Excess Demand Delay



Wellington airport experiences a higher level of delay than Auckland, a fact attributable to fluctuating capacity and to schedule distribution. Figure 10.5 depicts scheduled demand and capacity at Wellington.



Demand exceeds capacity at Wellington on a regular basis. While this excess demand is very small, and hence easy to clear on visual days, the situation is worse during instrument conditions. Figure 10.6 shows excess demand and congestion delay at Wellington.



While a small amount of congestion delay can be seen during instrument conditions above circling, the level of delay during below circling minima conditions is well in excess of this. Delay levels exceed 20 minutes and the period of congestion is two hours in the morning, broadening to four hours in the afternoon and evening.

The two types of delay shown here, schedule and congestion delay, may not be cumulative. If an aircraft is delayed through congestion due to excess demand, then it will not necessarily arrive for its next service at the appointed time. This deviation from scheduled time is likely to continue throughput the course of the day. This applies equally to any reason for delay – from congestion to late passengers and engineering difficulties. In other words, the fact that an aircraft is scheduled for a specific time does not guarantee that it will present itself for service at that time; and this may or may not be due to schedule or congestion delay.

Future Levels of Delay

Air transport traffic levels in New Zealand have experienced consistent growth over recent years. This trend is expected to continue for at least the next fifteen years. Wellington International Airport Ltd estimates Wellington traffic growth at 5% per annum with passenger numbers climbing from 3.2 million in 1996 to reach 6 million by 2011 (Wellington International Airport Ltd. Annual Report 1996).

Air traffic growth and constraints in the Asia / Pacific region (including New Zealand) are estimated in a report entitled 'Asia/Pacific Air Traffic – Growth and Constraints' produced by the Air Transport Action Group (ATAG) and published by the International Air Transport Association (IATA) Aviation Information and Research Department.

ATAG describes itself as "an independent coalition of organisations from throughout the air transport industry which have united to press for economically beneficial aviation capacity improvements in an environmentally responsible manner. ATAG is a leading proponent of aviation infrastructure issues including the economic benefits of air transport, the industry's superior environmental performance and the need for major improvements in airport and air traffic management capacity."

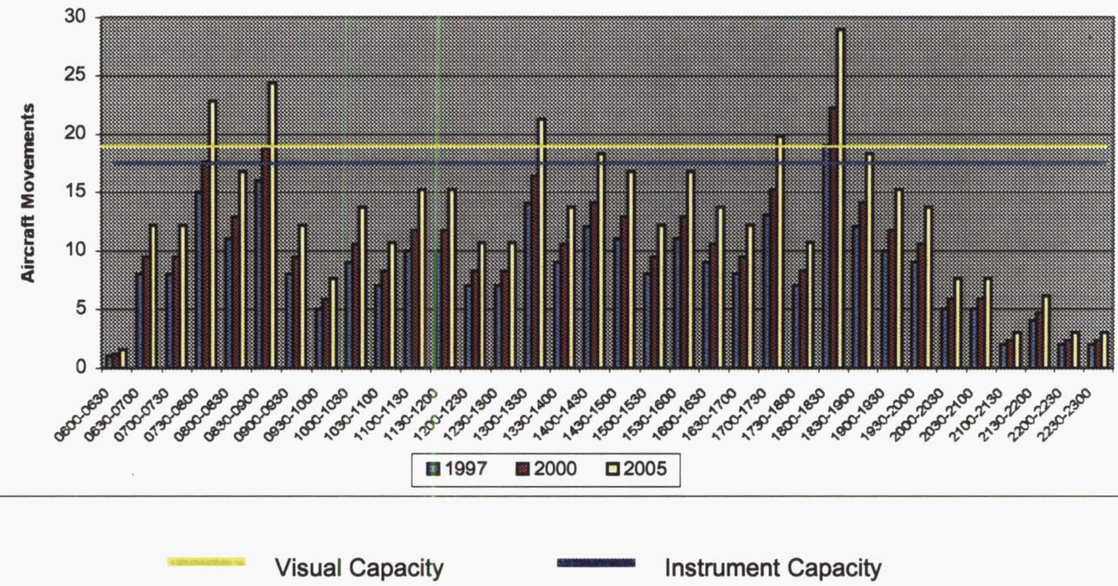
In this report, domestic passenger numbers within New Zealand are shown to have increased from 2.7 million in 1985 to 4 million in 1995 a rise of 48%. Similarly, international passenger traffic has grown 109% from 2.2 million to 4.6 million. Growth between 1995 and 2010 is forecast as 105% domestic passenger growth to 8.6 million in 2010 and 137% international passenger growth to 10.9 million.

The average annual rate of growth for the period 1985–1995 is 5.7%. The forecasted average annual rate of growth 1995–2010 is 5.4%. At the major international as well as domestic New Zealand ports, this level of forecasted growth has significant ramifications particularly for Wellington and Auckland airports.

Traffic growth at the rate of 5.4% per annum 1997 – 2005 has been simulated here in order to provide an indication of the level of future congestion and delay which would

be created by this levels of growth. This simulation assumes no change to aircraft type mix or schedule distribution. Figure 11.1 depicts Auckland forecast demand and capacity 1997 – 2005.

Figure 11.1: Auckland Scheduled Traffic 1997 - 2005
Forecast Growth @ 5.4% per annum



It can be seen that capacity is exceeded during instrument conditions for several periods by 2000, and during visual conditions by 2005. Excess demand and level of delay is shown by figures 11.2 – 11.4.

Figure 11.2: Auckland Schedule Excess Demand 1997

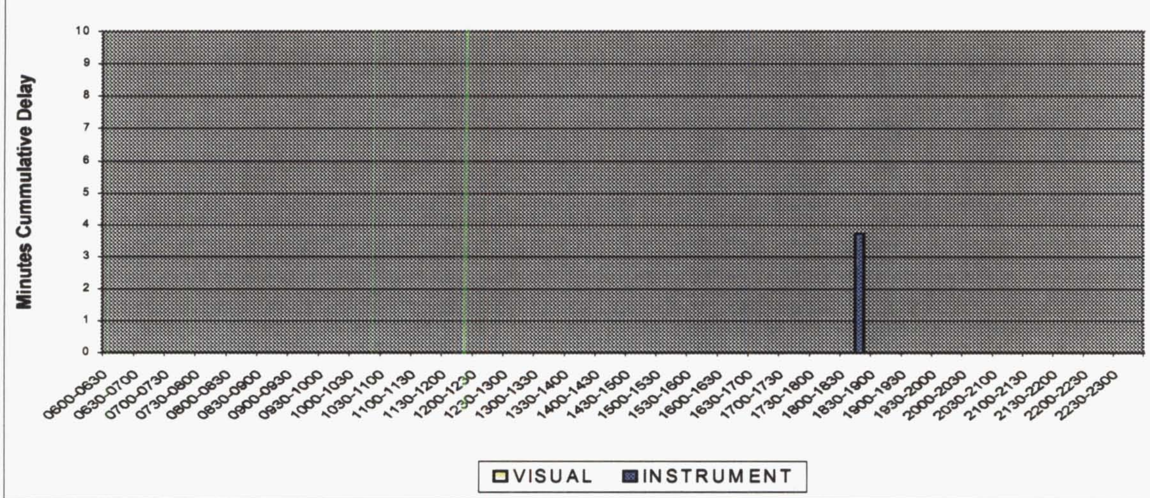


Figure 11.3: Auckland Schedule Excess Demand 2000

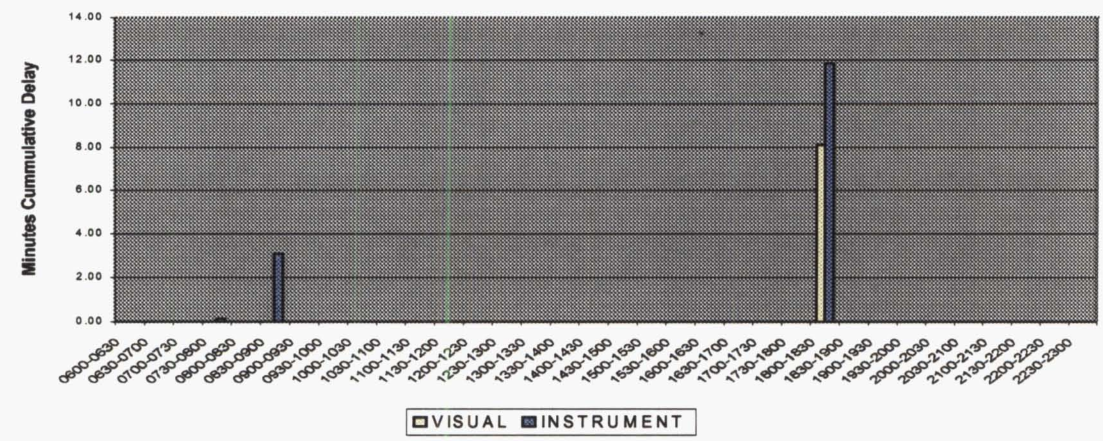
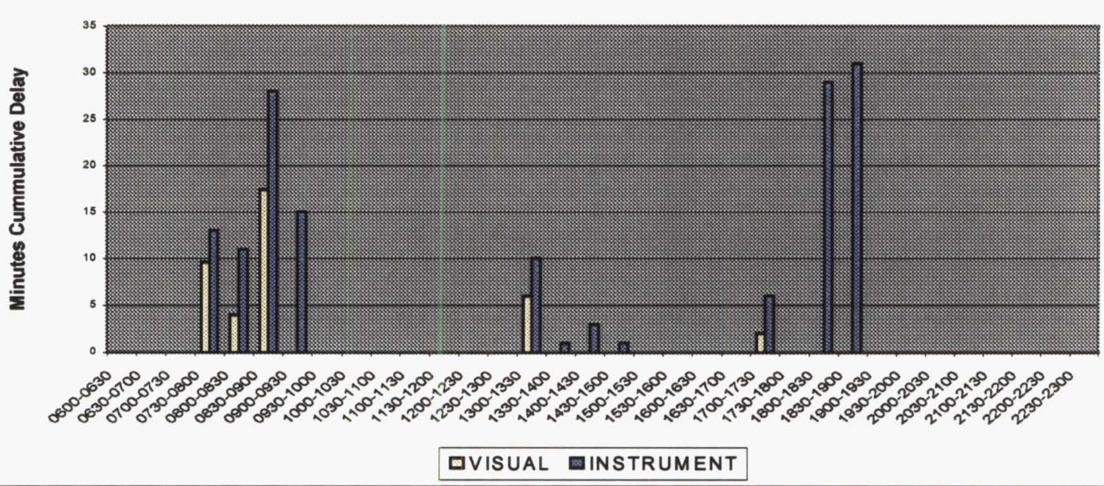


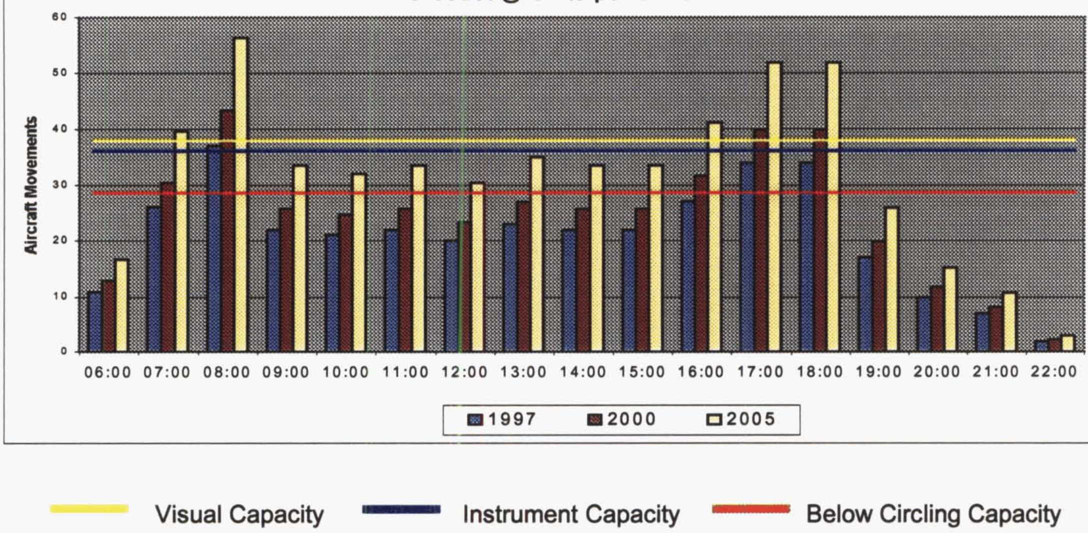
Figure 11.4: Auckland Schedule Excess Demand 2005



The level of delay due to congestion will rise from four minutes for onehalf hour period during instrument conditions to double this by 2000. Delay due to congestion is also seen during visual conditions – albeit briefly. Congestion delay will not reach significant levels until 2005 where congested periods are up to 2 hours long with delay levels around 30 minutes.

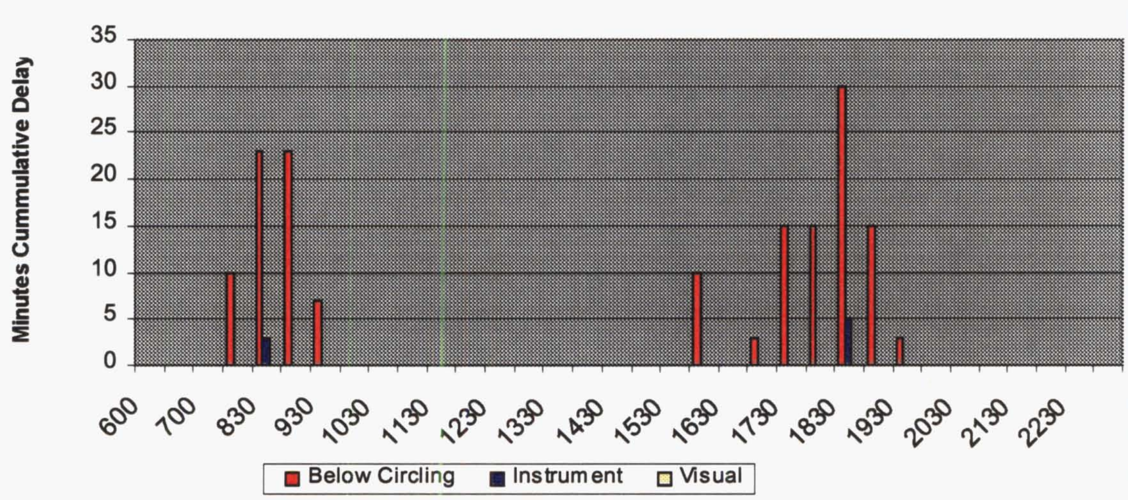
At Wellington airport, predictably the situation is more serious. During some weather conditions, the level of congestion related delay already exceeds that forecasted for Auckland in 2005. Figure 11.5 shows Wellington demand and capacity 1997 – 2005.

Figure 11.5: Wellington Scheduled Traffic 1997 - 2005 Forecast @ 5.4% per annum



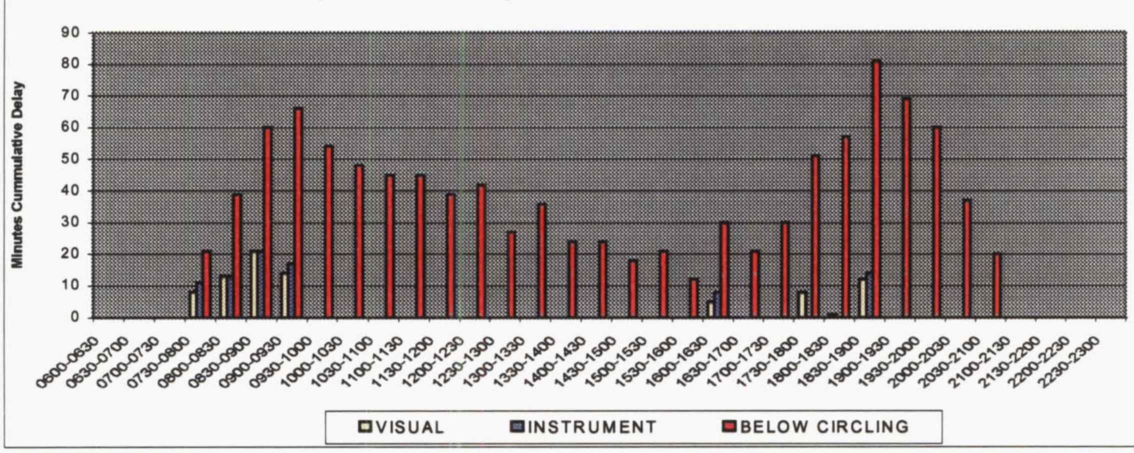
Capacity is exceeded at 1997 levels during instrument below circling conditions, resulting in congestion delay for periods of 1- 2 hours in the morning and 2 – 3 hours in the evening. As well as worsening of this condition, congestion can be seen to reach the instrument above circling and visual conditions by 2000 – a situation which would see the level of delay presently experienced only during below circling conditions a reality for all conditions. Figures 11.6 – 11.8 depict the level of excess demand and congestion delay this level of growth would incur at Wellington.

Figure 11.6: Wellington Excess Demand Delay 1997



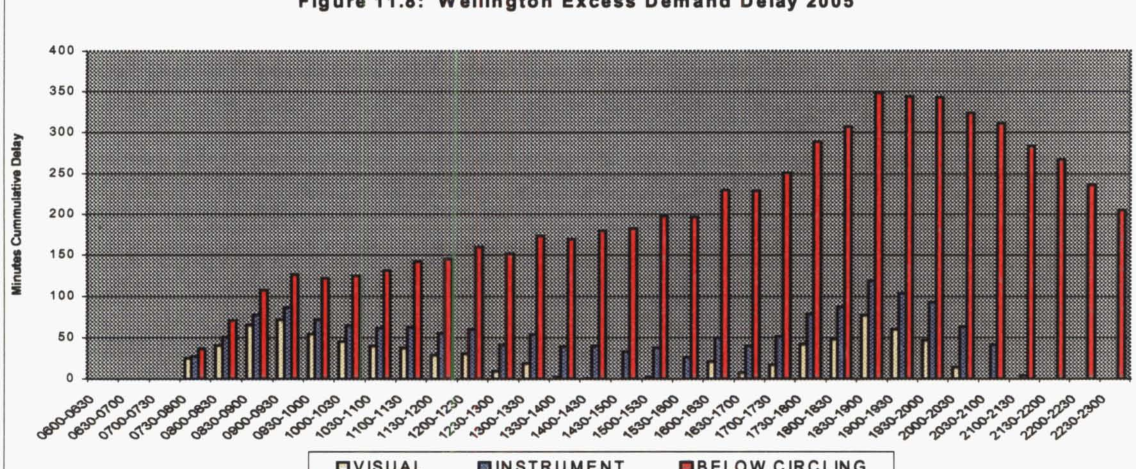
By 2000, delays during visual and instrument conditions above circling minima will reach the levels presently experienced during instrument below circling minima conditions. The congested period will be two hours long in the morning and approximately 1 hour in the evening. During below circling conditions, delay will be as high as 80 minutes, the congested period 13.5 hours.

Figure 11.7: Wellington Excess Demand Delay 2000



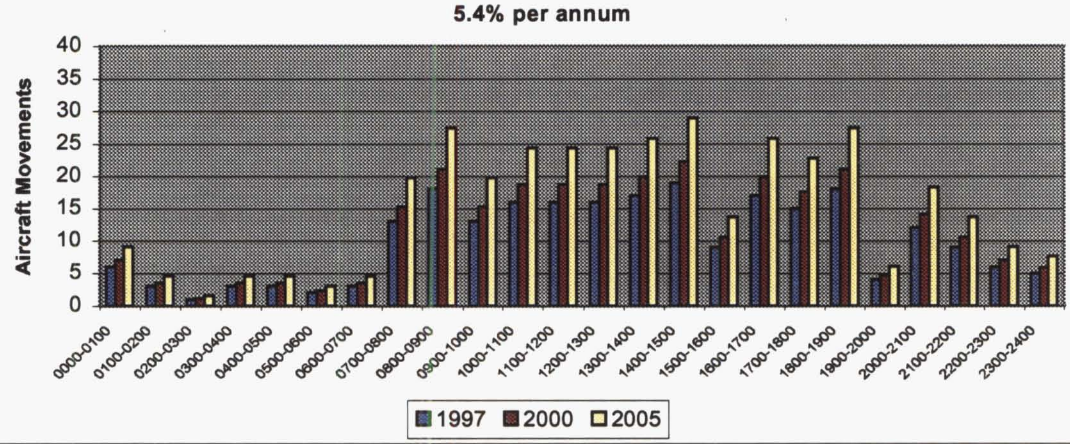
By 2005, congestion is continuous with delays exceeding 1 hour even during visual conditions. During below circling conditions, delays exceed 2 hours by 0830, rising to nearly 6 hours. Nearly 3 hours delay remains at curfew.

Figure 11.8: Wellington Excess Demand Delay 2005



Growth at Christchurch is largely unrestricted. Figure 11.9 shows scheduled traffic growth at 5.4% 1997 – 2005.

Figure 11.8: Christchurch Scheduled Traffic 1997 - 2005 Forecast Growth @ 5.4% per annum



By 2005 Peak traffic has not yet reached 30 movements per hour. This is insufficient demand to cause congestion. It will be a further 10 years (approximately) at this rate of growth before congestion becomes a major problem for Christchurch airport.

Summary

Airborne Delays

The level of delay at New Zealand's major airports is generally low. At Christchurch, delays average approximately three minutes, with little or no variation between visual and instrument conditions. At Auckland, delays similarly average 3 minutes during visual conditions, rising to 4 minutes when instrument conditions exist.

At Wellington airport, the level of delay varies considerably with weather conditions. During visual conditions, average delay is low – approximately three minutes. This rises slightly to an average of five minutes during instrument conditions, and steeply to an average of eleven minutes during conditions which are below circling minima. Peak delays during below circling minima conditions may exceed 1 hour in duration.

The annual cost of delays at New Zealand's major airports has been estimated in terms of total minutes of delay, and estimated aircraft fuel burn in delay.

	Minutes Annual Delay	*Annual Fuel Cost (Kg fuel)*
Wellington	291,650	4,451,257
Auckland	248,374	7,101,456
Christchurch	138,849	3,821,924

Total minutes of delay at Wellington are higher than either Auckland or Christchurch. Notably, Auckland accommodates 11,988 more IFR aircraft movements per year than Wellington and does so for a cost of 43,276 minutes less. Recorded delay at all three airports is similar (3 – 5 minutes average) and within the limitations of data recording, with the exception of periods during below circling minima conditions at Wellíngton.

These conditions occurs 11% of the time at Wellington, yet is responsible for 24% of recorded delays. These are real-time delays, not the product of flight plan or data recording limitations. The cost of delays during these conditions is some 69,996 minutes annually and approximately 1,068,302 Kg of fuel. A single day below circling minima will cost the industry some 1,750 minutes (29 hours) of airbornedelay, and approximately 26,708 Kg of aircraft fuel.

These delays have ongoing effects through both schedule and network disruption. Delays incurred by one aircraft may affect other aircraft if passengers are transferring from one flight to another. Additionally, any delay incurred by an aircraft will be carried on to its next destination – continuously, until sufficient time is saved either in the air or in ground turn-arounds to enable the time lost in delay to be recouped. To recoup 29 hours of delay across scheduled traffic is a feat any airline would find difficult to achieve.

Weather Conditions

Weather conditions also affect average runway throughput. At Auckland airport, average runway utilisation is 37 minutes per hour during visual conditions, 35 during instrument conditions. Wellington remains constant at an average of 37 per hour during both visual and instrument conditions, but drops to 32 per hour when conditions are below circling minima. Throughput at Christchurch is unaffected by weather conditions, averaging the demand rate of 20 per hour in all cases.

Visual conditions predominate at Auckland and Christchurch airports, accounting for approximately 60% of days. Instrument conditions above circling minima account for the remainder, excepting 1% and 3% respectively, which are instrument conditions below circling minima. At Wellington, a higher incidence of instrument above circling minima days occur, comprising some 51% of the total, with visual conditions accounting for 38% of the remainder. The incidence of below circling minima conditions is also higher at 11%. This is partially due to the higher minima's at Wellington.

At Auckland or Christchurch, the minimum cloud base under which aircraft are permitted to circle visually for a second attempt at landing is between 910 and 670

feet. At Wellington, jets may circle if the cloud base is above 1,500' and other aircraft if cloud base is above 1,000'.

Demand

The majority of demand for service at New Zealand's airports from commercial air transport aircraft is centred on Auckland, Wellington and Christchurch airports. These airports account for 63% of all air transport movements in New Zealand and are the main international as well as domestic ports.

Growth of traffic movements throughout New Zealand over the past decade has been substantial. In the past three years, IFR traffic has increased by 15%, from 453,542 movements in 1995 to 521,759 in 1997.

Wellington airport has experienced the most significant growth in air traffic numbers. IFR traffic numbers increased by nearly 10% in 1996 and by a further 4% in 1997. This has been despite a curfew limiting hours of operation to 0600 – 2300 introduced late in 1995.

Growth at Auckland and Christchurch has been smaller, approximately 3% annually. A major reason for the high level of growth at Wellington has been a shift toward utilising smaller aircraft types on a more frequent basis than previously. Although passenger numbers have increased, this growth has been far exceeded by the rate at which aircraft movements have increased. This is testimony to a clear trend toward greater frequency of flights by smaller aircraft, catering to consumer demand for convenience.

The pattern or distribution of demand at Auckland and Christchurch airports is relatively constant throughout the day. Scheduled demand is not completely smooth – both airports experience periods where several aircraft movements are scheduled for the same time. The delays, which result from this, are referred to as scheduled delay. Wellington also experiences problems with scheduled delay and this problem is exacerbated by a schedule pattern that contains large peaks in demand. Morning and evening peak demand periods exist during which any delay created is unlikely to be dispersed.

Capacity

Capacity at Auckland and Wellington airports has been calculated using capacity models developed by this author for the Airways Corporation of New Zealand Ltd. Both theoretical maximum capacity and realistic 'declared' capacity is shown, for varying weather states.

Maximum Runway Capacity

	Arrivals	Departures	1 Arr. / 1 Dep.
Auckland			
Visual Conditions	34	36	40
Instrument Conditions	28	36	37
Wellington			
Visual Conditions	31	35	43
Instrument Conditions	28	31	38
Below Circling Minima	21	30	33

Realistic Runway Capacity

	Visual	Instrument	Instrument Below Circling
Auckland			
Runway 05	38	36	NA
Runway 23	37	35	NA
Wellington			
	38	36	28

Maximum capacity is higher at Wellington then Auckland airport, but this is also extremely variable with weather conditions. Capacity during below circling minima conditions is approximately 75% of 'normal' levels. The reason for this is the requirement at Wellington to 'protect' the missed approach; due mainly to surrounding terrain which prevents aircraft from being turned at low levels under radar direction. Because of the wide variance of performance capability amongst the aircraft using Wellington airport, very large separations must be used in these conditions. The result is a sharp decrease in capacity.

It must be noted that 'below circling conditions' at Auckland and Christchurch airports will not reduce capacity unless runway closure occurs (as it may if conditions include fog). This is because aircraft may be turned at low altitudes under radar control. Because of the high terrain which surrounds Wellington, aircraft cannot be turned from the departure track under radar until a far higher altitude has been attained – hence the need for larger separations between them during these conditions, and the resulting decrease in capacity.

A 'single runway' capacity has been calculated for Christchurch airport, using the same methodology as the Auckland and Wellington models. This is not a true statement of the actual capacity of Christchurch, which is a multi-runway system, but it provides a useful comparison for Auckland and Wellington (note that a multi-runway system will have a higher, not lower, actual capacity than a single runway system). This single runway capacity calculation yields the following result:

Christchurch Airport Single Runway Capacity

	Arrivals	**Departures**	**1 Arr. / 1 Dep.**
Visual Conditions	36	44	43
Instrument Conditions	31	44	42

Causes of Delay

The single runway capacity of Christchurch is higher than either Auckland or Wellington. Comparison with Auckland and Wellington has been used to identify the extent to which differing factors are causes of delay at these airports. Greater uniformity of traffic mix is an obvious cause, and inputting the Christchurch traffic mix to the Auckland and Wellington capacity models tests the effect of this.

Auckland / Wellington Capacity - Christchurch Aircraft Type Mix

Instrument Conditions

	Arrivals	Departures	1 Arr. / 1 Dep.
Auckland	31 (+3)	44 (+8)	39 (+2)
Wellington	31 (+3)	42 (+11)	40 (+2)

The result is improved capacity at both airports. This is particularly significant for Wellington. The requirement to 'protect' the missed approach arises from performance differentials amongst the aircraft type mix. As well as increasing overall capacity, the consistency of performance of the Christchurch traffic mix greatly removes the requirement for large separations in order to protect the missed approach. In other words, if this type mix existed at Wellington, capacity on below circling minima days would be close to the level of above circling minima days.

Capacity at both airports is improved, but not to a level which matches Christchurch. Thus, aircraft type mix contributes to, but is not the sole cause of lower capacity at Auckland and Wellington. The only other differentiating factor between these airports is air traffic control procedures. This is identified as the remaining cause of 'less than optimal' capacity at Auckland and Wellington.

In the case of Wellington, air traffic control procedures are very similar to Christchurch, except where dictated by terrain avoidance constraints. At Auckland, conversely, it is found that the system of tower initiated departures (TIDs) utilises

larger separations than the fully co-ordinated system employed by Christchurch and Wellington. Capacity at Auckland could be enhanced by approximately 2 movements per hour (instrument conditions) by the use of more effective air traffic control procedures.

Aircraft type mix and air traffic control procedures (Auckland) have been identified as factors which contribute to delays by disallowing optimum runway capacity. Another factor which similarly affects runway capacity is the movement type mix. Runway capacity is lowest when an arrivals only sequence of movements occurs, and is optimised by a 1 arrival / 1 departure flow.
Normal scheduling at all of these airports is characterised by 'bunches' of arrivals followed by 'bunches' of departures. While it is recognised that consumer demand patterns and airline convenience may not support alterations to this scheduling pattern, it must also be recognised that a greater number of aircraft movements could be accommodated if the 1 arrival / 1 departure sequencing was observed. Runway capacity, in other words, would be higher.

Congestion is the result of too many aircraft trying to use airport resources – the runway – than may be accommodated. This has been identified in two forms:

The first is scheduled delay, where multiple aircraft movements are scheduled for the same time. In this case there is no other outcome but delay. These delays are usually of short duration, however, because airport capacity is not exceeded for any great length of time. Scheduled delay occurs frequently at all three airports examined.

The second form of delay due to excess demand is true congestion. This occurs when available capacity is exceeded over an extended period. Congestion may include scheduled delay, but is ultimately due to excess demand. Delays in this case may be substantial and are unlikely to be dispersed quickly – until some low demand period of sufficient duration occurs.

Airport capacity is not exceeded at Auckland or Christchurch airports, nor at Wellington during visual or instrument conditions which are above circling minima. Scheduled delay, therefore, is the cause of the low level of delay experienced on a daily basis at these airports. Although not exceeded, it is worth noting that capacity is reached during some periods at Auckland and Wellington during instrument

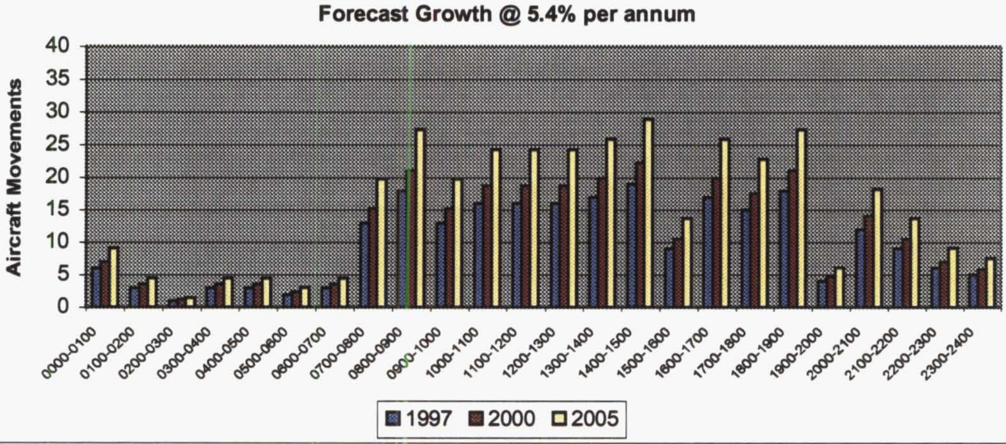
conditions. It is for this reason that any scheduled delay has a greater effect, in both duration and number of aircraft affected under instrument conditions.

True congestion exists only at Wellington airport during instrument conditions below circling minima. During peak demand periods, capacity may be exceeded by as much as 8 – 10 aircraft per hour. When combined with schedule effects, delays can become severe. Average delay during these conditions exceeds 11 minutes, and peak delays may exceed 1 hour. Congestion cannot be dispersed until a period of low demand occurs of sufficient length to accommodate these excess aircraft. Congestion at Wellington usually occurs for the duration of the busy periods 0730 – 1030 and 1630 – 2000.

Congestion in the Future

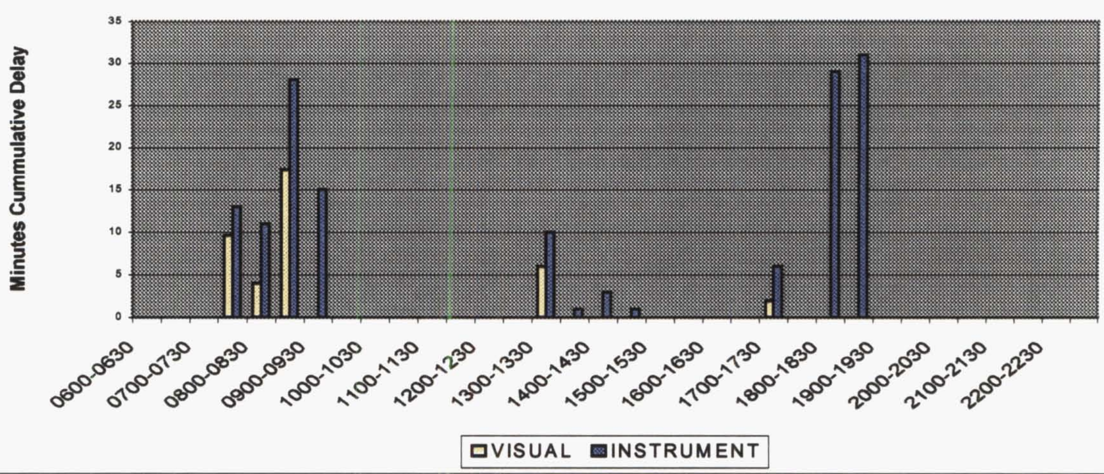
Airport congestion is already evident at Wellington airport during conditions below circling minima. Delays during other periods, and at other airports is due to schedule delay rather than congestion. But this will not remain the case. Air traffic has grown consistently over the past decade, and is forecast to continue to grow for at least the next fifteen years. The Asia/Pacific Region Forecast report issued by the Air Transport Action Group (ATAG) forecasts this growth at an average annual rate of 5.4% to 2010. The effect of this level of increased demand is substantial. Indeed, Christchurch is the only airport of the three which has the capability to absorb this level of growth without severe congestion resulting.

Figure 12.1: Christchurch Scheduled Traffic 1997 - 2005
Forecast Growth @ 5.4% per annum



Demand at Auckland airport presently exceeds capacity only for a single short period (1830-1900), where delay due to this excess demand is low – approximately four minutes. If demand for service increases at the rate forecast by ATAG, Auckland airport will experience a level of congestion which exceeds that presently experienced at Wellington during below circling conditions by 2005. Congested periods of approximately two hours duration will occur in the morning, early afternoon and evening, with delay levels up to 30 minutes duration.

Figure 12.2: Auckland Excess Demand Delay 2005



At Wellington airport, the situation is far more serious. While severe congestion is presently evident only during conditions below circling minima, a growth rate of 5.4% will quickly consume available capacity during instrument above circling minima, and even visual conditions. By 2000, congestion will be apparent during the morning period 0730-0930 under all conditions, with delays as high as 20 minutes. During below circling conditions, congestion will be complete. Delays appear at 0730 and will not be cleared until 2100, peaking around 80 minutes at 1830. This is clearly a situation which is intolerable, and must be avoided.

Figure 12.3: Wellington Scheduled Traffic 1997 - 2005 Forecast @ 5.4% per annum

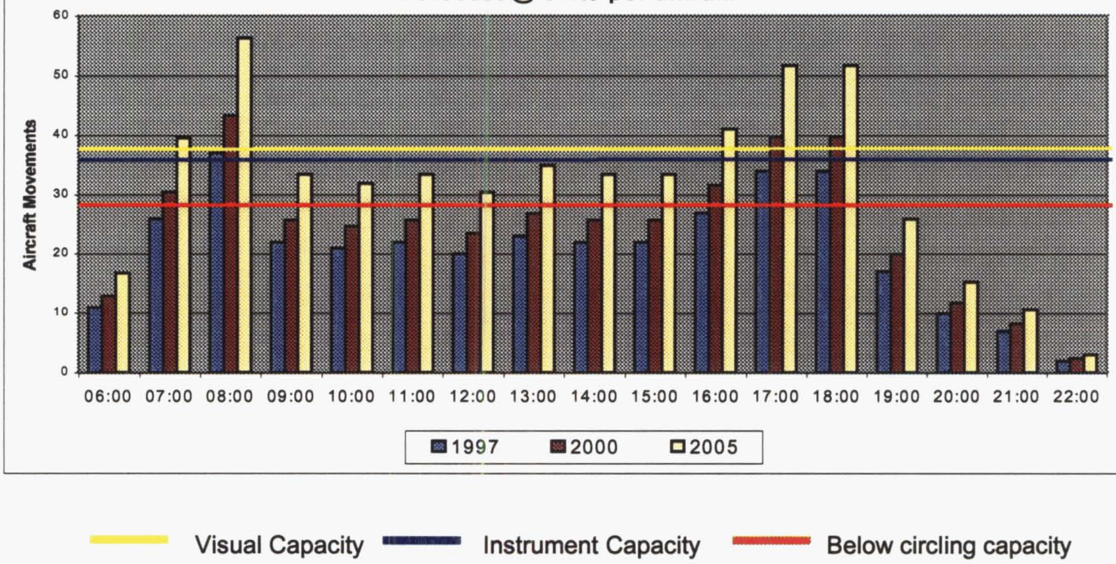
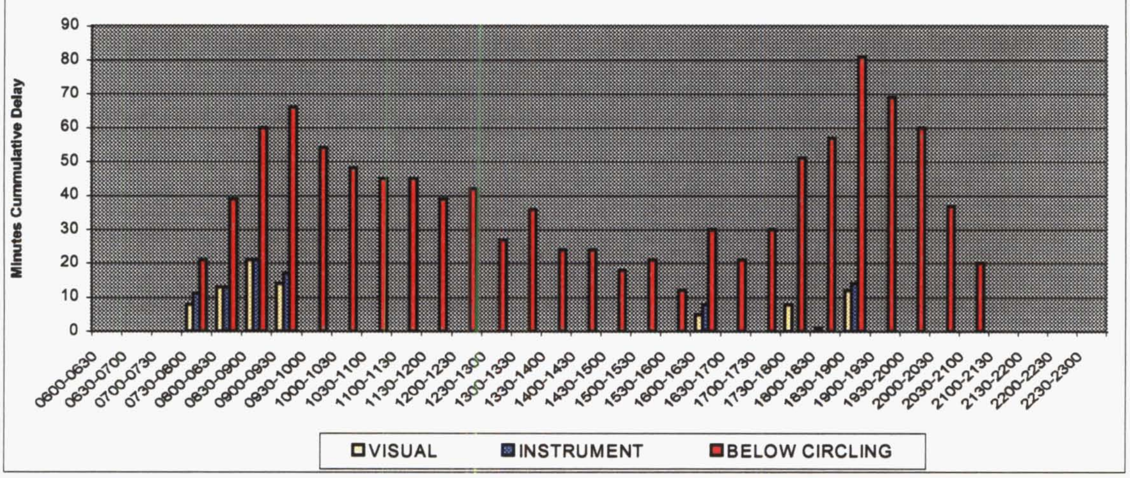
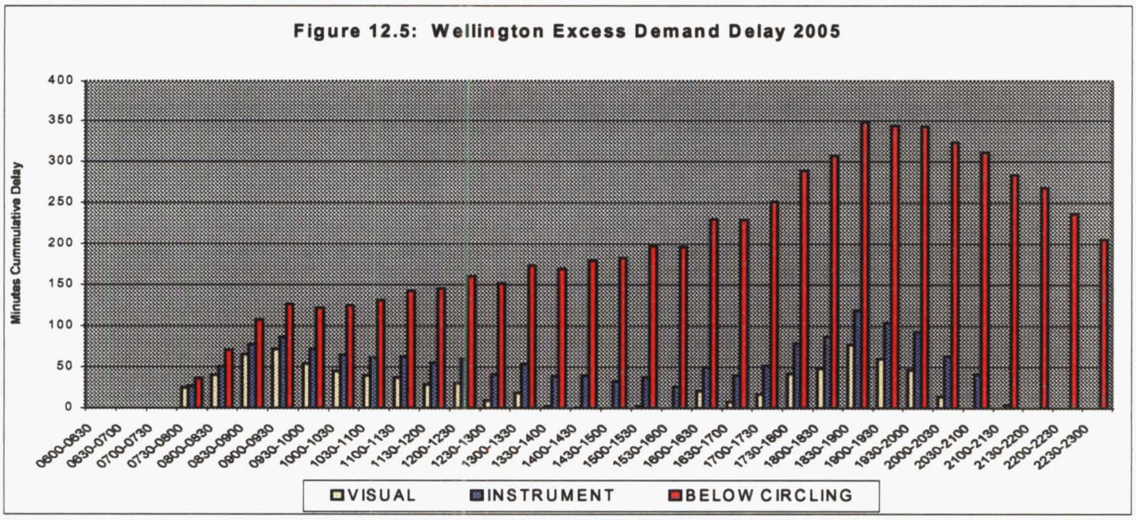


Figure 12.4: Wellington Excess Demand Delay 2000



By 2005, congestion is continuous during instrument conditions above circling minima, with peak delays of 90 minutes. Delays begin at 0730 and cannot be eliminated until 2100. During visual conditions, peak delay is 75 minutes, and congested periods are 0730-1330 and 1600-2030. Both of these scenarios depict situations which are far worse than presently experienced during conditions below circling minima. By 2005, delays during below circling conditions begin at 0730, peak at 350 minutes, with over 200 minutes delay remaining at the 2300 curfew.



Clearly this is a situation which cannot exist – the economic implications of aircraft incurring this level of delay would render operation into Wellington airport prohibitive. This is, however, the strongest possible reason for a solution to the congestion problem presently experienced to be sought and implemented. This scenario is an explicit statement of the level of congestion which will exist if changes to operations at Wellington airport are not devised.

Solutions

Any solution to the problem of congestion at New Zealand airports must take into account the causes of this problem. This research has identified several factors that disallow capacity maximisation, and others which give rise to congestion and delays.

Auckland Airport

Auckland airport has been shown to restrict maximum capacity through the air traffic control procedures it applies, and through a less than optimum aircraft type mix. Movement type mix (arrival / departure sequencing) is another factor which, if managed more effectively, could enhance existing airport capacity. While it is certain that significant gains could be made if these factors were addressed, it is unlikely that this alone will avert the threat of congestion at Auckland airport indefinitely.

Capacity enhancement to the level of 42 – 43 movements per hour could be expected to result if all of these factors were addressed and optimised. This would still result in some level of delay by 2005, but congested periods would be short. Delay levels beyond this date could become significant. Management of scheduled demand – that is to say, a more even distribution of aircraft movements throughout the course of the day - is one option which could enable Auckland airport to accept continued growth of air traffic movements, without significant levels of delay, for at least the next fifteen years.

The Auckland Airport Company has already taken a pro-active approach to this problem. Attempts are already underway to gain planning permission for a second runway. Parallel operations at Auckland would enhance total runway capacity to a level in the region of 70 movements per hour. Note that this is not double the single runway figure of 42 movements per hour. This is because parallel runway operations are usually engineered so that one runway handles arrivals, the other departures. Often this is dictated by the structure of arrival and departure routes to and from the

airport, as well as simplicity of operation. Operating two mixed-mode (arrivals and departures) runways in close proximity requires complex air traffic control procedures which must detract from efficiency.

Nevertheless, the addition of a second runway to the Auckland system will certainly produce sufficient capacity to handle forecast traffic growth well beyond 2010. It must also be considered that the proposals for a second runway at Auckland have not been prompted by concerns for capacity / congestion alone. Indeed, the major driving force behind this is the ability of the existing runway to continue to accept traffic.

Auckland's existing runway undergoes frequent maintenance at each end to repair surface damage due to wear and age. Under these conditions the runway remains operational with restricted runway length available. In the next few years, however, it will be necessary for maintenance work to be carried out on the centre portion of the runway. Under these circumstances, it will be impossible for the runway to accept any traffic at all. Given the extent of the expected repairs, this will result in Auckland airport remaining closed for a period of weeks. As New Zealand's major international airport, the loss of revenue and the level of inconvenience this would cause would be disastrous.

It is possible to accommodate forecast growth at Auckland for the next fifteen years by capacity optimisation and schedule management techniques alone. It seems very likely, however, that a solution well in excess of this will be implemented. The addition of a second runway to the Auckland system will effectively postpone the requirement for this optimisation by fifteen to twenty years.

Christchurch Airport

Christchurch is an airport that has several options available to accommodate a sustained rate of traffic growth. The present airport maximises its available capacity well, and it is unlikely that forecast growth of demand will approach available capacity levels until at least 2010.

Christchurch also has available options for increasing airport capacity. These include extending the present East-West runway, and even the addition of a second North-South runway. Indeed, the geographical location of Christchurch and the air routes to other locations, and the abundance of flat surrounding terrain would render likely the possibility a second North-South runway being utilised as a mixed-mode runway. In other words, should Christchurch ever face the requirement to build a second runway to accommodate traffic demand, the resulting airport capacity could be in the region of 80 – 90 aircraft movements per hour. It is likely to be many years before this level of capacity is required by Christchurch airport.

Wellington Airport

Wellington airport is not endowed with such a multitude of realistic options, however. It is also the airport which has the greatest existing and potential delay problem. As such, the need to find appropriate and effective solutions to congestion at Wellington is paramount. Options available to solve this problem include:

1. Additional runway development
2. Extension to existing runway
3. Relocation of airport to Paraparaumu or Masterton
4. Management of existing runway to maximise capacity

A Second Runway

Enhancing capacity through additional runway development is a far more complex issue for Wellington than for Auckland or Christchurch. The present airport at Wellington is built on land reclaimed from the sea. It exists on a narrow peninsula of land which is surrounded on either side by higher terrain. In order to construct a second runway, this terrain would need to be flattened. There is some doubt as to the feasibility of this, and certainly enormous cost would be involved.

It is also doubtful that a second runway would constantly solve the capacity problem. The minimum allowable distance between runways on which simultaneous aircraft movements can take place is 760 metres. While this distance might be achieved, during conditions below circling minima the lateral distance between aircraft operating from these runways would not be sufficient to provide protection for the missed approach. In other words, an aircraft operating from one runway would still require additional separation from another aircraft, even if that aircraft were utilising the second runway. The result of this is that capacity during below circling minima would still be reduced to its present level, despite the fact of two runways in operation.

On visual or instrument above circling minima days, a second runway at Wellington could raise capacity to approximately 80 movements per hour. This is a level which would be sufficient for many years. It does not address the poor weather congestion problem, however. Capacity during below circling minima conditions would be enhanced little by a second runway.

Extending the Existing Runway

The feasibility of extending the existing runway at Wellington is also under some doubt. The expense of such a project would be substantial, as additional land would need to be reclaimed for the purpose.

Extending Wellington's existing runway would be beneficial in terms of the size of aircraft which could use the runway, and in reducing the effect of large aircraft on capacity.

At present, the largest aircraft that utilise Wellington are Boeing 767s. These aircraft are operated by both Qantas and Air New Zealand, and provide an international service between Wellington and several destinations in Australia. These are the only international destinations available direct from Wellington. In order to fly further afield, larger aircraft with greater range are required. Although larger aircraft (such as the Boeing 747SP) can operate into Wellington, they can only do so at light weights. The runway at Wellington is too short to permit operations by heavily laden

aircraft of this size. This precludes any direct international service to destinations further afield than Australia.

Extending the runway, then, would allow additional flight services to be offered to international destinations. The effect, though, of extra heavy aircraft in the traffic mix would be detrimental to airport capacity. This is because of the larger wake turbulence separation that must be applied to all aircraft following behind a heavy category aeroplane.

At present, when a heavy aircraft flies an instrument approach, a 12 NM separation must be allowed behind it because of the distortion caused to the localiser signal of the ILS approach. This distortion is caused when an aircraft exits the runway via the last taxiway (which heavy aeroplanes almost always do) and is a factor of the siting of the localiser at Wellington. If the runway were extended, it is possible that a new position could be found for the localizer, thus eliminating the distortion problem.

In this case, the detrimental effect of heavy aircraft in the traffic mix could be reduced. If a runway extension induced no extra international flights by heavy aircraft, then it would have the effect of increasing capacity by a small margin through removal of the localizer distortion problem.

This is a vain hope however. Wellington has a population base of over 350,000 people, and as New Zealand's capital city, commands a high degree of business travel. The demand for international services is substantial. If it becomes possible (through runway extension) for airlines to offer more extensive international services, then it is almost certain that those services will eventuate.

It is worth noting that Air New Zealand has recently purchased three new Boeing 737-300 aircraft. These aeroplanes are a larger and faster variant of the Boeing 737 presently used on domestic services. Air New Zealand (as at 29 March 1998) intends to offer 26 new services between Australia and New Zealand (Auckland, Wellington and Christchurch) utilising these new aircraft. This is good news for Wellington airport – the Boeing 737 aircraft should be able to land at Wellington without requiring the use of the last taxiway to exit the runway, thus avoiding the localizer distortion problem.

These aircraft are not, however, capable of flying large distances. They can be utilised for Trans-Tasman crossings, but do not have the range to carry passengers much further afield. If runway extensions allow larger aircraft to operate at Wellington, then it is these which will be employed on any international services further afield.

Extending the runway at Wellington, therefore has the potential to reduce the effect of heavy aircraft in the traffic mix, but is almost certain to increase the number of heavy aircraft. The final effect on capacity will be detrimental.

Relocation

This is an option for Wellington travellers which was initially floated in the late nineteen-sixties. At that point in time, it was intended for operations at Wellington airfield to be relocated to Paraparaumu, some distance north of Wellington on the Kapiti coast. This scheme was rescinded, however, and Wellington airport was developed in its present form to handle all domestic and international aircraft traffic to the area.

This may be considered an unfortunate, even ill conceived decision. Many of the problems associated with Wellington (particularly the missed approach requirement) arise from the terrain that surrounds the airfield. Restricted runway length is another issue, also arising from the airport's location on reclaimed land. Neither of these difficulties would have applied to Paraparaumu.

This is no longer the case, however. The township of Paraparaumu has been allowed to extend so that housing now exists in close proximity to the airport. This housing would probably need to be acquired and demolished if Paraparaumu were to be developed into an international airport. There are three main reasons for this:

1. Runway length at Paraparaumu would need to be increased for full international services to operate.
2. Noise pollution and abatement considerations would require greater distance between housing and runway. Departure and arrival tracks should also be considered.

3. Additional land would be required for development of terminal, hangar, parking and engineering facilities.

It should also be noted that Paraparaumu is no longer publicly owned, having been sold to a private buyer in 1995. This does not necessarily preclude development, and could conceivably be a positive circumstance.

Paraparaumu is not the only location which could be considered as an alternative to the existing Wellington airport. Masterton could equally be considered. A similar distance from Wellington, Masterton does not suffer form the difficulty of close proximity housing and ample undeveloped land surrounds the airport, thus providing the possibility of expansion. Flat surrounding terrain ensures that none of the difficulties presently experienced at the existing Wellington airport would be evident at Masterton.

The cost of such a venture, at either location would be extremely high. The existing runways at these airports are neither long enough nor strong enough to cater for heavy jet traffic. As well as new runways, terminal and other airport facilities would need to be constructed. An indication of this cost may be given by the new terminal facilities presently being built at Wellington - a total of $60 million is given by the Wellington Airport Company as the cost of this construction.

As well as the requirement for more land, facilities and housing eradication, a link with Wellington City would need to be established. To create a viable alternative to the existing airport, travel to and from the Paraparaumu airport would need to be quick and convenient. A high speed rail network, or electric train could provide the answer, but again the cost associated with this must be high, particularly in the case of Masterton which is separated from Wellington by mountain ranges.

Managing Existing Resources

This research has identified the main causes of delay at New Zealand airports. Amongst these causes are factors which disallow capacity maximisation - aircraft type mix, movement type mix, and air traffic control procedures at Auckland - it also identifies delay due to excess demand – schedule delay and congestion.

One option to solve the problem, then, must be management of airport resources in such a way as to reduce or eliminate these causes of delay.

Aircraft type mix directly affects airport capacity through the wake turbulence separation that must be employed between successive aircraft movements. Similarity of aircraft type and performance is the only means to ensure minimum separation is available. Volume of passenger numbers during peak periods would suggest that regulation of aircraft types to medium category aircraft, in the 30 to 120 seat range is the appropriate standard.

Standardising the mix of aircraft types using the airport to medium category jets and turboprop aeroplanes has several distinct advantages:

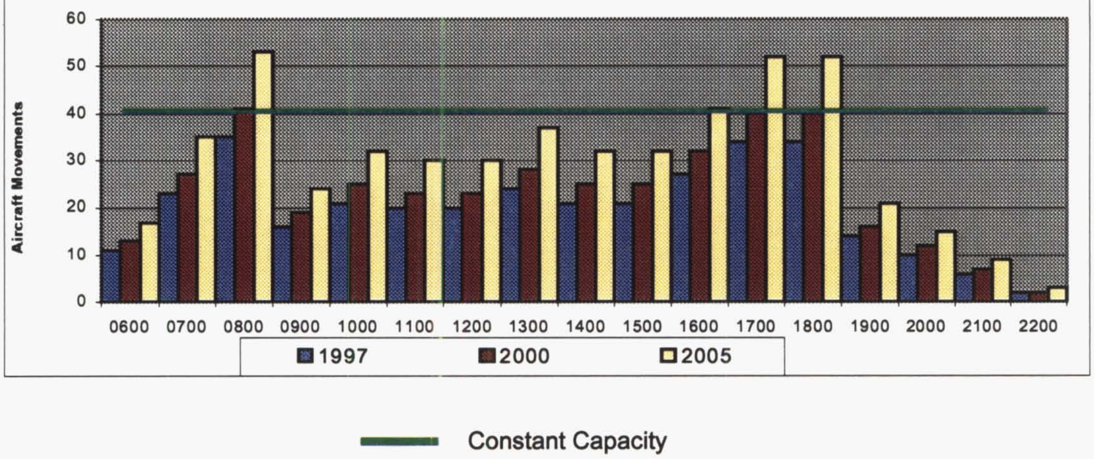
- Capacity enhancement through minimised separations between aircraft
- Reduction of traffic numbers as larger aircraft may be utilised less frequently to carry the passengers presently transported on light commuter aircraft.
- Standardisation of aircraft performance on approach and departure, thus allowing the standardisation of a missed approach profile. This would allow protection of the missed approach at Wellington without the need to provide larger separations between aircraft.

Restricting aircraft types using the runway to those which meet a standardised performance criteria, while making no difference to capacity during visual conditions, could raise capacity during instrument conditions to 40 per hour. More importantly, however, standardised performance would eliminate the need to provide larger separation in order to protect the missed approach. This does not remove the requirement to protect the missed approach, but removes the need for larger separations to do so. The result of this is that capacity degradation during instrument conditions below circling minima will be reduced or eliminated. Put another way, airport capacity during below circling minima conditions would be approximately 38 – 40 movements per hour, rather than the present 32.

This is a very significant gain. Indeed, this course of action has the ability to eliminate the congestion delay presently experienced at Wellington airport.

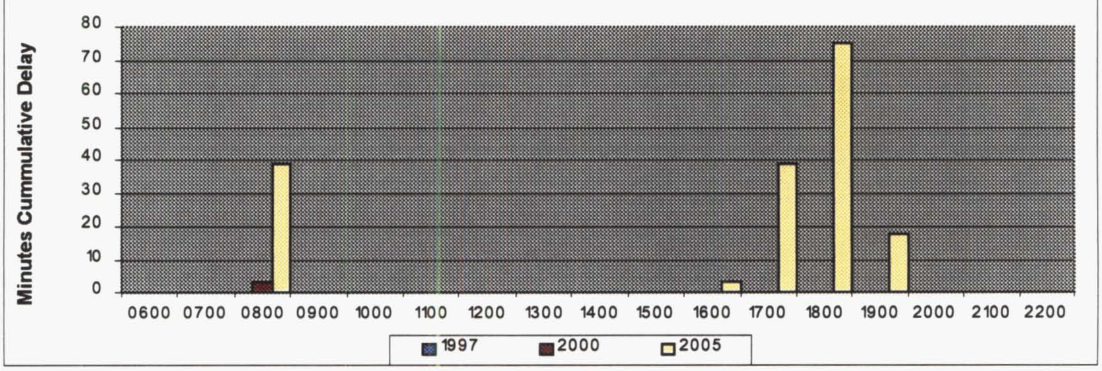
Delay due to congestion occurs at Wellington on every occasion that the weather is below circling minima. Small delays may occur at other times, largely due to schedule delay. These delays are larger on instrument days than visual, because demand is closer to capacity on these occasions. By enhancing capacity on below circling days to approximate the level of above circling days, delay may be reduced to a similar level. Figure 13.1 below depicts forecast growth at 5.4% to 2005, overlaid with the enhanced level of capacity which could result from the limiting of aircraft types.

Figure 13.1: Wellington Forecast Demand and Enhanced Capacity 1997-2005



Note that capacity is not reduced during below circling conditions - a constant 40 movements per hour is available throughout all weather conditions. Note also that this represents restriction of aircraft types only – the benefits of reduced aircraft numbers due to larger types and the smoothing of demand patterns which could be achieved by schedule management are not depicted.

Figure 13.2: Wellington Excess Demand Delay 1997-2005 - Enhanced Capacity



In reality, the benefits of this option would be higher than this. If larger aircraft types replaced small commuter aircraft, frequency of flight would also be reduced. A single Saab 340 or ATR 72 aircraft could replace 3 – 4 E110 Bandierante aircraft. This does not necessarily require that flight options for the commuting public be reduced. At present, the two main airlines offering regional services within New Zealand, Ansett and Air New Zealand operate largely duplicated schedules. Co-operative practices such as code sharing would allow the same frequency of flight options with fewer, larger aircraft.

Delays at New Zealand airports are due to true congestion only during below circling minima conditions at Wellington airport. At all other times, delay is the result of poor or uncoordinated scheduling. There are many periods at all New Zealand airports where several aircraft movements are scheduled for the same time – usually followed by periods where few movements are planned. The delay that results from this, while normally small, could be eliminated if a co-ordinated approach was taken to scheduling airport usage. As well as ensuring a smoother flow of existing aircraft movements, managing scheduled demand in this manner offers the opportunity to avoid creation of congested situations.

In addition to this, by managing scheduled demand with reference to available capacity, sequencing of traffic movements may be addressed. This takes two forms. The first is movement type mix, where capacity is maximised by a 1 arrival / 1 departure flow. At present, scheduling of traffic movements is characterised by 'bunches' of arrivals followed by 'bunches' of departures. Minimisation of this distribution could allow capacity enhancement of approximately 4 movements per hour in most situations.

The second benefit of managing scheduled demand is a greater ability to sequence aircraft in the most expeditious manner. For example, the time that must be left between a Boeing 737 and a following ATR 72 aircraft is less than between a Boeing 737 and a SW3 Metroliner. It is therefore more efficient to insert the ATR 72 between the Boeing and the Metroliner, as the three movements could then be completed in a lesser time than would otherwise be the case. This function is already performed to some extent by air traffic controllers, but could be achieved to a greater extent through schedule planning.

If airport resources were managed by these means, the outcome would be beneficial in several forms. First and foremost is the reduction, or possible elimination of the congested condition of Wellington airport during weather conditions below circling minima. Second, the delay experienced at Wellington during other weather conditions, and at other airports could be reduced or eliminated through management of traffic schedules. Third, enhancement of the existing capacity levels of these airports will be achieved through greater standardisation of aircraft types. Finally, this option offers greater opportunity for capacity maximisation through improved movement type mix.

The cost of this option must be contemplated in two forms. Primarily, the cost associated with upgrading of aircraft types, and subsequent operation of these aircraft must be considered. Initial purchase, maintenance, operating equipment, fuel and crew costs are the relevant components of this cost. This will be offset to some extent by the higher seating of these aircraft and the potential revenue this may generate. The cost will nevertheless be substantial, but cannot be considered in the same category as the cost associated with airport relocation or the construction of additional runways.

Conclusion

This research has shown that the majority of delays at New Zealand airports are due to poor scheduling of aircraft movements, rather than to true congestion. The exception to this is delays incurred during conditions of poor weather at Wellington airport, where capacity is greatly exceeded for substantial periods of time.

An appropriate solution, therefore, should beone which takes account of the causes of delay and the level of intervention necessary to effect a solution. The relative cost of delays must also be considered, as must the probable future extent of the problem. A further consideration is the time required to effect any solution.

Auckland and Christchurch airports each have a substantial level of available capacity. It is unlikely that delays due to congestion will affect Christchurch airport in the foreseeable future, unless the airport becomes subject to the type mix changes

and greater frequency of flight which characterises operations at Auckland and Wellington. Indeed, Christchurch would be more accurately consideredas a model solution to the problem of congestion than as a potential source of that problem. The option of expansion must also be considered as most possible for this airport, given the lack of terrain and space restrictions.

Auckland airport does not currently experience congestion. Delays at this airport are due almost exclusively to schedule delay – a problem which is most efficiently dealt with by resource management means than by wholesale expansion of capacity. Forecasted future levels of demand, however, indicate that capacity may well become a problem for Auckland within the next five to seven years. By 2005, congestion could reach the level presently experienced by Wellington airport on below circling days. Management of scheduled demand and air traffic control procedures, however, offers an adequate solution to the level of excess demand indicated by this forecast.

This research has shown that the capacity of Auckland airport could be enhanced significantly by the application of the co-ordinated system of air traffic control which is utilised at Wellington and Christchurch airports, and by improvements in the mix of aircraft types using the airport. As well as raising capacity, improving type mix also offers the benefit of reducing current levels of demand in terms of aircraft numbers. This benefit would extend to future operations. Managing schedule distribution and movement types provides the means for available capacity to be maximised.

By these means, it is possible to raise the available capacity of Auckland airport by approximately four aircraft movements per hour. While this is not sufficient to support continued growth of traffic numbers beyond 2005 without congestion occurring, this solution offers an immediate solution to the present problem of schedule delay and forecast congestion. This is probably the most significant aspect of this solution.

Wellington airport currently experiences a serious congestion problem during weather conditions which are below circling minima. For this reason, it is essential that an appropriate solution to this problem be identified and initiated immediately.

Cost issues cannot be ignored in any evaluation of a solution to congestion at Wellington (or any other) airport. The cost of relocation, or of extensions to the existing runway at Wellington must be considered in the tens or hundreds of millions of dollars. When balanced against a total industry cost of some 15,000,000 Kg of fuel annually, it is difficult to justify this expense. Further, the majority of this cost of delay stems from the schedule delay that occurs on a daily basis at all three airports.

This does not, of course, take account of the ongoing cost of delays in terms of crew, maintenance, and inconvenience. But these factors become important only when delays are extreme. The additional industry cost of any of these factors is unlikely to be significant when delays experienced are in the three to five minute range. True congestion, however, such as that experienced at Wellington airport raises both average and maximum delay. The ability of airlines and air traffic control to dissipate that delay is also reduced, thereby ensuring that ongoing effects of delay are more widespread. The size of the congestion problem at Wellington airport, combined with future forecasted levels of delay demand that an immediate solution be found to this problem.

Any attempt to either construct a second runway or to extend the existing runway at Wellington (cost and feasibility issues aside) is insufficient to solve the problem on the basis of time required alone. Both options will require reclaiming of land followed by runway construction. The time required to achieve this may be measured in years, rather than weeks or months. Further, this does not address the issue of capacity decline during conditions below circling minima. In other words, while additional runways or increasing existing runway length may allow some increase in normal available runway capacity, it will not provide a solution to the problem across all conditions. Given that congestion at Wellington occurs predominantly during below circling minima conditions, this option is, in fact, no solution at all.

For these reasons, the option of managing existing resources to maximise airport capacity is identified as the best option to solve this problem. This is the only available option which offers an immediate and feasible solution to the congestion problem, and at minimal industry cost. It should also be stressed that this option in no way precludes or prevents the simultaneous or future implementation of any other option. Rather, it is a solution which may be implemented equally effectively on its own or in conjunction with other options.

The principle requirements of this option are:

1. Restriction of aircraft types using the airport during peak demand periods to those which can meet standardised performance criteria – E.g. 170 Knots on final approach to a distance of 4 NM, and speed/climb performance criteria.
2. Management of demand schedules in accordance with available capacity.
3. Management of demand schedules to maximise capacity – via movement types and arrival/departure orders.

The principle benefits of this option are:

1. A large reduction in, or possible elimination of the capacity degradation that presently occurs during below circling minima conditions. In other words, airport capacity will remain nearly constant throughout all weather conditions (fog / runway closure excepted).
2. A small increase in total airport capacity.
3. A reduction of the total number of aircraft movements presently occurring through utilization of larger aircraft – thus providing spare capacity for some future growth.
4. A low cost and immediate solution.

Glossary of Terms and Abbreviations

ACNZ Airways Corporation of New Zealand Limited.

Aerodrome A defined area of land intended to be used wholly or in part for the arrival, departure and surface movement of aircraft.

Aerodrome Meteorological Minima The limiting meteorological conditions specified for the purpose of determining the usability of the aerodrome either for taking off or for landing.

AFTN Aeronautical fixed telecommunication network – a world wide system of fixed circuits provided, as part of the aeronautical service, for the exchange of messages and/or digital data between aeronautical fixed stations.

Ardmore Training Area Airspace surrounding Ardmore aerodrome which may restrict departure traffic from Auckland airport.

ATDb Aviation Traffic Database – a database of air traffic movements within New Zealand, including take-off and arrival times of flights, held by ACNZ.

ATAG Air Transport Action Group.

BADA Base of Aircraft Data – aircraft performance summary data reported by Eurocontrol.

CAA Civil Aviation Authority (N.Z.)

DFS Deutsche Flugsicherung GmbH. (Federal Republic of Germany)

DME Distance Measuring Equipment.

Eurocontrol European air traffic service provider

FAA Federal Aviation Administration (U.S.)

IATA International Air transport Association

IFR A flight conducted in accordance with instrument flight rules.

ILS Instrument Landing System – navigational system encompassing Height (glideslope) and range (localiser) information. Usually used in conjunction with DME.

IMC Instrument Meteorological Conditions: Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, less than The specified minima for visual conditions.

Knot Nautical miles per hour

Missed Approach The procedure to be followed if the approach cannot be continued and a landing made

Mixed mode Use of a runway for both arrival and departure movements

Movement Take off or landing.

NATS National Air traffic Service (U.K.)

NDB Non-directional radio beacon – a navigational aid for aircraft.

NM Nautical Mile

PACE Program for Airport Capacity Efficiency

Parallel Operations Simultaneous use of two parallel runways, usually one runway designated for arrivals, the other for departures

Radar Separation The separation used when aircraft position information is derived from radar sources.

Radar Vectoring The provision of navigational guidance to aircraft in the form of specific headings, based on the use of radar.

Rwy 34 Runway 34 – refers to runway vector – in this case, a runway oriented 340 degrees (magnetic). Opposite vector is 16 (160 degrees). Similarly, Runway 23 (230 degrees), with opposite vector 05 (050 degrees).

Separation Spacing of aircraft to ensure their safe movement in flight and while taking off and landing.

Single Mode Operations Use of a runway for specific purpose of take-offs OR landings

TIDs Tower Initiated Departures

Titahi Bay 13 NM north of Wellington, beginning of instrument final approach to Runway 16.

Tory VOR VOR located at 'Tory', S41 11 09, E174 21 45. Used as a waypoint and enroute hold for aircraft arriving at Wellington.

Vector Runway orientation (direction of use).

VFR A flight conducted in accordance with visual flight rules.

VMC Visual Meteorological Conditions: Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, equal to or better than specified minima.

VOR VHF Omni-directional radio range – a navigational aid for aircraft.

WIAL Wellington International Airport Company

AERODROMES / AIRPORTS

NZAA	Abbreviation for Auckland aerodrome.	*S*37 00 29	*E*174 47 30
NZAP	Taupo aerodrome	*S*38 44 23	*E*176 05 04
NZAR	Ardmore aerodrome	*S*37 01 47	*E*174 58 24
NZCH	Christchurch aerodrome	*S*43 29 15	*E*172 32 02
NZDN	Dunedin aerodrome	*S*45 55 41	*E*170 11 54
NZGS	Gisborne aerodrome	*S*38 39 48	*E*177 58 42
NZHN	Hamilton aerodrome	*S*37 51 59	*E*175 20 07
NZMF	Milford aerodrome	*S*44 40 24	*E*167 55 24
NZNP	New Plymouth aerodrome	*S*39 00 31	*E*174 10 45
NZNR	Napier aerodrome	S39 27 57	*E*176 52 12
NZNS	Nelson aerodrome	*S*41 17 54	*E*173 13 16
NZNV	Invercargill aerodrome	*S*46 24 54	*E*168 19 12
NZPM	Palmerston North aerodrome	*S*40 19 14	*E*175 37 01
NZPP	Paraparaumu aerodrome	*S*40 54 17	*E*174 59 21
NZQN	Queenstown aerodrome	*S*45 01 16	*E*168 44 21
NZRO	Rotorua aerodrome	*S*38 06 33	*E*176 19 02
NZTG	Tauranga aerodrome	*S*37 40 19	*E*176 11 46

NZWB	Woodbourne aerodrome	*S*41 31 06 *E*173 52 13
NZWN	Wellington aerodrome	*S*41 19 38 *E*174 48 19

AIRCRAFT

B767	Boeing 767 aircraft (Twin engine Jet, approx. 220 seats)
B747	Boeing 747 aircraft (4 engine Jet, approx. 420 seats)
B737	Boeing 737 aircraft (Twin-engine Jet, approx.130 seats)
BA46	British Aerospace 146 aircraft (4 engine Jet, approx. 81 seats)
DH8	De Havilland DHC-8 Dash 8 (Twin engine Turbo-prop, 43 seats)
SF34	Saab 340 (Twin engine Turbo-prop, 44 seats)
SW3/4	Fairchild Metroliner III (Twin engine Turbo-prop, 21 seats)
E110	Embraer Bandierante (Twin engine Turbo-prop, 14 seats)
PA31	Piper Chieftain / Navajo aircraft (light twin, approx. 10 seats)
C421	Cessna 421 aircraft (light twin, approx. 10 seats)
C208	Cessna 208 aircraft (single engine, 8 seats)
HEAVY	Heavy category aircraft (above 136,000 Kg maximum weight)
MEDIUM	Medium category aircraft (above 7,000 Kg, but less than 136,000 Kg maximum weight)

LIGHT	Light category aircraft (below 7,000 Kg maximum weight)
L TWIN	Light category twin engine aircraft (EG. PA31, C421)
Single	Light category, single engine aircraft (EG. C208, PA28)

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