New Southern Sky (NSS)
Benefits Assessment

Report to Civil Aviation Authority of New Zealand
to inform the New Southern Sky Governance Group

May 2021

Revision v1.1

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Executive Summary

This report reviews the benefits realised from the NSS programme's delivery of the NAANP. The 2014 Castalia economic analysis and subsequent reports recognised a benefits realisation period for NSS running from 2015 through 2034; this report estimates the benefits delivered to the end of 2020 including the impact of the downturn due to the public health response to the Covid-19 pandemic.

PBN has been progressively implemented through the period, and was substantially complete by the beginning of 2019. Flight efficiency benefits realised are in line with expectations from the 2018 Acuo CBA and include:

- 4.9 M kg fuel burn saved
- 15.4 M kg CO_2 emissions reduction
- $NZ 7.3 M saving in aircraft direct operating costs
- $NZ 5.7 M value of passenger time saved

PBN delivers a marginal gain to every flight using PBN approaches at the affected airports. As such, it continued to deliver benefits in proportion to the volume of air traffic during the downturn in 2020. Despite deep reductions during Covid-19 alert level 4, and ongoing international travel restrictions, the benefits realised during 2020 are more than half those anticipated in normal times as New Zealand's successful elimination strategy for the Covid-19 pandemic means that domestic travel is relatively unrestricted.

- 2020 total air traffic movements at airports with PBN enabled were 68.4% of normal levels
- During Covid-19 alert level 1, the domestic air traffic daily average was 82% of normal levels

Benefits at Auckland and Queenstown airports have been enhanced since the 2018 Acuo report:

- An additional PBN RNP AR approach to Auckland improves the efficient use of airport capacity.
- The Air New Zealand ATR72 fleet is approved to use RNP AR approaches and departures at Queenstown, with the benefit of a reduction in diverted/cancelled flights in poor weather.

The planned enhancements to MetService infrastructure and services have been delivered, enabling improved forecast quality, and weather-based decisions to be integrated into operations, and making weather information more accessible through digital delivery and graphical formats.

The ADS-B surveillance infrastructure is in place, with the fleet progressively being upgraded, although at a pace slower than hoped. Regulatory action in collaboration with users has resulted in significant cost reductions for microlight, glider, and special category aircraft (up to $NZ 7.15M based on estimates in the 2017 CBA), and Director approval for alternative position sources meeting certain requirements is expected to accelerate installation of alternative position sources for aircraft in these categories that previously were unable or unwilling to equip. The surveillance system resilience is to be augmented through the commissioning of a contingency surveillance network to increase system resilience and provide surveillance of non-cooperative targets.

The financial and resource constraints imposed by the downturn in air traffic has deferred some NSS programme components: airport collaborative decision making (A-CDM) with benefits in reduced taxi time and improved on time performance, and implementing PBN approaches at Napier and Gisborne. The potential benefits from A-CDM well exceed those from PBN, however reconsidering the business model may be important to achieving future delivery as costs and benefits do not fall on the same stakeholders.

With the NSS team disbanding in June 2021, there is a need to transfer benefit management internally within CAA. This report outlines approaches the Authority could select to implement an ongoing benefits management regime.

1 Background, Purpose and Approach

1.1 Background

Between 2009 and 2013 the CAA, in conjunction with the Ministry of Transport, Airways, MetService and stakeholders from across the New Zealand aviation sector, developed a National Airspace and Air Navigation Plan (NAANP) in response to the International Civil Aviation Organisation's (ICAO) Global Air Navigation Plan (GANP). In June 2014, the implementation of this plan, led by the CAA and branded New Southern Sky (NSS), began to deliver a ten-year, three stage NSS programme, covering eight separate domains, representing the whole of the aviation system in New Zealand.

The de-facto business case for NSS was an economic cost benefit analysis (CBA), which Castalia delivered in March 2014 and subsequently updated in April 2015. While the main premise of the plan was to deliver safety benefits, a major element of the CBA was to assess the benefits (primarily economic, social and environmental) to be delivered by a Performance Based Navigation (PBN) implementation plan. It outlined a range of interconnected areas where developments driven by the introduction of PBN were to be staged over a ten-year period to bring about significant improvements to New Zealand's airspace and air navigation system.

In 2018 with many of the initial changes implemented the CAA engaged Acuo Ltd to provide an independent and updated view of the expected costs and benefits being delivered by NSS. This used actual data from across the Air Traffic Management (ATM) system and was supported by a detailed technical analysis of operating performance benefits provided by Mahino Consulting Ltd.

1.2 Purpose

This report provides an evaluation of the benefits realised to date, and that may be anticipated in the future as a result of the delivery of the NAANP. Where possible it provides quantitative data on the benefits profiled in previous CBAs (Castalia 2014, 2015, ACUO 2018, ACDM 2019). Where it is not possible to provide quantitative data there is qualitative analysis and commentary. The reason for this evaluation is that the NSS team is disbanding in June 2021, and with the NSS programme reaching completion in 2023 it is appropriate at this point to deliver an evaluation of the benefits and progress on their realisation.

It does not analyse the full spectrum of planned investment and potential benefits associated with the NAANP as the costs and benefits of some elements either have not yet been quantified or, in the view of the reviewer, cannot be quantified sufficiently. This report has chosen to estimate quantifiable benefits at an airport level of detail rather than for individual flights as the cost of a deep-dive analysis is not considered best use of resource given the known large reduction in traffic and the current volatility in New Zealand's aviation system caused by Covid-19.

Covid-19 has had a significant impact on the benefits realisation of the NSS programme. However, benefits, particularly from PBN, accrue in proportion to the volume of traffic. Although lower traffic volume curing the Covid-19 period obtains fewer benefits, it is anticipated that benefits continue to accrue in the present and may be anticipated in the future.

For consistency with earlier reports, previous CBA consultants Mahino Consulting Ltd has been contracted to provide expert analysis. Furthermore, numerous external stakeholders (Airways, Air New Zealand, BARNZ, NZ Airports Association) have contributed data and been consulted on draft reports.

The purpose of this report is threefold:

- Provide a quantitative / qualitative update on the benefits profiled in previous reports

- Outline a framework that will use levels of aviation activity to make an approximate determination on what percentage of the benefits profiled are being delivered.
- Use this framework to approximate the impact of Covid-19 on benefits realisation and to outline the pros and cons of different models for benefits realisation reporting to the NSS programme's end in 2023 and for the life of the benefits delivery period recognised in the Castalia and Acuo reports to 2034.

1.3 Approach

The guiding principles used in the 2018 Acuo report remain the same.

That is "a standard national cost-benefit analysis approach (Treasury's Guide to Social Cost Benefit Analysis (2015), evaluating the extent to which the project is an economically efficient use of resources. The approach is based, to the extent possible, on the national costs and benefits of a NSS programme - a New Zealand welfare perspective – rather than benefits to any group or organisation. Costs and benefits are assessed over the life of the NSS programme and ten years beyond (as used by Castalia) and measured against a counterfactual of what would otherwise have happened. The costs are the costs the NSS programme imposes on the economy (valued at the opportunity costs of the extra resources a NSS programme uses) and the benefits are the extra outputs resulting from the project at values that indicate consumer utility. These values are typically estimated from the willingness of consumers to pay for the NSS programmes' extra goods and services.

Costs and benefits are assessed over the whole period, summed into a single net present value (NPV) indicating whether the use of resources in this NSS programme generates returns over and above the cost of the capital and other costs required."

The scope of this evaluation follows that report and does not seek to quantify any benefits previously unquantified.

The constraints accepted by this report are that a qualitative approach would provide a more appropriate avenue of evaluation. Given the well known large reduction in traffic and current volatility in the sector, and the recency of the 2018 Acuo CBA, the reduced uncertainty that could be obtained by a more in-depth analysis of large quantities of data from the ATM system at Airways may not justify the significantly greater resource required.

As a result, there are a number of assumptions that have been made in the process of delivering this evaluation. They are:

- Covid-19 has had a significant impact on benefits realisation
- The impact of Covid-19 on air traffic has been similar across the country
- The 'as built' PBN implementation is consistent with the design intentions previously modelled
- The fleet and mix of routes flown domestically are similar to the past, except for frequency of operation and passenger load factors at times. A sensitivity test is provided for this assumption.
- The benefits of PBN will be realised for those flights that operate

2 Aviation Activity Levels Since Covid-19

2.1 Covid-19 Timeline

Restrictions on personal movement began in New Zealand on 14 March 2020, with a requirement that anyone entering New Zealand must self-isolate for 14 days. On 19 March the borders closed to all but New Zealanders and permanent residents.

The four level Covid-19 alert system was announced on 21 March 2020. The country immediately entered level 2, transitioned to level 3 on 23 March, and level 4 on 25 March. Over succeeding months, the country stepped down through the levels, returning to level 1 on 8 June.

On 8 August, following an outbreak of Covid-19, the Auckland region returned to level 3, and the rest of the nation to level 2. Restrictions were stepped down over the subsequent weeks, and the country returned to level 1 on 23 September.

The border remained closed until the commencement of quarantine free travel from Australia on 19 March 2021.

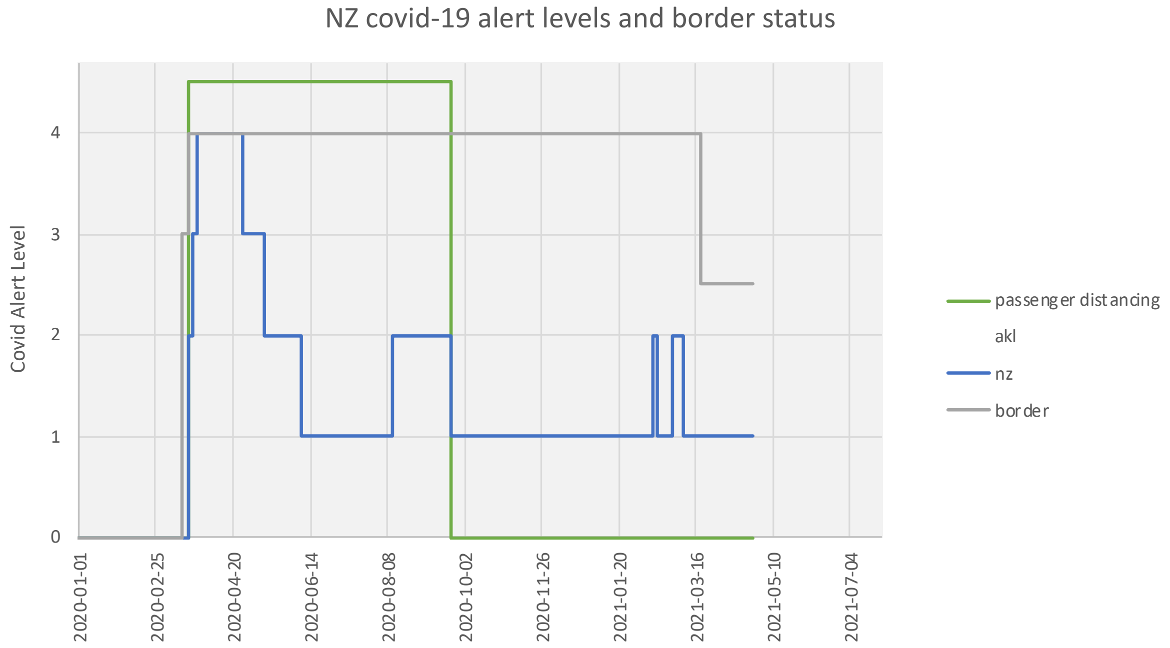


Figure 1 New Zealand Covid Level Timeline

From the start of the Covid-19 response, until 24 September 2020, physical distancing was required on aircraft, reducing the available seats on each flight.

Figure 1 shows the Covid-19 response timeline[1]. The chart shows New Zealand and Auckland Covid-19 alert levels through 2020 and early 2021. The 'border' status is shown at level 3 where full quarantine is required, level 4 when the border is closed, and level 2.5 where the border is open to arrivals from some countries. Passenger distancing is shown when it applied, at level 4.5 for clarity.

2.2 Impact of Covid-19 Response on Aviation Activity

In brief, the constraints on aviation of the Covid-19 alert levels are:

[1] Data source: covid19.govt.nz

- Level 4: People are required to stay at home other than for essential personal movement. Non-essential businesses closed. Travel is severely limited.
- Level 3: People are required to work from home if possible, remain in their household 'bubble' when not at work or school, and remain physically distanced from others. Travel between regions is heavily restricted.
- Level 2: Air travel is permitted, including for recreation and tourism, with caution
- Level 1: Air travel is permitted.

The restrictions on movement and association required by the Covid-19 alert levels created a sharp drop in flight frequency, and in supply and demand for seats. Elevated Covid-19 alert levels restrict the number of passengers that can be carried when physical distancing is in place, and limit the number of passengers seeking or permitted to travel.

The downturn in flight and passenger numbers had two other important effects: the impact on aviation businesses has led to deferring the delivery of some elements of the NSS programme, (mainly industry infrastructure projects) and changing demand has had a material impact on the price of fuel.

This report aims to evaluate the delivery of benefits from NSS to date, taking changes in these factors into account to the extent practicable. Both the changes during 2020, and during the previous five years are discussed in more detail as part of the analysis below.

2.3 Estimating Activity Affecting NSS Benefits

As the previous CBAs outlined, the benefits of the PBN NSS programme will vary with changes in the quantity of air traffic. It is a logical and pragmatic approach for this report to use aviation activity levels as a yardstick to approximate the benefits realisation.

2.3.1 Analysis Framework

The 2018 Acuo report is based on a detailed analysis of air traffic activity during a reference year (2016), by assessing the benefit that would be obtained by each flight as a result of efficiencies gained from the NSS programme implementation. This report aims to estimate the same benefit figures where practicable for each year of the NSS programme to date, by scaling the 2016 reference year according to the key factors that vary over time and location. Rather than using the 'big data' techniques based on a complete set of data for aircraft movements, it scales the 2016 baseline using weighted average figures for the key input factors in each year.

Flight efficiency benefits from the PBN implementation depend on the relative orientation between the runway and the route of flight and are therefore distinctly different for each airport. It follows that this report's analysis operates at the airport level of detail. Furthermore, as it is well known that passenger load factors have been significantly different from normal in some periods during 2020, passenger benefits are separately analysed, based on estimates of the varying load factors along the time line.

Factors Affecting Benefits

Figure 2 below maps the main benefit categories identified in the 2018 Acuo report to NSS deliverables and other parameters that affect the value of the realised benefits.

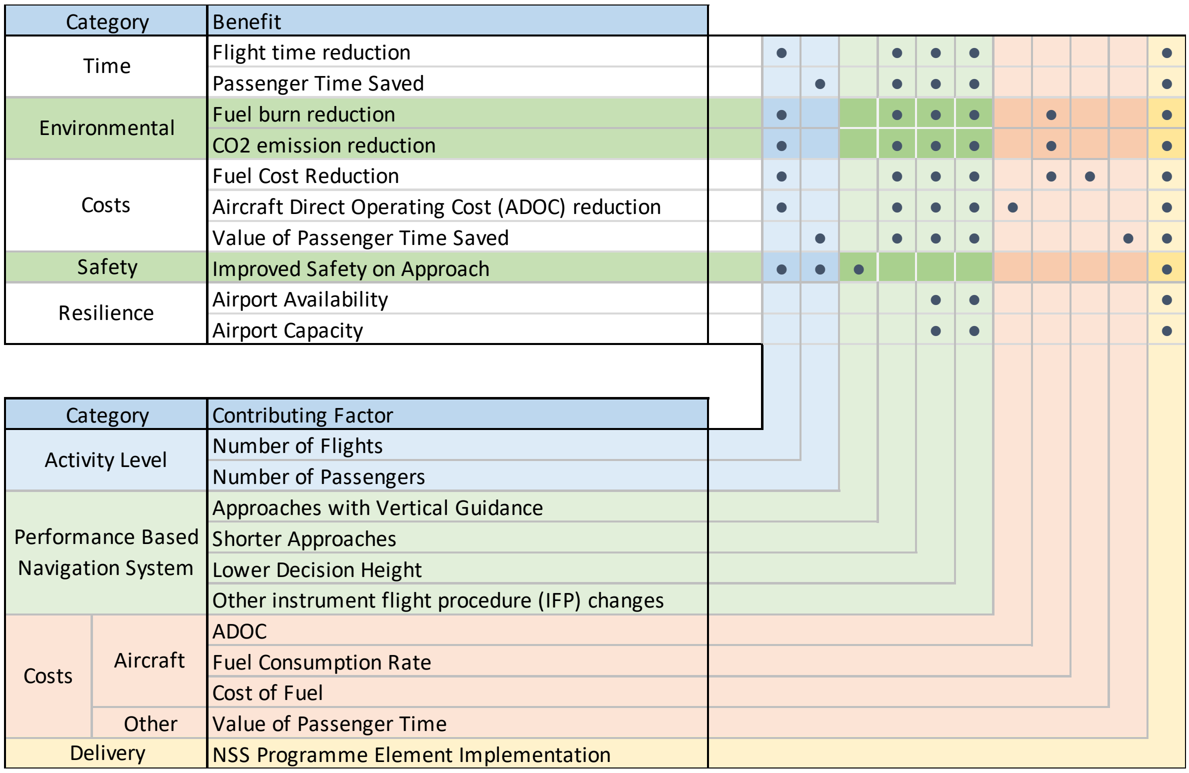


Figure 2 NSS Benefits and Contributory Factors

To approximate the time, environmental, and cost benefits of the PBN implementation, the framework estimates annual change factors for the key contributing variables in aviation activity on flights benefitting from PBN. These are:

- Change in number of flights
- Change in number of passengers
- Delivery of PBN infrastructure

The framework also estimates annual changes in key parameters:

- Change in the cost of fuel
- Change in aircraft direct operating costs (ADOC)
- Value of passenger time

The next section of the report evaluates each of these, both for the Covid-19 era in 2020, and for the preceding five years.

Data Sources

Parameter	Data	Source
Flight Data	Monthly IFR movements at Attended Aerodromes	Airways New Zealand
	Route, Aircraft Type, Available Seat capacity	Air New Zealand
Number of Passengers	Monthly traffic statistics	Auckland International Airport Wellington International Airport
Delivery of PBN Infrastructure	Implementation Dates	Airways New Zealand
Fuel Price	USD Jet Fuel Price NZD/USD exchange rate	US Jet Fuel Price Monitor Reserve Bank of New Zealand
Change in ADOC	Produce Price Index	Statistics NZ
Value of Passenger Time	Value of Time – Public Transport Users	Ministry of Transport
Baseline NSS Benefit Value	All benefit categories	Acuo/Mahino report 2018, Civil Aviation Authority of NZ

Table 1 Data Sources for Benefit Estimation

2.3.2 Aircraft movement numbers

Covid-19 Effect

During 2020, traffic levels varied greatly, in line with restrictions imposed by the Covid-19 alert levels, with near nil traffic in April, ongoing low international movements, a steady re-establishment of domestic traffic with a drop in August/September due to the Auckland Covid-19 outbreak and Covid-19 alert level 3.

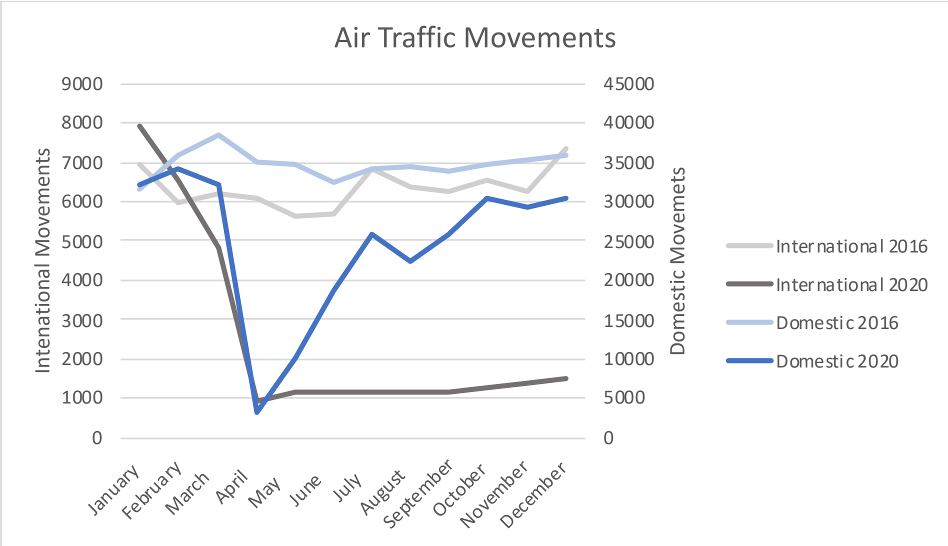


Figure 3 Air Traffic Movements 2016 and 2020

Although there was a near cessation of flights during Covid-19 alert level 4, the successful elimination of the pandemic in New Zealand allowed domestic air traffic to return to a large extent. As a result, the reduction in the value of benefits is smaller than might have been expected. The annual traffic movements at airports with PBN-enabled benefits in 2020 are 68.4% of the previous year.

Trends Since 2015

For earlier years, from 2015 on, the 2018 Acuo report presumed 5% annual compounding growth based on the long-term trend in passenger numbers. This has been close to the growth in international arrivals, with 4.5% compound annual growth between 2015 and 2019 (19.25% total increase), however domestic traffic grew more slowly, by 6.29% (1.53% compound annual growth). In practice, air traffic growth in New Zealand has been variable with many airports showing a shallow decline in movements and some showing a steady growth since 2015[2].

There is a clear division over the last few years between those airports with more or less static or declining IFR movements, and those that showed growth prior to 2020. The following data is sourced from Airways NZ monthly traffic volume statistics.

Most regional airports have more or less constant or declining traffic over the medium term, focussing on the years since 2016. The exception is Wanaka, which had a notable upswing in 2020 from the steady medium-term figure of around 100 movements per year (+/-30) to 263 movements in 2020 with the commencement of new services by Sounds Air in November 2020.

[2] Airport air traffic movement numbers in this section are sourced from Airways New Zealand

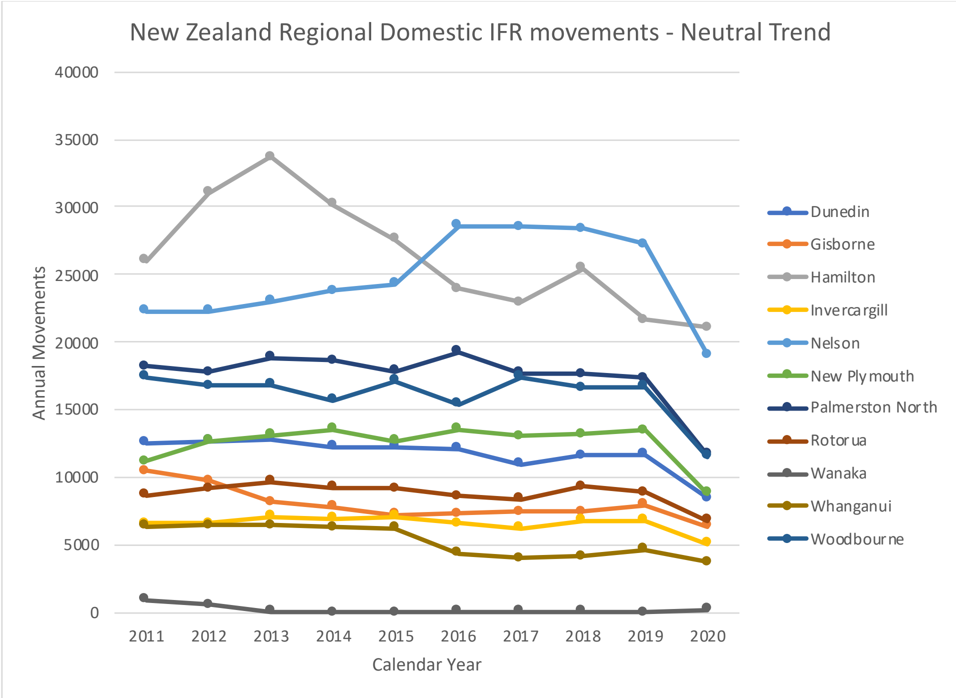


Figure 4 Annual IFR Movements - Regional Airports with static growth

Three regional airports showed firm growth in traffic from around 2015 until 2020.

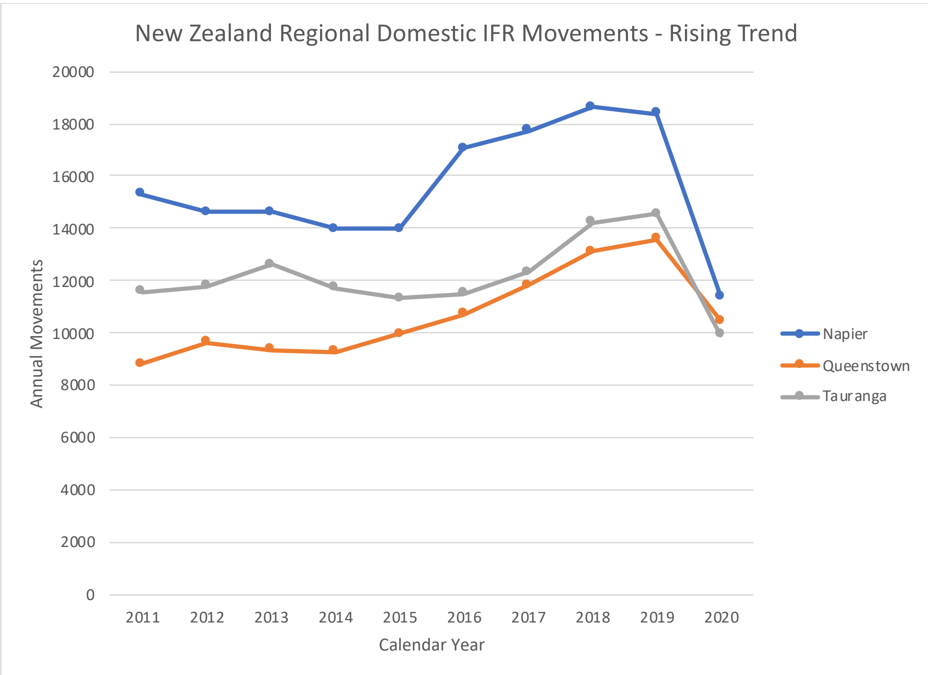


Figure 5 Annual IFR Movements - Regional Airports with growing traffic

At the main centre airports, domestic IFR traffic has been more or less constant in the medium term, except for steady growth at Auckland above the longer-term level, since 2016.

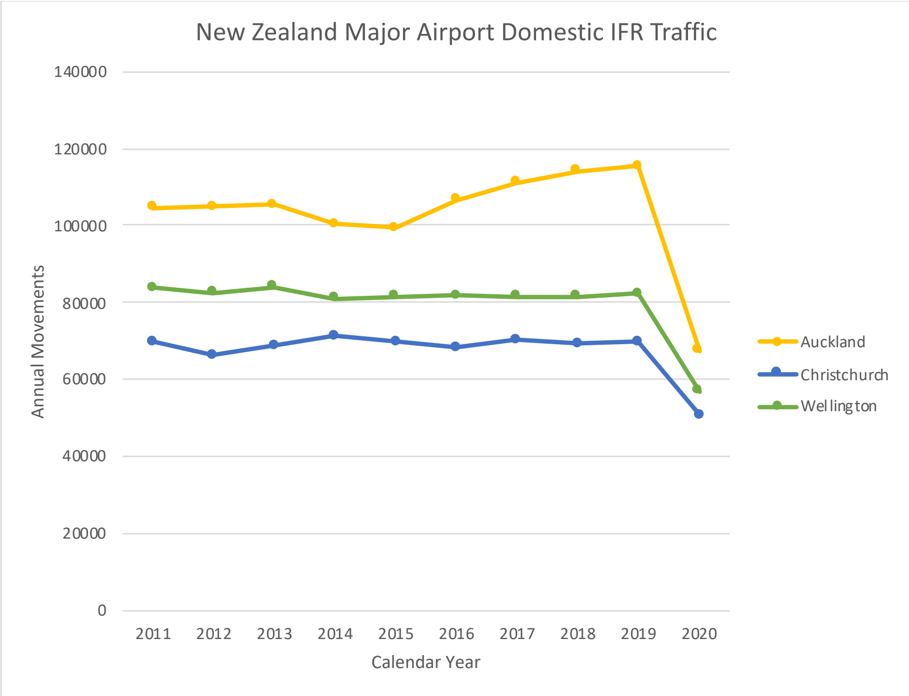


Figure 6 Major Airport Annual IFR Movement Trends

Over the medium term, international movements have increased strongly in Auckland and Queenstown. Christchurch showed a steady annual increase until 2017, and Wellington a more or less constant volume of international traffic except for a small step increase around 2015. For comparison, the volume of international overflights shows a similar, if slightly stronger medium term, rising trend, levelling off in 2018.

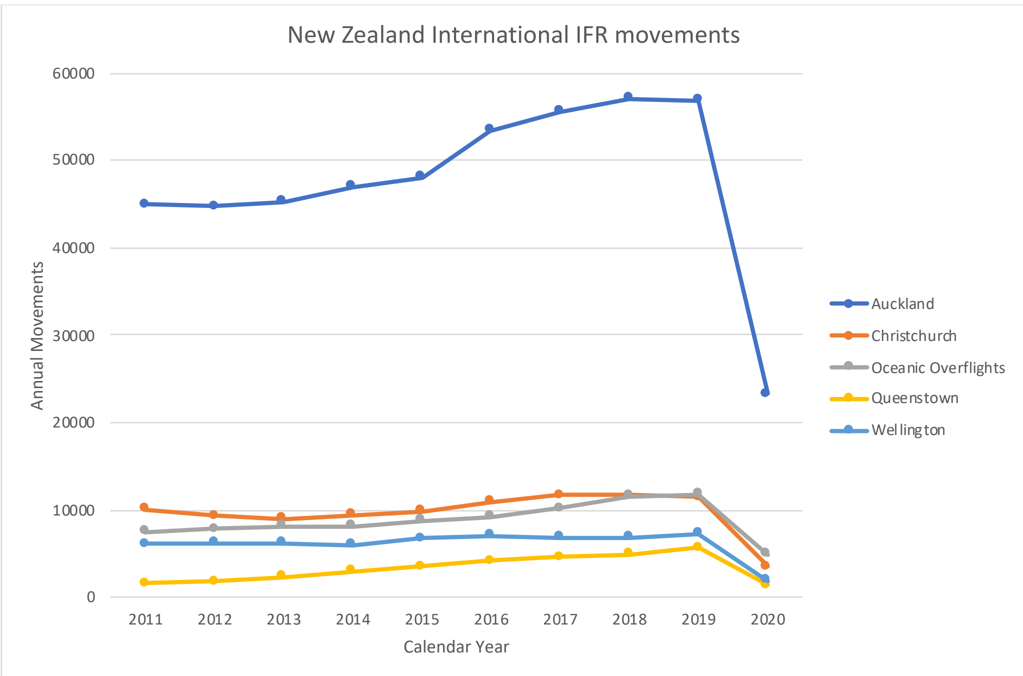


Figure 7 Annual International IFR Movement Trends

The net effect of the generally modest growth in traffic is to reduce benefit realisation a little, compared with that anticipated. Nonetheless, the benefits continue to be delivered by the NSS programme initiatives as a marginal gain to every flight using the PBN approaches.

2.3.3 Passenger numbers

The 2018 Acuo analysis calculates the value of passenger time saved, by estimating the annual number of passengers, using nominal constant load factors for domestic and international flights, and the estimated seat capacity of each flight. The model was calibrated against known passenger numbers at Auckland and Queenstown in 2015 and 2016, and agreed within 2.8% (Queenstown, domestic).

This analysis takes the same approach, by calibrating the modelled passenger numbers against the those reported by Auckland international airport.

Traffic figures published by Auckland International Airport show a steady climb in both international and domestic passengers[3], consistent with the increase in the number of flights, until the start of the Covid-19 pandemic.

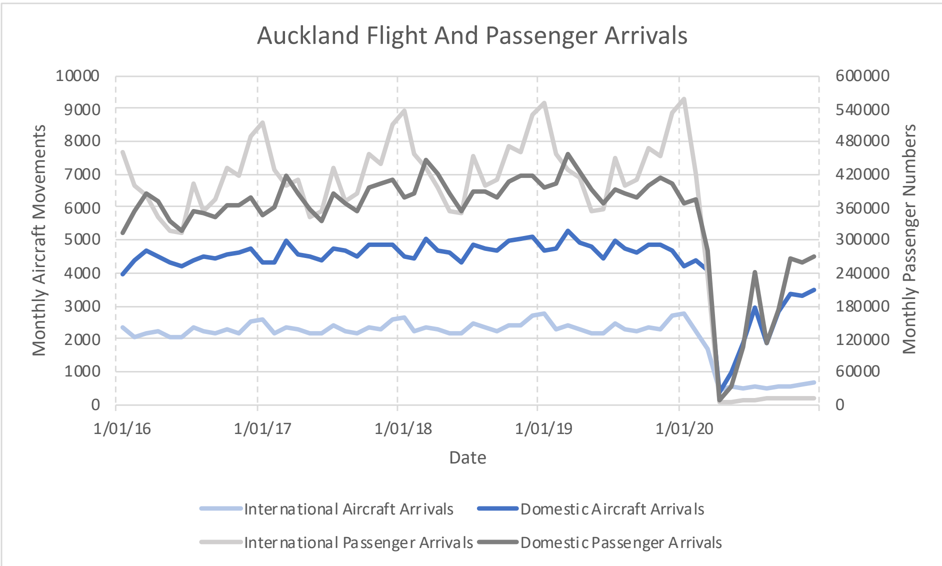


Figure 8 Monthly Passenger Arrivals – Auckland

Covid-19 Effect

During 2020, passenger volume was limited by Covid-19 lock-downs, and partly by the requirement for physical distancing on board aircraft. International passenger numbers remain low, however domestic travel recovered to 67% of pre-pandemic levels by the end of 2020, and close to that level in July 2020 before the outbreak of Covid-19 and alert level 3 in Auckland in August.

Figures from both Auckland and Wellington show the average domestic passenger load returning to typical levels when New Zealand is in Covid-19 alert level 1, including while physical distancing was in place[4]. There is a clear consistency in the trend at both airports, although a different scale. Schedule data supplied by Air New Zealand shows that this was achieved by using some higher capacity aircraft on certain domestic routes (A321neo, Boeing 777, and Boeing 787)[5] for short periods.

[3] Passenger figures source: Auckland International Airport monthly traffic updates
[4] Source for Wellington passenger figures: Wellington International Airport traffic reports
[5] Source: Air NZ flight data (supplied)

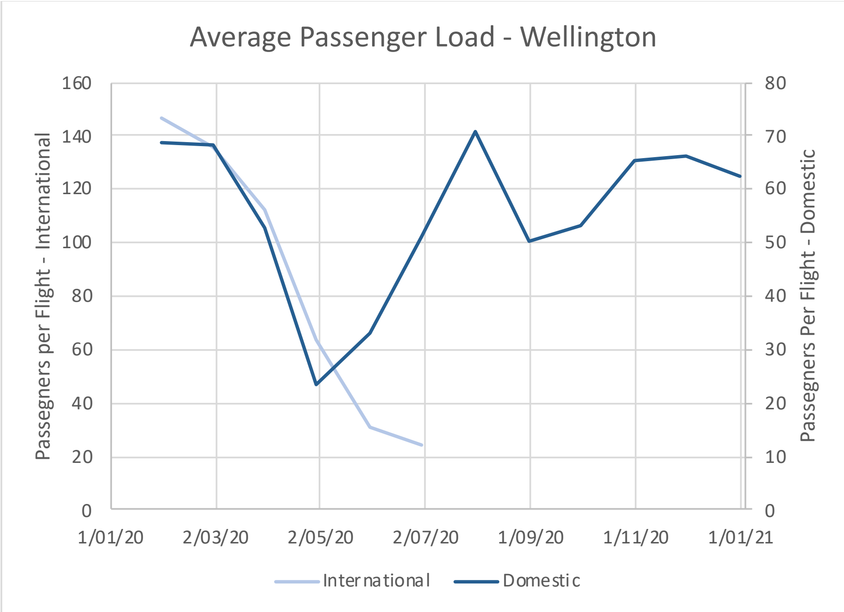


Figure 9 Average Passenger Load – Wellington

International passenger loadings have stayed low throughout 2020 since the start of the pandemic.

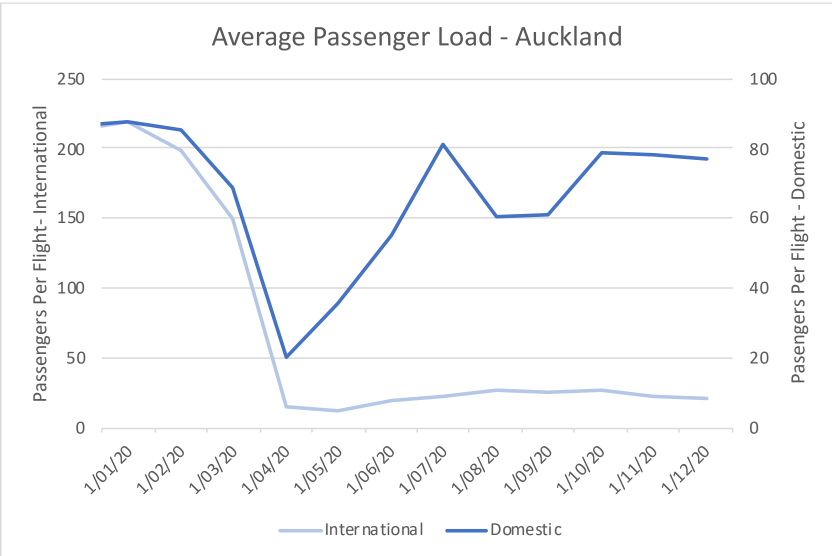


Figure 10 Average Passenger Load – Auckland

Figure 9 and Figure 10 illustrate the average load factor for international and domestic flights arriving at Wellington and Auckland. The impact of elevated Covid-19 alert levels is clear, with fewer passengers willing to travel during an elevated Covid-19 alert level period. Interestingly, the load factors return to normal levels between lock-downs, and since. This does not reflect a rise in passenger numbers which have not returned to normal. Rather, it is in part due to the airline response to changing travel demand, which is to alter or reduce schedules, and select aircraft with different capacity to service the demand for travel.

The effect for PBN benefit realisation is to reduce the passenger time savings, however with relatively standard load factors in practice the benefit rises and falls with the changing number of aircraft movements.

2.3.4 PBN programme delivery

The delivery of the PBN programme has been progressive throughout the period, and occurred in stages over several years at major aerodromes. The PBN implementation at most locations aligned with plan, though deferrals did occur. PBN implementation is reliant on a range of stakeholders with sometimes competing priorities and constraints around resource. Extensive lead-in time can be required, particularly for airspace change and for community noise engagement relating to sensitive flightpath changes.

The PBN implementation for Hawkes Bay and Gisborne has been affected by the Covid pandemic. In response to the drop in revenue resulting from the drop in air traffic, Airways New Zealand called for a review of service requirements at several airports, including Gisborne and Hawkes Bay. A decision was made to defer development of navigation infrastructure at those airports until future service requirements are confirmed. PBN implementation at these two locations has been deferred until at least the end of 2022.

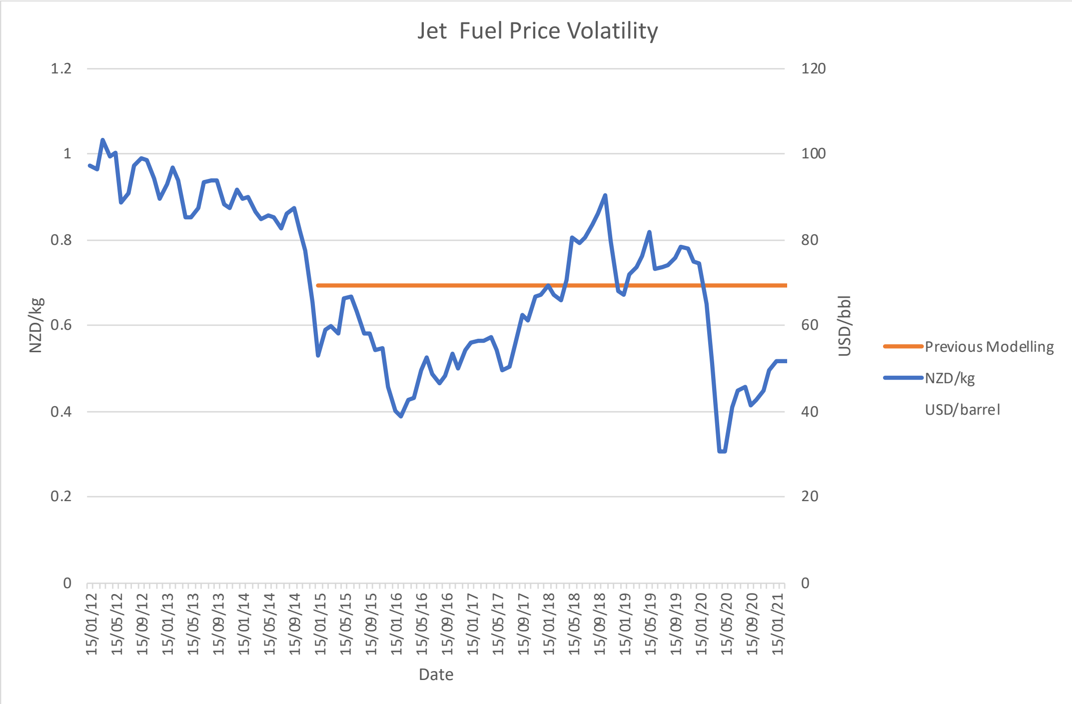
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
NZQN	15/11/2012										
		NZWN	24/07/2014								
		NZNV	24/07/2014								
		NZWK	18/09/2014								
			NZCH	2/04/2015							
			NZAA	28/05/2015							
			NZDN	23/07/2015							
				NZRO	10/11/2016						
				NZHN	10/11/2016						
				NZWU	10/11/2016						
				NZTG	10/11/2016						
				NZPM	10/11/2016						
					NZWB	14/10/2017					
					NZNP	9/11/2017					
						NZOH	24/05/2018				
						NZNS	8/11/2018				
					Planned	11/08/2018	NZWP	23/05/2019			
						Planned	8/11/2018			NZGS	1/12/2022
						Planned	8/11/2018			NZNR	1/12/2022

Table 2 Full Benefit Commencement Dates - PBN Implementation

2.3.5 Fuel Price

The price of jet fuel has fluctuated continuously over the period, as have air traffic volumes. For this reason, whereas the 2018 Acuo analysis used a nominal representative fuel price, this analysis estimates a monthly weighted fuel price from the fuel price in USD, the NZD/USD exchange rate and the New Zealand air traffic volume at the time.

Overall, there is a reduction in the cost of fuel saved. The weighted cost of fuel saved as a benefit of the PBN implementation during the period is 0.616 NZ$/kg, an 11.3% reduction.



Data source: US Jet Fuel Monitor (fuel price), Reserve Bank of New Zealand (NZD/USD exchange rate)

Figure 11 Jet Fuel Price Fluctuation

2.3.6 Value of Passenger Time

The 2018 Acuo report used the value of time for road users in the Economic Evaluation Manual developed by NZTA/Waka Kotahi and published in 2002, using a single figure averaging business and leisure values.

This analysis uses updated figures from the NZTA/Waka Kotahi "Monetised Costs and Benefits Manual" (February 2021). The values have been revised down – a 30.1% reduction.

Purpose	2002 Value	2020 Value
Business	33.16	23.85
Leisure	10.84	6.90
50/50 Business/Leisure	22.00	15.375

Table 3 Value of Passenger Time

3 Impact of Covid-19 on NSS Benefits

3.1 The Benefit of Shorter Flightpaths

The cost, fuel burn, and environmental advantages of PBN arise from design changes to the instrument flight procedures which are enabled by the nature of PBN. PBN incorporates area navigation, which enables arbitrary flight paths not constrained to flying direct lines to or from ground-based navigation aids as was previously the norm using conventional navigation systems. Procedure designers took advantage of this flexibility to design shorter approaches at the airports served by PBN, creating a marginal advantage for each flight using these PBN approaches[6]. This shortened flight path gives rise to the reported benefits of reduced flight time: reduced fuel burn, other aircraft direct operating costs, exhaust emissions, and passenger time.

The marginal gains for each flight on the instrument approach depend on the relative alignment between the inbound flight path and the landing runway. Flights arriving directly toward the duty runway fly “straight in”, and no benefit can be obtained. Flights arriving from the opposite direction save twice by flying a shorter distance to their final turn, and then a shorter approach. The benefit of PBN for shorter approaches therefore depends on the route and runway used and flight frequency per route/runway pairing.

The scale of savings also depends on how much shorter the final approach is. The design “template” used at most airports created approaches 2nm shorter than previous but, as discussed in the 2018 Acuo report, this differs at Auckland, Wellington, Christchurch, and Queenstown due to local details including terrain and the opportunity to use tailored higher precision RNP AR procedures.

The net benefit of the shorter PBN flightpath depends on the accumulated marginal flight distance advantage obtained by each flight, and therefore varies with the total volume of air traffic using each instrument flight procedure. Net savings overall are simply the aggregate of the marginal gains for each flight and rise or fall with the change in the total number of flights. Modelling the benefits therefore needs to take into account the reduction in approach path length, and the route and frequency of flights.

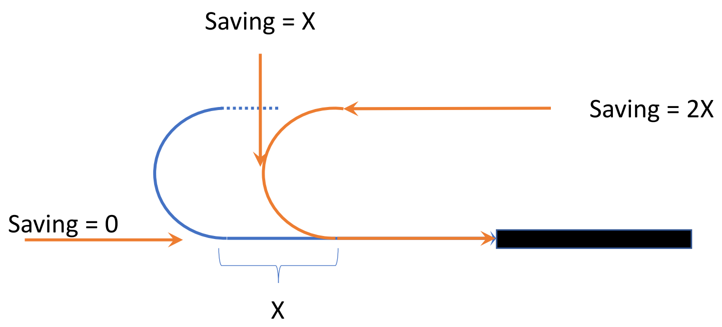


Figure 12 PBN Approach Path Distance Reduction

3.1.1 Benefit Estimation

This analysis aims to estimate approximately the NSS programme benefits, by scaling the 2016 benefits model used in the 2018 Acuo report appropriately to account for changes in activity, cost factors, and PBN implementation dates.

[6] PBN design includes departures, enroute, arrivals and approaches. Track-shortening has been enabled for all phases of flight; approaches provide the most obvious and measurable savings. Quantifying realised benefits for other than approach phase of flight is challenging and resource intensive owing to the variety of off-route flying that can occur due to interventions such as radar vectoring and weather avoidance.

A finer time granularity is needed to adequately model the effect of the significant changes in activity over short periods of time during 2020. To better capture the impact of short-term variability this analysis uses a monthly granularity for rapidly changing factors, including aircraft movement numbers, passenger numbers and fuel price. Relevant monthly data is available for the period covering the NSS implementation phase (2015 onwards), making this technique applicable to the NSS programme as a whole.

Estimating the benefits delivered by NSS by scaling the previous analysis is necessarily approximate. The result depends on the degree to which the period being estimated diverges from the fixed aspects of the 2016 model. The following description of the estimation method identifies where approximations may occur.

As with the 2018 Acuo report, Auckland and Queenstown airports are omitted from this section of the analysis, and treated separately.

Number of Arriving Flights

This analysis uses IFR movement data supplied by Airways which is believed to be accurate.

Flight Distance Saved

Flight distance saved is proportional to the number of flights. It is estimated by scaling the 2016 model according to the number of flights in the estimation period.

In scaling the model year, the implied assumption is that the ratio of traffic between the various routes in later years are sufficiently similar to make the scaling approach valid. Because benefits resulting from flight path reduction are route dependent, this assumption is sensitive to a change in the ratio of traffic volumes between the various routes serving each airport.

A sensitivity analysis shows that the approximation uncertainty resulting from this assumption is small. Comparing Air New Zealand flight data for the 2018 and 2019 summer seasons (November through February) with flight data for calendar year 2020 shows a maximum variation in flight distances saved of between -5.1% and +3.8% at some airports in certain months due to change in the *relative* frequency of flights on the routes serving the airport . However, the maximum variation coincides with minimum traffic levels, when the flight schedule differed most from normal schedules. Weighted for traffic volume, the net effect on *annual* accumulated benefits is to understate the benefits in 2020 (for Air New Zealand) by 0.75%. Because domestic IFR traffic is dominated by Air New Zealand, this level of uncertainty is likely to be indicative of the accuracy of the method. Conservatively, a 1% margin of error could be assumed.

Flight Time Saved

Flight time saved is proportional to the number of flights, and the speed of each aircraft. It is estimated by scaling the 2016 model according to the number of flights in the estimation period.

The quality of this estimate depends on the mix of aircraft types on each route being substantially similar to that in 2016. From flight data supplied by Air New Zealand, it appears to be true for most routes prior to 2020. The 2018 Acuo model used a standardised figure for aircraft speed in three broad categories: heavy jet, medium jet (single aisle), and turboprop aircraft. Provided that services are not substantially replaced by aircraft in a different category the approximation should be reasonable. The speed difference between heavy and medium jet in the 2018 Acuo model is 8%, however the difference between turboprop and jet is 2:1. There is no evidence of a large-scale change from turboprop to jet services. Substituting larger aircraft on Christchurch-Auckland services occurred to some degree during the early part of the Covid-19 pandemic, however these too occurred at low traffic periods. The resulting modelling error at an annual scale is also modest.

Fuel Saved

Fuel saved is a function of the flight time saved, the fuel consumption rate of each aircraft, and the number of flights. It is estimated by scaling the 2016 model according to the number of flights in the estimation period.

The quality of this estimate depends on how similar the fleet in the period being modelled is compared with 2016. This is a function of the fleet mix using the routes/runways and the comments on approximations for “flight time saved” apply. The fuel flow difference between the aircraft categories is typically 4:1. For example, the use of larger jet aircraft on domestic routes during winter 2020 will mean that the scaled model will under-state fuel consumption, and therefore under-state the savings benefits.

Value of Fuel Saved

This benefit is estimated by multiplying the fuel saved by the fuel price at the time. The model uses monthly fuel price in NZ$ illustrated in Figure 11.

The estimate is approximate to the extent that airline fuel price hedging and supplier prices make the airline’s fuel cost differ from the model. The outcome is expected to be closer to actual than the use of a fixed global weighted average price.

ADOC Saved

This benefit is a function of aircraft time in use, and varies with flight time saved. This estimate scales the 2016 model by the number of flights, the same scaling factor used for flight time saved.

The value of this benefit is affected the cost of crew, maintenance and insurance as outlined in the 2018 Acuo report. This report inflates ADOC annually using the producer input price index from Statistics NZ.

Number of Passengers

The number of passengers is estimated by scaling the average passenger load for domestic and international flights. The percentage change is calibrated at a reference airport and applied to the 2016 model estimates for each airport in the same time period.

The passenger load factor in this analysis has been calibrated using reported flight numbers and passenger throughput at Auckland International Airport. This calibration is done at monthly granularity to capture the highly variable load factors throughout 2020 in particular. However, because passenger data is available for the entire period being considered, the method has been applied throughout.

As the 2016 model already contains the differences between airports in 2016, applying the same percentage change to each is expected to reasonably approximate the monthly passenger numbers for each location, provided that the relativity between airports remains similar, and the passenger load factors for aircraft at that airport vary in a similar way at all of the airports in the study.

Although counter intuitive, given the apparent variability in aviation and the rapidly changing circumstances in 2020, this expectation may be realistic, particularly for the domestic fleet, as the model covers the main airports of New Zealand (essentially a closed network) and the passengers departing one are the arrivals at another. A sample check shows that the model prediction for passenger numbers at Wellington International Airport are reasonably consistent with published figures, varying from the published figures for 2020 by 0.9%, and in 2016 by 2.2%.

Passenger Time Saved

The benefit of passenger time saved is estimated by multiplying the passenger load by the flight time saved. This figure is therefore subject to the same uncertainty as described for flight time saved.

Value of Passenger Time

This benefit is estimated by multiplying *passenger time saved* with *the value of passenger time*.

PBN Implementation dates

This analysis includes benefits at a destination from the completion date of the PBN approach implementation onwards. Start dates for benefit realisation have been revised from those used in the Acuo report for Christchurch and Wellington airports because the benefits of shorter approaches could be realised at these airports from the time that PBN 'RNAV' approaches were implemented (on the dates in Table 2), whereas the Acuo report used later dates when 'RNP AR' approaches were also implemented. In net present value terms, revising the Acuo estimates for the new dates adds around $1.2m in fuel savings and $2.5m ADOC savings over the period 2015-2019.

3.1.2 Quantified Benefits

Using the above method of approximating the benefits from PBN, for the airports included in the 2018 Acuo study, produces the following result for the period from 2015-2020[7].

The benefits estimated in this report are consistent with the adjusted Acuo estimates. The fuel cost and ADOC savings estimated in this study for the years 2016 through 2019 are within +4%/-4.3% of the revised Acuo estimates. Overall, the estimates in this report, based on actual traffic volumes, are 6.7% lower than the adjusted Acuo estimates which are based on an assumed steady 5% annual increase in traffic relative to 2016 traffic volumes. As noted previously, actual traffic growth has been lower than was assumed.

Year	Arrivals using PBN	Average Flight Distance Saved (nm)	Total Flight Distance Saved (nm)	Flight Time Saved (mins)	Fuel Saved (kg)	Fuel Saved (NZD)	CO2 Saved (kg)	ADOC Saved (NZD)	Passenger Time Saved (hours)	Value of Passenger Time Saved (NZD)
2015	56,400	2.49	141,000	28,800	442,000	256,000	1,390,000	617,000	33,800	519,000
2016	102,000	2.67	274,000	55,000	888,000	420,000	2,800,000	1,240,000	69,400	1,070,000
2017	115,000	2.54	291,000	59,400	936,000	542,000	2,950,000	1,370,000	74,200	1,140,000
2018	129,000	2.39	308,000	64,200	983,000	755,000	3,100,000	1,510,000	79,300	1,220,000
2019	130,000	2.38	310,000	64,700	990,000	742,000	3,120,000	1,530,000	80,700	1,240,000
2020	89,100	2.31	206,000	44,200	639,000	324,000	2,010,000	999,000	35,900	552,000
Total	**622,000**	**2.46**	**1,530,000**	**316,000**	**4,880,000**	**3,040,000**	**15,400,000**	**7,260,000**	**373,000**	**5,740,000**

Table 4 Approximate PBN Benefits Delivered 2015-2020

[7] Note that totals may not equal the sum of the column due to rounding. The figures are shown to 3 significant digits, acknowledging the approximate nature of this analysis.

Comparing 2019 and 2020 directly illustrates the impact of the pandemic on NSS programme benefits.

Year	Arrivals using PBN	Average Flight Distance Saved (nm)	Total Flight Distance Saved (nm)	Flight Time Saved (mins)	Fuel Saved (kg)	Fuel Saved (NZD)	CO2 Saved (kg)	ADOC Saved (NZD)	Passenger Time Saved (hours)	Value of Passenger Time Saved (NZD)
2019	130,000	2.38	310,000	64,700	990,000	742,000	3,120,000	1,530,000	80,700	1,240,000
2020	89,100	2.31	206,000	44,200	639,000	324,000	2,010,000	999,000	35,900	552,000
Difference	-41,100	2.35	-105,000	-20,500	-351,000	-418,000	-1,110,000	-534,000	-44,800	-688,000
	-31.6%		-33.7%	-31.7%	-35.4%	-56.3%	-35.4%	-34.8%	-55.5%	-55.5%

Table 5 The Effect of Covid-19 on NSS PBN Benefits

The pandemic occupied much of 2020. Provided that New Zealand can manage the virus, 2020 may represent the worst case of the pandemic impact. The reduction in annual flight-related benefits is approximately 35%, passenger benefits reduce by 56% (due to lower passenger load factors) and the fuel cost saving benefit is 56% lower due to the lower price of fuel. As previously mentioned, the fuel price figures have higher uncertainty due to purchasing effects not able to be taken into account, such as hedging, buying and pricing practices for New Zealand operators.

Approximate impact of Covid-19 in 2020	Difference between 2019 and 2020
Non-fuel aircraft related benefits	-35%
Passenger benefits	-56%
Fuel cost benefit	-56%

Table 6 Approximate Impact of Covid-19 on Benefit Realisation in 2020

These results are proportional to the downturn in traffic volumes. Compared with 2019, domestic movement numbers reduced by 32%, and international by 62%. That the benefits reduced by approximately the reduction in domestic traffic is consistent with the findings in the Acuo report that the majority of benefits accrue to domestic operations, and the fact that international traffic in normal years is just 16% of the total (9.4% in 2020).

The last observation illustrates the paradox created when assessing NSS programme benefits. These benefits are marginal improvements to an operation. The reduction in benefits in fuel, emissions, and costs do not represent a loss of value, but have reduced because the very same costs, fuel burn, and emissions were not being incurred due to a reduction in aviation activity. Each flight continues to receive the same benefit enabled by PBN.

In summary, the benefits of PBN continue to be realised for applicable flights using the system, making the benefit realisation resilient and sustained.

4 Future Scenarios for NSS Benefits

This chapter describes the potential for other as yet unrealised benefits of PBN and the NSS deliverables, and the effect on benefit realisation of foreseeable operating scenarios during the recovery from Covid-19.

4.1 Airport Accessibility and Resilience

The Kaikoura Earthquake demonstrated the value of airport accessibility for Search and Rescue, Medivac, and general air transport operations to support a community affected by a natural disaster which disrupted normal ground transport supply lines. It is reasonable to suppose that these air services also have value in normal times.

The resilience of these services in a variety of weathers depended on the existence of Instrument flight procedures (IFP) enabling approach and departure from Kaikoura to continue in instrument meteorological conditions. The IFP might be thought of as the aeronautical version of an all-weather road to the airport.

PBN procedures deliver this benefit with more flexible options for flight path routing than conventional IFP, and more promptly and affordably as they need not depend on installing any ground-based navigation aid. The relative simplicity and affordability of implementing new PBN IFP presents the opportunity to improve the resilience and accessibility of regional and community airports which may not previously have considered IFP to be economically viable.

Developing IFP access to regional and community airports may require the current funding model to be reconsidered. Although PBN navigation infrastructure has been implemented by Airways at most airports with an air traffic control service, funded from Airways revenue, few other airports have PBN IFP. However, an air traffic control service is not essential at low traffic airports. For airports with low levels of IFR traffic or little need for operational services from Airways, infrastructure investment is unlikely to be justifiable for Airways, or recoverable from IFR charges. Alternative funding options may need to be considered in these cases where the benefits of IFP for airport accessibility and community resilience may be more social than directly economic and funding from local operators, airport revenue, community rates, national infrastructure budgets or other alternatives might be considered appropriate.

4.2 Foundation for Realising System-Wide Benefits

The infrastructure delivered by NSS lays a foundation for stakeholders to develop further improvements to the aviation system effectiveness through the combined effects of the component parts and collaborative operational initiatives.

PBN enables a more predictable trajectory for flights. In turn this could be used by airlines, ATC, airports and ground-handlers at airport turn-rounds to optimise the timing and flow of air traffic across the network. Section 5.3 below discusses the potential benefits of airport collaborative decision making (A-CDM). Following that, future integration between A-CDM and the existing air traffic flow management (ATFM) can be anticipated to deliver yet more benefits in flight efficiency and on time performance – improving environmental and financial performance as well as passenger experience. Current work by CANSO the air traffic control industry trade association is developing guidance for stakeholders when integrating the operation of A-CDM and ATFM and points to significant possible benefits for users of the air traffic network[8].

[8] CANSO Guide on ATFM/A-CDM Integration, published in October 2020.

As mentioned in the 2018 Acuo report and the 2019 A-CDM report, the benefits from this kind of integration and collaborate go beyond the benefits directly enabled by any one part of the NSS deliverables, creating a result greater than the sum of the parts. New Zealand may be well placed to realise these benefits as it has the advantage of a largely closed network and a small number of stakeholders, well known to each other, who would need to collaborate. It is realistic to suppose that the benefits to stakeholders themselves may be sufficient to motivate an industry led body of work.

4.3 Recovering Post Covid-19

The benefits enabled by the NSS programme rise and fall with changing air traffic levels. Although there is much uncertainty about future levels of air traffic for both the timing and the scale of any recovery, the experience of 2020 can illuminate the range of future benefits that may be realised over the remaining benefit realisation period. This section describes possible future scenarios.

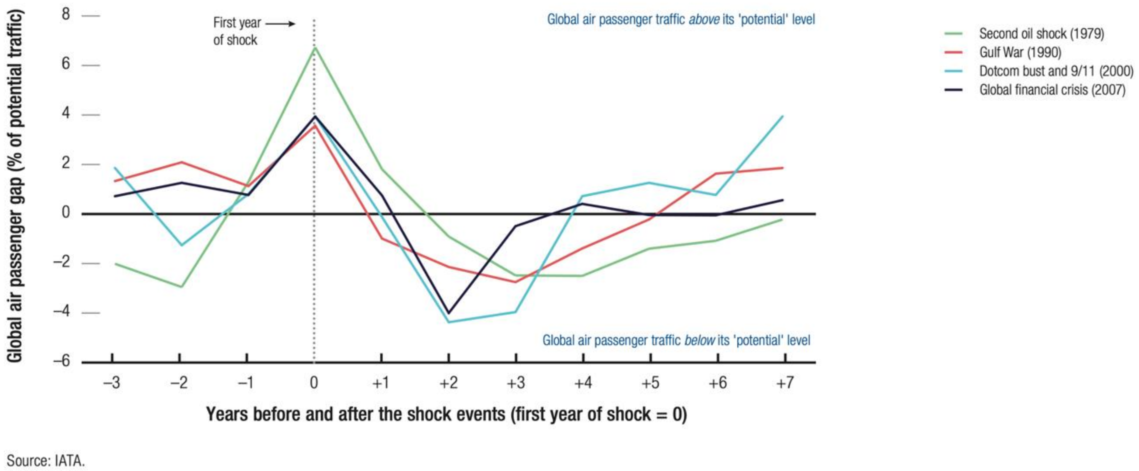
4.3.1 Impact of Previous Shocks on Global Air Travel

For the airline industry, “black swan” events are not rare. Since 1970, shocks that affected air travel include

- 1979 oil shock
- 1980s economic slow down
- 1990-1992 Gulf War
- 2000-2001 “Dot-com bust” and 9/11 New York terrorist attack
- 2002-2004 SARs outbreak
- 2008 Global financial crisis
- 2009 Swine flu pandemic
- 2010 Eyjafjallajökull volcanic eruption

The depth and recovery period varied between each event, as did its geographical spread. At the peak of the SARs crisis in 2003 air traffic at Hong Kong was reduced by as much as 80%[9] but the public health response to the epidemic limited its spread – traffic in many other locations was less effected.

An IATA study of shock events shows that, apart from what turned out to be temporary deviations during the crisis periods, the underlying rate of air traffic growth long term since 1970 has been 4.4% per year[10]. Figure 13 illustrates the nature of the recovery from selected past events over the subsequent several years. Relative to the trend, the shallowest yet longest lasting event was the 1979 oil shock which was followed by an economic slowdown through the 1980s.



[9] Hong Kong Yearbook 2003, https://www.yearbook.gov.hk/2003/english/chapter13/13_20.html
[10] “Global Air Passenger Markets: Riding Out Periods of Turbulence”, David Oxley and Chaitan Jain, IATA 2015

Figure 13 Relative Change in Global air Passenger Volume Before and After Selected Shock Events

Interestingly, the shocks all began at a point of above-trend traffic, as did the Covid-19 pandemic. This suggests that recovery, if and when it happens, is likely to be toward a lower level than that of 2019. This hypothesis is supported by the statistics from the IATA study.

The IATA study characterised the passenger traffic response to shock events based on the events in the study. The result is shown in Figure 14 below. Based on events in the study, "Approximately 72% of the impact of the initial shock persists one year after the event. Two years on, the effect of the shock on global air traffic is down to just over one half of the initial effect, while after five years the effect is just under one-fifth of the initial impact."[11]

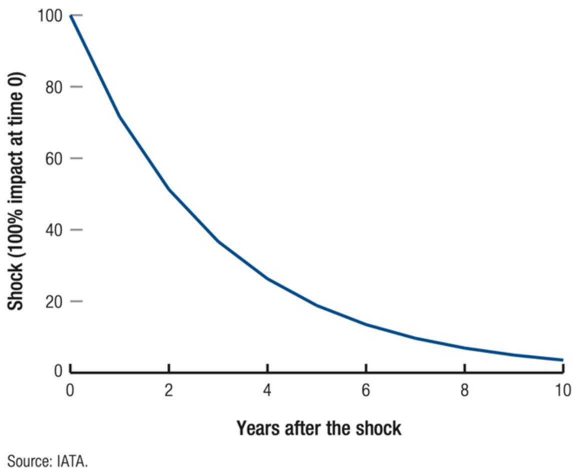


Figure 14 Impulse Response Function of Global Air Passenger Traffic to a Shock (100%) In Time

4.3.2 Future Scenarios for New Zealand

Factors affecting future growth of air travel

The scale and timeline of the growth of air traffic following the current Covid-19 pandemic are obviously uncertain. The main factors of as yet unknown character likely to influence the recovery of air travel include:

- The success of public health initiatives globally to control the pandemic.
- The recovery of public confidence to travel on health and reliability grounds (fear of becoming stranded during a lock-down or travel restriction).
- Other shocks, either for public health or economic reasons.
- Emerging long-term effects of public sensibilities about greenhouse gas emissions.

Accordingly, this report makes no estimate for the eventual scale of recovery, nor the timing of each stage. However, a plausible set of stages can be inferred from the history of 2020. To develop these scenarios, this report makes the following two, conservative, assumptions:

1. Global elimination of the pandemic is required for a return towards the previous normal

The way in which viral illness spreads has become well known during the pandemic. Many are now familiar with the effective reproduction number 'R' from epidemiology, where the R value depends on the characteristics of the illness, the conditions for transmission, and the immunity of the population. (Of these, only *conditions for transmission* can be changed before a method of creating immunity exists). A contagion in conditions with an 'R' value above one will multiply exponentially through a population.

[11] IATA 2015, Annex A

Ongoing epidemics threaten a recovery from the current situation due to the potential for a virus mutation to overcome human immunity. An unfortunate test case exists in Manaus, Brazil (pop 2.2M). A largely uncontrolled Covid-19 epidemic ran its course during 2020, peaking in May. By October 2020 76% of the population had a detectable antibody response[12], above the theoretical threshold for herd immunity[13], and there were modest levels of ongoing illness. However, since late January 2021 a new and larger wave of epidemic has occurred in the city. A new 'P1' variant of the SARS-Cov-2 virus is thought to contribute to the severity of the current wave, due to some (still being researched) combination of three factors: by being more infectious, by overcoming existing immunity, and/or because existing immunity fades over relatively short periods of time.

Active epidemics create the conditions required for the virus to mutate and evolve. This evolution can potentially overcome existing immunity in people who have already contracted the illness previously and potentially the immunity provided by vaccines, making some level of ongoing travel restrictions likely until the disease is controlled globally.

In particular, sudden although perhaps temporary prohibitions on travel that would spread new variants of the virus seem likely. It is also possible that a zone of the world might emerge in which elimination of the virus is maintained and immunity from certain variants has been achieved through vaccination. Reasonably free travel might be possible between countries in that zone, provided all were confident that the zone remained protected from new variants emerging elsewhere. At the time of writing, New Zealand is closed to all travel from India, including by returning expatriate New Zealanders, yet is usually open to quarantine free travel between NZ and the states of Australia, except for occasional temporary closures to eliminate small outbreaks.

2. Quarantine and managed isolation processes will continue in the meantime

Prior to immunity being developed, the only tool to control the spread of disease is to change the conditions for transmission, including via travel restrictions (varying with Covid-19 alert levels) and physical distancing imposed during raised Covid-19 alert levels.

Apart from the obvious impact on travel and tourism, in other sectors the effect of New Zealand's Covid elimination strategy has been to largely maintain economic activity along with a low death rate in comparison to global results[14].

Location	GDP year on year growth Dec 2019 to Dec 2020	Covid-19 death rate per million population
Taiwan	3.11%	0.21
New Zealand	-2.9%	5.4
Australia	-1.1%	35.7
Canada	-5.4%	643.8
USA	-1.16%	1727.3
UK	-9.8%	1878.7

Table 7 Impact of Covid-19 Response on GDP and Death Rate for Selected Locations

We therefore expect these restrictions will continue until the global situation is controlled.

[12] "Three-quarters attack rate of SARS-Cov-2 in the Brazilian Amazon during a largely unmitigated epidemic", Lewis F Buss et al, *Science* 15 Jan 2021, published by American Association for the Advancement of Science. https://doi.org/10.1126/science.abe9728

[13] Resurgence of Covid-19 in Manaus, Brazil, despite high seroprevalence", Ester C. Sabino et al, *The Lancet*, 27 January 2021

[14] GDP data: Statistics New Zealand; Office of National Statistics (UK); Bureau of Economic Analysis, US Dept. of Commerce (USA); Australian Bureau of Statistics; Statistics Canada; National Statistics Taiwan; Death rates: World Health Organisation Covid-19 explorer, Johns Hopkins University Coronavirus Resource Center (Taiwan)

3. Essential travel will include air freight

As part of maintaining economic activity, a level of air freight is currently supported. Air freight volumes through Auckland airport over the last 5 years are shown in Figure 15.

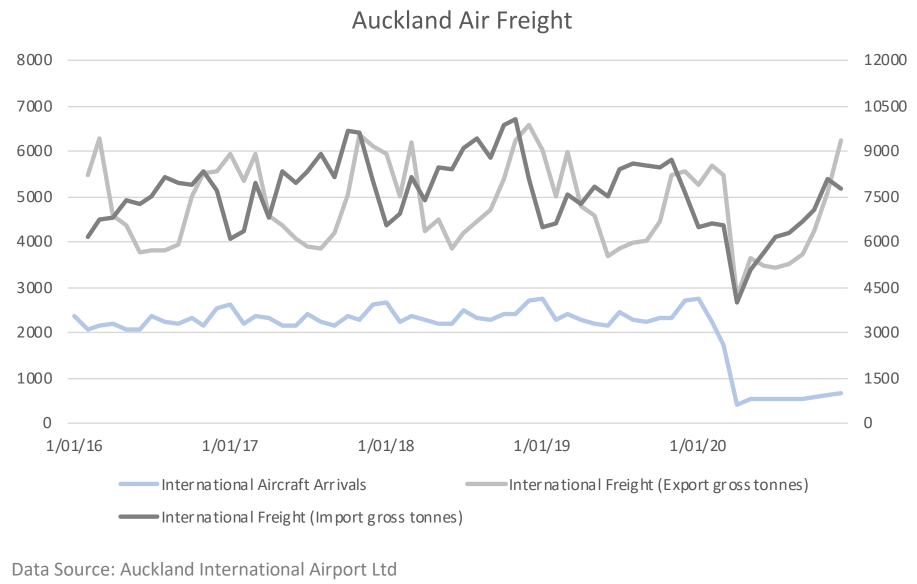


Figure 15 Auckland Air Freight Volume Timeseries

Foreseeable air travel scenarios

Given the public health background, four distinct scenarios could plausibly occur in the medium term, with the country moving between each depending on the circumstances, in order to maintain the elimination strategy for the pandemic.

(a) Complete lockdown apart from essential travel (Covid-19 alert level 4).
(b) Local/Regional Covid-19 alert level 3 restrictions, with level 2 elsewhere (short term to stamp out a localised outbreak).
(c) Covid-19 alert level 1: unrestricted domestic travel, international border tightly controlled
(d) Covid-19 alert level 1, international border open to selected countries / regions, with temporary short notice closures as required

Of these, the first three occurred during 2020. To the extent that the past can act as a reference, the movement data for these periods may illustrate the kind of traffic volumes to be expected.

The following table shows the traffic volumes experienced in 2020, relative to 2016 (level 0 in the table below). 2016 is used as the reference year, primarily because the rapid growth of international travel in 2017-2019 appears to be above the long-term trend, and 2016 may therefore be more representative of the 'average' year. The table is based on the daily average traffic for periods of 2020 corresponding to the scenarios above. Level 1 is taken from July, November and December data, Level 3 from the part of August in which Auckland was at Covid-19 alert level 3, and level 4 from April 2020.

No data is presented for scenario (d) above, as at the time of writing the quarantine free travel between Australia and New Zealand is relatively recent, the travel demand is yet to stabilise and the arrangement continues to be subject to short term closures on various routes due to outbreaks of Covid-19 in some Australian states.

Condition	Domestic Traffic Level	International Traffic Level
level 0	100%	100%
level 1	82%	21%
level 3	52%	16%
level 4	12%	15%

Table 8 Air Traffic Volume at Various Covid-19 alert levels in 2020 Compared with 2016 Reference Period

5 Qualitative Update on Key NSS Benefits

5.1 Efficiency and Capacity – Auckland Terminal Area

Efficient use of Capacity

Since the previous reports, a third PBN RNP AR approach 'S' to Auckland from the south has been implemented to join a 6.5nm final approach. It is intended to be used by domestic traffic, has a daily limit of 25 movements due to noise concerns and is well used.

The limit on daily total movements means that the approaches can be fully utilised, even when total traffic volume is lower than pre-Covid times. From data supplied by Airways, the usage of the approach dropped with lower traffic volumes through 2020, but recovered to normal levels by November 2020, despite lower overall movement numbers. This means that benefits enabled by PBN are fully realised as soon as enough traffic exists, even when overall traffic is reduced.

The primary objective of having several alternative approach paths converging on the final approach at different distances is to efficiently optimise the use of airport capacity. Airways approach manager system (AMAN) pre-selects the target approach for each aircraft to optimise the spacing between each as they land. The increased variety of approaches allows a more finely tuned selection, with the result that airport capacity can be more fully utilised yet efficiently by reducing the cost of airborne holding and radar vectoring that would otherwise be necessary.

The benefit of these approaches is realised through an interplay between the PBN procedure design, and the flow management processes applied by Airways. The Acuo report measured the flight efficiency gains by analysing the flight path of every flight in periods when the approaches were in use (in trial) compared with adjacent periods of time over several months. Because the counterfactual is a mix of visual approaches and radar vectoring in the same general area, the evidence showed little overall gain in flight efficiency, but a clear advantage in sustaining flight efficiency at higher flow rates, by reducing delays due to congestion owing to improved predictability of flight timing. When the airport is busy flight efficiency does not deteriorate as would be expected if no flow and capacity management systems were in place, and the variety of PBN approaches enables that benefit.

It is reasonable to expect this benefit to be realised even at lower traffic levels, as the benefit is realised at peak traffic times. At peak traffic times, the airport capacity is fully utilised, and this tends to be the case even with much lower daily volume. A return to traffic levels experienced in 2019 will be likely simply to mean that the peak flow period is longer lasting. The benefit of the combined PBN design and flow management process should mean that this benefit is realised both at high and at lower daily traffic volumes.

Flight Efficiency

The Acuo report did show clear flight efficiency advantages for the RNP AR arrivals to Auckland on the northern side of the airport, where the counterfactual would be a longer approach using ILS or, now, PBN on the same flight path. These approaches are used by international flights, so it can be expected that the benefits for these flights will fall and rise in line with international traffic volumes. The approaches also have limited daily use due to noise constraints (maximum 16 per day), so the benefits could be realised at quite low traffic levels. The full benefit of these approaches can be expected to be realised with quite modest levels of international arrivals.

5.2 Accessibility – Queenstown

Air New Zealand ATR72 Certified for RNP AR at Queenstown

The Air New Zealand ATR72 operations into Queenstown have been approved to use RNP AR since 20 December 2020. This development raises the benefits realised by RNP AR approaches at Queenstown.

The Acuo report identified the key benefit is a reduced number of diversions in bad weather. The benefit can now be realised for ATR72 flights. The Acuo report estimated a 67% reduction in the number of diversions.

The value of the benefit has also increased for two reasons. Previously, ATR72 flights may be cancelled even when a landing is likely given the weather forecast, because the conditions may be below those required for a non-RNP AR departure and the aircraft would end up stranded in Queenstown, disrupting much of the rest of its daily schedule.

Secondly, the ability to operate using either jets or the ATR72 gives the airline flexibility in poor weather, reducing the cost of diversions, as a third option is practicable. The Acuo report valued this benefit on the basis of the cost of diversion. The main options were either to divert to a nearby airport (usually Invercargill) and bus the passengers to Queenstown, with an associated non-revenue flight to reposition the aircraft, or alternatively to return to origin and accommodate the passengers on a subsequent flight. A third option is now practicable: cancel one or more ATR72 flights, and consolidate passengers on the same day in a single jet flight. This reduces the passenger delay, removes the need for ground transportation, and leaves the ATR72 aircraft available for the remaining days schedule without the need for repositioning. The cost of this option can be expected to be lower in both flight costs and passenger time, raising the relative benefit realised by the RNP AR capability.

5.3 Environmental – A-CDM

The 2019 A-CDM report identified the potential to remove avoidable waste taxi-out time on departure, and the potential to improve on time performance on arrival as the key benefits of A-CDM. From the estimates in the 2019 A-CDM report, the net present value of realising reduced taxi-out time alone from 2022 through to 2034 (using New Zealand Treasury guideline inflation rate of 2% and discount rate of 6%) is NZ$ 81.2 M, a greater benefit than that of PBN. There is a commensurate environmental benefit as the avoided taxi-out time reduces fuel burn and CO_2 emissions.

These benefits remain to be realised as although much of the technical infrastructure has been installed at Airways, and Auckland and Wellington Airports, the associated process changes (‘pre-departure sequence planning’, and aligning the operational objectives of airport, gate handler and ATC stakeholders) and some essential information services (communicating key timing information to gate handling staff and pilots, and accurate enough prediction of flight arrival times) are not in place.

It would be unusual during a disruption of the scale of the Covid-19 pandemic response if all the NSS implementation projects ran to schedule. Despite ‘buy in’ by participants, the A-CDM implementation has stopped during 2020 due to the urgent priorities of airport and ATC stakeholders, both of which are facing significant loss of revenue, the challenge of downsizing operations that do not scale back easily, and the need to reconfigure operations to support the public health response to Covid-19. In Auckland Airport’s case, this included reconfiguring the terminal area to create ‘green’ and ‘red’ zone public spaces, manage separating flight crew from passengers and associated myriad changes to operations and passenger flows.

Despite the potential size of the benefit, the business model for A-CDM may need to be revised before a successful project could be completed as the current business model does not align costs and benefits. Implementing it requires expenditure on process change by airports, gate agents, and ATC, yet the benefits accrue to airline operators. At the same time, all stakeholders are challenged by significant revenue shortfalls and may find the current model difficult to justify as an investable proposition.

5.4 Safety

The Acuo report identified the safety benefit for flights using runway-aligned approaches with vertical guidance (most PBN approaches in New Zealand have this characteristic). The safety on these approaches compared to those without vertical guidance improved significantly, based on large scale statistical studies.

This benefit applies to every passenger on aircraft flying PBN approaches and will simply scale with the number of passengers. This benefit is enduring – wherever PBN has been implemented this benefit will be realised in full by all passengers.

5.5 Implementation of Infrastructure Components

5.5.1 Surveillance – ADS-B

ADS-B Infrastructure completed

The National ADS-B Network was commissioned and fully integrated with the Skyline ATM system on 12 September 2019 and has been in operational use since, with 26 ADS-B receiver sites. These have extended the surveillance coverage volume to achieve an estimated 45% increase over previous MSSR surveillance coverage.

This extension will realise the safety benefits identified in "The 2017 Cost Benefit Analysis of ADS-B Implementation for Below FL-245" (2017 CBA), namely improved (reduced) search and rescue time for missing aircraft, and improved ability for ATC to assist aircraft outside controlled airspace in the event of an emergency, loss of situational awareness and the like.

The key benefit of extended coverage is Safety. Improved (reduced) search and rescue time can be expected for any aircraft accidents occurring within or near to the extended coverage area. ADS-B transmissions contain a unique identification code for each aircraft, allowing the last known location of any particular aircraft to rapidly be discovered. It is reasonable to assume that this will reduce the time required to locate missing aircraft. Additionally, as mentioned in the 2017 CBA, ATC may be able to assist aircraft outside controlled airspace in the event of loss of situational awareness

ADS-B OUT in all controlled airspace and equipage levels

As of 08 Feb 2021, the ADS-B OUT in all controlled airspace rule is now in place with a delayed mandate date of 31 December 2022. This delay of one year was designed to give appropriate relief to a sector dealing with the impacts of Covid-19. Equipage levels have increased significantly since 2018, but are still slower than desired to enable a safe transition by the mandate. As of the end of April 2021, there are 1477 aircraft equipped with ADS-B OUT, out of a total of 4959 aircraft on the CAA register[15].

NSS has identified a 'target' sector of aircraft that will definitely require ADS-B OUT to operate beyond the end of 2022. This sector consists of those who reported commercial activity to the CAA in the year up to February 2020, plus those aircraft who were assumed to be based from, or regularly operate in, controlled airspace – this sector totals approximately 2700 aircraft. However, this estimate was largely based on assumptions and old data, so alternative methods of determining this sector are being considered. Currently this is focused on those aircraft equipped with the necessary transponders to enter controlled airspace – that being Mode A/C or S transponders. The number of aircraft with only Mode A or C transponders is still being investigated, based on Airways ability to accurately confirm how many aircraft are equipped with a Mode S transponder.

[15] The total number on the register is a 'snapshot' that varies. Many of these aircraft will never enter controlled airspace or require a transponder.

As of 30 April 2021, 1894 Mode S addresses (individually identifiable aircraft) have been detected by the ATM system. Of these, 1477 have been confirmed to be transmitting ADS-B data. This shows that almost 80% of Mode S equipped aircraft have already upgraded to ADS-B. Based on current uptake rates, this will increase to 88% of Mode S codes being part of an ADS-B system by the end of 2022.

The pace of installation can be expected to accelerate given recent regulatory action. NTC91.258 revision 2 was released in November 2020, and provides the potential for position sources that do not meet the listed Technical Standard Orders (TSO) to be used as part of an ADS-B system. CAA Director approval would be required. AC91-24 revision 1 was released in February 2021, and provides a blanket Director approval for position sources that meet certain requirements.

The result of this regulatory action opens a pathway for the use of smaller, and potentially lower cost, position source equipment. This is particularly useful for special category aircraft (including amateur-built, warbirds and others) and microlight aircraft. These groups comprise approximately one-third of the aircraft register. Many were reluctant, or simply unable, to install ADS-B prior to the release of the NTC and AC revisions. This regulatory roadblock has now been reduced.

A roadblock continues to exist for gliders, for which the Acceptable Technical Data (ATD) needed to install ADS-B equipment is not widely available. Current action under way by CAA product certification group, in conjunction with proposals by Gliding New Zealand, aims to define ATD allowing gliders to equip with ADS-B, presuming that a regime acceptable to the Authority and practicable for gliding can be defined, affecting approximately 350 aircraft[16]. Gliding New Zealand perceive resolving this road block to be urgent given the number of aircraft to be fitted with ADS-B before the end of 2022.

Safety Benefit – Improved Pilot Situation Awareness

"The 2017 Cost Benefit Analysis of ADS-B Implementation for Below FL-245" (2017 CBA) identified that "greater situational awareness in *uncontrolled* airspace was the most likely and most beneficial outcome to all users, given the potential for voluntary [adoption of] ADS-B IN".

Through the NSS roadshows and anecdotally in the general aviation (GA) community it is becoming clear that this observation is being realised.

A clear benefit of ADS-B IN is enhanced situational awareness. When used as an aid to the VFR pilot's visual scan, it is perceived as a material advantage that can improve the pilot's ability to see and avoid other traffic, reducing potential collision risk. Balanced against this advantage, there is also an increased risk of pilot distraction. Whether the benefit of improved situation awareness exceeds the dis-benefit of distraction may depend on the quality of pilot training in the use of ADS-B in. NSS is preparing pilot briefing material on good practice in the use of ADS-B IN.

Although not mandated, enthusiasm for ADS-B IN appears to be motivating operators to equip with ADS-B IN as well as ADS-B OUT, and creating peer-to-peer social expectations that pilots will leave ADS-B OUT switched on at all times. CAA may wish to track ADS-B IN adoption levels (through the grant scheme) as an indicator of a well-received safety benefit. That it is being adopted voluntarily and widely indicates the value that the aviation community place on this benefit.

CBA changes – cost of equipage

The 2017 CBA states "The incidence of upgrade costs fall most heavily on older and/or lower cost aircraft for which equipment with an STC applicable to those aircraft is less likely to exist, and disproportionately affects the Microlight aircraft sector who suffer from a lack of equipment with an applicable STC, high upgrade costs (due to power requirements) and operate in controlled airspace

[16] There are 346 gliders or power gliders on the NZ Aircraft Register at the time of writing.

relatively infrequently.” The same statement about microlights can also be applied to other special category aircraft and to gliders.

The combination of the revisions to NTC91.258 and AC91-24, plus the proposed solution for gliders, may change the cost benefit analysis significantly. The 2017 CBA estimates the cost for installation on these type of aircraft at $13,500, and for microlights that choose not to equip due to it being perceived as uneconomic, a fall in aircraft value of perhaps $15,000.

In contrast, these two regulatory actions when successfully completed, open the way for cost reductions. Suitable low power consumption equipment is available at approximately $4500-$5500[17] (2017 CBA estimated $7000-$8000), and certification costs of $3000-$5000 per aircraft may have been removed. The cost for these classes of aircraft to equip is therefore approximately halved.

Furthermore, the Government subsidy of up to NZ$2500 (plus GST) to offset the cost of equipage, while not changing the system wide cost of change, changes the perceived value of ADS-B for subsidised aircraft owners and brings the outlay closer to the value the owner may be willing to pay. This can be expected to increase the equipage rate, reducing the number of microlights, and other aircraft, suffering a loss of value and the regulatory impost costs.

Although an approximation, as an illustration of scale: using the figures from the 2017 CBA[18] reducing the cost of ADS-B equipage by 50% for amateur-built, microlight, and glider category aircraft results in a cost reduction of $7.15M.

CBA changes – contingency surveillance

In New Zealand, the ADS-B system derives the position of aircraft from GPS (as received by the aircraft), which is subject to occasional disruption from space weather (solar radiation). In the interests of resilience, a contingency surveillance system for both cooperative (transponder equipped) and non-cooperative targets is to be commissioned. This is an additional cost not included in the 2018 CBA. Non-GNSS surveillance will provide for continued operations, if possible, during a disruption to GPS or ADS-B. Continued non-cooperative surveillance will provide additional benefits for/against traffic with no transponder.

5.5.2 MetService

The MetService component of the NSS programme has been delivered in full, including new weather radar, automatic weather stations at airports, lightning detection systems, improved terminal area forecasts (greater granularity in time), runway condition reporting, agreed electronic and graphical product delivery, and improved (GRIB2) weather forecast data for ATC and aircraft operators. The planned benefits of improved weather information should be fully realised.

5.5.3 Air Traffic Management System Upgrade (Skyline X)

Airways announced in March 2017 that it will replace its current ATM platforms with Skyline X in a large-scale project. The system was planned to become operational in New Zealand’s domestic airspace in 2020 and in oceanic airspace in 2021. However, the impact of Covid-19 has seen a revision of this project’s deliverables and timeline with domestic transition now intended for March 2022 and Oceanic capability to follow at a date to be confirmed.

[17] Equipment identified by Gliding New Zealand retails in New Zealand for approximately $4500 and can be suitable for all aircraft categories mentioned here.

[18] ADS-B CBA 2017 total required costs to upgrade to ADS-B from table 2 “Costs of proposed ADS-B < FL-245 mandate” p16; costs for each aircraft category from table 7 “Costs and Benefits of Aircraft Equipage” p 25

5.6 Regulatory Enablers

PBN Tranche 1 rules at NPRM

A significant piece of work from the CAA policy team will see a large set of new rules introduced for PBN, the operation of which should allow for a smoother utilization of this new technology and ultimately more benefits realised. At the time of writing this report the rules have progressed to the NPRM stage with a scheduled completion date of mid-2021.

6 Future NSS Benefits Reporting

With the NSS team disbanding there is a need to transfer benefits management to a routine process within CAA, and continue to monitor and report on benefits realisation. This section outlines approaches to ongoing benefit measurement and reporting.

This section assumes that benefit attribution identified in previous reports remains valid, so that the benefits being reported are in fact the result of NSS initiatives.

6.1 Benefits Measurement

6.1.1 Minimum Practicable Method

The simplest credible approach follows the method used in this report: pragmatically scaling the well-studied traffic patterns of 2016.

Measurement

The benefits are estimated by

- Scaling according to the relative volume of traffic in the year being estimated
- Valuing according to the time varying parameters in the year being estimated

Measurement Method	Metric	Scaling Factor: Traffic Levels (% of 2016)			Time Varying Parameter (value in current year)				
		Movement Volume	Passenger Volume	Auckland northern approach utilisation	Fuel Price	ADOC	Value of passsenger time	PBN implementation	ADSB in equippage
Scaled 2016 Baseline	Flight time saving	X		X				X	
	Passenger Time Saving	X	X	X				X	
	Fuel burn and CO2 saving	X		X				X	
	Fuel cost saving	X		X	X			X	
	ADOC saving	X		X		X		X	
	Value of passenger time saving	X	X	X			X	X	
	Safety (APV)	X		X				X	
	Safety (ADS-B in)								X
	Value of avoided diversions (QN)	X							

Table 9 Scaling Method of Metric Estimation

Data requirements

This method could be computed using annual total aircraft movement and passenger numbers at relevant airports, and current values for the time varying parameters. It makes the assumptions listed in this report about the similarity of the current year with 2016.

Quality Risks

Dated baseline: The 2016 baseline may become dated as the aircraft fleet evolve to more fuel-efficient types, and the airline schedule diverges over time from the relative route frequencies in 2016.

- The benefits of shortened approach paths are the aggregate of the gain for each flight, however there can be large differences at an airport between flights from different origins (depending on the angle from which the flight joins the final approach). The 2016 baseline would be a reasonable basis for measurement only to the extent that the overall percentage of arrivals from various routes to each runway remain similar to 2016. Any significant change will affect the accuracy of the estimated distance saved, and all dependent metrics

- The fuel burn of flights depends on the aircraft types being flown. The fuel burn estimate will become less dependable as the fleet evolves to more fuel-efficient types, or the schedule uses a different balance between various sized aircraft compared with 2016.

Special case 1: The value of avoided diversions may vary depending on the aircraft type. The values estimated in the 2016 Acuo report presumed jet only domestic traffic. This value will need to be re-estimated in the light of emerging ATR72 traffic, and subsequently a decision taken about the quality of a metric computed from gross movement numbers without the level of detail that includes aircraft type.

Special case 2: The value of flight efficiency benefits at Auckland depends on the utilisation of the northern RNP AR approaches by international traffic. Airways New Zealand keep records of their use to ensure their utilisation is within the agreed noise related constraints. This data would be needed in addition to the general IFR movement data for all airports.

A-CDM: The 2019 A-CDM report identified a set of metrics useful for both implementation (process quality) and benefit monitoring of the A-CDM programme. Of these, three key areas could represent the realised benefits to aircraft operators from a successful A-CDM project in the long term.

- *Avoided taxi out time* (metrics as above for aircraft time saved: fuel, CO_2, fuel cost, ADOC, and passenger value of time)
- *Improved on time performance* (metrics to be quantified and validated as part of A-CDM project, but would be based on estimates of the avoided cost of off-schedule operations)
- *Reduced block time* (this is the impact of creating system-wide efficiency in the network, with airborne delays reducing as a result of A-CDM coordination. Valued as for other aircraft time savings: fuel, CO_2, fuel cost, ADOC, and passenger value of time).

These metrics are not in place. Ideally, an A-CDM implementation would create them and a validated baseline. Estimating these benefits will need flight-by-flight level detail for on and off-blocks, gate used, runway used, and landing and take-off times for each aircraft turn-round at an airport, along with the airline schedule times for the flights.

6.1.2 Updated Baseline

The quality risks of the simple method may be mitigated by periodically updating and re-validating the 2016 baseline to take account of changing route schedules, and the evolution of the fleet.

Revalidating a baseline can be expected to involve an optimised version of the process used in the Acuo report:

- Using a complete set of flight data
  - Every flight, including landing and take-off time, aircraft type, origin and destination airport and runway, estimated aircraft available seat capacity; and for A-CDM: aircraft schedule, and on and off-blocks timing.
- Computing the distance saved per flight from the route and destination runway
- Estimating the time and fuel saved from the distance saved, and nominal aircraft speed and fuel flow statistics
- Estimate the passenger load using airport passenger statistics

Auckland PBN Benefits

The benefits of PBN in Auckland result from a complex interplay between the flow management system, the navigation infrastructure, and the arrival and departure traffic demand. Benefits may or may not occur depending on air traffic congestion. The flight efficiency benefits identified in the Acuo report were primarily for aircraft using the northern RNP AR approaches, where the counterfactual would be using the (longer) RNAV or ILS approach. Re-validating the baseline for this benefit would require either data from Airways showing the aircraft types that used the RNP AR approaches, or flight path data allowing the analyst to generate statistics about the frequency of use and types of aircraft utilising those approaches.

6.1.3 Technical Skill Set

There is no avoiding a minimum amount of data processing to measure NSS programme benefits. Both the annual scaling method and updating the baseline can conceivably be achieved with good medium-level spreadsheet skills (does not require document automation or macros), or using database skills. Of the two options, the use of database methods is more efficient and effective. These are significantly less labour intensive and more readily audited for correctness.

6.1.4 Optimising Reporting Costs

The emergence of commercial aviation data integration services creates an opportunity to avoid much of the labour cost of benefit estimation.

Currently the data are assembled from a variety of stakeholders and other sources, some of which are not readily electronically readable (e.g. supplied in PDF form). Data engineering of this kind also usually involves a significant amount of work collating and "cleaning" the data, for example – resolving conflicts where data from different sources are not in agreement and combining the data from diverse sources. This kind of 'prep' work can consume a large part of the labour required for benefits estimation.

CAA may wish to investigate the trade-off between the labour involved in collating and cleaning data and the ability to simply procure the data required for NSS programme benefits reporting in a cleaned, validated, and electronically readable form. The commercially available data sets include flight-by-flight level detail, and all of the required data items, which means that annual updates based on this data have the potential to be both more cost effective and more accurate as this method would reduce the uncertainty created by the many assumptions required when working at month or year levels of detail.

6.2 Transition to Business As Usual

The New Zealand Treasury document "Managing Benefits from Projects and NSS programmes: Guide For Practitioners"[19] has guidance for change management as a "bridge" to transition from a NSS programme organisation to embedding benefit management into business-as-usual. Key aspects to consider as the benefits reporting becomes business-as-usual include:

- Governance: Ongoing benefits reporting is ideally owned by an appropriate unit, and the cadence of annual reporting maintained by being incorporated into routine regular reporting processes for that unit
- Capability: Ensure the BAU team have the necessary equipment, resources, and capability to continue the reporting cycle. It may not be cost effective to create or maintain in-house skills if these would be used part time. Alternatively, an external analysis service might be periodically engaged for specialist work.
- Evolution: It is reasonable to expect that emerging benefits and dis-benefits will arise over the period to 2034 as the aviation system evolves. The reporting system ideally would involve judgement and enquiry from operational expertise to identify emerging change to the nature of benefits, and revise the benefit measurement method as necessary.

[19] https://www.treasury.govt.nz/sites/default/files/2019-11/TSY-managing-benefits-guidance-nov2019.pdf