AIRSERVICES AUSTRALIA

AIR TRAFFIC CONTROL GROUP

Collaborative Decision Making for Optimisation of Network Management

An Operational Concept V1.0

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1. Overview

1.1 As air traffic demand increases and use of available capacity becomes more problematic, and as user and community expectations for flight efficiency, predictability, flexibility and environmental effectiveness grow, the management and integration of the 'whole of network' will become increasingly critical to effective air traffic management.

1.2 Through the next 20 years, Australian air traffic demand is expected to increase by 70%-100% - effectively a doubling of current demand, placing strain on both airport and terminal area capacity, and in some cases en-route airspace capacity – particularly when disruptive events such as convective weather or fog occur.

1.3 Whilst initiatives are underway to increase capacity, it will become increasingly necessary to develop capabilities to both balance available capacity against demand, ensuring that the user community has equitable and consistent access to all potentially available capacity in the system - and to fully utilise new capacity as and when created.

1.4 This balancing of demand and capacity has traditionally been the unilateral domain of the Air Navigation Service Provider (*ANSP*) air traffic flow management function. Through the next 20 years that function will be expanded and augmented with a range of distributed capabilities and responsibilities, and integrated to become the International Civil Aviation Organisation (*ICAO*) envisaged Global Air Traffic Management (*ATM*) Operational Concept component Demand and Capacity Balancing (*DCB*).

1.5 For Airservices Australia, the existing capability for managing the network must evolve from its current focus on demand management, to one encompassing 'whole of business trajectory' and 'cross-stakeholder' collaborative capacity and network efficiency management – utilising **Collaborative Decision Making** across all phases of flight, from Strategic Planning to Tactical and Dynamic Operations.

Context

1.6 The Air Traffic Control (*ATC*) Group ATM 5-Year Plan identifies as a primary service outcome "*...the optimisation of end-to-end ATM system traffic management performance through the continuing development and deployment of System Wide Information Management, implementation of Collaborative ATM, and cost-effective optimisation of demand against system capacity in collaboration with the operational service domains and our customers*[1]...".

1.7 Sustaining that goal through the next 15-20 years will present significant challenges. As traffic levels increase, user performance envelops tighten, and currently available 'latent' capacity[2] is absorbed, whole-of-network management will become the key component of the ATM system – and in

[1] *ATC Group ATM 5-Year Plan 2010-2015, page 53, paragraph 9.2.1*

[2] *Latent capacity is capacity in the system that is available without significant infrastructure or technological changes, but which is either not used, or not used effectively. It can be accessed by changes to operational procedures, better forecasting, more effective coordination and so on.*

particular, a key driver in the Performance Based Approach (*PBA*) to ATM. This has already been recognised in the US Next Generation (*NextGen*) program and the European Single European Sky ATM Research (*SESAR*) Joint Undertaking and is under active discussion in the Australian ATM Strategic Planning (*ASTRA*) process.

1.8 This evolution will require the development and implementation of effective data and information collection, management and sharing processes, network operations plans and strategies, and collaborative planning and decision making processes that extend well beyond the current tactical and pre-tactical timeframes into strategic and very strategic. It will also require broadening of the stakeholder engagement level to facilitate sustainable growth in capacity based on a rigorous understanding of demand scenarios.

This Document

1.9 This operational concept outlines a range of changes in network management that will evolve through the next 15-20 years. Key to the concept is the principle of 'whole of network' information utilization, management and interchange, enabling a significant change in the roles of all participants within the Australian ATM system. This philosophy is underpinned by evolution to a holistic **Collaborative Decision Making** environment, where the diverging expectations and interests of all members of the ATM community are balanced cooperatively to achieve a 'best business outcome' for all stakeholders.

1.10 This document is written to be entirely consistent with the ICAO Global ATM Operational Concept (*GATMOC*) vision for future demand and capacity balancing, which envisages:

> *"…Demand and Capacity Balancing will strategically evaluate system-wide traffic flows and aerodrome capacities to allow airspace users to determine when, where and how they operate, while mitigating conflicting needs for airspace and aerodrome capacity. This collaborative process will allow for the efficient management of the air traffic flow through the use of information on system-wide air traffic flows, weather and assets. Key conceptual changes include:*
>
> *a. through collaborative decision making at the strategic stage, assets will be optimized in order to maximize throughput, thus providing a basis for predictable allocation and scheduling;*
> *b. through collaborative decision making at the pre-tactical stage, when possible, adjustments will be made to assets, resource allocations, projected trajectories, airspace organization, and allocation of entry/exit times for aerodromes and airspace volumes to mitigate any imbalance; and*
> *c. at the tactical stage, actions will include dynamic adjustments to the organization of airspace to balance capacity, dynamic changes to the entry/exit times for aerodromes and airspace volumes, and adjustments to the schedule by the users…."*

1.11 The components discussed in this document do not predispose the need for or use of any particular technology (*currently available or in development*) - they may be satisfied with procedural solutions but through the medium and long term will inevitably require technical innovation.

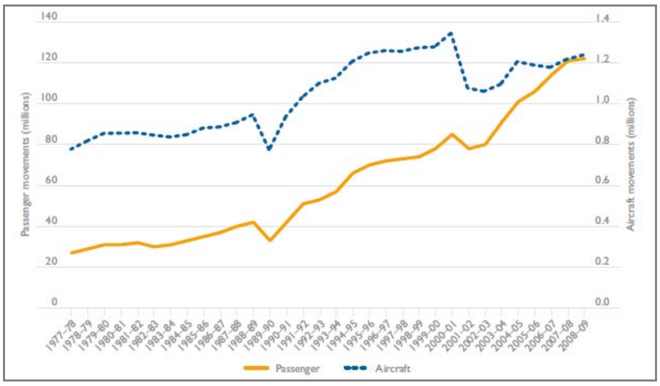
2. Understanding Network Demand

2.0.1 As indicated in the ATM 5 Year Plan (*2010-15*), the evolution of Air Traffic Services (*ATS*) through the next 20 years will be influenced by a number of challenges. A key challenge to the efficient management of the Australian air traffic network will be the ability to effectively cope with increasing demand across Service Delivery Environments (*SDE*) – or more precisely, the effective management of capacity against that growth in demand. Network management will migrate from a traditional role of demand management, where traffic is 'constrained' against available capacity, to one of network optimisation and capacity facilitation – it must become a 'value partner' for the user community.

2.0.2 If demand is the challenge, then it is important to understand how and where that demand will present, and the likely effect not only at individual locations, but across the network.

2.1 Forecast Demand

2.1.1 The number of aircraft operating through Australian airspace and into Australian airports has been increasing consistently through the last 30 years. On average, according to BITRE[3], passenger movements have increased by 5% p.a., whilst aircraft movements have increased by around 1.5% p.a., in the same period. The disparity between passenger and aircraft growth rates is related to several factors, including the pilots' strike in 1989/90, the 9/11 terrorist attack and the collapse of Ansett in 2001, and the move to larger aircraft with greater load factors. Without these factors, aircraft movements may have risen by around 2-3% p.a.



<u>Fig 1: Historical Air Passenger and Aircraft Movements through all Australian Airports</u>

(BITRE, 2009 – Research Report 117 – Aircraft Movements through Capital City Airports to 2029/30)

2.1.2 Planning for future services requires an understanding of historical trends and current actual movement data – **and** accurate forecasting. There are currently several sources of actual and forecast data – however, none are specifically tailored to the needs of network management.

En-route

2.1.3 For the en-route environment, the only readily available trend and forecast data comes from BITRE. There is some corroborating information from ICAO and the International Air Transport Association (*IATA*) – but not at a level of fidelity for Australian planning purposes. Actual movement data

[3] Bureau of Infrastructure, Transport and Regional Economics

– whole of system and sector by sector is available within Airservices – but is currently difficult to extract and utilise, and its consistency is problematic.

2.1.4 Forecast data available from BITRE indicates an average year-on-year traffic demand growth of 3%. In some areas (*Western Australia resource areas, Queensland oil and gas fields*) the demand growth will be higher. In the absence of solid data, it is difficult to predict the growth figures but it is likely to be in the order of 5% p.a. in the short term. There is some evidence that the growth in Queensland regional services will cascade through to Brisbane – this is evidenced by a forecast growth of 4% p.a. at Brisbane Airport[4] for the next 5 years (*levelling at 3% in the out years)*.

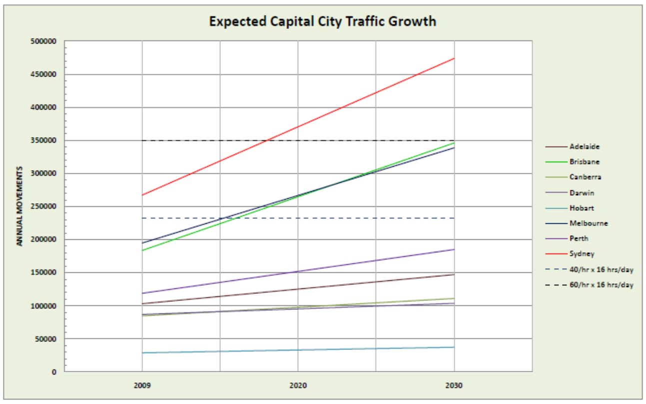


Figure 2: Expected Capital City Traffic Growth

2.1.5 In the short term (*+5 years*), the current key traffic corridor of the 'J-Curve' is and will continue to be the most critical network management area. This is borne out by the discussion on airports below. Traffic flow management into and around Perth Airport is also likely to become an increasing focus area.

2.1.6 In the medium and longer term, as east-coast major airport capacity is absorbed, en-route airspace feeding into the J-curve will increasingly be subject to network management constraints. This will be exacerbated by increased focus on user requirements for increased flight efficiency (*e.g., user preferred routes*) and the need to manage aircraft emissions profiles.

Airports

2.1.7 Airport forecast data is available from a number of sources. First, the major capital city Airport Master Plans provide an airports' view of traffic growth. From those plans, traffic growth is forecast at between 2% and 4% year on year – with Brisbane forecast at around 3.5% p.a., Melbourne at around 2.2% p.a., and Sydney at around 2% p.a. BITRE has provided a number of data sets – some based on GDP growth, others based on historical trend. Airservices' airport movement data is more accurate and helps to establish historical trends – but

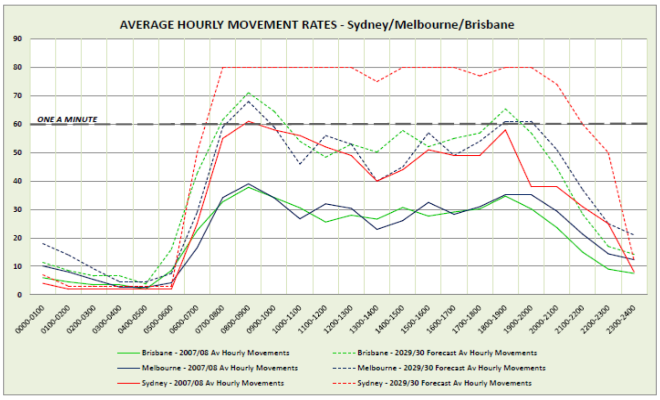


Figure 3: Detailed Average Hourly Movement Analysis – ML/SY/BN

[4] *Brisbane Airport Master Plan 2009*

forecasting is problematic.

2.1.8 It is important to note that whilst a difference of 1% in notional growth rates will have a marginal effect on short term (*+5 years*) predictions (*e.g., 17% vs. 20% growth*), that same discrepancy can have a significant effect on long term (*20 years*) predictions (*e.g., 70% vs. 100% growth*) – which in turn can have a significant effect on investment decisions, capability options, and so on.

2.2 Network Effect

2.2.1 Network effect refers to the phenomenon that demand needs hourly airport capacity at both the departure and the destination airport, at the appropriate departure and arrival hour of each flight. If one of the airports on an airport pair is more congested than the other, the less congested (*or uncongested*) one will suffer from unaccommodated demand, even though it has sufficient capacity itself.

2.2.2 Where only one city pair airport is critical (*e.g., Sydney*) and other airports (*e.g., Brisbane or Melbourne*) have capacity, the network effect is relatively benign. However, as traffic grows the interdependency between city-pair airports becomes critical. By 2020, for example, both Melbourne and Brisbane will have traffic demand at the same level as Sydney currently experiences – and Sydney itself will have 30% more traffic.

2.2.3 As shown in Figure 3 this demand overlaps for substantial periods of the day – if one airport experiences capacity shortfall, it will cascade critically through the network and through other major airports and out into the regional feeder airports. Solutions currently available – e.g., airborne or ground delay programs will lose their effectiveness, complexity increases and parking space is not available.

2.3 One a Minute

2.3.1 The hour by hour analysis and forecasts also present another challenge. At present, with the exception of Sydney, airport 'peak and trough' demand is such that disruptions caused by adverse weather, or other system disturbances can generally be absorbed across the day. As traffic grows, however, the scope for absorbing disruptions will disappear, and the flow on effects of a disruption at an individual airport will be become significant – even without the network effect *(this is already evident at Sydney when delayed flights conflict with curfew times)*.

2.3.2 By 2030, Brisbane and Melbourne airports will need a capability to sustain 60 movements an hour (*one movement a minute*) for significant parts of the day, in all weather conditions. Sydney will need to be able to sustain demand of 80 movements per hour (*capped*) for 15 hours a day, in all weather conditions and all runway configurations.

3. Optimising Network Operations

3.1 Optimisation of network operations is essentially about the increasingly fine balancing of variable capacity and variable demand to ensure that each available capacity opportunity (*airspace or runway slot*) in the system is consistently presented for use, and that the users are given an opportunity to consistently access that presented capacity – not just at a single node or location, but across their integrated operations.

3.2 In circumstances where capacity consistently exceeds demand, there is generally no significant need to introduce flow or capacity management initiatives – slots are always available, and are used as required. Where there is competition for a particular slot, basic ATC interventions (*vectoring, speed control, etc*) manage the conflict.

3.3 In the past, where flow management initiatives were introduced, their primary application was either in the protection of the ATC system against overload, or to manage environmental or other expectations at a particular node. Rarely were such initiatives implemented for the benefit of the broader stakeholder community. Now, where demand does start to regularly exceed capacity, whilst some focus is placed on developing new capacity, given the long lead times for major infrastructure improvements (*new runways, taxiway upgrades, new parking gates etc*) most emphasis is on better utilisation of currently available capacity – or in many cases, simply transferring the capacity shortfall to the user through ground delay programs, demand limiting, and so on.

3.4 This is exacerbated by the traditionally tactical and reactive nature of the system – from an ANSP perspective aircraft are managed as they present on a 'first come first served' basis, and from a user perspective aircraft are presented to the system when they are ready, generally regardless of scheduled times. It is further exacerbated by the open nature of the system – that is, the inability to consistently control significant variables such as weather, system outages, landside disruptions, etc - and the relative lack of fidelity in strategic forecasting and tactical interpretation of available capacity. To a large extent, given the relative situational awareness monopoly, network management is currently a unilateral decision making process, managed by the ANSP.

3.5 Effectively managing the expected increase in traffic demand within a limited capacity environment, whilst promoting an environment within which airspace users can continue to grow their businesses, requires a change in network management paradigm that integrates a much larger volume of situational awareness information, and establishes an increasingly fine granularity of decision making and business rules. This cannot be done unilaterally – it requires distribution of responsibilities, flexibility in system responsiveness, and integration of management.

3.6 The key to further improving demand/capacity management is in utilising all available information from affected stakeholders to support a collaborative environment where all stakeholders participate in determining the best actions to balance demand against available capacity. This is best achieved through the implementation and use of **collaborative decision making** capabilities.

4. User Focused Network Management

4.1 Enhancement of network management is essentially a user-driven performance expectation. In developing network management collaborative decision making strategies it is critical to understand the customer's operating model, and, working with the customer and other stakeholders, to sustain customer value. This is not simply about collaboration in the days and hours before a flight – it is about integrating planning processes and cycles at all points in the customer planning cycle – from Very Strategic through Strategic, Pre-tactical, Tactical and importantly Post-Tactical for performance analysis.

4.2 The 'airline' elements in Figure 4 below (*based on an IATA model*) are typical of an airline planning cycle – variations can be made to represent military and business aviation planning cycles, but the general flow remains the same.

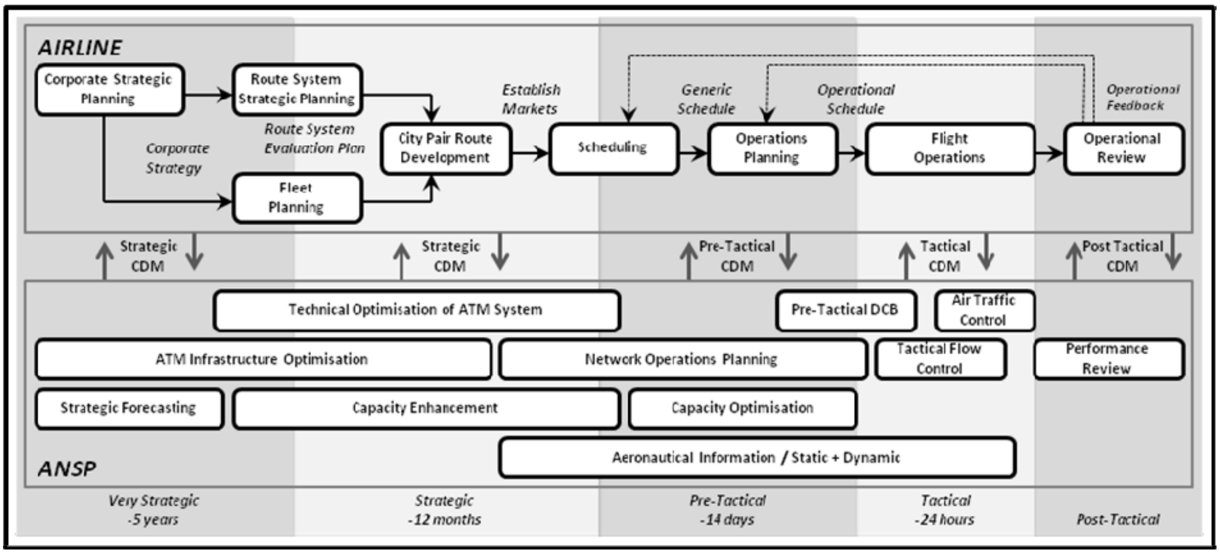


Fig 4: Future ANSP/Airline Network Management Interaction

4.3 At present, the collaborative interaction between ANSPs and the user tends to occur in the Tactical and Pre-Tactical timeframe. In the evolution of network management, the collaborative processes will extend through all phases of the customer planning cycle.

4.4 It's also important to understand the key performance context – i.e., why airlines (*and users in general*) want or expect improvements in network operation. Most current performance goals around flow and network management centre on delay reduction and 'on-time' performance. These are important factors for airlines, as they relate directly to schedule maintenance, which in turn responds to two drivers – passenger expectations, and critically for an airline, aircraft utilisation.

4.5 An airline's investment in aircraft is substantial, and it is critical that the airline can operate its schedule as predictably and reliably as possible, with as few aircraft as possible.

4.6 The reality of the last 30-40 years is that airlines have 'adjusted' their schedules to cater for the unpredictability and unreliability of ATM network operation as a whole. Often, the scheduled time for a flight of, say, one hour (*e.g., Melbourne-Sydney*) will be shown as almost 2 hours. With an added turn-around of one hour, the entire cycle for a notional one hour flight becomes 3 hours. This nominally limits the cyclic aircraft utilisation to 8 flights a day. An improvement in predictability of just 30 minutes per flight (*i.e., 2½ hours per cycle*) can increase daily aircraft utilisation by almost 2 flights – around 20%.

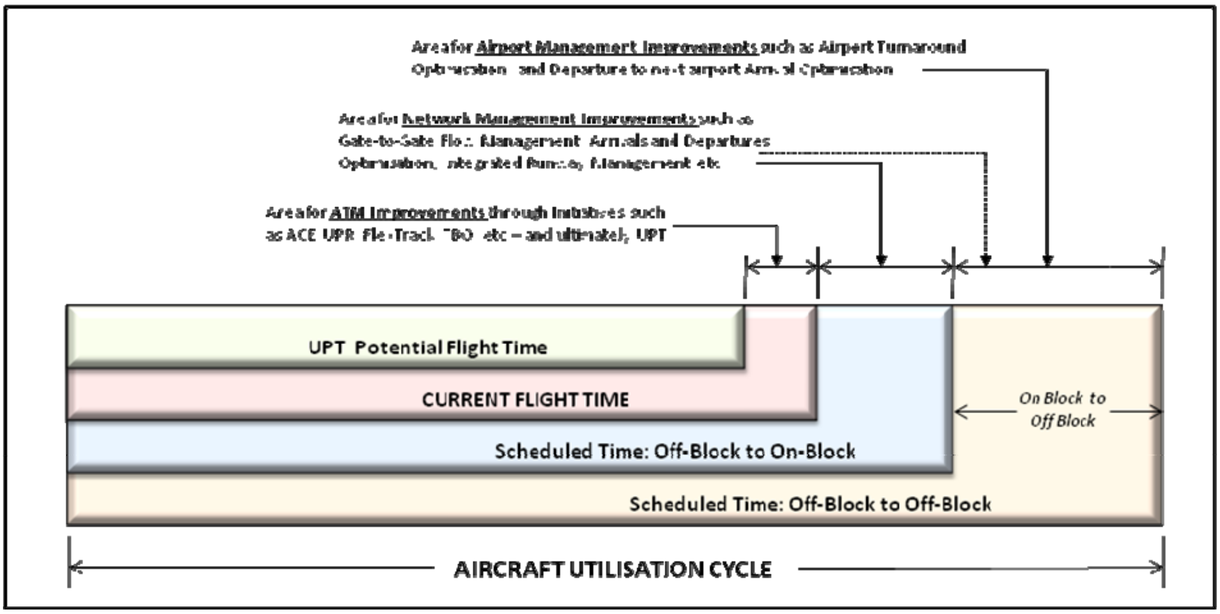


Fig 5: Aircraft Utilisation Cycle – ATM and Network Management Enhancement Opportunities

4.7 ANSPs contribute to this improvement in cycle time in three ways. The first is by improvements to operational trajectories – moving towards User Preferred Trajectories through an ATM Improvement program.

4.8 The second and more significant contribution will come from improvements to network management, improving predictability and consistency, so that airlines will have confidence to reduce scheduled off-block to on-block times. In addition, by reducing the need for ground holding, there will be a small contribution to the reduction in on-block to off-block time.

4.9 The third contribution will be in the provision of collaborative decision making capabilities to facilitate improvements to airport management – most significantly optimisation of airport turnaround.

4.10 The airline expectation is that a cumulative improvement in the three areas – ATM, Network and Airport performance – will allow an increase in aircraft utilisation – or significantly a reduction in the number of aircraft required to operate a schedule.

5. Airports – The Critical Node

5.1 Airports are critical network nodes. For any discussion of enhancing network management it is important to understand some of the key factors affecting airport performance. Airports face many challenges - economic, commercial, political, operational, environmental and/or regulatory. Coupled with physical airport land and airspace constraints, these influence the longer-term strategies and the ability of airports to pro-actively develop new capacity – or to provide infrastructure to mitigate congestion.

5.2 Congestion is already a limiting factor at a number of Australia's airports for at least some part of the day – as traffic demand increases through the next 20 years it will become the major constraint on network performance. Furthermore, future traffic growth is likely to generate congestion at airports that are not yet experiencing capacity problems.

5.3 There are several airport-related factors affecting network performance but two are critical. The first is taxiway availability and management - i.e., the ability to get aircraft to runways in an appropriately sequenced and time-ordered manner, and the ability to get aircraft from runways to gates without causing congestion. The second is consistent and predictable apron management – i.e., the ability to reliably turn aircraft around at parking gates to meet network or departure time requirements.

5.4 Establishing new infrastructure to achieve these goals – from parking gates and aprons through to taxiways and runways - requires long lead times and significant capital expenditure. Requirements for aerodrome facilities are developed as a component of an airport master plan with a 20-year horizon. They are generally determined on the basis of forecasting and modelling in consultation with the user community – and to a lesser extent with the ANSP. Clearly in the short to medium term the most realistic option is to utilise existing infrastructure more effectively.

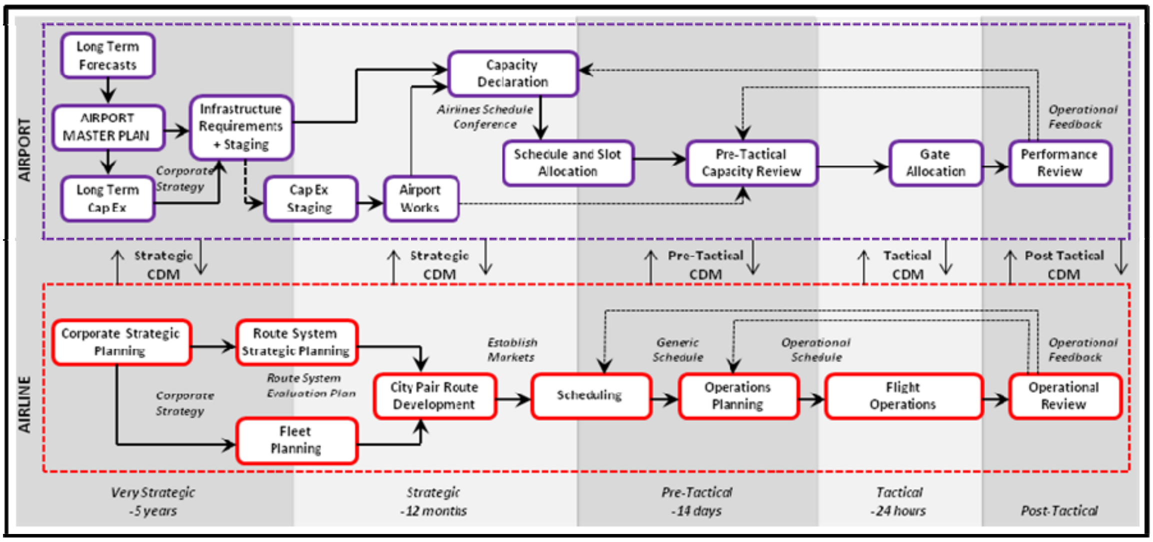


Fig 6: Airport/Airline Network Management Interaction

Taxiways

5.5 Taxiways are the airport arteries, connecting runways to parking areas. Given the long developmental lead times, land and other infrastructure constraints (*e.g., road underpasses, electrical ducts, etc*) and cost, taxiways are strategically designed to best facilitate the most commonly operated aircraft or runway operating modes and available 'real estate'. Consequently, taxiways and runway entry/exits cannot be optimal for all aircraft types or operating modes. Lack of physical space – and the fact that taxiways generally only allow aircraft to operate single file in one direction - precludes the provision of capability to 'adjust' aircraft sequences at or on the way to holding points.

5.6 Where slot time compliance requirements are relatively coarse (*e.g., ±15 minutes*), this does not have a significant effect on the network – but as compliance requirements become finer (*e.g., takeoff slot time ±1 minute*) taxiway management will become critical to network performance. From a network management perspective, therefore, it will become increasingly essential that the use of existing taxiways, runways and runway exits is planned and coordinated to a high level of fidelity across all affected stakeholders.

Apron Management

5.7 Apron turn-around performance (*i.e., the management of an aircraft from 'on-blocks' to 'off blocks'*) is affected by a number of factors. These include operations related to determination and allocation of arrival gates or parking positions, de-confliction of traffic on aprons, management and manipulation of aircraft onto and off gates or parking locations, and allocation of ground-handling equipment and loading/unloading resource to an aircraft. It also includes all of the elements relating to passenger movement in a terminal, luggage and cargo management, aircraft maintenance and gate re-allocation, dispatch activities, contingency gate management and a range of other activities. These operations are often managed by different stakeholders. It is the sum of these elements that contribute to the "turn-around time" of an aircraft.

5.8 Any one of these elements can lead to a delay against ATM agreed departure or arrival times, negotiated in some cases many months in advance. The ATM system is not currently configured to coordinate these activities – however, airlines deal with them on a daily basis, and have clearly established procedures for managing the various components. Extending this daily collaboration across all stakeholders – including the ANSP – will ensure that a greater focus is placed on network management. This is best achieved through the implementation and use of **collaborative decision making** capabilities.

5.9 Managing turn-around time is obviously important for network management – but for airport operators there is another key benefit. Currently scheduling unreliability forces airport operators to up to 10% of gates to facilitate 'off schedule' operations. In the case of a terminal with 30 gates 3 gates would be set aside. If one of these gates can be made available for planning rather than contingency purposes, notional gate capacity – and therefore system capacity - could be increased by up to seven aircraft operations per gate per day.

6. Collaborative Decision Making – an Operational Concept

6.1 Overview

6.1.1 The benefits of using **Collaborative Decision Making** (*CDM*) for enhancement of network management are very wide and varied in nature. Even at the most basic level of purely improving the distribution of existing information amongst users and stakeholders, thereby creating common situational awareness, significant benefits can be achieved with relatively low investment.

6.1.2 Common situational awareness requires a new approach to information sharing; however its initial implementation does not require major investment in information networks. It can be achieved initially by simply interfacing existing systems to provide better quality data based on common information elements and interactions. This interfacing can start on an ad-hoc basis initially, but will require the progressive development and introduction of commonly agreed standards and procedures – ultimately leading to the development of an integrated system wide information management (*and distribution*) capability, supported with enhanced (*aeronautical*) information management.

6.1.3 To realise all the potential benefits of CDM through the next 20 years all of the components described in this operational concept will need to be implemented and a network-wide approach is necessary. In practice, a phased, bottom-up approach will have to be followed, with each implementation step delivering an incremental benefit, which will become even more significant as the CDM concept components mature and are implemented more broadly.

6.1.4 Some of the components – particularly those related to airport optimisation – cannot be implemented in isolation – to work effectively they require the implementation of supporting components. As indicated previously, this does not imply the need to implement technology – but it does require the establishment of procedures and practices that provide the base capability of the underpinning component. The operational concept therefore assumes that some components are implemented before the others are considered – or are implemented in parallel.

6.1.5 The operational concept also assumes that the existing data (*situational awareness and decision making*) and information management infrastructure will remain, with changes to existing systems (*or deployment of new systems*) kept to the minimum required to support the implementation of the components. In all cases, cost-effectiveness must be a primary consideration.

6.1.6 Providing information and better quality network management induces costs for all stakeholders that should be balanced by higher benefits. Arguably, the provision of information by one party that improves network overall management has a value, and that value should be reflected through quantifiable and measurable benefit both to the provider (*return on investment*), and to the other network stakeholders (*cross-industry business case*).

6.1.7 Accordingly, in order to quantify the benefits it is important to obtain an agreement on Key Performance Indicators and the use of recorded data for evaluation purposes. Post-tactical data analysis is an important, required activity with a view to monitoring and improving all CDM related activities.

6.1.8 In addition, for all components, appropriate procedures are needed to enable CDM stakeholders to discuss issues and improvements and to agree on action if a partner does fulfill its commitment.

6.2 A Layered Approach

6.2.1 CDM comprises a number of components and is applied at several layers, each one acting sequentially with an increasingly fine level of network performance granularity – but with an increasingly higher level of performance responsibility on, and collaborative engagement between each involved stakeholder.

6.2.2 The first layer focuses on whole-of-system Demand and Capacity Balancing and is established on an Australia-wide basis – though application may initially be restricted to certain time periods, or to certain specified areas/traffic flows. The second and third layers respectively focus on Capacity Optimisation and Network (*or Schedule*) Optimisation, and are applied on a location specific basis – i.e., for a particular metering point, for an airspace volume, or more predominantly for a particular airport or set of airports.

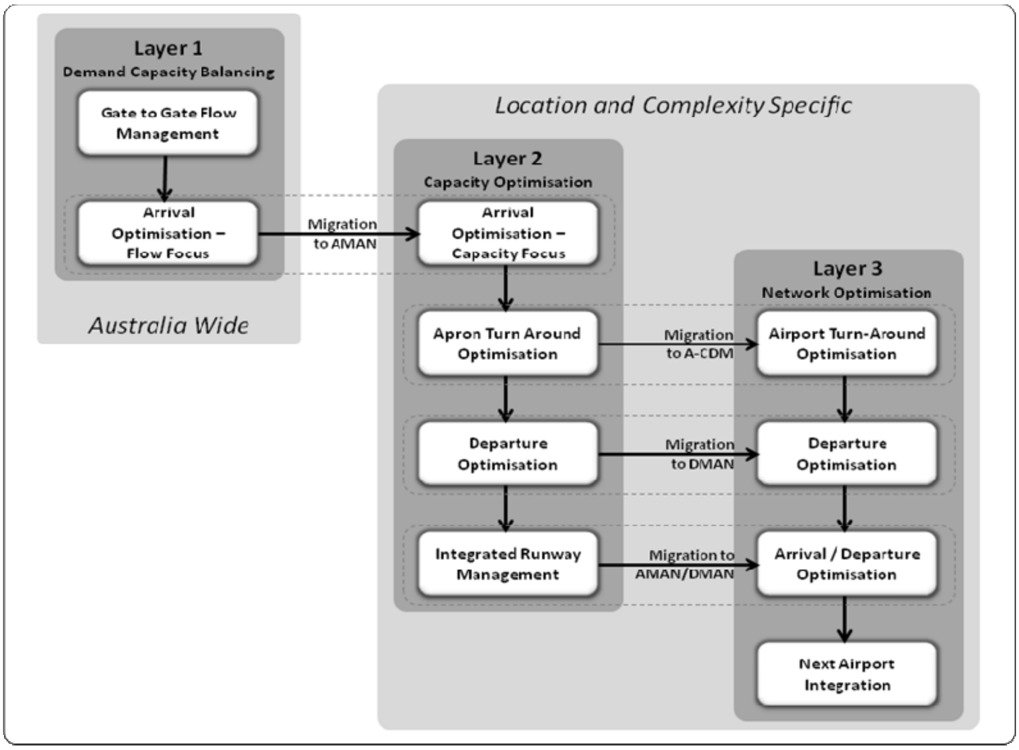


Figure 7: Collaborative Decision Making for Enhanced Network Management - Components

6.2.3 Layer one has two components – Gate-to-Gate Flow Management, and Arrival Optimisation. Layer two has four components - Arrival Optimisation, Apron Turn-Around Optimisation, Departure Optimisation and Integrated Runway Management – i.e., the integration and optimisation of arrivals and departures streams at a particular airport. Arrival Optimisation is an extension of the same component at Layer 1, but focused now on capacity optimisation.

6.2.4 The third layer has four components - Airport Turnaround Optimisation, Departure Optimisation, integrated Arrival and Departure Optimisation and Next Airport Integration (*integration of departures at one airport to next airport arrivals*). The first three of these components are extensions of the same component in Layer 2, but with higher fidelity requirements and a specific focus on network optimisation (*i.e., for the ATM network as a whole*) – and for airlines, schedule optimisation.

6.2.5 The components in layers 1 and 2 focus on processes that need to be established to achieve an outcome – this need not necessarily involve deployment of technical or technological solutions (*at least not in the first instance*), but may simply involve the development and promulgation procedures based business rules – e.g., traffic management procedures, prioritisation instructions, standard taxiway routes, etc. In Layer 3, more sophisticated capabilities and higher fidelity collaborative decision making processes are deployed.

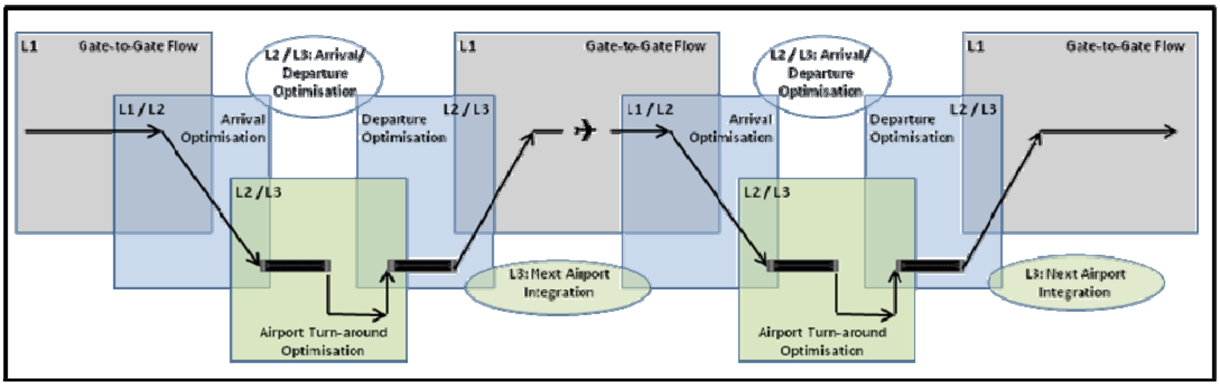


__Figure 8: Collaborative Decision Making – Layered Application[5]__

6.2.6 Each component is supported at increasing levels of granularity by Local and System Wide Information Management capabilities, collaborative decision making processes and protocols (*business rules*), and enhanced situational awareness capabilities such as A-SMCGS.

6.2.7 Each layer of CDM and its associated components also involves temporal decision making – that is, the decision making processes are not simply conducted on the 'day of flight' but involve multi-stakeholder interactions in the Strategic, Pre-tactical, Tactical and Dynamic timeframes to establish the business rules for optimum network performance. Necessarily the level of fidelity of decisions made

[5] *The diagram is illustrative only. The representation of gate-to-gate flow, for example, is meant to indicate application across the network but not with the level of granularity of arrival and departure optimisation. It is also meant to indicate that gate-to-gate flow does not (significantly) encompass airport operations.*

further away from the actual 'time of flight' will be influenced by the availability and quality of system data and information – and the ability to predict, forecast and manage system disturbances such as weather, airspace restrictions, etc.

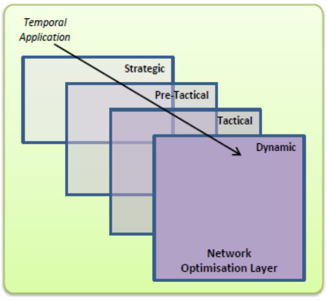


Fig 9: Temporal Application

6.2.8 Each layer of CDM also changes the levels of responsibility of stakeholders. For example, the effective operation of gate-to-gate flow is primarily the responsibility of the ANSP – however, the effective operation of turn-around optimisation at an airport is primarily the responsibility of airlines in concert with airports.

CDM Component	Primary Outcomes	Stakeholder Compliance	Available Situational Awareness	Shared Situational Awareness	Stakeholder Information Sharing
Layer 1: Demand and Capacity Balancing					
Gate-to-Gate Flow	• Prevention of ATC overload • Reduction in airborne delay	Flow Unit: High ATC: Medium User: Low	High	Low	Low
Arrival Optimisation	• Better flow to specific airports • Slot/regulatory compliance	Flow Unit: High ATC: High User: Medium	High	Low	Medium
Layer 2: Capacity Optimisation					
Arrival Optimisation	• Arrival integration for capacity • Collaborative prioritisation • Increased predictability	Flow Unit: High ATC: High User: Low	High	Medium	Medium
Apron Turn Around Optimisation	• Better predictability for departure planning • Pre-cursor to higher fidelity Airport CDM	Flow Unit: High ATC: High User: Medium Airport: Medium	High	Medium	Medium
Departure Optimisation	• Structured departure slot allocation • Collaborative prioritisation	Flow Unit: High ATC: Medium User: Medium	High	High	Medium
Integrated Runway Management	• Runway capacity optimisation • Increased airport efficiency	Flow Unit: High ATC: High User: Medium	High	High	Medium
Layer 3: Network and Schedule Optimisation					
Airport Turnaround Optimisation	• Collaborative decision making • Distributed responsibilities • Enhanced apron management • Focus on network performance	Flow Unit: High ATC: High User: High Airport: High	High	High	High
Departure Optimisation	• Precise takeoff time allocation • Collaborative prioritisation and slot re-allocation • Better apron management	Flow Unit: High ATC: High User: High Airport: High	High	High	High
Arrival Departure Optimisation	• Runway capacity maximisation • Increased airport efficiency	Flow Unit: High ATC: High User: High Airport: High	High	High	High
Next Airport Integration	• Collaborative decision making • Distributed responsibilities • Focus on network performance	Flow Unit: High ATC: High User: High Airport: High	High	High	High

Table 1: CDM Component Overview

6.2.9 As already indicated, CDM across the network is operated with a range of layer options – some airports or nodes applying more layers than others, with minimal overall network effect. However, as traffic demand increases, and the network effect becomes more dominant, it may be necessary for stakeholders to anticipate and accelerate the deployment of additional layers. On this basis, the initial design of the situational awareness (*surveillance, communications, etc*) and information sharing capabilities (*SWIM, AIS/AIM/IM, etc*) must anticipate the need for extended application well beyond initial system design requirements.

6.2.10 As each layer is implemented, the emphasis moves from the management of individual aircraft to a specific slot, through to the management of slots as a whole, where the critical consideration is what needs to be done to ensure an available or released slot is utilised by any available aircraft. It is also about slot usage rather than slot compliance. This is the ultimate goal of network optimisation – but it requires a high level of engagement and commitment across all stakeholders.

6.3 Layer 1: Demand and Capacity Balancing

Gate to Gate Flow Management

6.3.1 Gate-to-gate flow management is responsible for (*relatively*) coarse optimisation of overall traffic flow through the network, and intervention to prevent overload at specific locations when demand exceeds capacity. In general terms it concentrates on sets of individual flight segments from take-off to landing – though the regulating of traffic flow may (*and generally will*) require ground delay which may have disruptive downstream flow-through effects on user schedules.

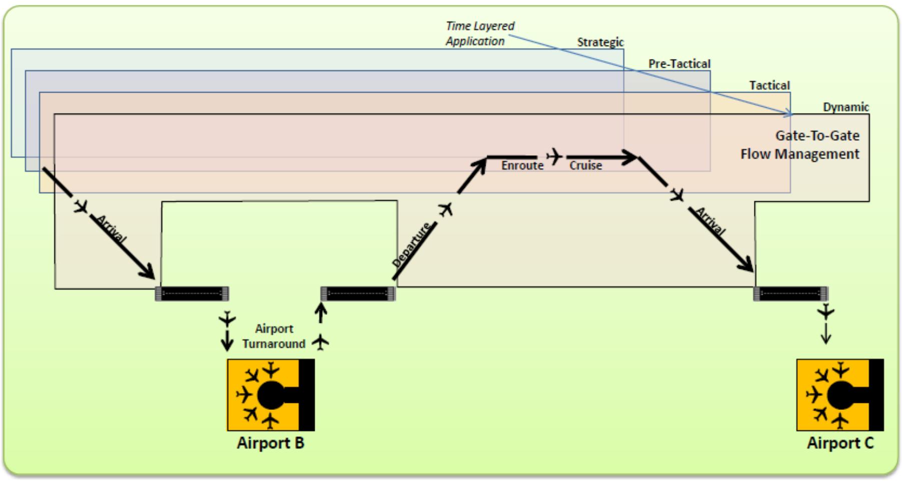


Figure 10: Gate-to-Gate Flow

6.3.2 Despite the relative coarseness or granularity of individual slot management, air traffic flow management is actually supported by high-fidelity situational awareness capabilities for monitoring system capacity and system demand (*partly because it already exists, but mostly to facilitate integration with the next layers when/where applied*). It also provides a mechanism for managing traffic flows when imbalances occur.

6.3.3 The air traffic flow management system monitor flights arriving at and departing from airports in general, and critical airports in particular, while tracking demand and capacity. The system also monitors airspace volumes, and critical nodes (*entry/exit points, holding points, etc*). When an imbalance exists, users are able to analyse data and model demand management and options to determine the optimal solution for managing the imbalance. Once a solution has been identified, the system permits the other users to view and participate in refining the solution to reach a mutually agreed position.

6.3.4 Air traffic flow management system tools allow modelling to take place in the strategic timeframe – i.e., in the 6-12 month pre-flight horizon – to enable general refinement of schedules, and development of initial network operations plans. The main limiting factor at the strategic horizon is fidelity of capacity information – at best historical averages can be applied – but known capacity shortfalls (scheduled *works, known deficiencies*) can be factored at this stage.

6.3.5 Air traffic flow management is most effective in the pre-tactical timeframe – typically in the 4-48 hours pre-flight horizon – where potential tactical constraints (*works, staffing, rosters, equipment availability, etc*) can be mitigated, and only dynamic variables (*weather, system failure, etc*) remain.

6.3.6 There are a number of limiting factors to the network wide effectiveness of the air traffic flow management layer – though for some stakeholders these are in fact system positives. In general, allocated slots tend to have wide compliance margins (*e.g., ± 15 mins, or -5 mins/+10 mins, etc*) which provide a relatively substantial buffer for airlines above and beyond built in schedule buffers. This can result in a perception that demand and capacity is balanced, but a reality that aircraft are still subject to departure delays, or en-route/terminal area 'trajectory adjustment'.

6.3.7 The more substantial shortfall is the downstream effect of imposing ground delay on individual flights that cascades through the network – particularly when an individual aircraft is operating multiple legs in a high density corridor (*e.g., Melbourne-Sydney-Brisbane*).

6.3.8 In the current demand environment this can generally be managed by tactical or dynamic intervention to prioritise certain individual flights – but as demand increases, and capacity is reached or exceeded more regularly, implementation of higher fidelity management will be required.

Arrival Optimisation – Flow Focus

6.3.9 The gate-to-gate flow function is relatively course with wide compliance margins. Where traffic flows are concentrated (*e.g., east coast of Australia*) it is beneficial to implement capabilities for better optimisation of flows into particular airports (*e.g., Sydney, Melbourne, Brisbane etc*).

6.3.10 Arrival optimisation begins the process of introducing target windows of metering times for aircraft. It also introduces the integration of tactical and pre-tactical flight streams – i.e., it allows the integration of aircraft waiting to depart for a particular destination with aircraft already airborne en-route to that same destination.

6.3.11 Such capabilities will eventually evolve from a Layer 1 Demand and Capacity Balancing role to a Layer 2 Capacity Optimisation role and should be developed to support such an evolution.

6.4 Layer 2: Capacity Optimisation

Arrival Optimisation – Capacity Focus

6.4.1 Within the network, as demand increases, the flow of traffic through certain key nodes becomes increasingly critical to capacity and specific focused management processes need to be applied. In Australia those nodes are key airports on the east coast (*Sydney, Melbourne, Brisbane*) together with Perth in the short term, with the set likely to expand through the next 20 years.

6.4.2 It will become increasingly important to more precisely regulate/meter the flow of traffic at the runways associated with these airports, and at particular airspace nodes around these airports, to ensure both that all available capacity is utilised, and increasingly that traffic is presented to runways in arrival sequences that best maximise capacity (*taking into account weather, wake turbulence etc*), and company preferences for arrival priority.

6.4.3 Arrival sequence optimisation aims to enhance runway capacity through sequencing and metering the flow of aircraft entering a particular airspace volume(*s*) such as a TMA, to provide predictability and at the same time minimise the impact on the environment, by reduced holding and low-level vectoring.

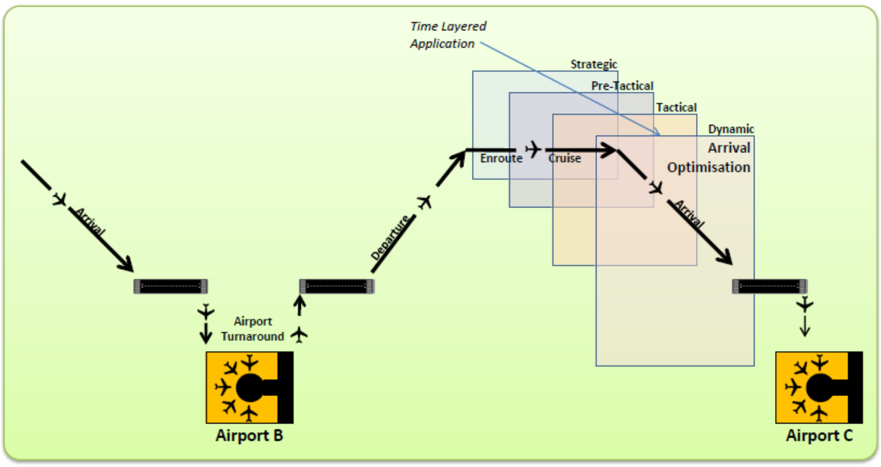


Fig 11: Arrival Optimisation

6.4.4 To meet these objectives, arrival sequence optimisation provides a sequence at the runway, and an expected time at the runway or the time at/over different fixes (*together with applicable tolerances*). It gives priority to linear delay absorptions (*i.e., ground delay, speed control, path stretch*) instead of holding patterns. Planning functions also help to reduce controller workload, particularly in case of system disturbance (*such as runway closure*).

6.4.5 Whilst the development of business rules for arrival sequence management occurs in the strategic timeframe, its application is most dominant in the pre-tactical phase (*for shorter haul flights*), or in the tactical and/or dynamic phase of network management for longer haul aircraft.

6.4.6 Arrival sequence optimisation requires a higher level of compliance (*with fix times, sequencing instructions etc*) – but whilst it provides a higher level of predictability (*about specific aircraft*) and responsiveness (*at specific airports*), it is not necessarily designed to enhance overall network effectiveness.

6.4.7 The key benefit is flexible and adaptive responsiveness to a changing operational situation, such as controller actions, revised operational capacity, re-prioritization and weather impacts.

Apron Turn Around Optimisation

6.4.8 Optimisation of arrival streams is only one part of the airport capacity enhancement equation. To fully optimise capacity it is necessary to manage the departure streams, and to pre-tactically and tactically integrate arrival and departure streams. This is not simply a case of allocating a certain block of arrivals and/or departures per hour – this is about increasing the predictability of departures so that they can be allocated specific departure times or slots.

6.4.9 To do this effectively, it is necessary to have a degree of control or predictability about aircraft turn around on the apron – i.e., to have some communicated certainty about when aircraft will be ready to present into the departure stream.

6.4.10 In Layer 2, the ATC/airline level of fidelity is relatively fine – but the airline/airport buffer is relatively large – that is, the scheduled push back times for airlines takes into account the potential turn around disturbances. The airport and ground handling components are not part of the ATM decision making process at this layer – this occurs formally in the airport turn around optimisation in Layer 3.

6.4.11 Apron Turn Around Optimisation is a necessary pre-cursor to Layer 2 (and Layer 3) Departure Optimisation.

Departure Optimisation – Capacity Focus

6.4.12 Departure optimisation at Layer 2 is primarily focused on increasing capacity at particular airports. The aim is to better predict specific departure stream demand, and to be able to flow departure stream traffic to runway holding or departure points in sequences that not only optimise the terminal area management, but also present aircraft to the en-route flow in a way that reduces the need for tactical intervention (*e.g., ensures spacing between two aircraft bound for the same destination is sufficient to avoid downstream holding or path stretching, etc*).

6.4.13 The fidelity of departure optimisation is critically related to the predictability of apron turn-around – better apron predictability allows better departure management and better integration of departures with arrival streams. Because of the uncertainties associated with apron management, Layer 2 departure optimisation is a pre-tactical and tactical function, with strategic action being limited to broad schedule planning, and airport infrastructure optimisation.

6.4.14 Departure sequence optimisation as a second layer CDM application is more critical at airports that already have, or anticipate having departure capacity constraints. Those airports that have high levels of taxiway or runway flexibility will not necessarily need to apply it, but it is a necessary pre-requisite for implementation of third layer CDM[6] and for effective integration of arrival and departure streams.

Integrated Runway Management

6.4.15 Having established separate processes for optimisation of arrival and departure streams, and developed processes for increased apron turn around predictability, the next natural component of capacity optimisation is the integration of arrival and departure streams to maximise runway utilisation.

6.4.16 The aim of integrated runway management is to manipulate aircraft in both arrival and departure streams to provide de-conflicted arrival and departure slot opportunities. This can be achieved tactically through time-based target window allocation (*e.g., 3 minute spacing at arrival fixes, 2 minute spacing between landings, etc*) or dynamically (*e.g., ATC path stretching to achieve a 6 or 7 mile spacing between arrivals to allow a departure*).

6.4.17 Given the level of fidelity of the various streams, it is likely that at layer two, integrated runway management will be a tactical/dynamic function, with pre-tactical actions limited to broad determination of 'per hour' arrival/departure mix, and runway configuration acceptance rates.

6.5 Layer 3: Network (*Schedule*) Optimisation

6.5.1 In layers one and two, the predominant focus has been on the interaction between the ANSP (*ATC and Flow Management*) and the Users to determine optimal flow and sequencing. To a large extent, the operation of the various capabilities in these levels is based on a relatively large embedded turn-around performance component in user schedules, updated on a reactive pre-tactical or tactical basis when flights are in a position to begin the next flight segment.

[6] *The prerequisite is the process – it may be a set of procedures or prioritisation rules - not necessarily a technology or technical capability.*

6.5.2 In addition, the flow and sequencing capabilities for arriving streams is in effect terminated once an aircraft is sufficiently far from a runway that its position will not interfere with following operations. Levels one and two are gate-to-gate focused – or more precisely gate-to-apron or gate-to-arrival taxiway – and manage series or blocks of individual flights without consideration of the 'next flight segment'. Effectively the management clock resets for each flight. Level three is about integrating those individual flights and effectively managing airline schedules and 'whole of network'.

6.5.3 Whole of network efficiency is highly dependent on traffic predictability which is in turn dependent on common and shared situational awareness across a much broader range of stakeholders than involved in layer one and two – most critically airports. It also requires a broadening of the responsibility envelop – with more partners involved and more decision making points.

Airport Turnaround Optimisation

6.5.4 Currently, where there is no effective linkage between airborne and ground flight segments, deviations from the planned traffic situation will not be transmitted to the network. The knock-on effect that deviations from the plan produce on the network are not anticipated downstream by airlines or the ANSP. This will result in a large number of missed slots or non-compliance with the slot allocation requirements and as such in inefficient use of the available en route and airport network capacity.

6.5.5 Unlike apron turn around optimisation, which is focused on increased predictability for individual flights, airport turn-around optimisation is aimed at enhancing predictability and reliability on the ground for all ground flight components (*taxi-in, parking, ground handling, push back etc*), and linking the completion of one flight to the start of the next by the same aircraft (*tail tracking*). It is about whole of airport effectiveness and efficiency.

6.5.6 It is primarily an airport ground operations/airline coordination function; however, its criticality to whole of network operations, and the fact that airports generally operate as independent nodes within the overall system (*i.e., are not directly interconnected*) requires the direct engagement of the ANSP (*Airservices*) – as a collaborative partner, and as the local and system wide information manager (*and major situational awareness information holder*). Airservices also has a significant role as a key decision maker in the (*necessarily*) integral arrival and departure optimisation components[7].

6.5.7 To be effective, airport partners must work together and share data and information more efficiently and transparently. The establishment of a common operational picture, with the same meaning to all stakeholders, will allow improved decisions based on more accurate and timely information. This will allow each stakeholder to optimise their decisions in collaboration with other stakeholders, integrating their preferences and constraints with the actual and predicted situation.

[7] *As indicated previously this does not infer the need (in the first instance) for arrival and/or departure optimisation technology – only the processes/procedures need to be in place.*

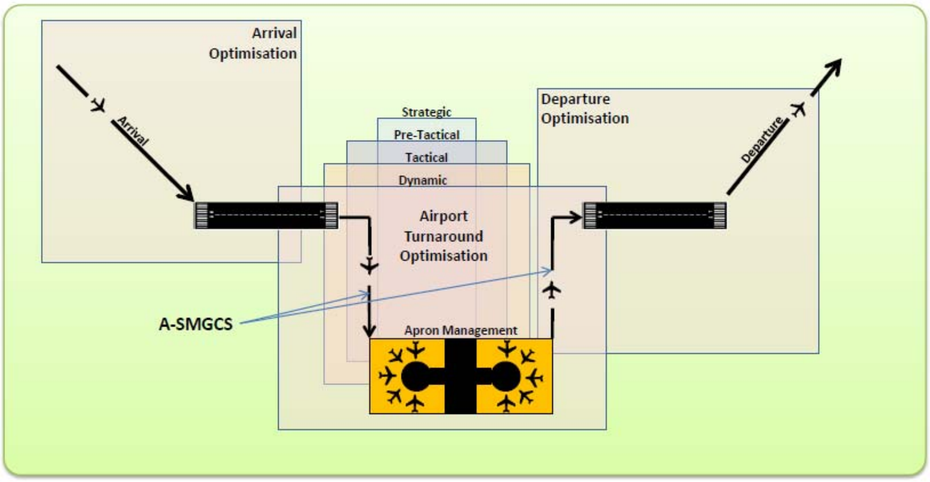


Fig 13: Airport Turn-Around Optimisation

6.5.8 Whilst an information rich environment is essential to airport turn-around optimisation, it also has a significant potential to impede performance. In the strategic timeframe, in the establishment of the business rules for airport turn-around optimisation, the most critical consideration is the establishment of hierarchical decision making processes that are aimed at ensuring that responsibility for compliance is delegated effectively so that overlap is avoided. It is also critical to establish linkages to arrival optimisation and departure optimisation processes – simply getting aircraft in and out of gates or aprons on time does not guarantee that aircraft can actually reach a departure point at a target time.

6.5.9 In the pre-tactical timeframe, the key focus is on the pre-departure sequencing process. One of the main outputs of the airport turn-around optimisation process will be a very accurate target takeoff time (*e.g., ± 1 minute*) which will not only enhance ground planning but can be used to improve en route planning as well as to more accurately plan the management of the whole of Australian airspace – i.e., to enhance the effectiveness of the level 1 and 2 components.

6.5.10 In the tactical and dynamic timeframe, the focus is on ensuring that aircraft are manipulated onto and off gates to ensure that either a pre-determined takeoff slot is achieved – or more critically that if it cannot be used, it is immediately available for use by another aircraft. This requires immediate or near immediate access to decision making processes at the aircraft (*either by the pilot, or ground handling staff*) when slot compliance is in doubt, so that the slot can be re-allocated, and a new slot determined.

6.5.11 In order to work effectively, turn-around optimisation needs to be supported by arrival and departure optimisation. There is no point achieving a high level of fidelity in getting an aircraft off an apron if it is not possible to get the aircraft to the departure point or airborne on time, or from an arrival runway to the apron so that it's turn-around clock can be started. As indicated previously, this does not require the implementation of technology – it can be achieved procedurally.

Departure Optimisation – Network Focus

6.5.12 Departure sequence optimisation in Layer 3 aims to present aircraft for departure at the runway holding point in a sequence that integrates the user's departure time expectation (*schedule*), anticipates potential downstream arrival sequence or air traffic flow management requirements, and factors/mitigates the departure capacity constraints (*network*). There are four major constraints on the departure capacity of an airport:

- ***Aircraft Mix at Runway*** - different aircraft wake vortex standards, runway entry and roll-time restrictions, etc
- ***Terminal Area Departure Paths*** – limitations of standard departure procedures, segregation of multi-runway departure paths, arrival/departure crossovers, etc
- ***Manoeuvring Options at Runway Holds*** – availability of holding/run-up bays, multiple runway entry points, etc
- ***Taxiway Manoeuvring Options*** – availability of apron exit options, taxiway options, etc

6.5.13 As with Layer 2, departure sequence optimisation as a third layer CDM application is more critical at airports that already have, or anticipate having departure capacity constraints. It will be critical for those airports that have limited taxiway or runway flexibility. Departure sequence optimisation complements and enhances airport turn around optimisation – it is essential to be able to move aircraft from aprons to departure points optimally – delays or congestion on taxiways degrades apron performance.

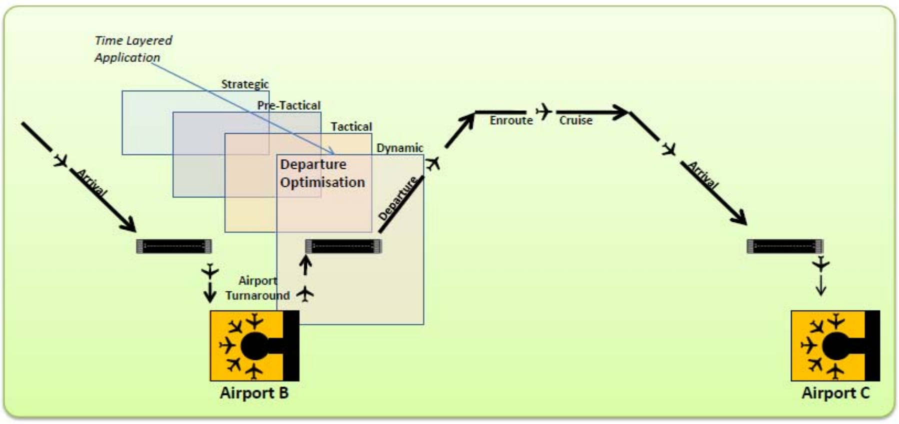


Fig 12: Departure Optimisation

6.5.14 Business rules are developed in the strategic time frame, and will factor average taxi times, typical terminal area airspace management practices, potential airline preferences, typical apron management constraints, and so on. Pre-tactically, airline departure sequence preferences are established, and known or anticipated parking positions, taxiway and departure runway configurations etc are factored. Tactical application of departure sequence optimisation is focused not only on presenting aircraft in a particular order at the runway, but also on minimising dynamic delay and reducing queuing – i.e., leaving start-up and push-back as late as practicable.

6.5.15 Departure sequence optimisation enables improved response and reaction to unforeseen events and can therefore reduce the negative impact of such an event (*e.g., instantaneous runway closure due to accident, weather changes etc*). By constantly monitoring and distributing information departure sequence optimisation enables dynamic plan updates based on the current situation and timely distribution of the information to the different operators and stakeholders at the airport.

Arrival / Departure Optimisation

6.5.16 As runway capacity is reached more consistently, it is important to ensure that an integrated approach is taken to managing arrival and departure streams – both to ensure that airport/gate throughput is maintained, but more critically to leverage the constraints in each stream to create capacity opportunities.

6.5.17 This is particularly important when there are varying wake turbulence categories in arrival and/or departure streams (ne*cessitating a larger arrival or departure slot, within which another aircraft may be landed or departed)*, or when there is an emphasis on arrivals over departures (*or vice versa*). It is also important when multiple runways are being used for uni-functional streams (*one runway for arrivals, one runway for departures*) and there are gaps that may be utilised for the opposite function.

6.5.18 In Layer 3, arrival/departure optimisation for the concept of high and consistent runway throughput requires both integration of the arrivals sequence optimisation and departures sequence optimisation functionality – and a high level of information sharing and situational awareness fidelity, and target window compliance (*from both users and ATC*), as the critical dependency is the precise interspersing of landing and departing aircraft in a high workload environment.

6.5.19 Of particular importance from a dynamic perspective is the interaction between the ATC Tower function and the ATC Arrival/Approach function. Precise taxiway management is also essential to ensure that the runway is vacated when required by landing aircraft, and that departing aircraft are delivered to the runway threshold in the correct sequence and at the time required – in all weather conditions. Airport routing and guidance aids developed in more advanced functions of A-SMGCS (*for example*) are expected to contribute to even more precise taxiway management.

Integration of Departures to Next Airport Arrivals

6.5.20 Most airports operate as independent nodes within the ATM system and their individual operation can have significant impact on either upstream or downstream operations. This is particularly important when those upstream or downstream airports are critical nodes, with high demand or capacity constraints. The last component of the collaborative decision making framework is the integration of sequencing operations at one airport – in particular departures - with the arrival component of operations at the next airport for any particular aircraft.

6.5.21 This integration of planning across the network is essential from a user perspective for the maintenance of predictable schedules – with schedule maintenance issues being amortised and managed across a series of flights (*by the same aircraft*). The aim is not, for example, to eliminate delays, but to use the integrated system to prioritise operations for one or more flights to mitigate the effect of that delay.

6.5.22 In practice, this means that rather than integrating a departure and subsequent arrival for one flight, a departure at one airport may actually be integrated into an arrival stream 2 or 3 flights downstream. This is the ultimate goal of tail tracking (*management of an airframe associated with a series of flights*).

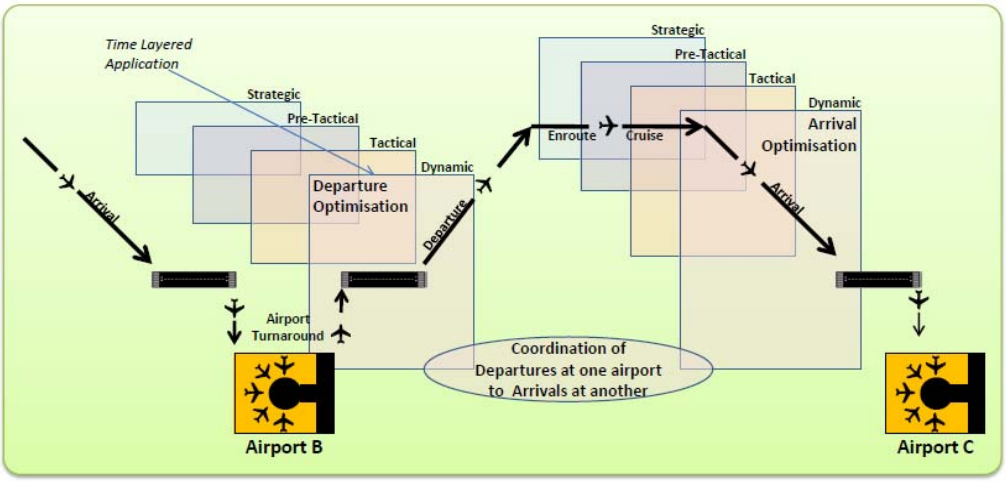


Figure 14: Integration of Departures to Next Airport Arrivals

6.5.23 In the strategic timeframe, business rules are established for managing aircraft through the system rather than individual flights. This requires close integration of intended business outcomes, prioritisation of city pairs, etc. Because the management process extends across a series of airports, the CDM process is necessarily more complex than layer 2 activities, and will need to be supported by a range of automated modelling and decision support tools.

6.5.24 The need to integrate CDM at several airports also means that managing system variables (*weather, etc*) becomes more complex. For this reason, higher fidelity management will generally be left to the pre-tactical timeframe – with significant overlap into tactical. This means that whilst individual flights will be managed tactically, there will be a simultaneous pre-tactical management process related to downstream flights by the same aircraft. In addition, the post-tactical flight analysis will become a significant input to tactical and pre-tactical management of downstream flights.

Appendix 1: CDM - Extract from the ICAO ATM Operational Concept

10. COLLABORATIVE DECISION MAKING[8]

10.1 Collaborative decision making will allow all members of the ATM community, especially airspace users, to participate in the ATM decision making that affects them. The level of participation will reflect the level to which a decision will affect them.

10.2 Collaborative decision making will apply to all layers of decisions, from longer-term planning activities through to real-time operations. It will apply across all concept components of the ATM system and is an essential element of the operational concept.

10.3 Collaborative decision making means achieving an acceptable solution that takes into account the needs of those involved. All participants will therefore require a spirit of cooperation. A balance is required because collaborative decision making is primarily invoked to resolve competing demands for an ATM resource and to organize a safe sharing of that resource among airspace users.

10.4 The time available for achieving a collaborative decision decreases from the strategic to the tactical stages. In the most tactical of situations, there may be no time to consider options; however, wherever such situations can be foreseen, collaborative decision making will have been previously used to determine agreed procedures for such cases. For example, rules for determining priorities for accessing an ATM resource will have been collaboratively agreed in advance. Therefore collaborative decision making can be applied both actively and, through agreed procedures, passively.

10.5 Effective information management and sharing will enable each member of the ATM community to be aware, in a timely manner, of the needs, constraints and priorities of other members in relation to a decision-making issue.

10.6 Collaborative decision making can occur among airspace users directly, without any involvement of an ATM service provider.

10.7 Where a service provider is involved in collaborative decision making because of a requirement of the ATM system, it is often the ATM service provider that will propose a solution for consideration by the airspace user because the service provider will be aware of the requirements of other users and service providers and the collaboratively agreed rules for resolving competing requests for an ATM resource. However, because it is an information-rich environment where the airspace user may have access to the same information as the service provider, the airspace user will understand why a particular solution has been proposed.

10.8 If time permits, a user can propose an alternative solution that addresses a user's preference that is not known to the service provider. In the same way, the service provider can reject the user's proposed solution because of an ATM requirement that the user is not aware of. This illustrates how important full sharing of appropriate information is in order to have timely collaborative decision making.

[8] *Global Air Traffic Management Operational Concept – ICAO Doc 9854 – Appendix I*