Runway Capacity Assessment

Presented by Singapore

ICAO APAC Airport and Airspace Capacity Assessment Workshop

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CAAS

Agenda

1. Background
2. Factors affecting Runway Capacity
3. Establishing Strategic Runway Capacity
4. Determining Operational Runway Capacity
5. Post Operational Review

Background

Why is there a need for runway capacity assessment?

- Sets the baseline for aerodrome operations
- Ensure traffic growth in a sustainable manner
- Allow ANSPs to understand the variable operational constraints and its relevant impact
- Provide clarity on controller workload and safety margins
- Planning for future infrastructure

How accurate runway capacity can help to support efficient ATM operations

- Understand on the need to implement measures to regulate demand pressure (e.g., airport slot allocation, ATFM measures)
- Better assessment on the potential benefits of future ATM initiatives (e.g., FF-ICE, SWIM, TBO) to be ready for future growth

Factors affecting Runway Capacity

- Runway capacity is:
  - Defined as number of aircraft movements (landings and take-offs) that can be actualized on runways within a time period in a sustainable manner
  - Expressed in aircraft movements per hour (amph)

Operational Performance Factors

ATC performance
(Operational buffer & sequencing)

Runway occupancy performance
(Pilot Performance)

Runway operations mode
(segregated/mixed)

Other (exogenous) Factors

Weather (including wind)

Wildlife Hazards

Disruptive events / activities
(e.g. unexpected drones, unknown ac)

Design and Planning Factors

Design
(once set it is not easy to change, e.g. infra on ground, in air etc)

- Number and orientation of runway(s)
- Airfield design
  (end-around taxiways, rapid exit taxiways etc)
- Instrument Flight Procedures
  (ILS, SID, STAR)
- Separation minima (safety distance)

Planning
(can be dynamic)

- ATC and ATM Procedures
  (Simultaneous Independent Parallel Approaches)
- Runway availability
- Airspace availability
  (space to manoeuvre aircraft)
- Traffic mix
  (wake turbulence, turboprop vs jet aircraft)

Declared vs Operational Capacity

- **Declared (Strategic) Capacity** is the number of aircraft provided with ATC service should not exceed that which can be safely handled by the ATS unit concerned
- **Operational capacity** is the expected capacity associated with the tactical situation at the airport. Dynamic factors may result in an operational capacity inferior to the declared capacity
- In nominal operating situation, the strategic and operational capacity would be the same
- **Airport capacity** could be the same as strategic runway capacity if there are no limitations in terminal capacity e.g. parking stands, ground handling services, check-in counters and security checkpoints

Establishing Strategic Runway Capacity

Methodology used for Changi Airport

- **Monte Carlo simulation used to determine maximum strategic arrival capacity**
- **Calculated in 15- and 60-minutes blocks**
- **Considers factors such as:**
  - Aircraft mix distribution
  - Wake Turbulence Separation Minima
  - Aircraft approach speeds on finals
  - Additional in-trail spacing
  - ATCO operational buffer between aircraft
  - Mode of runway operations
- **Results are further validated using Fast Time Simulation (FTS) and Human-in-the-Loop Simulation (HITL)**
  - Provides additional verification of operational feasibility to manage arrival rates

Establishing Strategic Runway Capacity

Incorporating Local Constraints/Considerations

* Images from open-source internet

- **Firebreaks**
  - Reduction in strategic runway capacity at periodic intervals
  - Introduced as a built-in buffer for ATC to clear traffic after peak periods to prevent delay accumulation
- **Runway Maintenance**
  - Based on duration of scheduled inspection / maintenance, strategic runway capacity is reduced to take into account runway unavailability
  - For shorter runway inspection periods (e.g., 5-10 mins) which may not follow its planned schedule as strictly, strategic runway capacity is reduced from a 3-hour block instead to accord more flexibility to meet airlines' scheduling needs

Determining Operational Runway Capacity

Planned Events

Events impacting runway capacity in Changi

- National Day Parade and rehearsals
- Air Defense Exercises
- Singapore Airshow

Strategic Phase

- Initial estimation of runway capacity based on planned event details
  - Assessment of runway impact due to airspace closure duration
- Coordination with Airport Operator (AO) and Airspace Users (AU) for flight rescheduling to facilitate planned closures

Example: A 30 minutes closure may reduce runway capacity by 50%

Pre-tactical Phase

- Refinement of operational runway capacity estimates incorporating operational considerations from ATC

Example: Proximity of holding stacks which may prevent runway utilization immediately after re-opening of airspace

Tactical Phase

- Finalization of operational capacity using day-of-event weather forecast and other real-time factors

Example: Adverse weather during or immediately after re-opening may necessitate additional adjustments to planned capacity

Determining Operational Runway Capacity

Unplanned Events

Forecasted Inclement Weather

In-Trail Spacing Requirements
Determined while taking into consideration runway conditions, visibility and surface wind conditions

Forecasted Surface Wind Direction
Affects runway configuration and vectoring patterns

Duration of Weather Impact
Longer periods of adverse weather further constrain runway throughput

Operational Capacity

Disruption to ATM resources

Type of Disruption
- Disabled aircraft on runway
- Runway surface damage (e.g., potholes)

Duration of Runway Unavailability
Includes expected time for incident resolution and asset clearance

Service Recovery Timeline
- Full recovery post-disruption rectification
- Phased return to normal operational levels

Weather Forecast Support
Real-time wind and weather data guide safe recovery planning and capacity recalibration

Determining Operational Runway Capacity

Methodology used to assess reduction in runway capacity

Adverse Weather Event

- Key factor: In-trail Spacing achieved based on historical events or commonly coordinated by ATC
- Additional considerations: Forecasted surface wind affecting take-off conditions, more crucial during inter-monsoon season
- Methodology
  - Operational Airport Arrival Rate (AAR) = Typical aircraft ground speed over threshold / Required In-Trail Spacing

Disruption to ATM resources

- Key factor: Type and duration of outage to ATM resource
- Additional considerations: Changes to ATC separations/in-trail spacing requirements
- Methodology
  - AAR and Airport Departure Rate (ADR) are dynamically calculated and should factor in the above considerations
  - Use pre-established hourly arrival-departure ratio to determine the AAR and ADR during prolonged runway disruption
- Develop playbooks for different ATM resource disruption scenarios and expected impacts

Post Operational Review

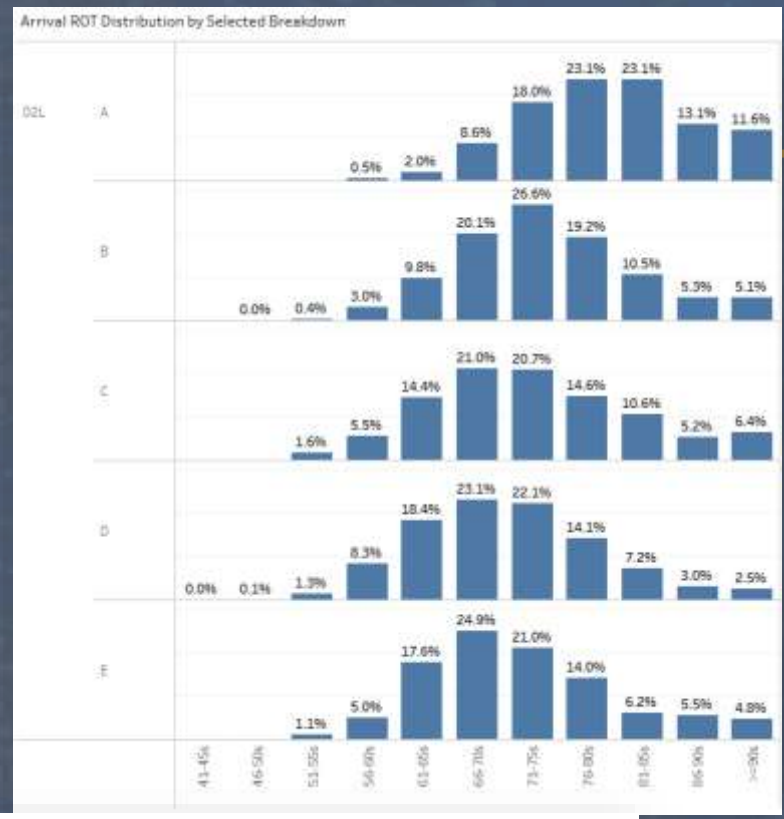
Strategic Runway Capacity

- At Changi Airport, the strategic runway capacity is reviewed every three years – or more frequently when necessary – to ensure continued operational effectiveness
- POA is a key component of this cycle. It provides valuable insights into the accuracy of prior assumptions and serves as a reference point for future capacity assessments
- The POA also helps to identify operational areas that may benefit from improvements, supporting efforts to enhance both safety and efficiency of ATM operations

Post Operational Review

Monitoring Runway Capacity Utilisation

- Arrival Runway Occupancy Time (ROT) Performance
  - Changi Airport measures arrival ROT using A-SMGCS based on aircraft transponder
  - Calculated from the time the aircraft crosses the runway threshold, to the time when the aircraft is 120 metres perpendicular from the runway centreline
  - ROT performance is shared with airlines and pilots are encouraged to vacate the runway via the first available Rapid Exit Taxiway (RET) as quickly as practicable
  - Improving ROT performance enables ATC to apply the minimum wake turbulence separation required on final approach and minimise the occurrence of missed approaches due to occupied runway



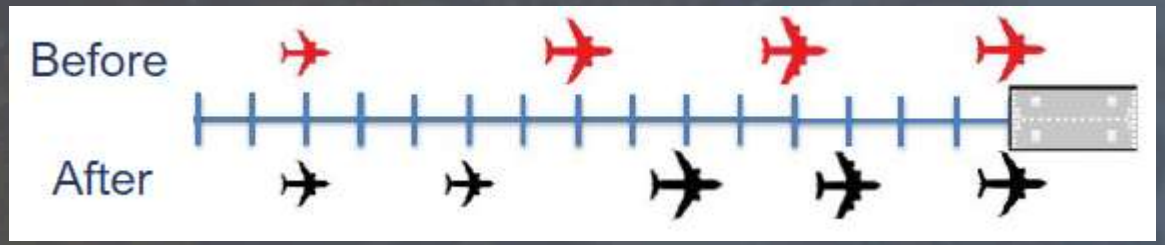
		% of arrivals	Average ROT
02L	A	2.6%	80.48
	B	44.8%	74.52
	C	1.6%	73.43
	D	49.8%	70.93
	E	1.1%	72.36

Post Operational Review

Changes to ATC Procedures to optimise runway capacity

- Changi Airport implemented Wake Turbulence Group for Arrivals in February 2022
- Utilises the seven wake turbulence groups (Group A-G) instead of the four wake turbulence categories (J, H, M, L)
- Allows for more efficient arrival spacings with varied traffic mix
- Changi Airport saw an overall increase of 1-2amph from the implementation Wake Turbulence Group for Arrivals

Aircraft category		*Wake turbulence radar separation minima*
Preceding aircraft	*Succeeding aircraft*	
A380-800 [SUPER (J)]	A380-800 SUPER (J)	4 NM
	HEAVY (H)	6 NM
	MEDIUM (M)	7 NM
	LIGHT (L)	8 NM
HEAVY (H)	SUPER J	4 NM
	HEAVY (H)	4 NM
	MEDIUM (M)	5 NM
	LIGHT (L)	6 NM
B757 (M)	MEDIUM (M)	5 NM
	LIGHT (L)	6 NM
MEDIUM (M)	MEDIUM (M)	3 NM
	LIGHT (L)	5 NM



		Succeeding Aircraft						
		Group A	Group B	Group C	Group D	Group E	Group F	Group G
Preceding Aircraft	Group A		4 NM	5 NM	5 NM	6 NM	6 NM	8 NM
	Group B			4 NM	4 NM	5 NM	5 NM	7 NM
	Group C					3.5 NM	3.5 NM	6 NM
	Group D							4 NM
	Group E				3 NM			4 NM
	Group F							
	Group G							

Thank you

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