Regional Focus

canso

Advancing ATM Research & Development in the Asia Pacific

Spotlight on ASI

Thursday 14 January 2021

08:00 – 10:00 CET

Moderator

Mr. Hai Eng Chiang

Director Asia Pacific Affairs

CANSO

Peter Jackson

Professor, Head of Pillar (ESD) and Director of Aviation Studies Institute (ASI), SUTD

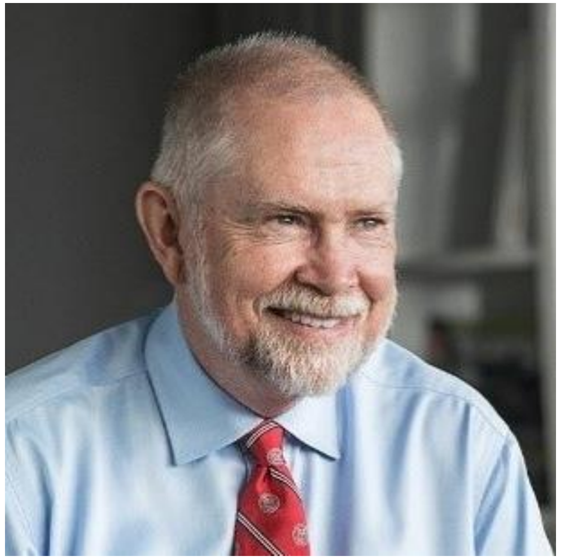
Nuno Ribeiro

Assistant Professor, Engineering Systems and Design, SUTD

Karthyek Murthy

Assistant Professor, Engineering Systems and Design, SUTD

Speaker



Peter Jackson

Professor, Head of Pillar (ESD) and Director of Aviation Studies Institute (ASI)

SUTD

Introduction to ASI and its Research Projects

January 2021

Overview of ASI

- Established jointly with the **Civil Aviation Authority of Singapore**

- Aims to be a **world-leading research centre in aviation and air traffic management** (ATM):

    - Conduct **operational, economic and policy research** in aviation and air traffic management

    - Provide **new insights, perspectives and potential solutions** to challenges faced by the aviation community

    - Nurture a community of **local and global talents** based in Singapore to promote **sustainable aviation growth** for the region

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Civil Aviation Authority of Singapore
Enabling opportunities through aviation

Aviation Studies Institute

ASI

Importance of Institute to Singapore

- Aligned to the aim of seamless skies through defragmentation and digitalisation of ATM to **facilitate the development of safer and more efficient air travel**

- First ATM R&D centre in Singapore that focuses on operational, economic and policy research to **generate insights for improving and transforming ATM operating models**

- Enables stakeholders to adopt solutions that can **enhance operational efficiency, increase capacity and global interoperability**, and **facilitate dialogue on region-wide collaborative approaches**

CAAS
Civil Aviation Authority of Singapore
Enabling opportunities through aviation

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Importance of Institute to Education

- Contributes significantly to **Aviation thrust of SUTD's strategic growth plan**

- Embraces SUTD's bold advocacy for design innovation to tackle practical problems in the Aviation policy domain from a **system design perspective** and leverage the **computational tools of data analytics, optimisation and reinforcement learning**

- Complements and enhances **SUTD's aviation focus in research and education**, and offers students **a macro view of the aviation system**, and a deeper understanding of its value creation to stakeholders

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Research Agenda and Focus Area

Faculty Members

Peter Jackson
Institute Director of ASI
Professor and Head of Pillar
Engineering Systems and Design

Costas Courcoubetis
Professor
Associate Head of Pillar
Engineering Systems and Design

Karthyek Murthy
Assistant Professor
Engineering Systems and Design

Nuno Ribeiro
Assistant Professor
Engineering Systems and Design

Wang Xingyin
Assistant Professor
Engineering Systems and Design

Summary of ASI Research Projects

Airport Connectivity
Develop automated tool for constructing the airport connectivity graph and analysing it for centrality

Airfield Management & Economics
Develop optimization model and conduct simulations to support airport slot allocation process

Network Capacity
Build analytical model of ASEAN airspace with current airline flights to hypothetically discover when and where bottlenecks arise

Information Sharing
Identify, quantify and examine network-wide benefits of information sharing in the ASEAN context

Emerging Policy Issues
Conduct policy studies focusing on convergent, interdisciplinary research and education in aviation systems

Translational Research
Translate tools, techniques and expertise into practical applications

Airport Connectivity

- **What makes one hub more "central" than another?**

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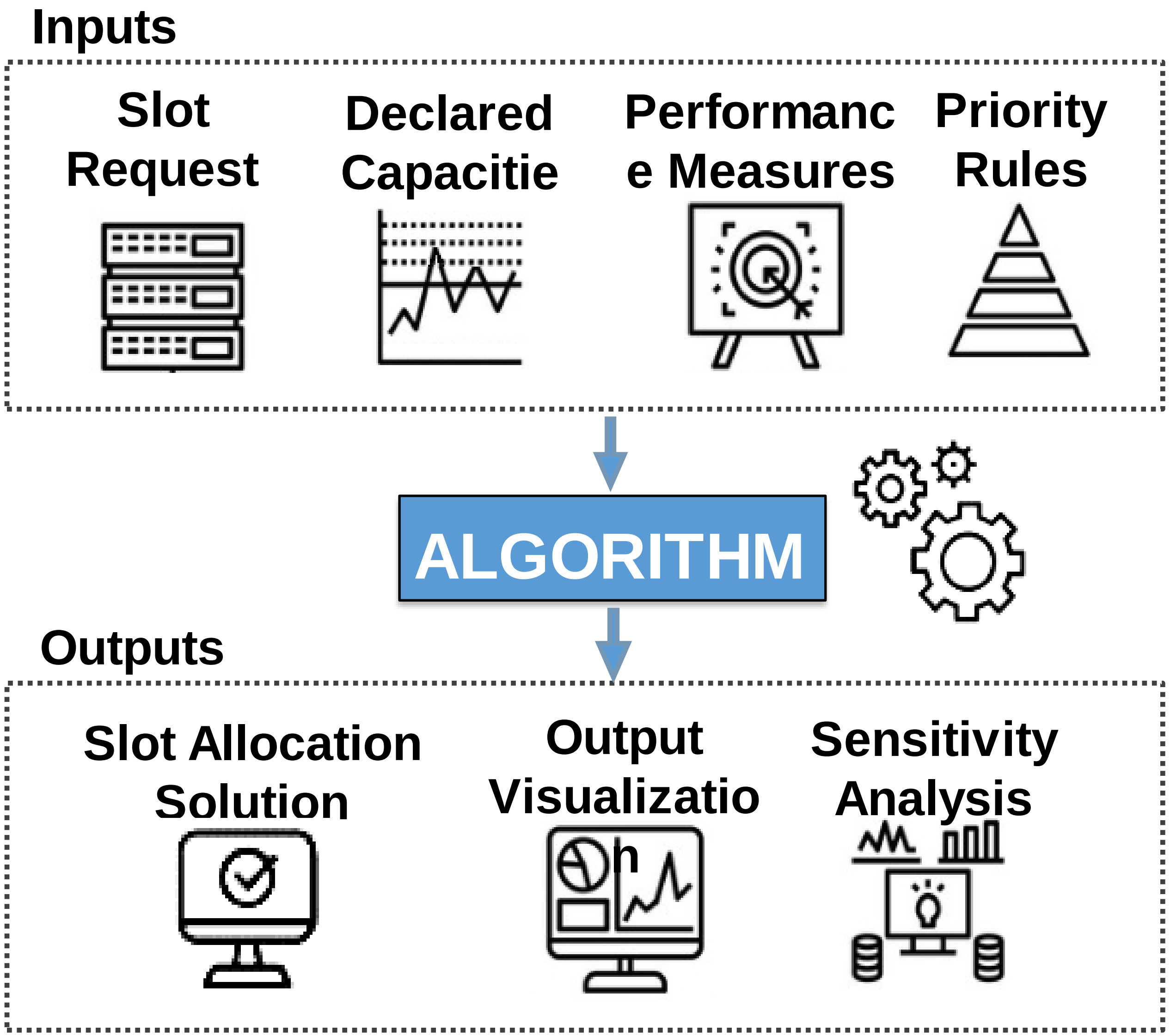
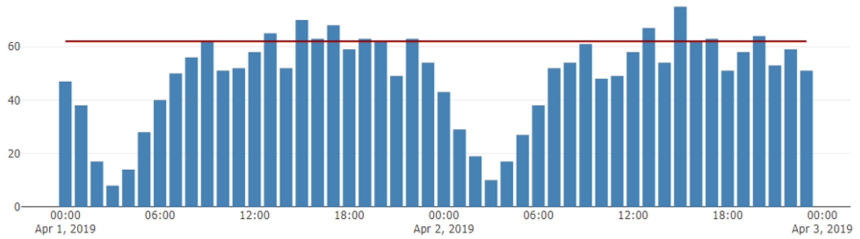
Airfield Management and Economics

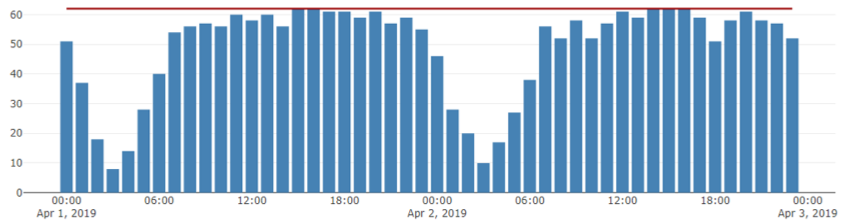


Slot Requests



- **How best to estimate and allocate slot capacity?**

Slot Allocated



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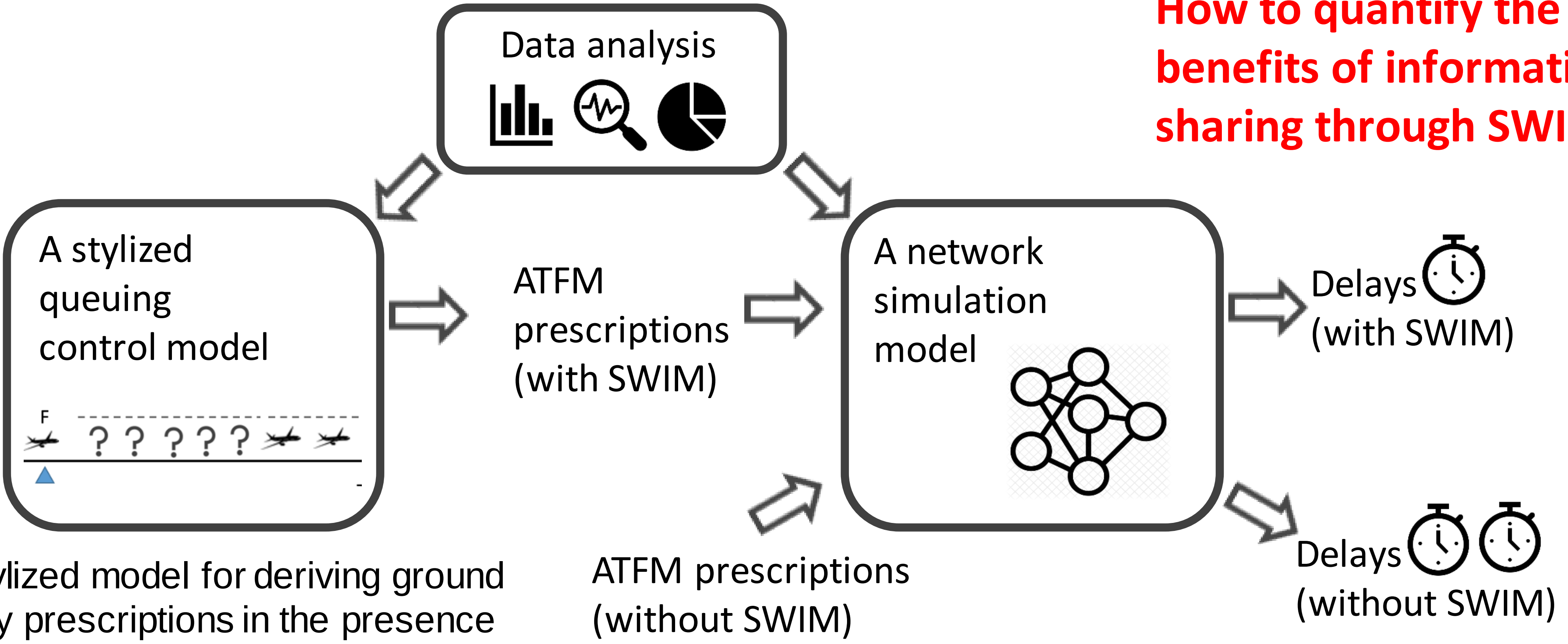
Information Sharing

How to quantify the benefits of information sharing through SWIM?



- A stylized model for deriving ground delay prescriptions in the presence of SWIM infrastructure
- A network simulation model for yielding delay estimates for the ground delay prescriptions in SWIM and non-SWIM settings

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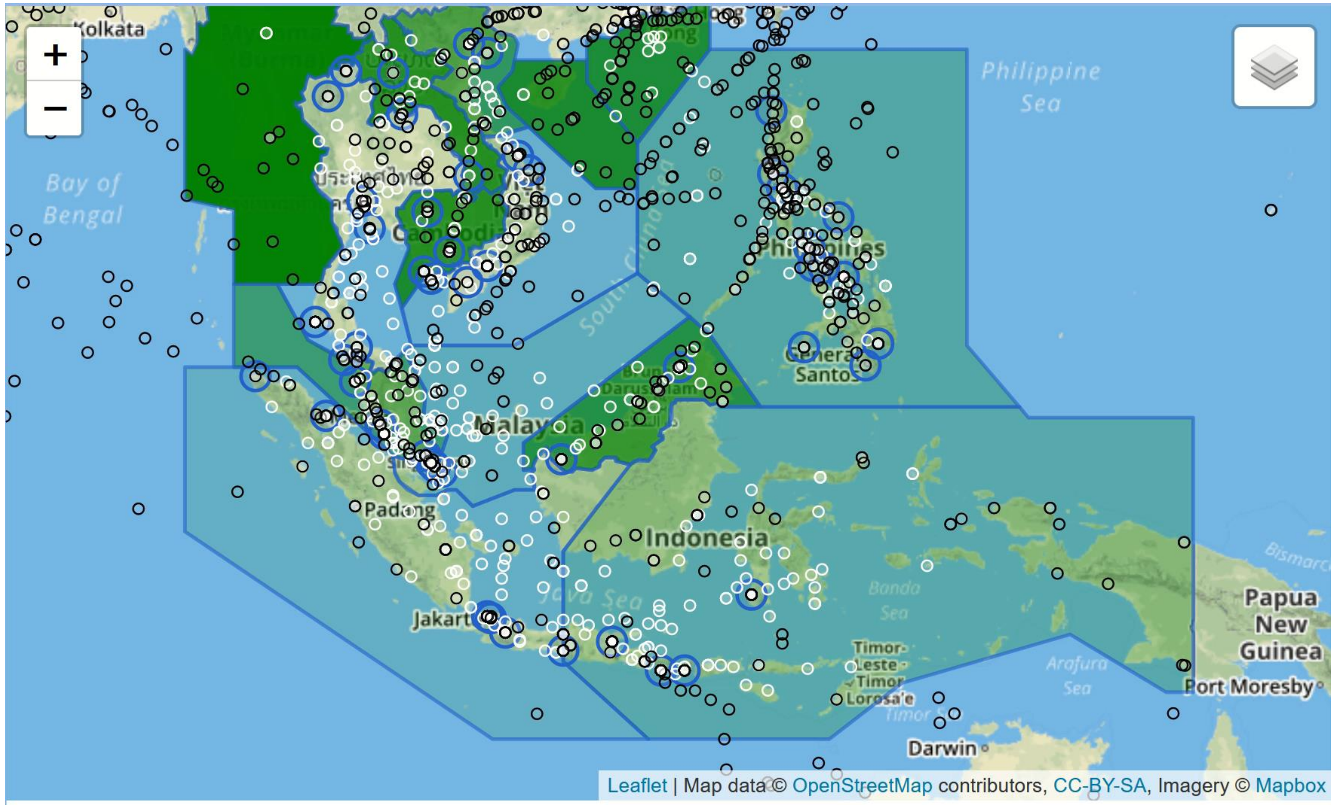
Network Capacity

- **Where are the ‘pinchpoints’ in the ASEAN aviation network?**



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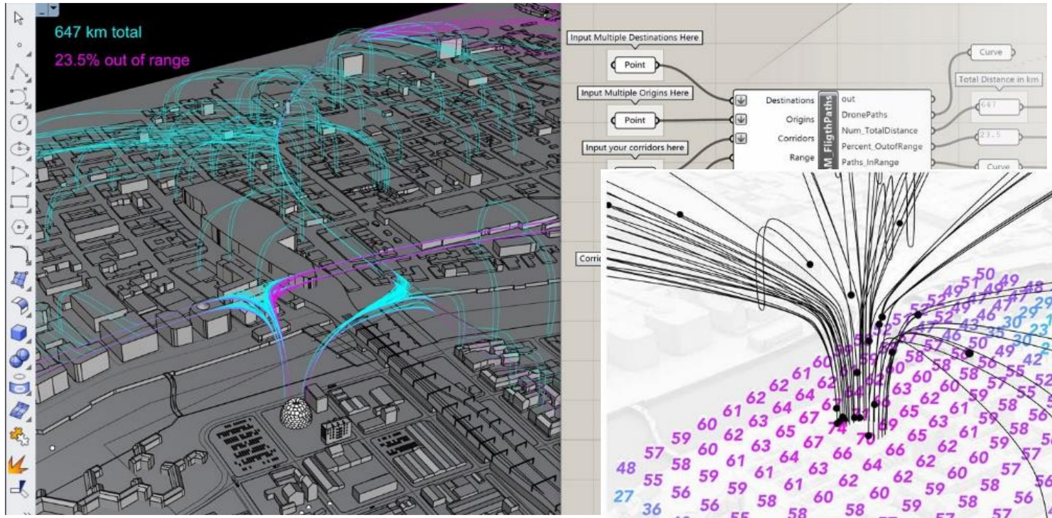
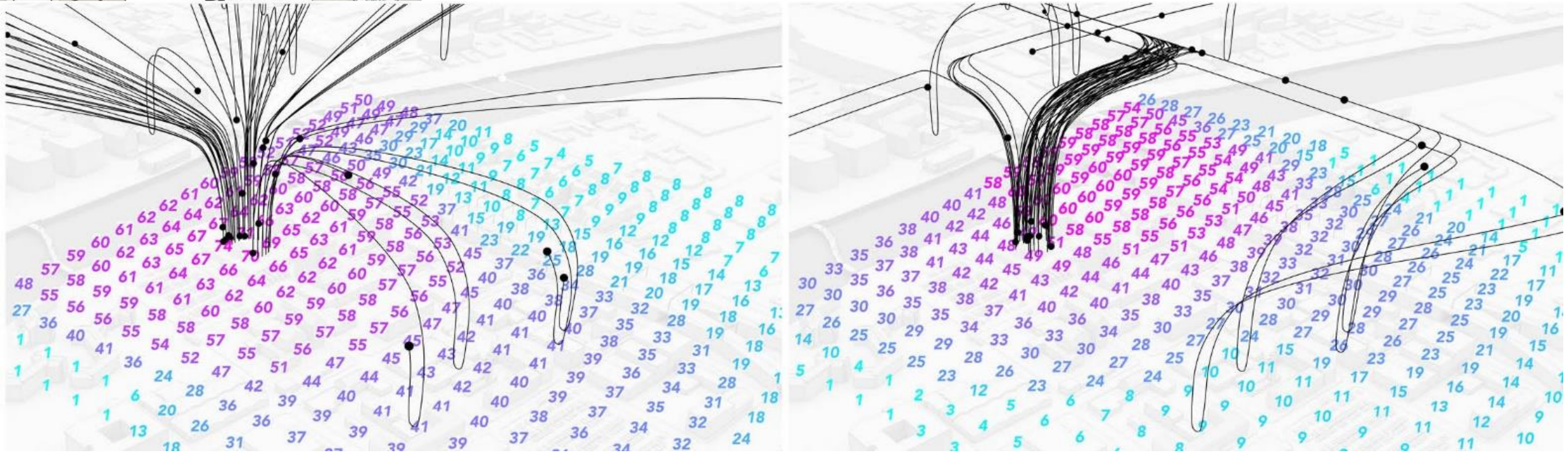
Emerging Policy Issues

- Simulation models of drone traffic
- Collaboration with: Peter Ortner, SUTD ASD
  - Noise pollution from drone delivery

What will be the impacts of high-volume drone delivery services?



Model of flight path scenarios (Glasgow)



Comparison: noise simulation from direct drone flight paths (left) v.s. corridor-based drone flight paths (right)

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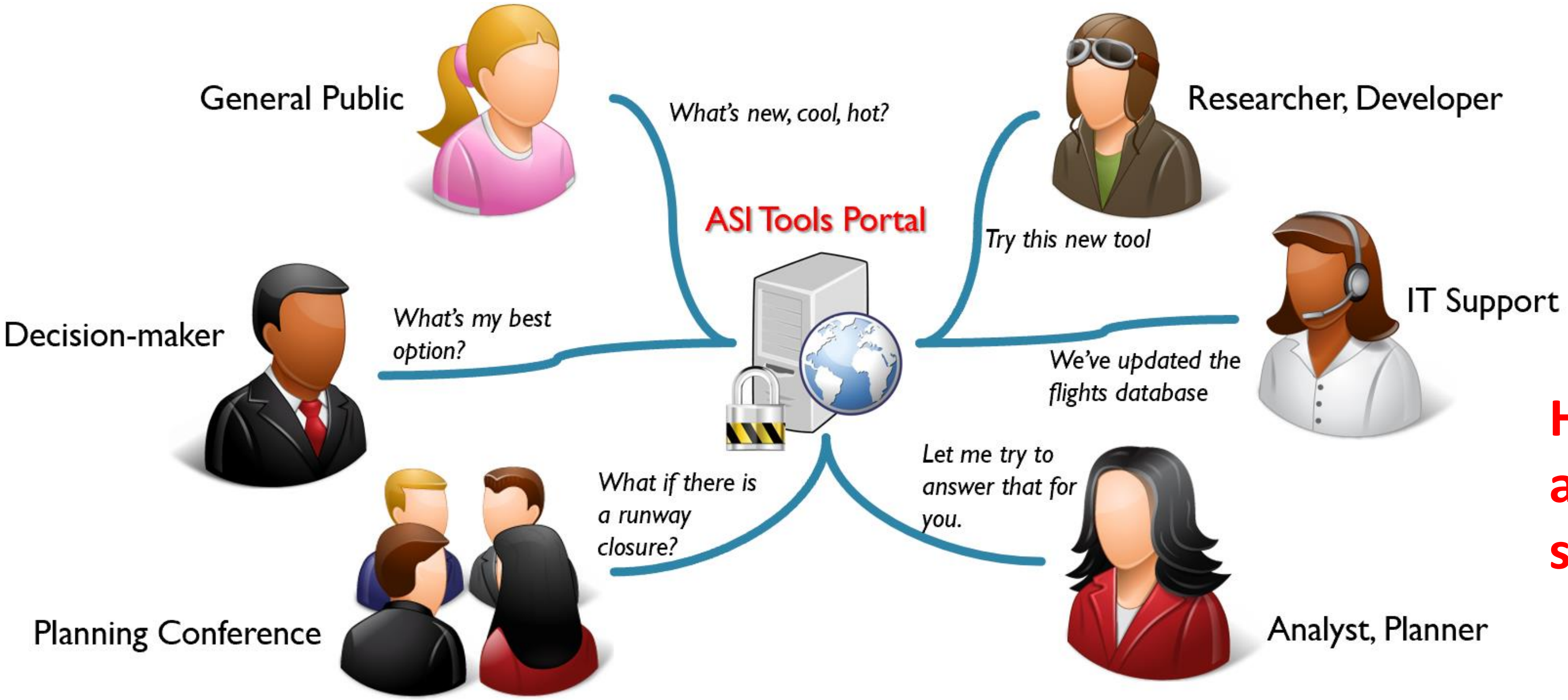
Translational Research



How to deliver aviation analytics to multiple stakeholders?

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White Papers

- **ASI White Paper: Restarting International Air Travel Within ASEAN, December 2020**

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Thank you

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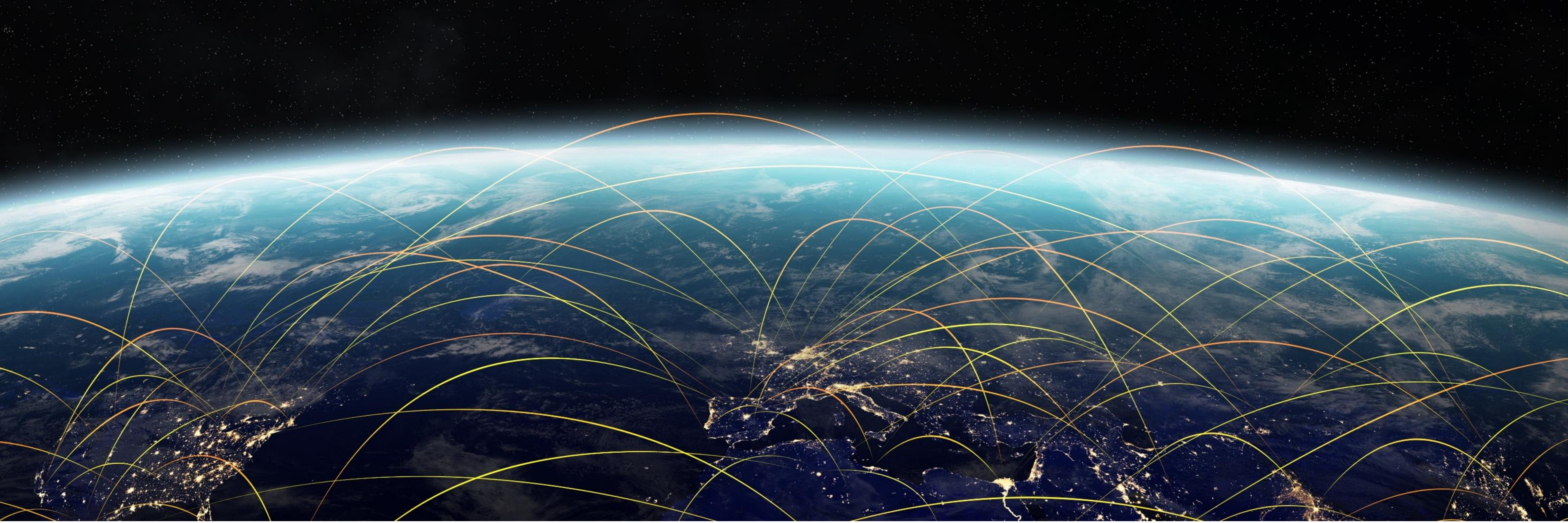
Spotlight on ASI



Introduction to ATM Air Traffic Capacity in a Post-COVID ASEAN Region

Peter Jackson, Director, Aviation Studies Institute, SUTD

Civil Aviation Authority of Singapore

Enabling opportunities through aviation

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What a Difference a Year Makes!

Pre-COVID-19

- Growth in global commercial air travel highest in Asia-Pacific
- 3-4% annual growth rate, with volume doubling in 12-15 years
- Airport expansion plans throughout region
- Some airports to double capacity in 10 years
- Global competition to hire air traffic controllers
- Congestion in air routes: South China Sea and Bay of Bengal

Post-COVID-19

- Global contraction in air travel ~50%
- ASEAN international travel down by 97% in April-October 2020 from 2019
- Airport construction projects suspended
- Bankruptcies, hiring freezes, and layoffs
- Air cargo increased 30%
- Rise of video-conferencing and home delivery

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The Network Capacity Project

Pre-COVID-19 Concerns

- Prepare for coming ‘capacity crunch’
- Take integrated view of ASEAN region
  - Capacities of airports in region
  - Capacity of en-route control
- Identify bottlenecks and systemic relationships
  - Propagation of delays through the network
- Advance regional cooperation in solving systemic issues
  - New routes
  - Targeted investments

Post-COVID-19

- Concern for capacity crunch is less urgent
- Concern shifts to retaining ATC talent
- As demand returns, where will controllers be needed in region?
- How will shifting demand patterns affect capacity plans?

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Network Capacity Optimization

Use Case

- Tool optimizes network flows in ASEAN region subject to capacity constraints. Scenarios allow study of ripple effect from short-term schedule disruptions.
- Tool has front-end interactive manipulation of capacity assumptions and exploration of resulting traffic patterns plus back end support for high performance computing, optimisation and analytics

Benefits

- Provides opportunity to CANSO partners to discuss network effects of capacity constraints.
- Decision-makers can engage in "What-If" discussions and gauge critical numbers.
- Users are able to build scenarios, examine resulting traffic patterns, and compare performance across scenarios.

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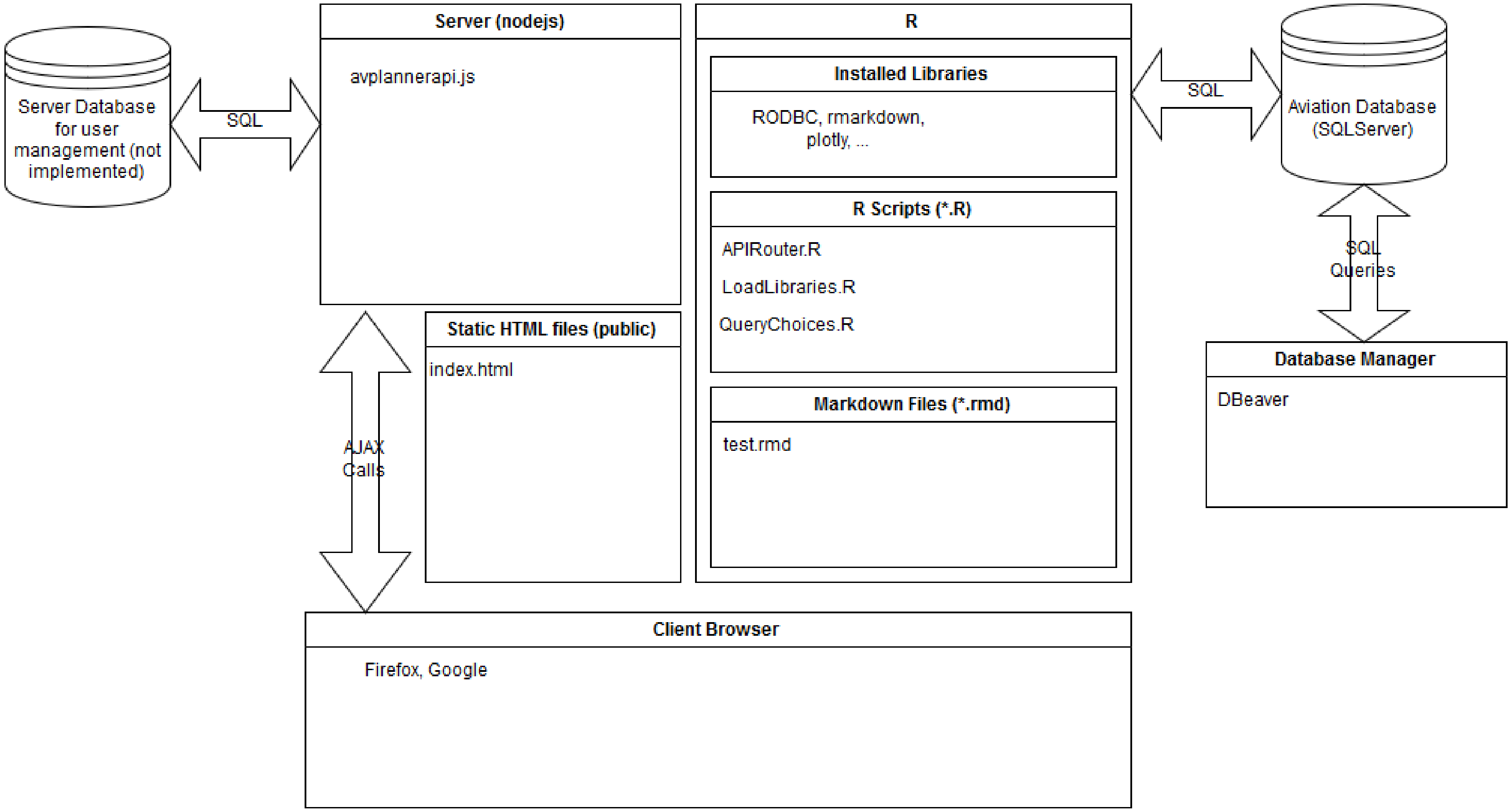
ASI Tools Architecture

- Analytics projects are now too data-intensive for spreadsheet deployment
- Need web-based service to facilitate dialogue



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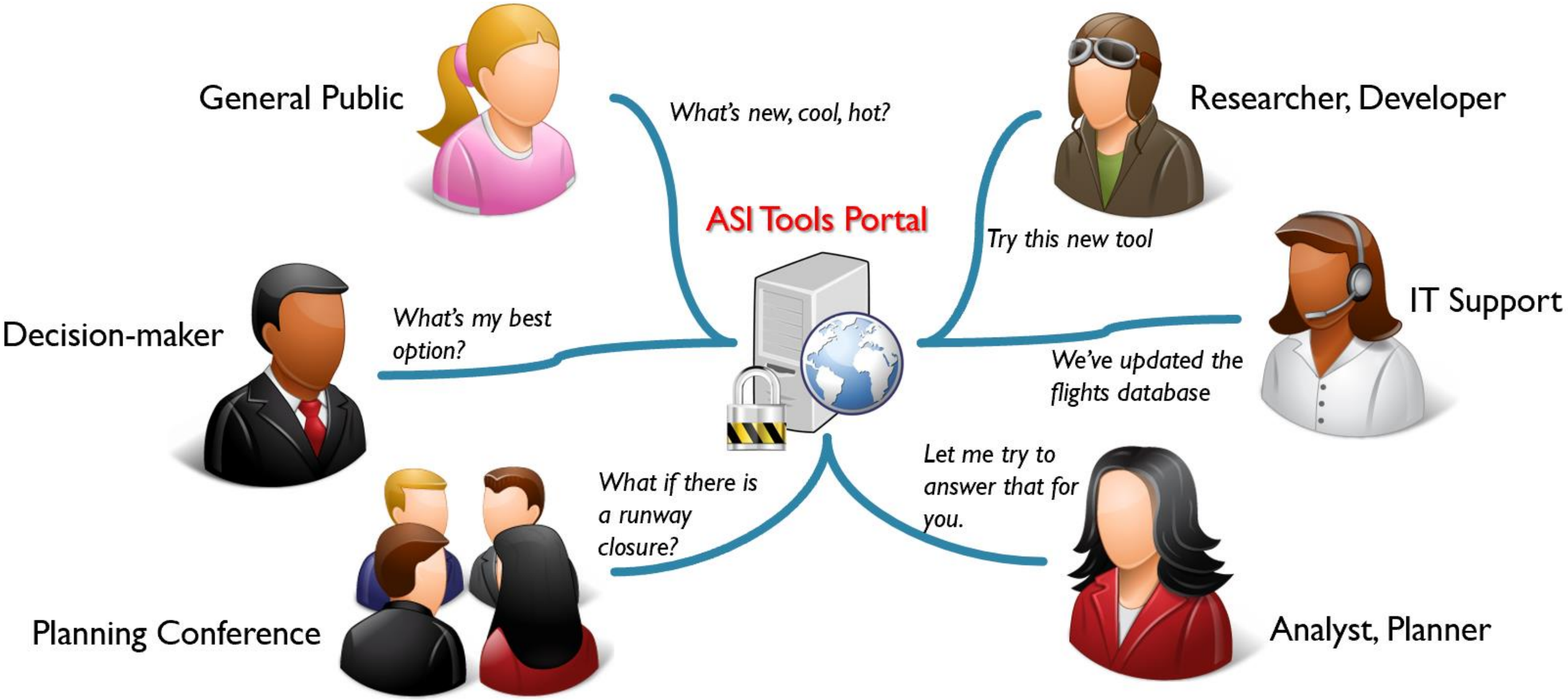
Design Thinking: Analysis as a Service



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Elements of Network Capacity Analysis

- Regional focus: ASEAN countries
- Capacity of airports and of en-route control
  - Capacity envelopes (arrival and departure constraints)
  - ATC workload constraints
- Schedule-driven: time of day peaks
- Systemic relations: propagation of delays through connecting flights
- Routing alternatives: weather, volcanic activity
- Responses to capacity shortfalls: ground delays and flight cancellations
- Intra-region traffic and long-distance
  - Differential use of delay programs

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Network Capacity Analysis Tool

- Air Traffic Flow Management (ATFM) approach
  - Not for operational control (!)
  - Use for planning and simulation, “What if?” analysis
- Based on 4D-trajectory optimization
  - For greatest realism of systemic relations
- State-of-the-art
  - Now including flight connections (for delay propagation analysis)
- Analyst-friendly interface

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State of Tool Development

- Prototype was demonstrated at Singapore Air Show 2020
- Advances in optimization
  - Included flight connection optimization
- Database development
  - Working on developing capacity envelopes for ASEAN international airports (using pre-COVID-119 data)
  - Documenting en-route control sectors for ASEAN region
- Extending application to translate evolving schedules into regional ATC needs

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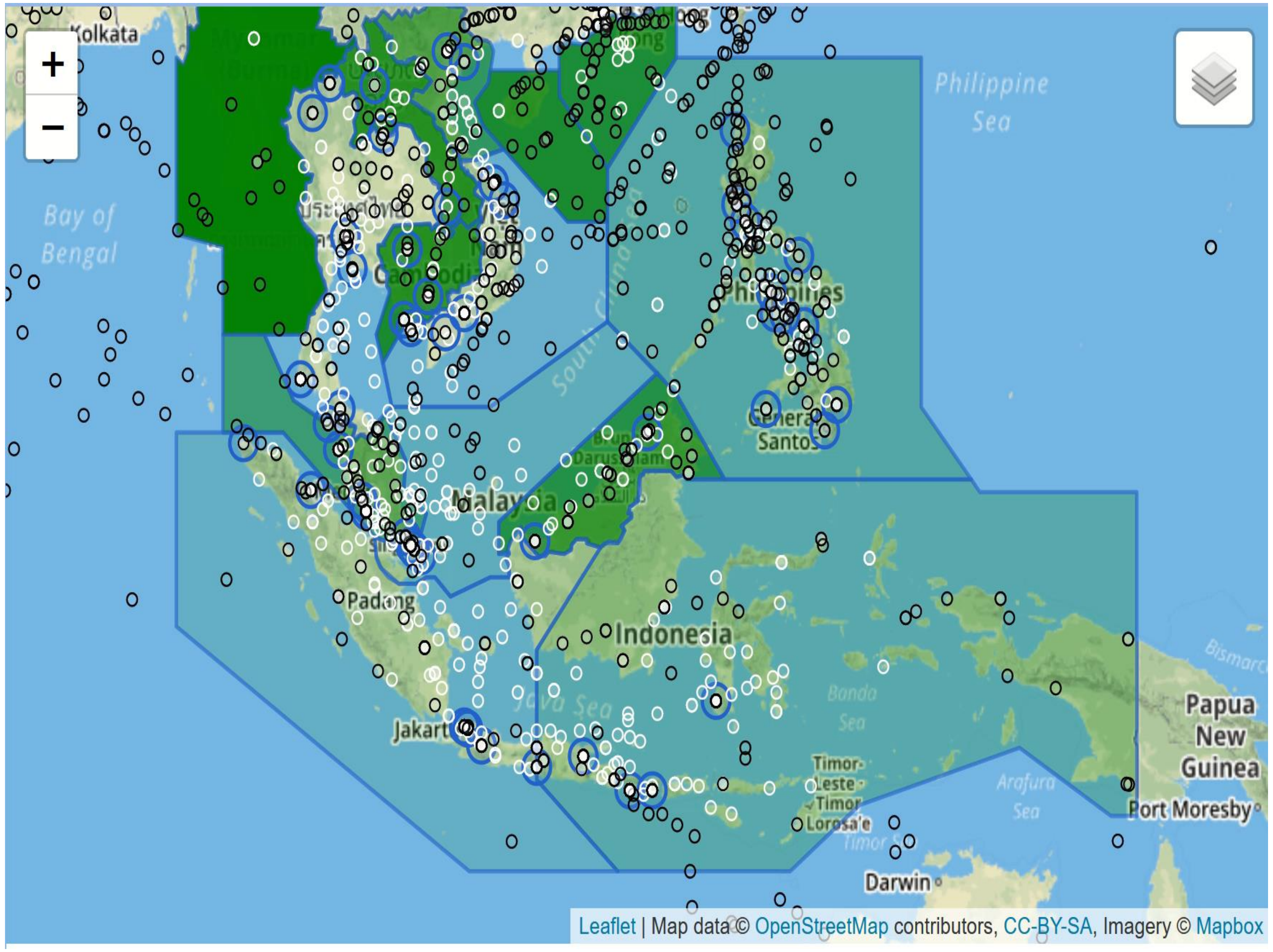
Demonstration

Demonstrated prototypical optimization-based planning and simulation tool at Singapore Air Show 2020



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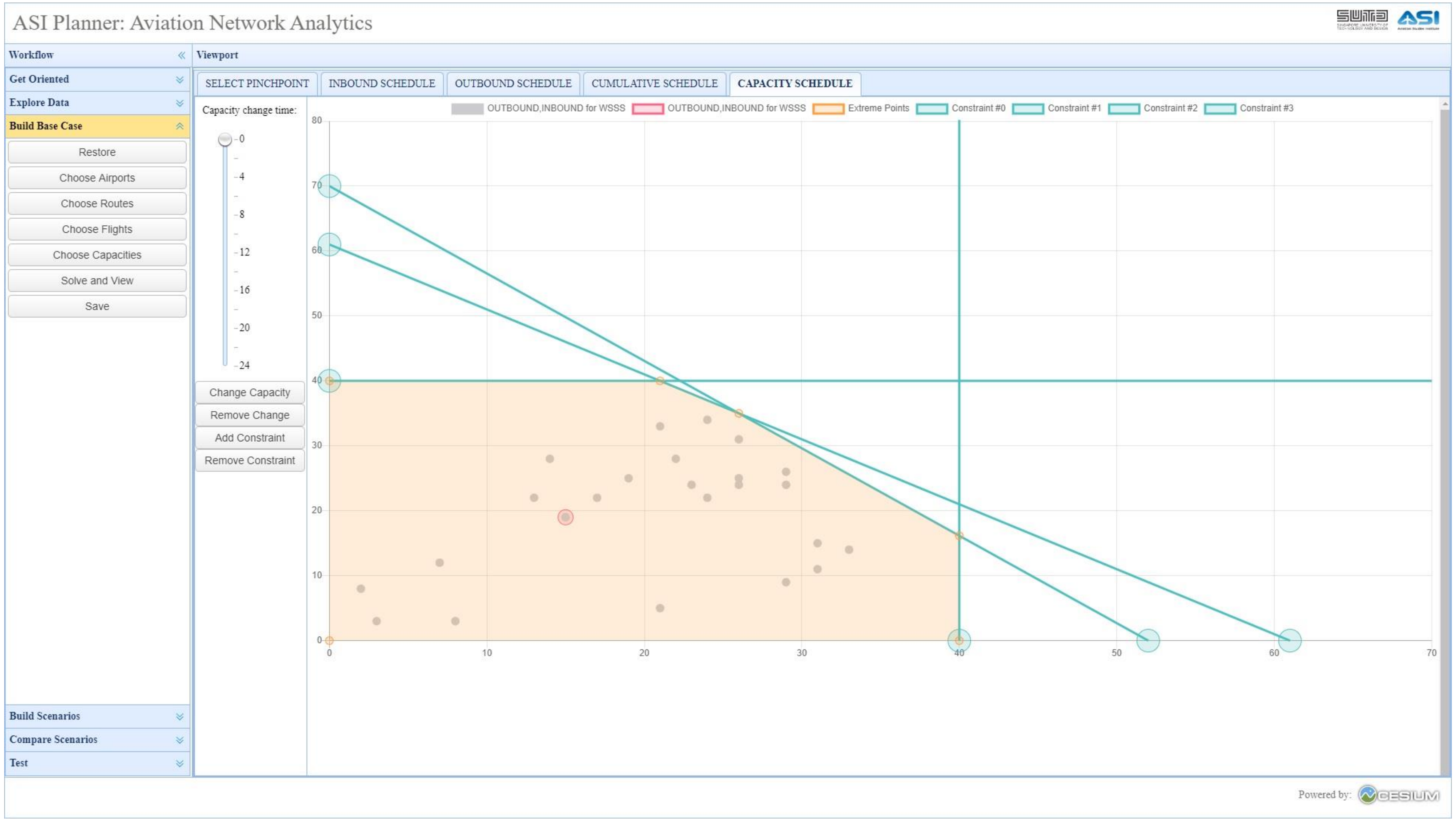
Representation: Capacity Envelope

Describe airport capacity in terms of envelope for arrival and departure rates by time of day



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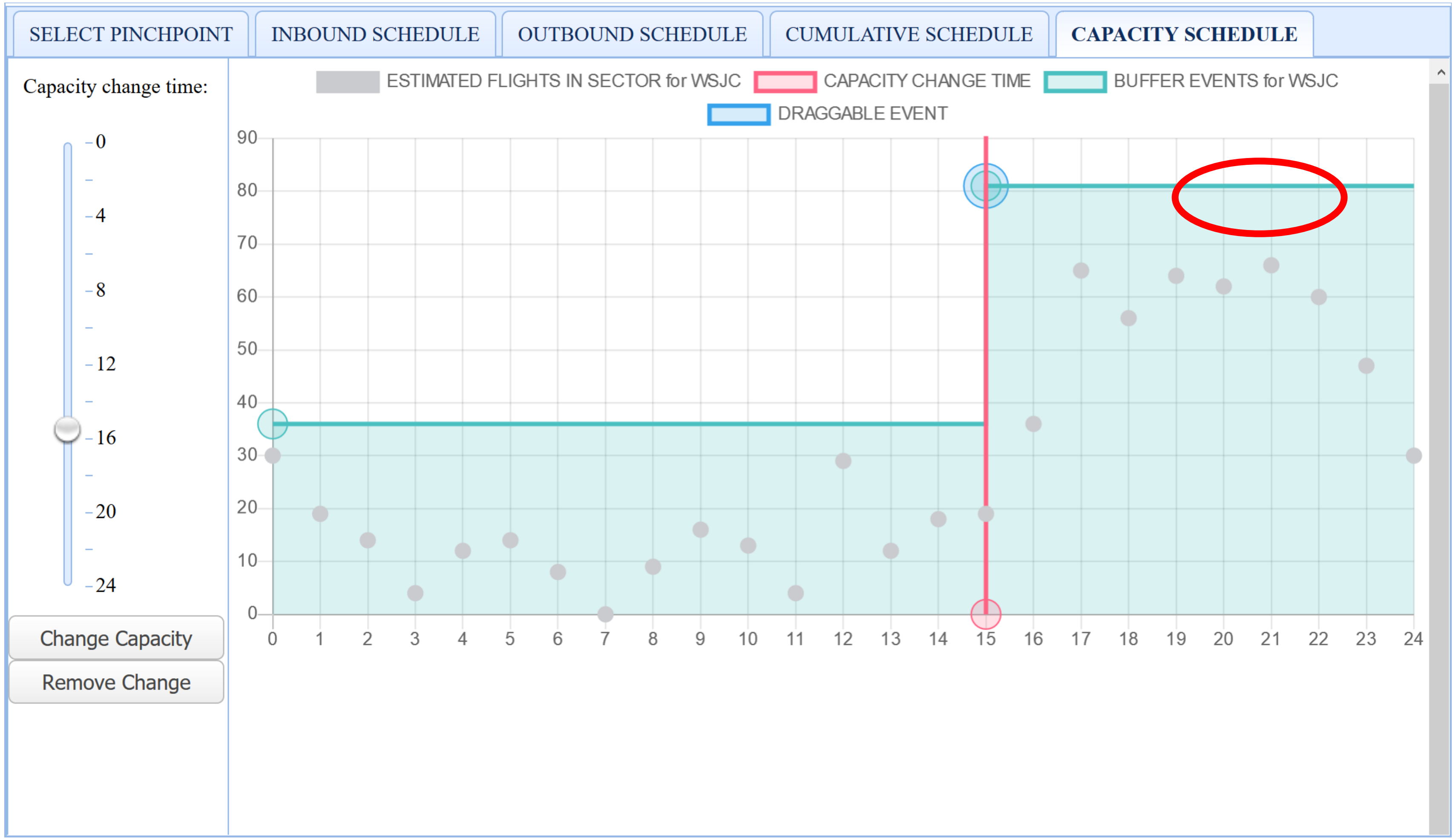
ATC Workload Constraints



For sector-level constraints, apply limits to ATC workload by time of day

- (Refined model under development)

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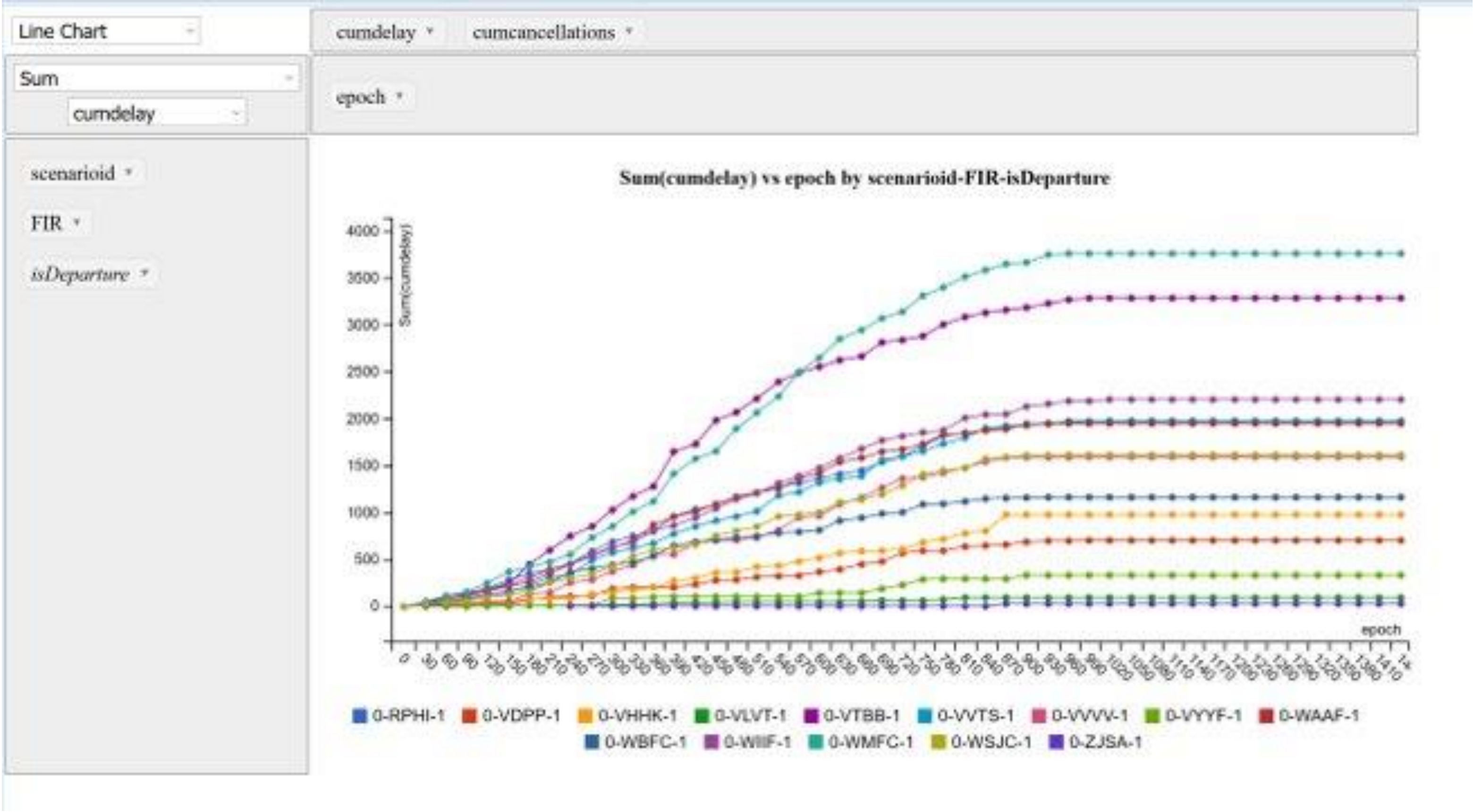
Impact Analysis (Sample)

Examine quantitative impact of runway closures on flight delays from neighbouring flight information regions



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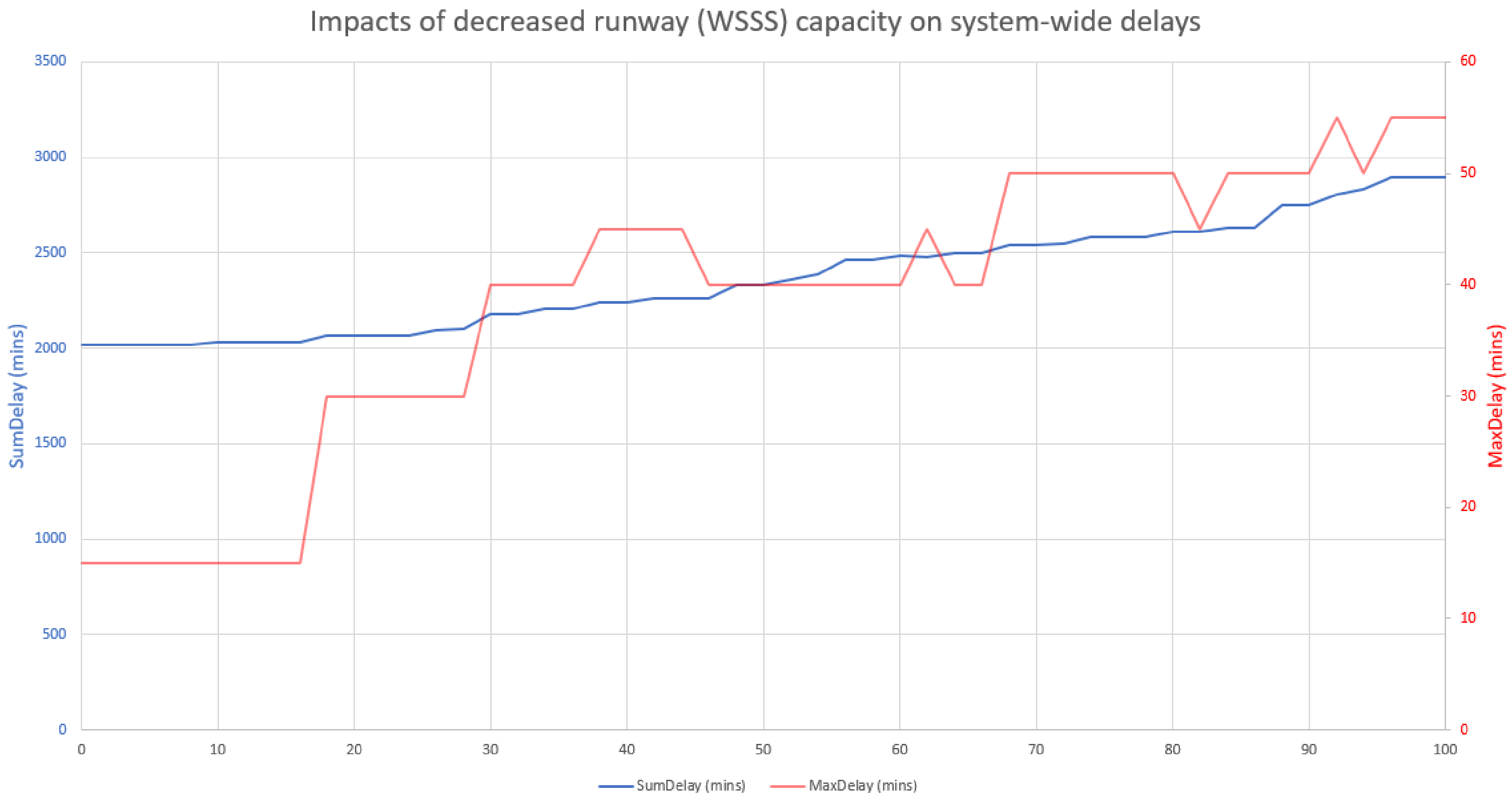
Sample Impact Analysis

The impact of incremental capacity reductions for Changi Airport arrivals & departures for one hour at peak demand, showing system-wide delays and maximum delays (there were no cancellations)



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Extended R&D, 2020: ATM Workload Calculator

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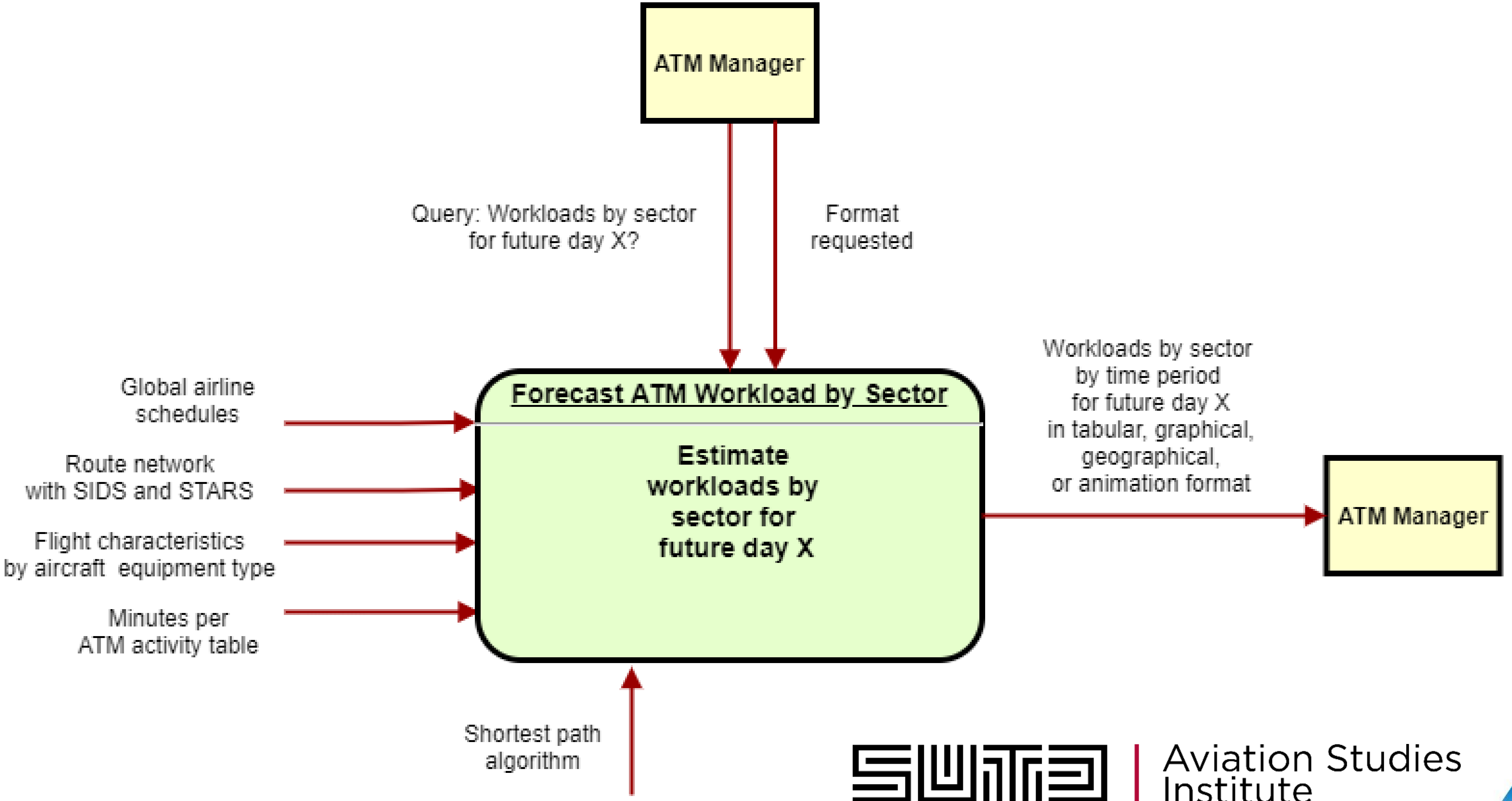
Forecast ATM Workload by Sector



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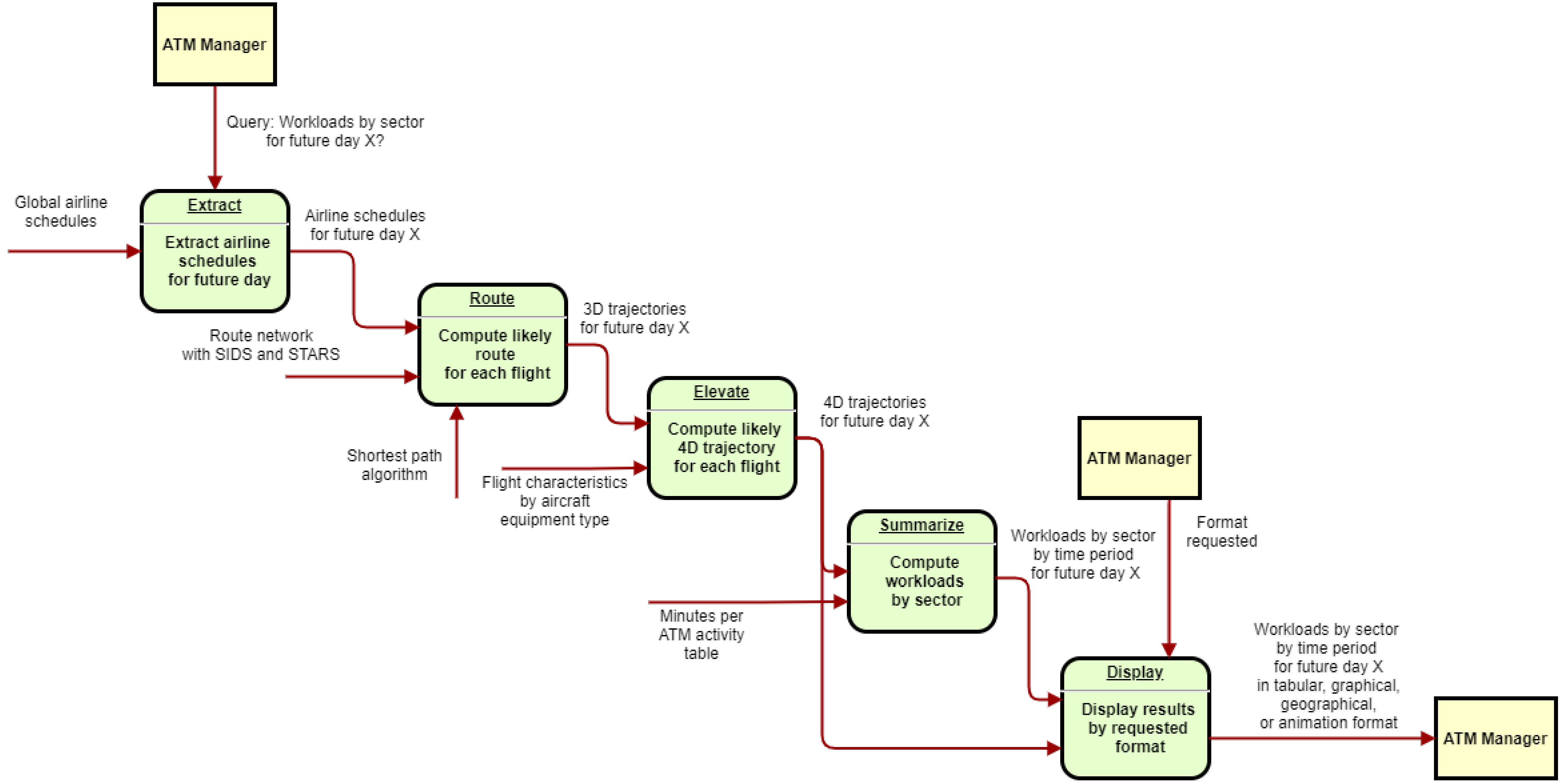
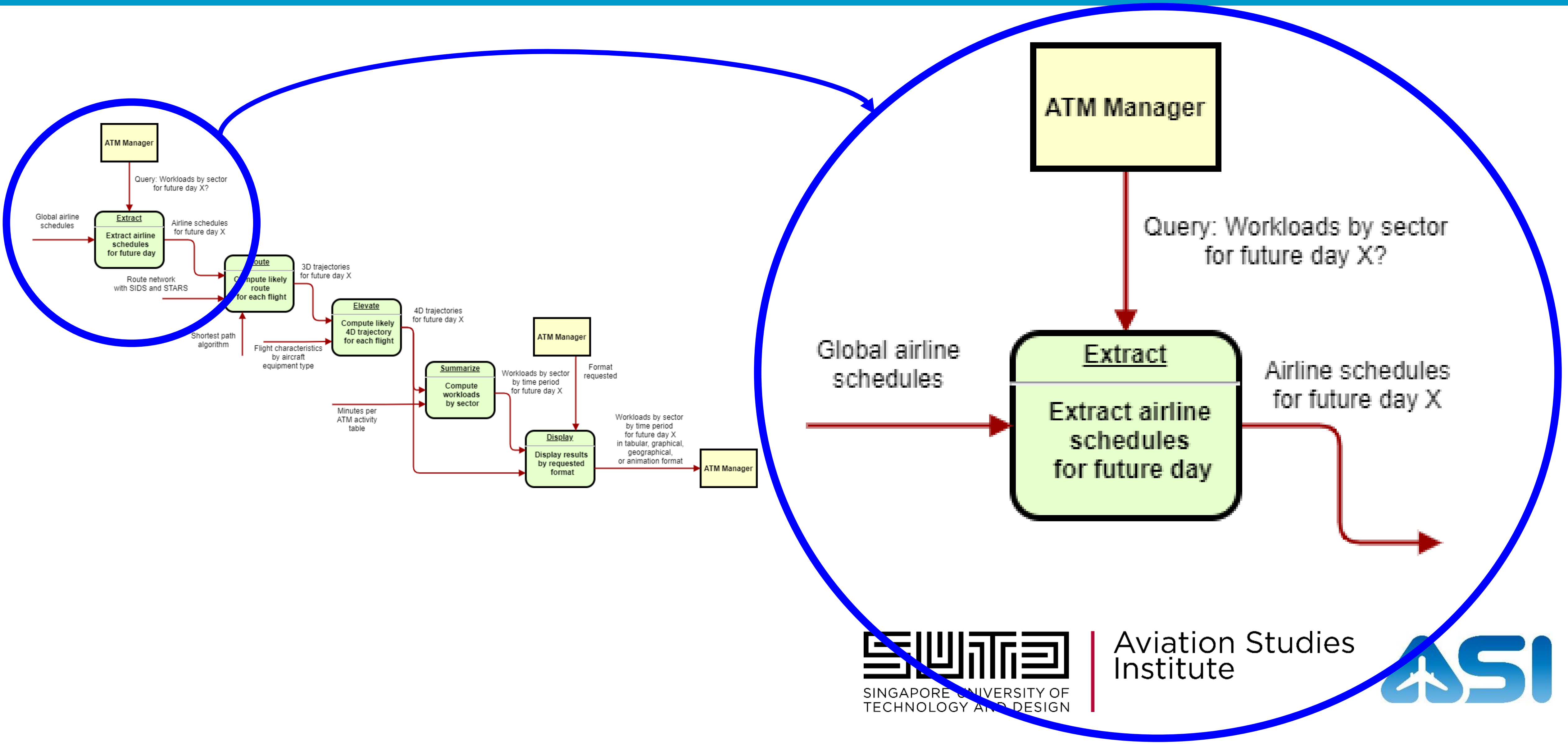
Software Workflow: ATM Workload Calculator



Extract



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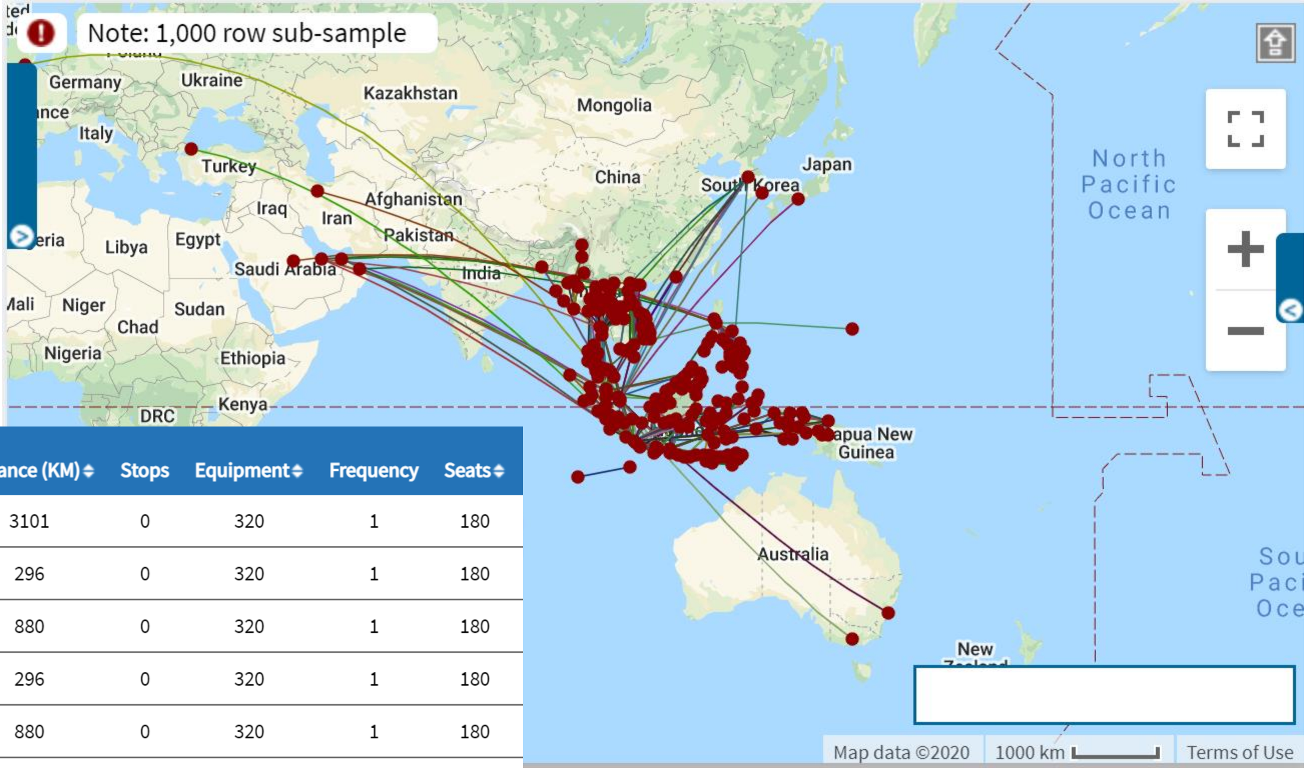
Extract Flight Schedules for Future Day

- OAG Schedules Analyzer



Published Carrier	Flight Number	Origin	Destination	Departure Time	Arrival Time	Op Days	Elapsed Time	Distance (KM)	Stops	Equipment	Frequency	Seats
2P	2482	TAG	ICN	1640	2245	1234567	05:05	3101	0	320	1	180
3K	685	SIN	KUL	1255	1355	1 4 6	01:00	296	0	320	1	180
3K	201	SIN	CGK	0745	0835	1	01:50	880	0	320	1	180
3K	686	KUL	SIN	1435	1540	1 4 6	01:05	296	0	320	1	180
3K	202	CGK	SIN	0915	1205	1 4 6	01:50	880	0	320	1	180
5J	562	CEB	MNL	0855	1025	1234567	01:30	565	0	32N	1	188
5J	566	CEB	MNL	1315	1445	1234567	01:30	565	0	32N	1	188
5J	582	CEB	MNL	1545	1715	1 3 5 7	01:30	565	0	32N	1	188
5J	647	MNL	PPS	1435	1605	1 3 5 7	01:30	584	0	320	1	180

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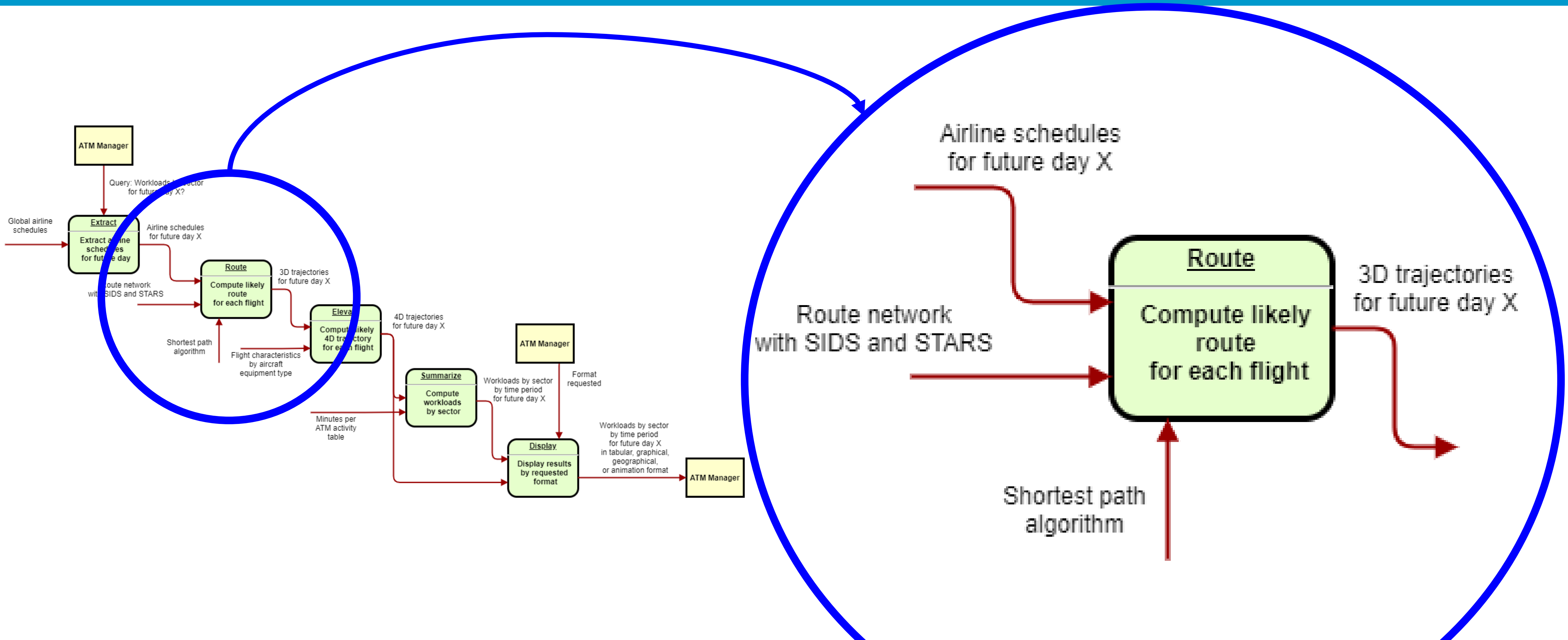
Route



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Source Documents

- eAIP documents for ASEAN countries
  - ATS Routes
  - R-Nav Routes
  - SIDS and STARS
  - Sector boundaries and flight levels

ENR 3 ATS ROUTES

ENR 3.1 ATS ROUTE

Route Designator	[Route Usage Notes]								
Significant Point Name	Significant Point Coordinates								Remarks
	Track MAG	Dist (NM)	Upper limit / Lower limit	Minimum flight altitude	Lateral limits (NM)	FL series ↓	FL series ↑		Controlling unit Remarks
A339									
▲ BOLUG	040000N 1304636E								
	013° 193°	40	UNL FL145	FL150	50	Odd	Even		
△ POXEL	043909N 1305536E								
	013° 193°	61	UNL FL145	FL150	50	Odd	Even		
▲ SHREE	053900N 1310924E								

Route Network for ASEAN Region

- Routes captured from AIP documents
- In process of adding SIDS and STARS
  - (Some airports not connected yet)

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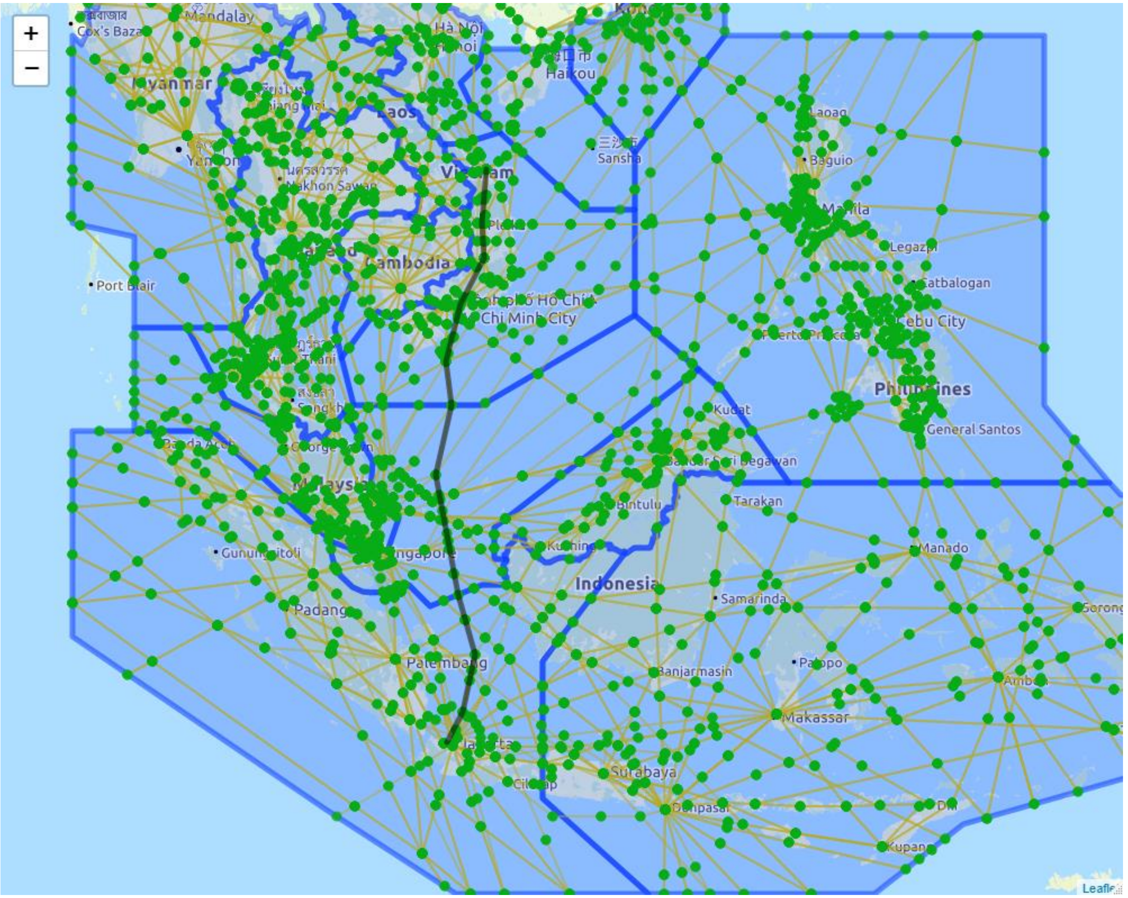
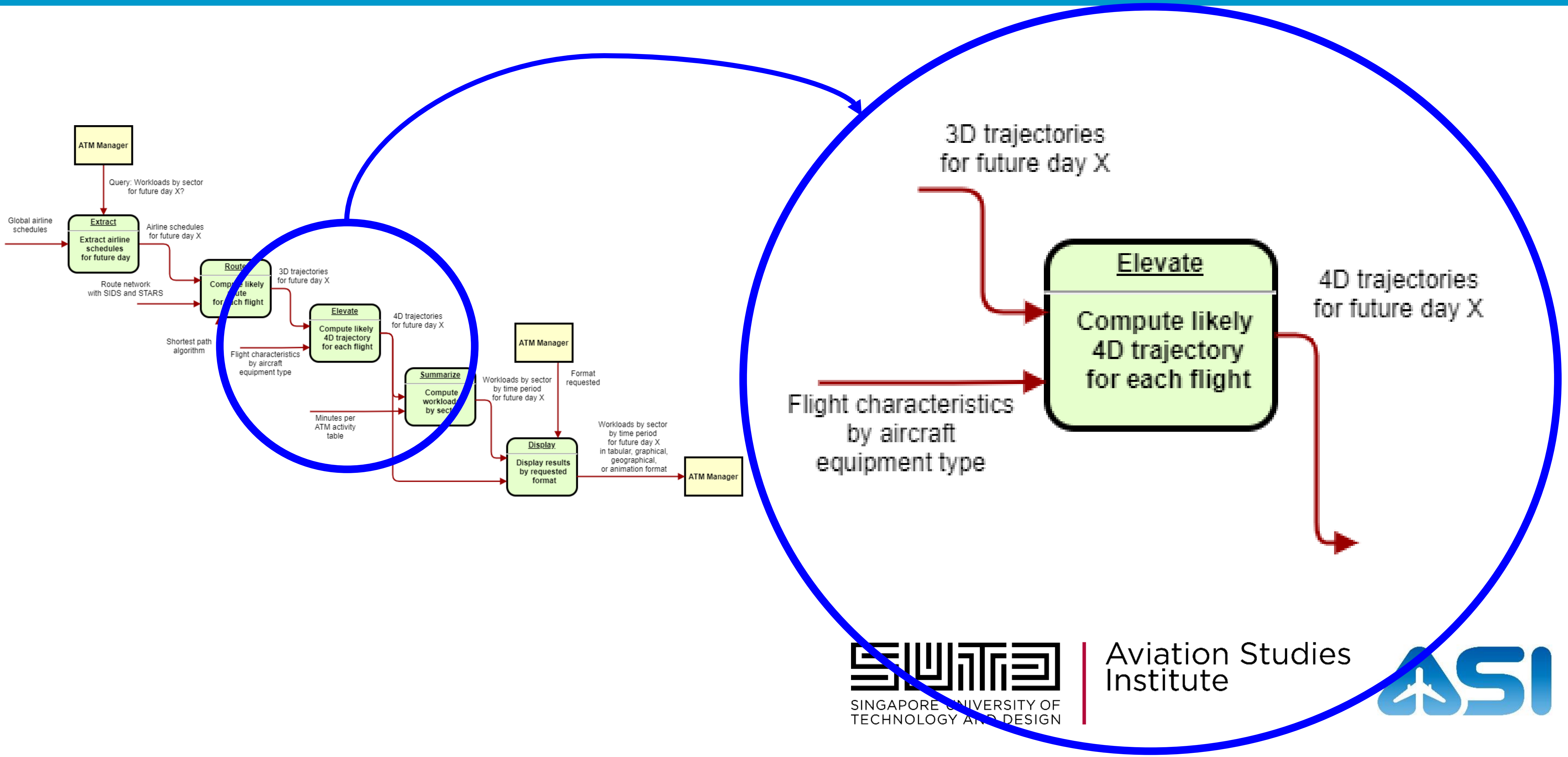
Compute Shortest Path

- Dijkstra's Shortest Path Algorithm returns the waypoints for path from Origin to Destination
- Compared against http://rfinder.asalink.net
  - Some anomalies found in route network (update as discovered)



Elevate



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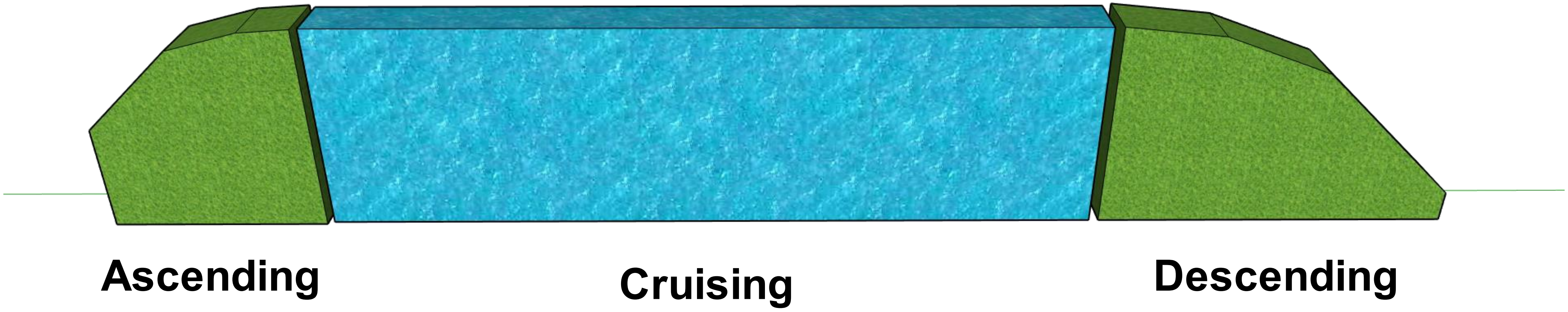
Estimate Flight Level Profile



Equipment Information

- Equipment specification are used to obtain the flight level profile
- Specifications are unique to each equipment used

Flight Stage	Value	
Climb to 5000ft	IAS	190kts
	ROC	1500 ft/min
Climb to FL150	IAS	320 kts
	ROC	2500 ft/min
Climb to FL240	IAS	320 kts
	ROC	1300 ft/min
Climb to Cruising	IAS	0.83 MACH
	ROC	1000 ft/min
Cruise	TAS	520 kts

Adapted from: Contentzone for Equipment A388

ROC – Rate of Climb
IAS – Indicated Airspeed
TAS – True Airspeed

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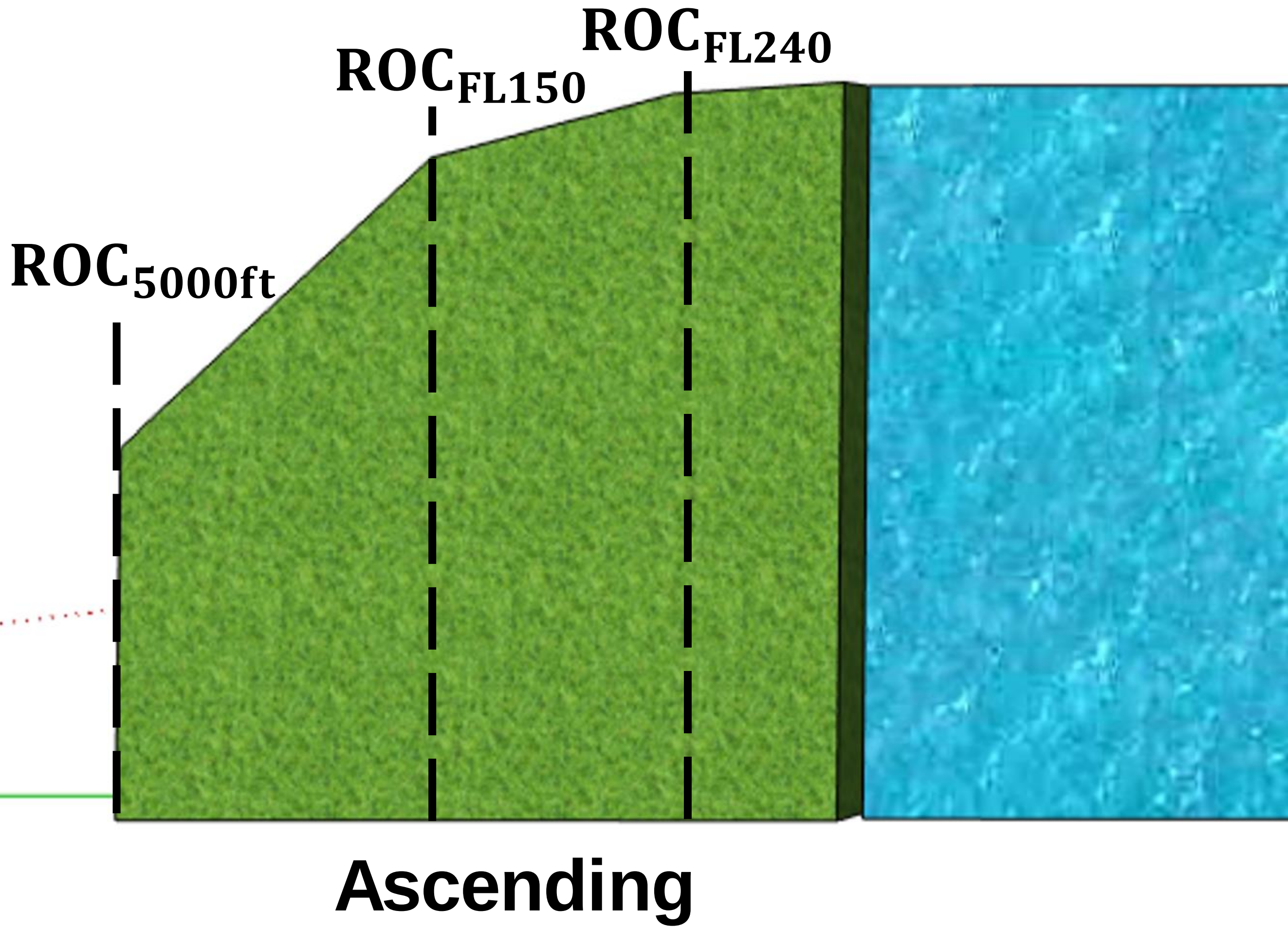
Calculations Based on Equipment Type

- The rate of climb of an aircraft at different stages of ascending is used to obtain the time needed to reach the cruising altitude.
- The time can be used to obtain ground distance travelled during the ascent.



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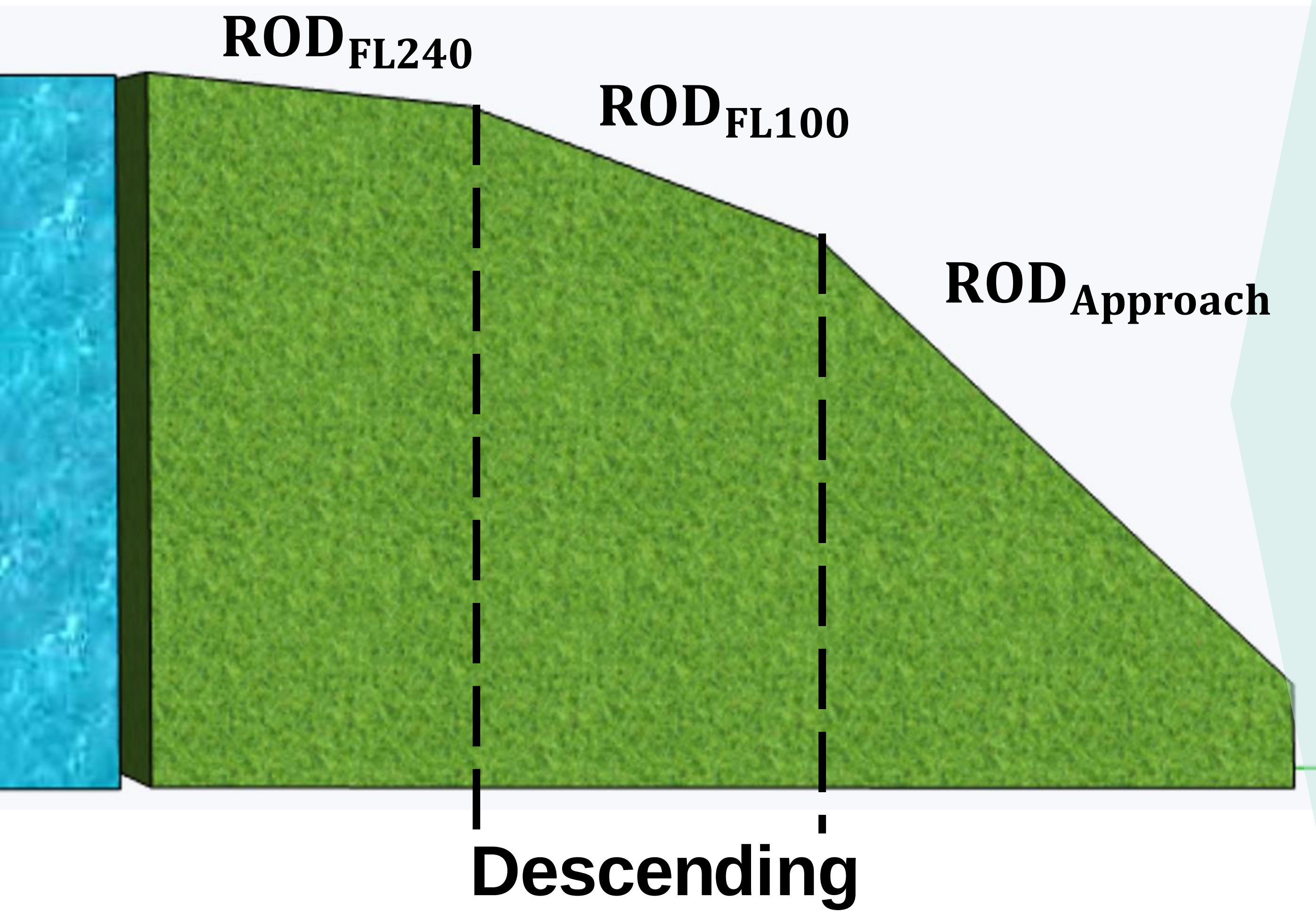
Cruising altitude of flight

Cruising

- Cruising altitudes used:

Types of Flight	Cruising Altitude
Most Flights	FL 310
Short Flights (<2hrs Elapsed Time)	FL 240
Flight with Small Aircraft	FL 100

Altitude of flight



- The same method is repeated to calculate the ground distance covered during the descent.
- The remaining distance is the cruising distance of the flight.
- Altitude of flight during ascending and descending is linearly interpolated from the airport altitude using the rate of descent of the equipment at the different stages of descent

ROD – Rate of Descent

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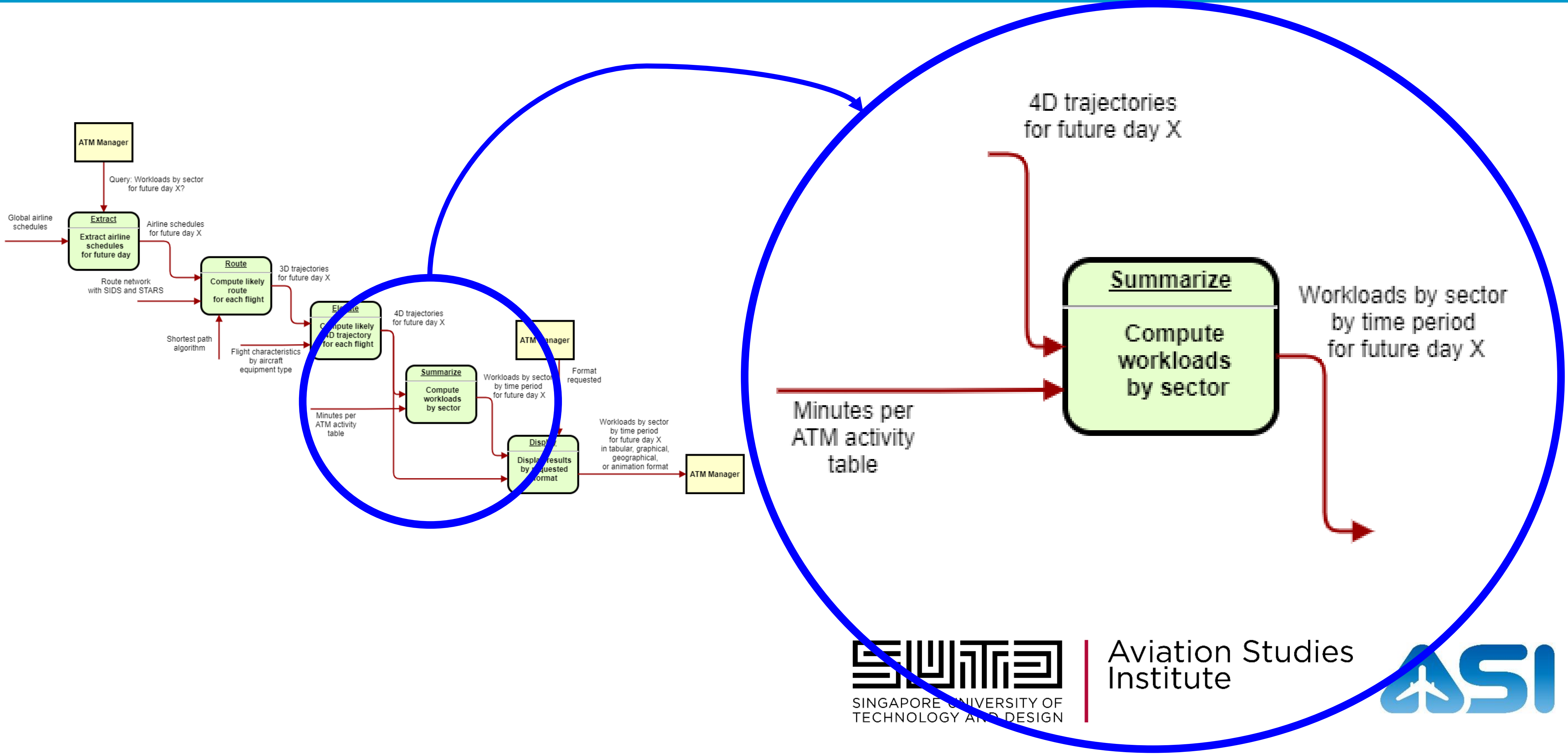
Summarize



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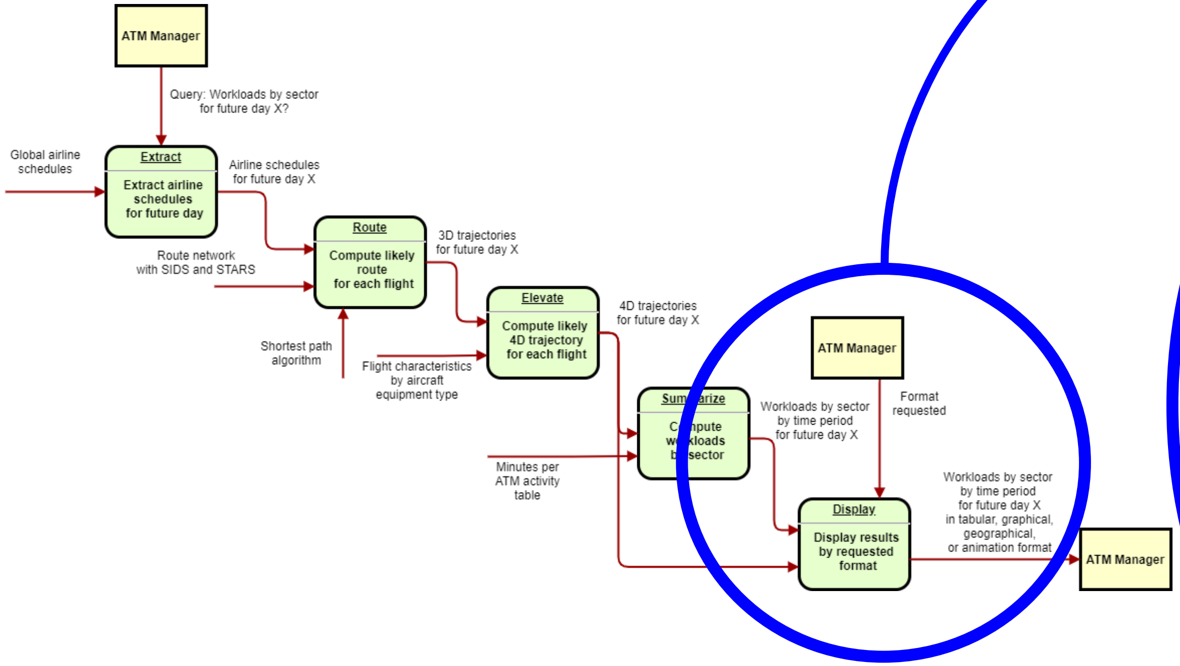
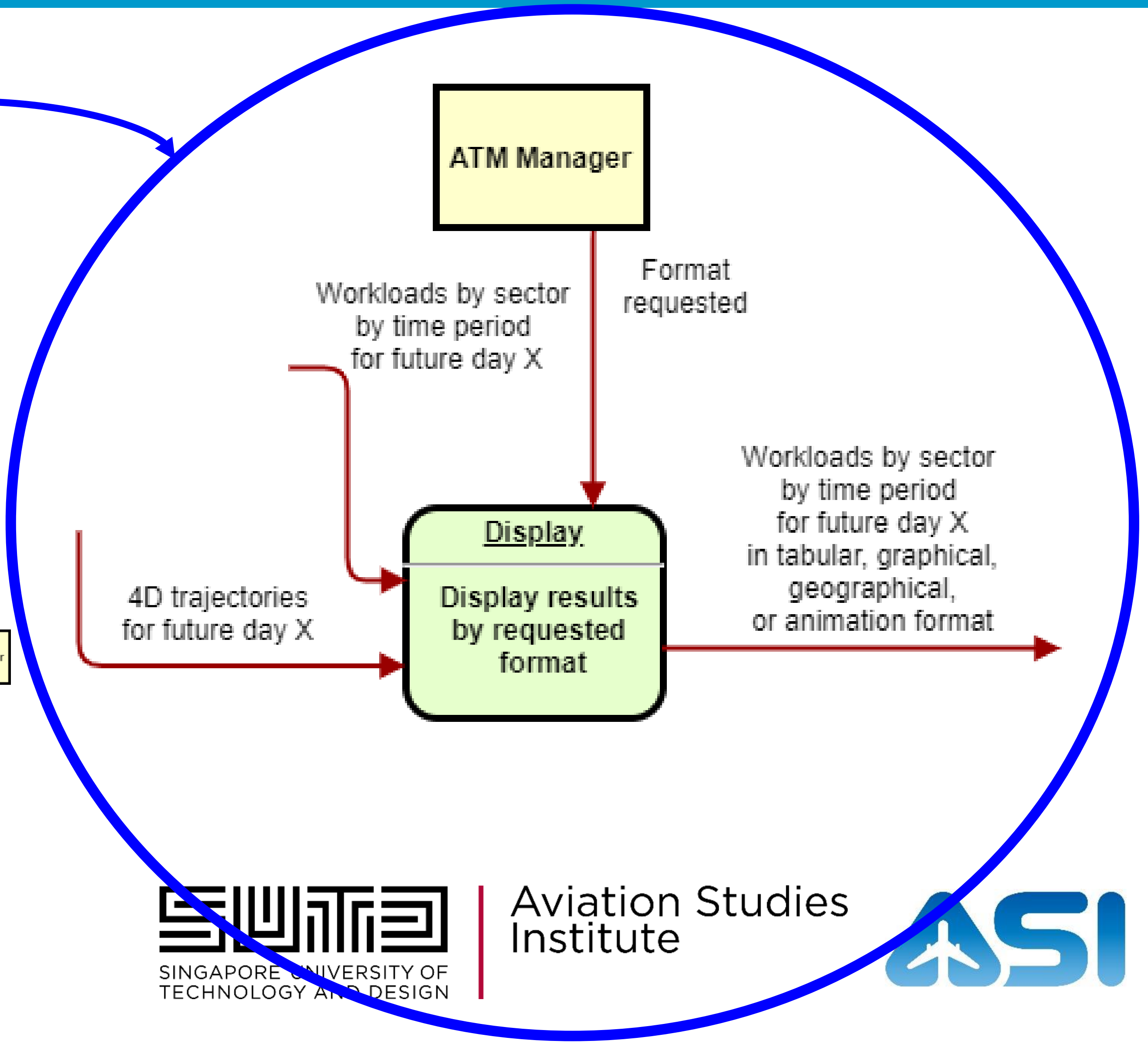
Workload By Time Period by Sector

	A	B	C	D	E	F	G	H
1	time	sector	FIR	country	ascending	cruising	descending	workload
2	0	KL	WMFC	Malaysia	2	8	0	6
3	0	CAMB1	VDPP	Cambodia	0	2	0	1
4	0	CAMB2	VDPP	Cambodia	0	0	0	0
5	0	YANGON1	VYYF	Myanmar	0	2	0	1
6	0	YANGON2	VYYF	Myanmar	0	2	0	1
7	0	YANGON3	VYYF	Myanmar	0	1	0	0.5
8	0	YANGON4	VYYF	Myanmar	0	0	0	0
9	0	MANILA N(	RPHI	Philippines	2	0	0	2
10	0	MANILA EA	RPHI	Philippines	0	0	0	0
11	0	MANILA SC	RPHI	Philippines	1	9	1	6.5
12	0	MANILA W	RPHI	Philippines	0	0	0	0
13	0	MACTAN	RPHI	Philippines	1	5	0	3.5
14	0	MACTAN E.	RPHI	Philippines	0	4	0	2
15	0	MACTAN W	RPHI	Philippines	1	1	0	1.5
16	0	MANILA O(	RPHI	Philippines	0	0	0	0
17	0	HANOI1	VVVV	Vietnam	1	0	0	1
18	0	HANOI2	VVVV	Vietnam	0	4	1	3

- In each 5-minute interval, count number of aircraft ascending, descending, or cruising within each sector
- Convert to ATC minutes of workload
  - ATM-specified parameters (under development)

Display





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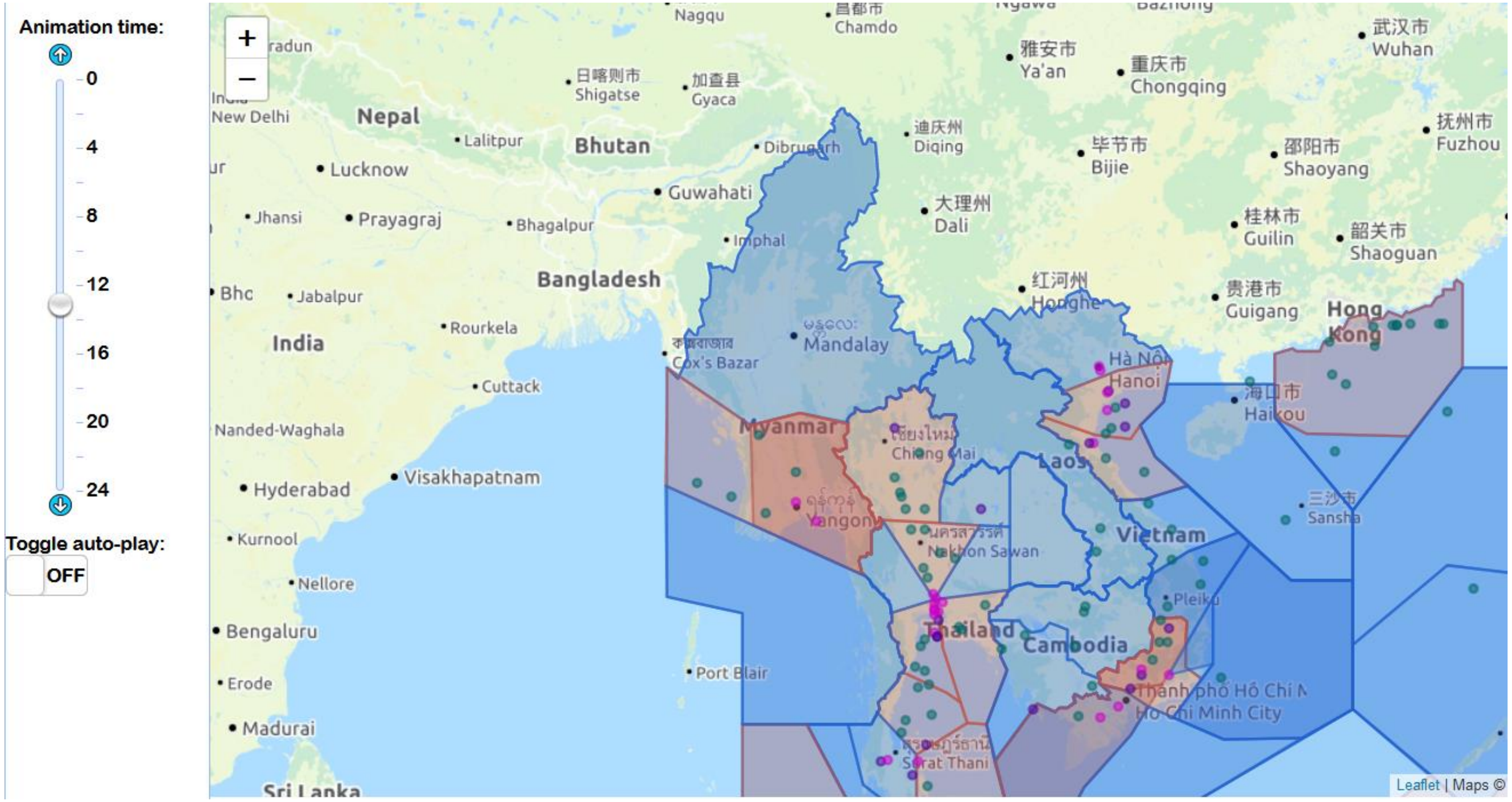
Animate Flights and Workload

- Animate flight trajectories (color code flight level changes)
- Animate sector workload (color-code sector)



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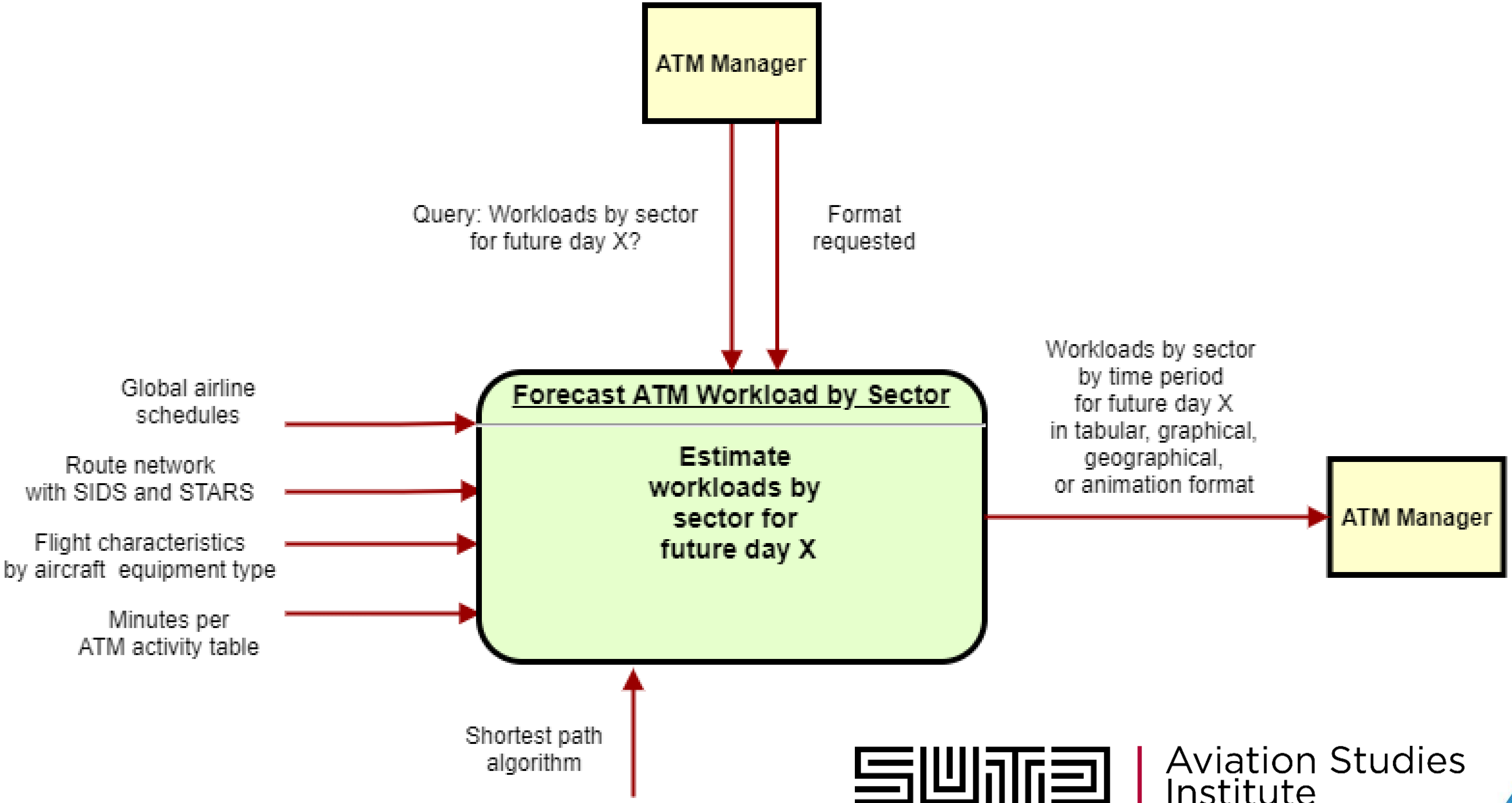
Workload Heatmap By Sector By Hour

country	FIR	sector	0	1	2	3	4	5	6	7	8	9	10	11	12
Cambodia	VDPP	CAMB1	5.50	8.00	12.00	13.50	12.50	10.50	18.50	10.50	14.50	15.50	4.50	6.50	7.
		CAMB2	8.00	10.00	24.00	18.50	17.00	20.00	22.50	17.00	24.50	21.50	11.00	18.00	10.
China	VHHK	HK SOUTH	1.00	4.50	4.50	3.00	2.00	3.50	0.50	1.00	2.50	5.00	1.50	2.50	1.
		HK TMA	50.50	35.00	51.00	42.00	44.00	20.50	18.50	38.50	45.00	44.50	29.50	28.50	42.
	ZJSA	SANYA	11.50	17.00	25.00	13.50	12.00	20.50	15.50	15.50	22.00	21.00	5.50	9.00	14.
	WAAF	UJUNG PANDANG UBNO	99.50	131.00	122.50	142.00	122.00	182.00	145.00	141.00	134.50	113.50	109.00	86.50	80.
		UJUNG PANDANG UBSO	74.00	59.50	104.50	112.00	127.00	110.50	118.50	93.50	61.50	42.00	18.50	8.00	7.
		UJUNG PANDANG UBWE	69.00	60.50	76.50	67.00	61.00	83.50	67.50	78.00	72.50	70.50	76.50	37.50	55.
		UJUNG PANDANG UPBN	121.50	128.50	162.00	120.00	161.50	182.00	132.00	137.50	108.50	122.50	69.00	63.50	61.
		UJUNG PANDANG UPE	224.00	192.00	206.50	247.50	217.50	207.50	201.50	181.00	142.50	61.00	33.00	19.00	6.
		UJUNG PANDANG UPKN	41.50	67.50	50.50	39.00	49.00	59.00	52.50	39.00	42.00	55.00	35.50	29.50	24.

- Detailed tabular reports are available with drill-down, color coding, and charting

Forecast ATM Workload by Sector



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In Summary

Use Case

- Tool optimizes network flows in ASEAN region subject to capacity constraints. Scenarios allow study of ripple effect from short-term schedule disruptions.
- Tool has front-end interactive manipulation of capacity assumptions and exploration of resulting traffic patterns plus back end support for high performance computing, optimisation and analytics

Benefits

- Provides opportunity to CANSO partners to discuss network effects of capacity constraints.
- Decision-makers can engage in "What-If" discussions and gauge critical numbers.
- Users are able to build scenarios, examine resulting traffic patterns, and compare performance across scenarios.

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Regional Focus

Advancing ATM Research & Development in the Asia Pacific

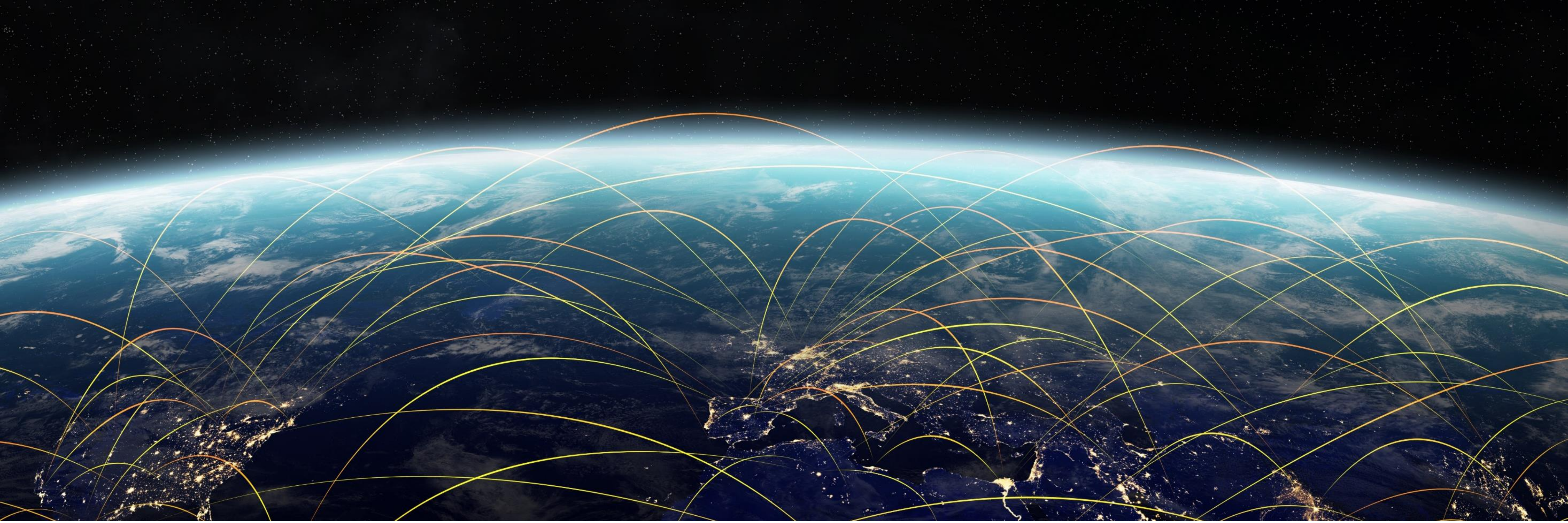
Spotlight on ASI

Speaker

Karthyek Murthy

Assistant Professor, Engineering Systems and Design

SUTD



Understanding the benefits of System Wide Information Management (SWIM) from an Air Traffic Flow Management Viewpoint

Karthyek Murthy

Civil Aviation Authority of Singapore

Enabling opportunities through aviation

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Background of the problem considered

- Communication between neighbouring Air Navigation Service Providers (ANSPs) is largely limited to voice handoffs of en-route aircraft from one air traffic controller to the next
- A key enabler in all major ATM modernisation efforts is the System Wide Information Management (SWIM) infrastructure, which is seen as a digital data-sharing backbone supporting seamless exchange of information among various stakeholders
  - Access to real time, relevant and reliable aeronautical, flight and weather information

SWIM infrastructure → Improved information sharing → Improved predictability → Improved resource allocation → Better operational outcomes & lesser environmental costs

Questions specific to the ASEAN context

- ICAO standards map a general pathway to System Wide Information Management (SWIM) enabling electronic sharing of aeronautical and meteorological data
- In the SESAR and Nextgen modernisation programs, the specific information sharing setup and related regulations for large regions are established through a common regulatory body.
- The ASEAN setting presents fundamentally different challenges.
  - How does the additional information translate into reduced delays in the distributed setting?
  - What is the trade-off between granularity of data and system performance?
  - What are, or should be, the economic incentives to share data between ANSPs?

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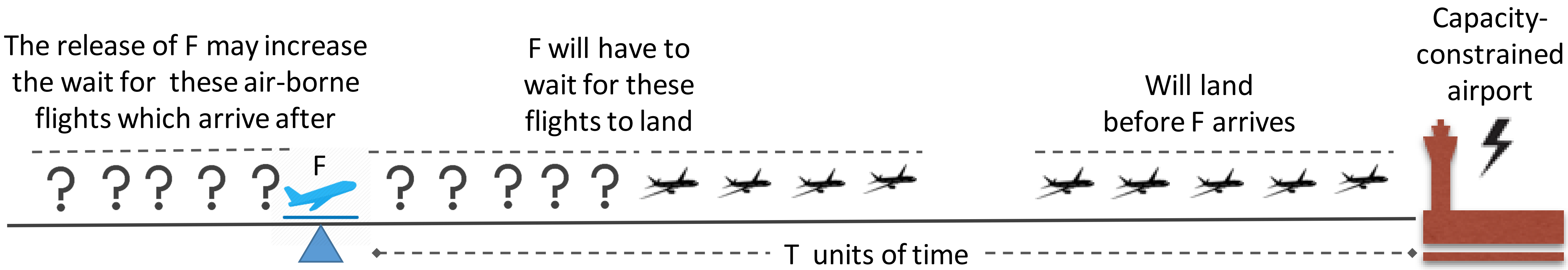
Investigating the efficacy in ATFM via Ground Delay Programs

- Ground Delay Programs (GDPs) constitute a prominent ATFM measure
  - flights delayed from scheduled departure times
  - transfers anticipated airborne delays to the ground; no fuel costs and safety costs while in ground
- Objective: To quantify the scale of airborne and ground delay savings that can be achieved with the improved predictability resulting from the availability of network-wide real-time positional, weather and capacity information



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Ground delay program optimization

Use case

- Tool optimizes ground delay assignment in collaborating airports given airport acceptance rate (at the affected airport), real-time positional information and en-route capacity constraints
- Tool specifies the reductions in airborne and ground delays for a given configuration of collaborating airports and regions sharing real-time positional and capacity constraint information.

Benefits

- Helps bring out effective ATFM strategies for future data-rich environments
- Users can inform various capacity reduction scenarios, airport acceptance rates and gain an understanding on resulting airborne and ground delays
- Gives an understanding of how increased collaboration in information sharing and decision-making translates to decreased delays (costs)

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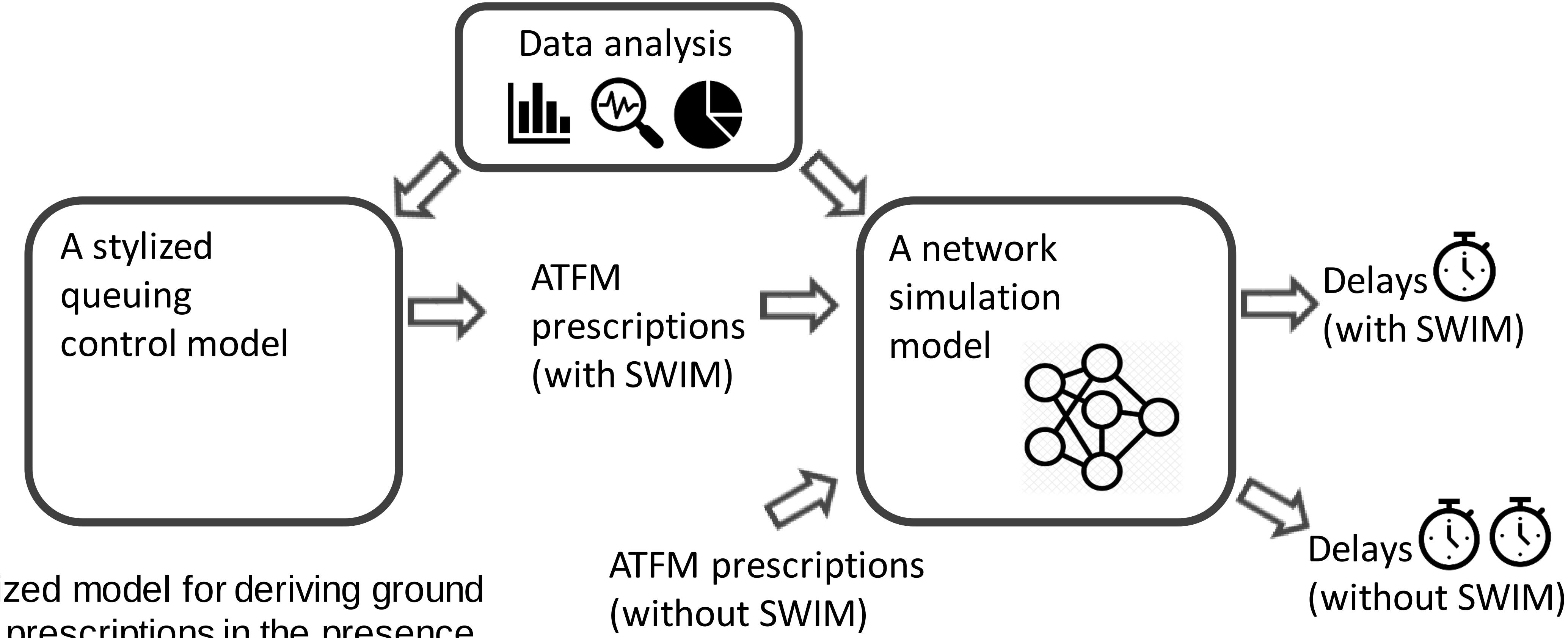
Elements of ground delay program optimization



- A stylized model for deriving ground delay prescriptions in the presence of SWIM infrastructure
- A network simulation model for yielding delay estimates for the ground delay prescriptions in SWIM and non-SWIM settings

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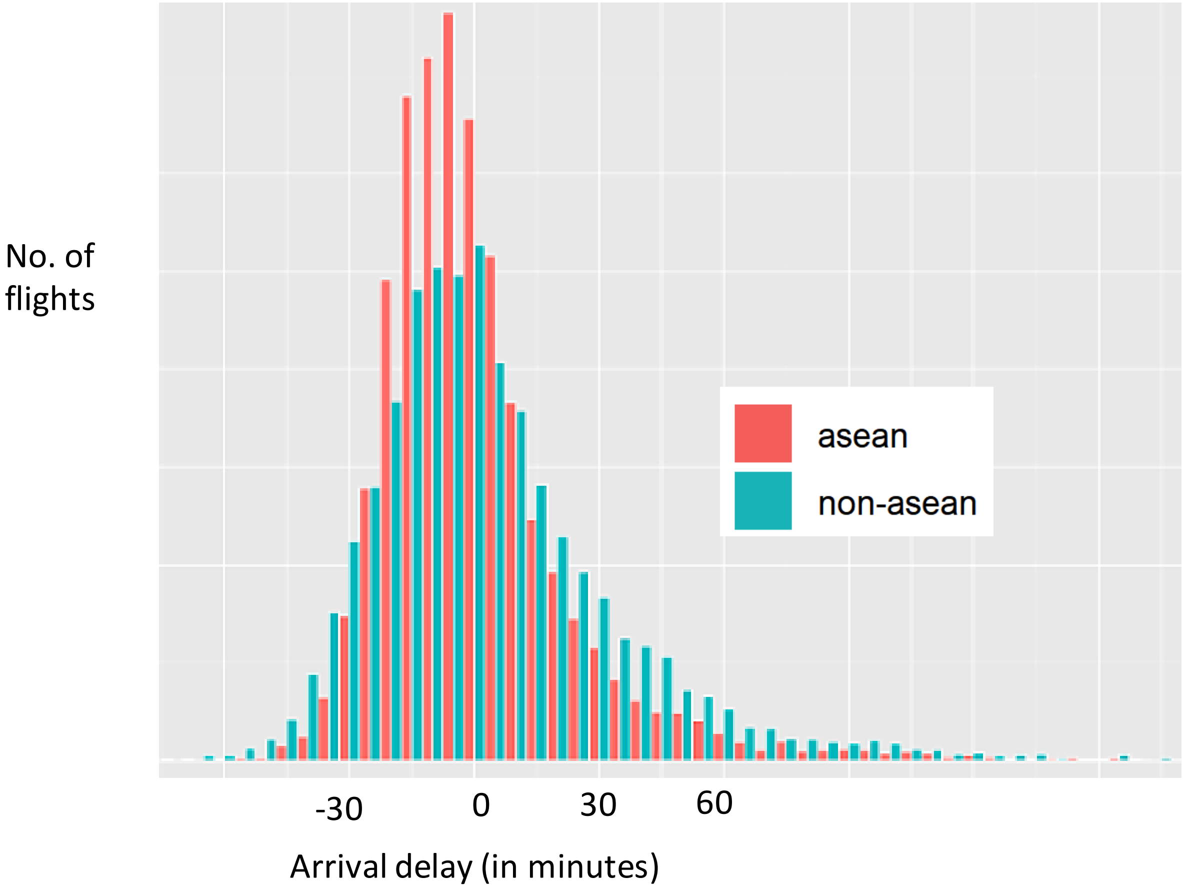
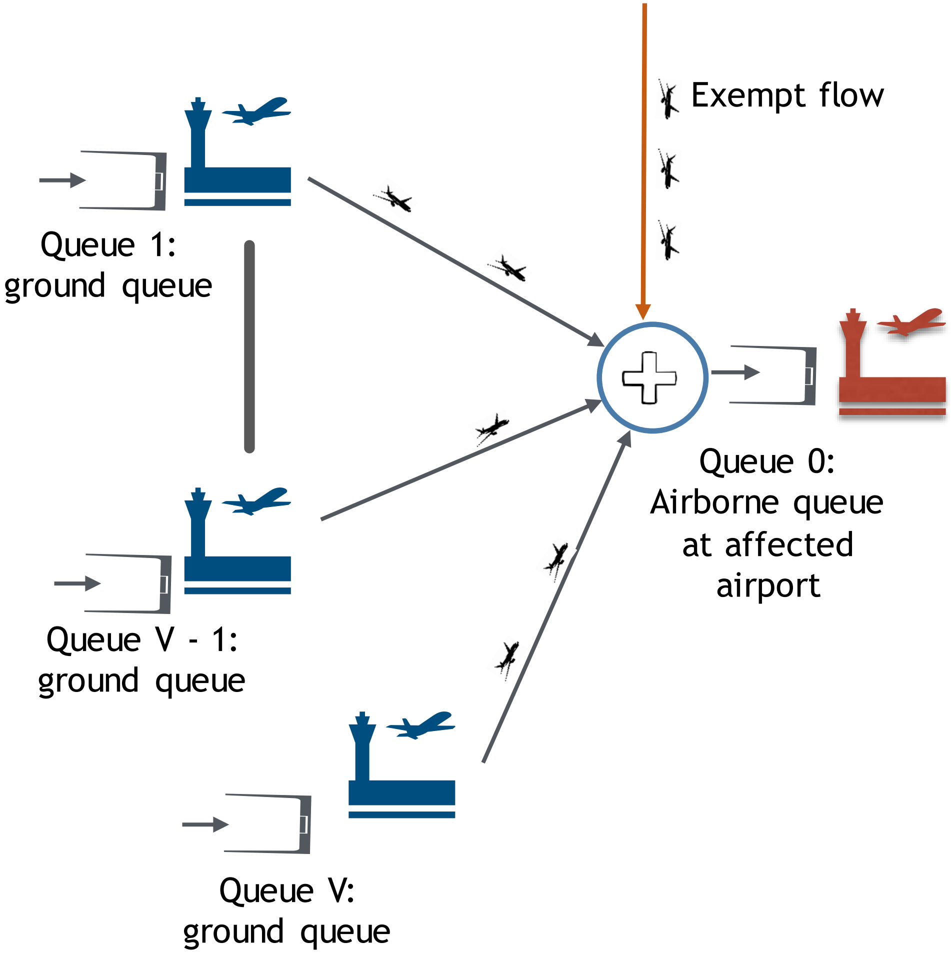
Q1. How to perform ATFM differently in the presence of SWIM?

- GDP essential in situations where the exempt + participating flows rates exceed the acceptance rate
- Exempt flow: Flights which do not participate in GDP (a greater source of variability in arrival delays)





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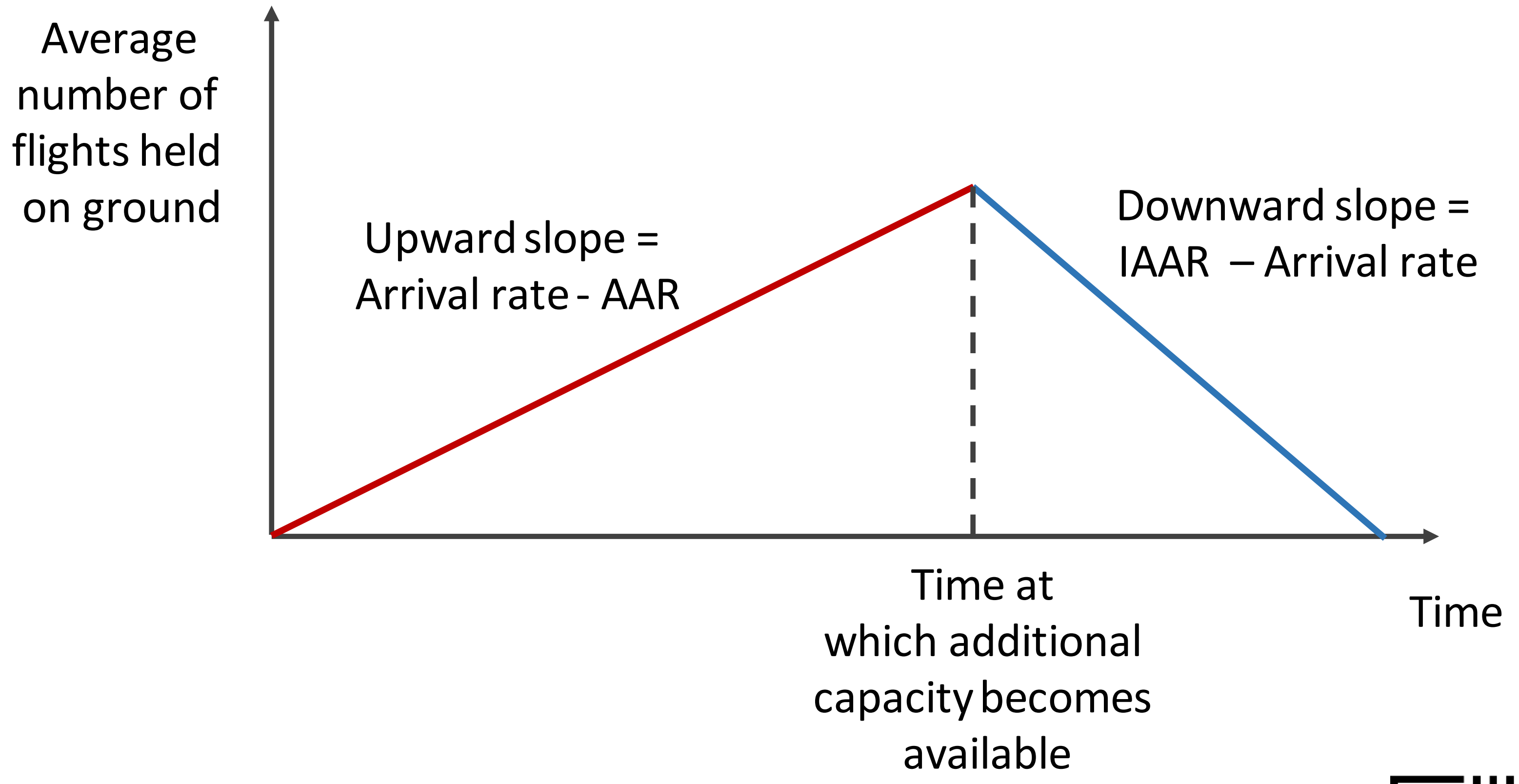
Analysis of ground-held delays



- Observation: A key parameter in determining the average ground holding costs is the set Airport Acceptance Rate (AAR), and is less sensitive to the other specifics of the GDP implementation
- Note:
  - AAR and Improved AAR (IARR) are not the same as the intrinsic capacity of the airport during the concerned period
  - buffer capacity = intrinsic capacity – employed airport acceptance rate

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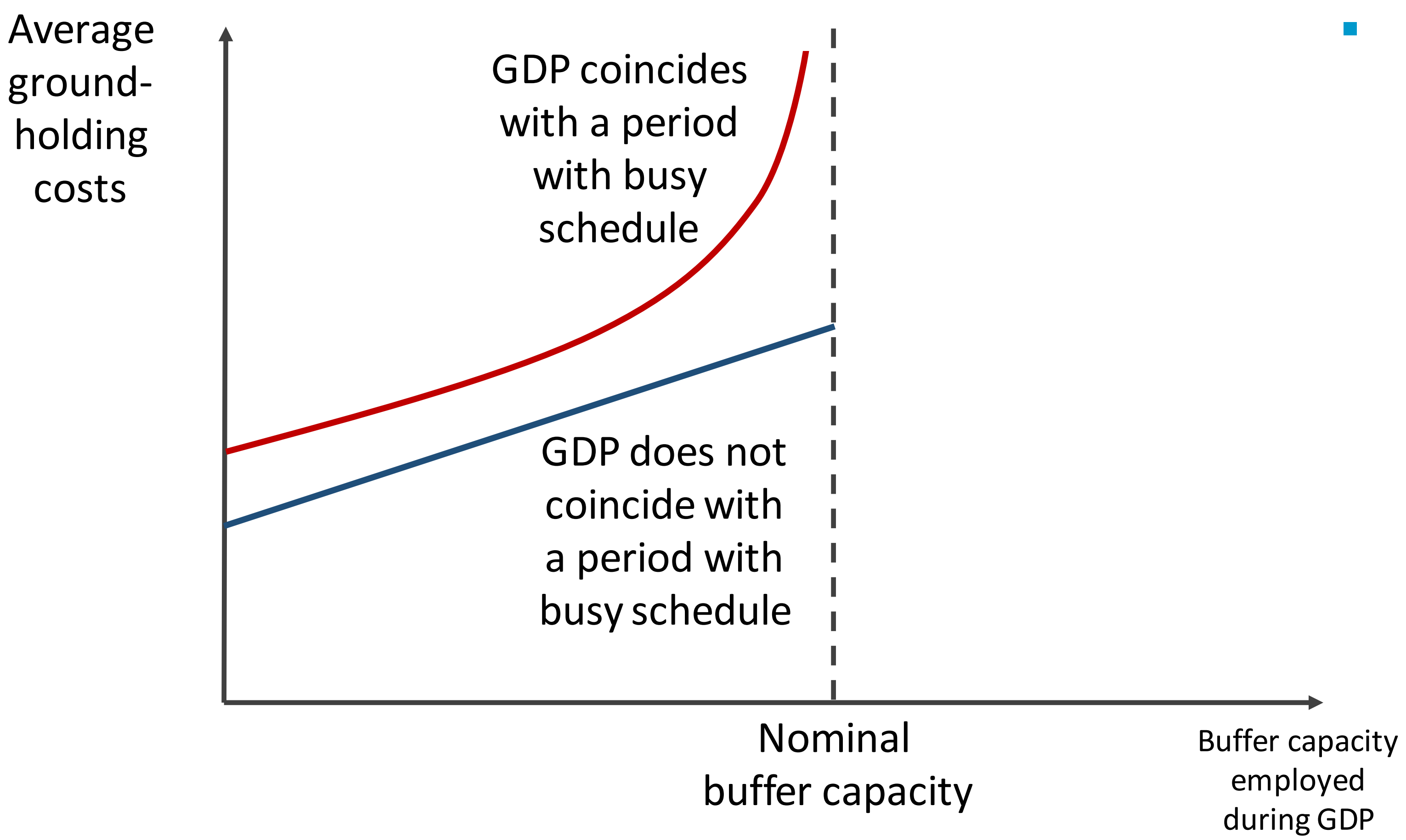
Analysis of ground-held delays



- If the schedule during the period has full slot utilization, then the buffer capacity usually employed has to be necessarily reduced to achieve downward slope

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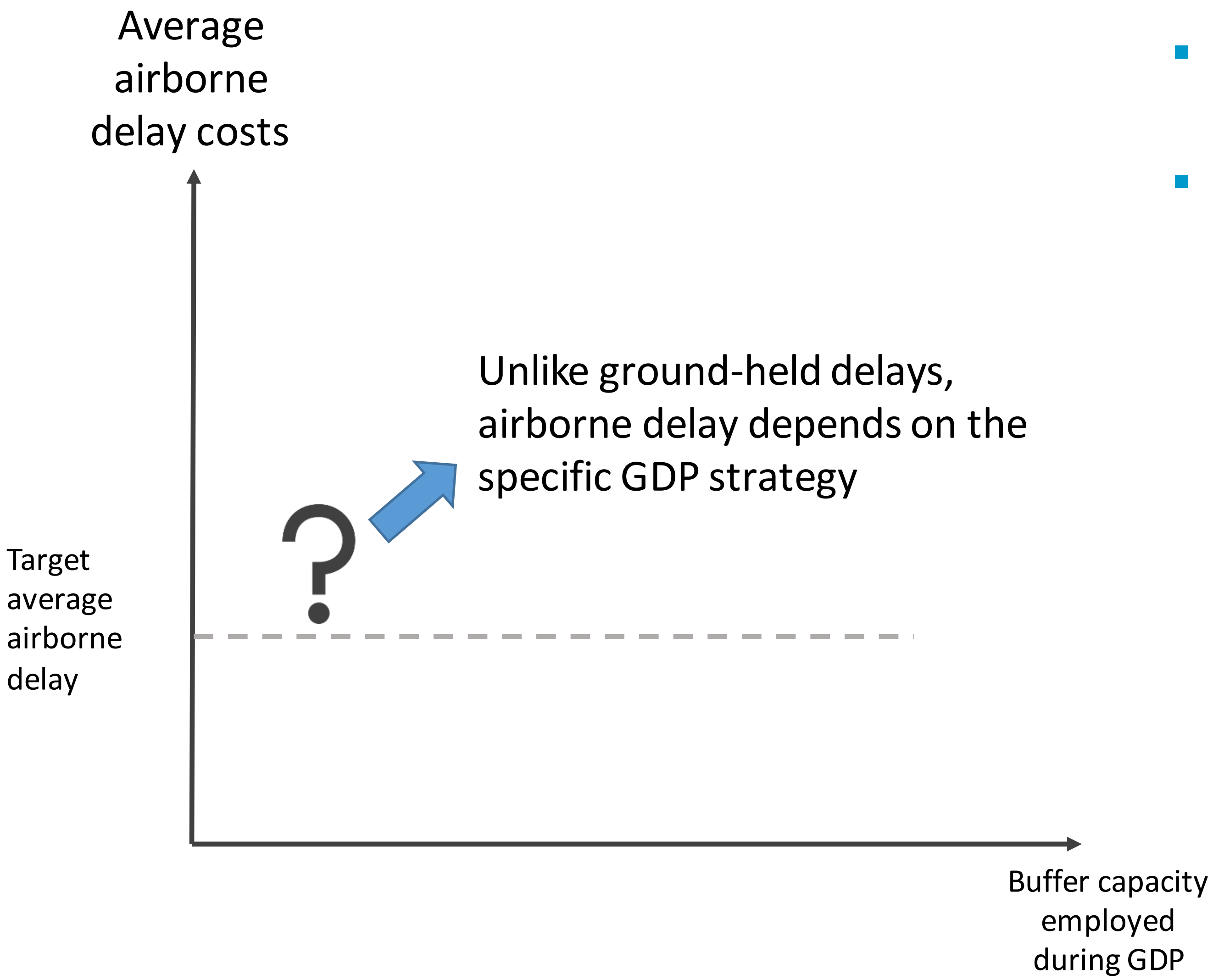
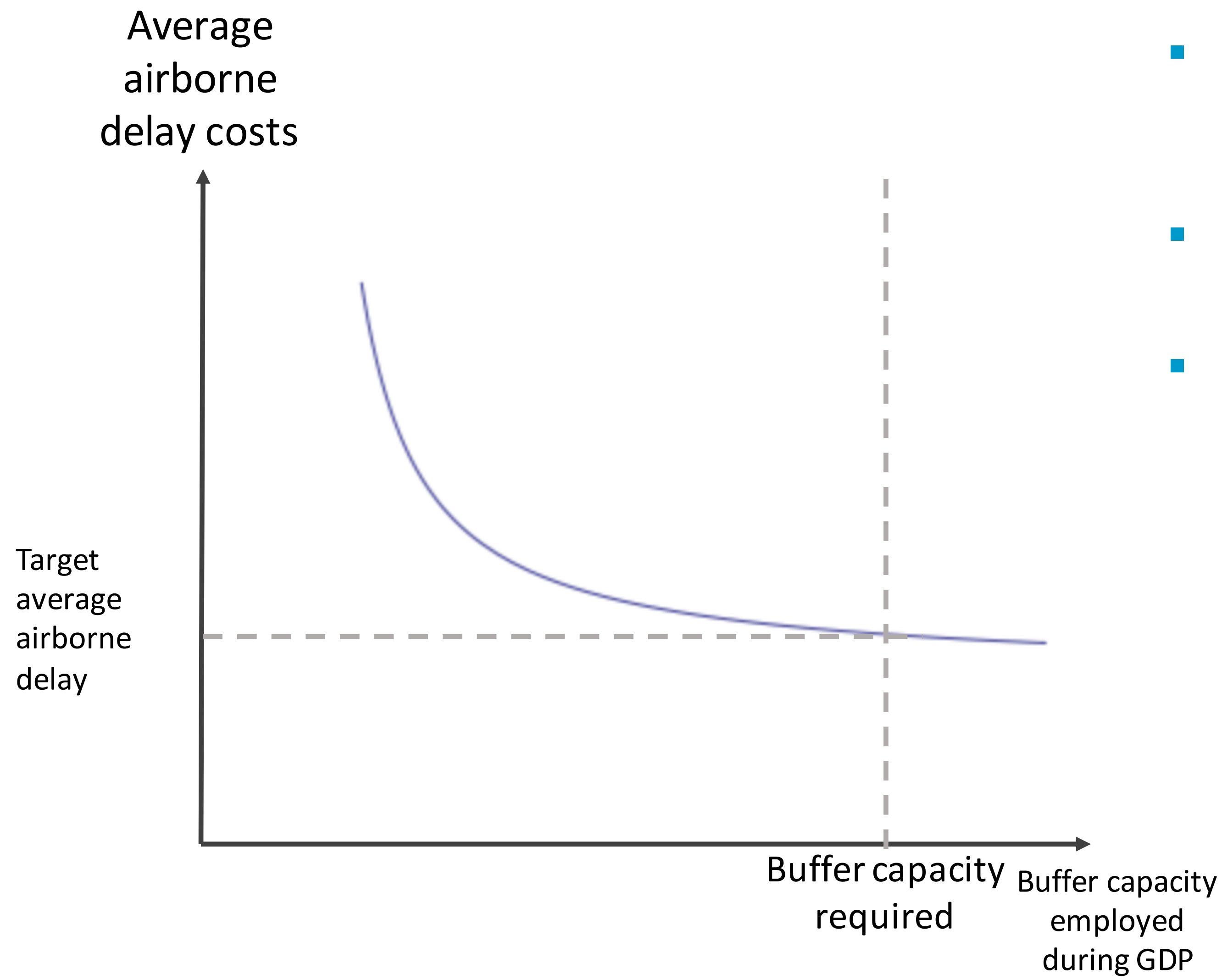
Analysis of airborne delays



- What is the minimum airborne delay achievable with the chosen AAR?
- Posing the question in terms of the AAR helps in
  - Decoupling the analysis of the ground delays from that of the airborne delays
  - Interpretable, and compatible with existing GDP design flow

Airborne delay: Constant ground holding



- Constant ground holding: Upon fixing AAR, a fixed ground delay is assigned for each flight departing from the airports participating in GDP
- Discards all information except cumulative arrival estimates
- High delays in periods of congestion created by higher than usual flow of exempt flights

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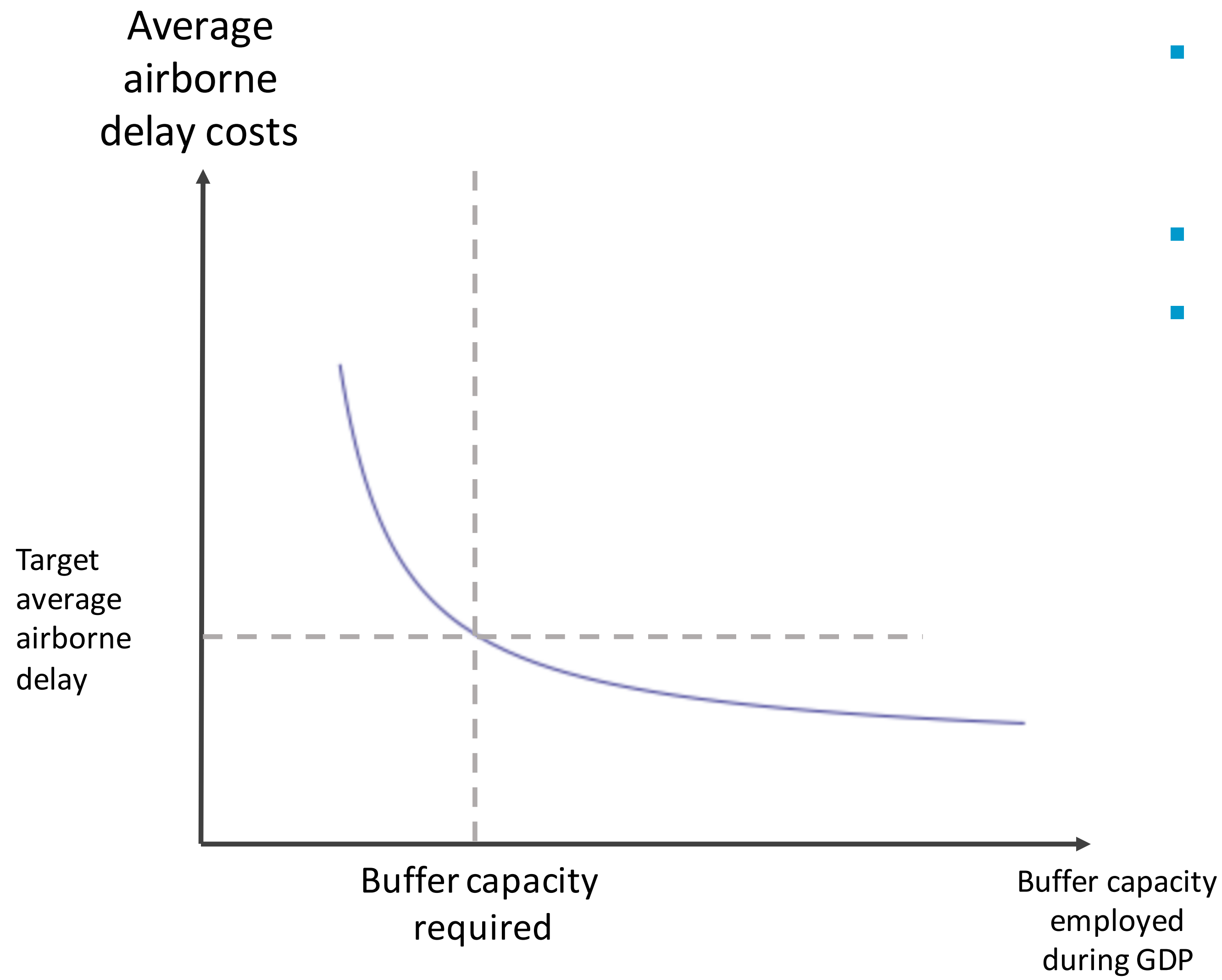
Airborne delay: Schedule-based ground holding



- Schedule-based ground holding: Upon fixing AAR, a delay is assigned based on the no. of slots needed for the exempt flights
- Present multi-nodal GDP follows this approach
- Delay cost incurred is a fraction of the delay costs incurred in the fixed ground holding

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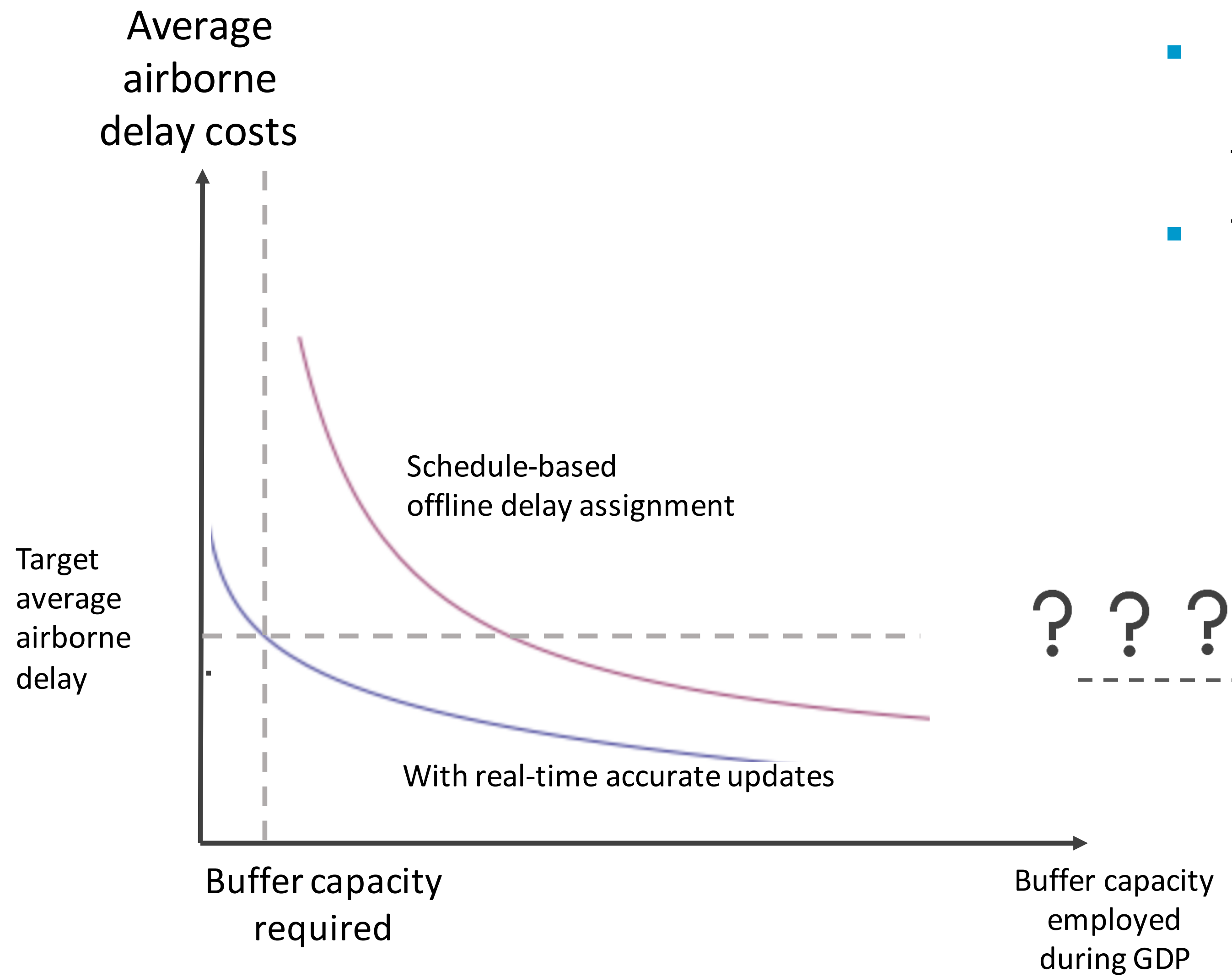
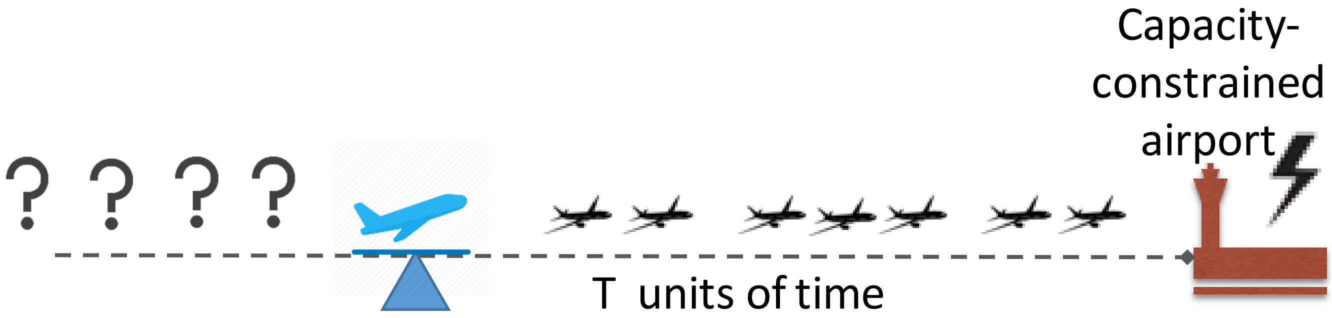
Airborne delay: Dynamic assignment with accurate arrival profiles



- Dynamic assignment with accurate arrival profiles: Have "accurate" prediction information for up to the travel duration of the flight
- The resulting average delay can be as small as the logarithm of the delay achieved by the schedule-based approach



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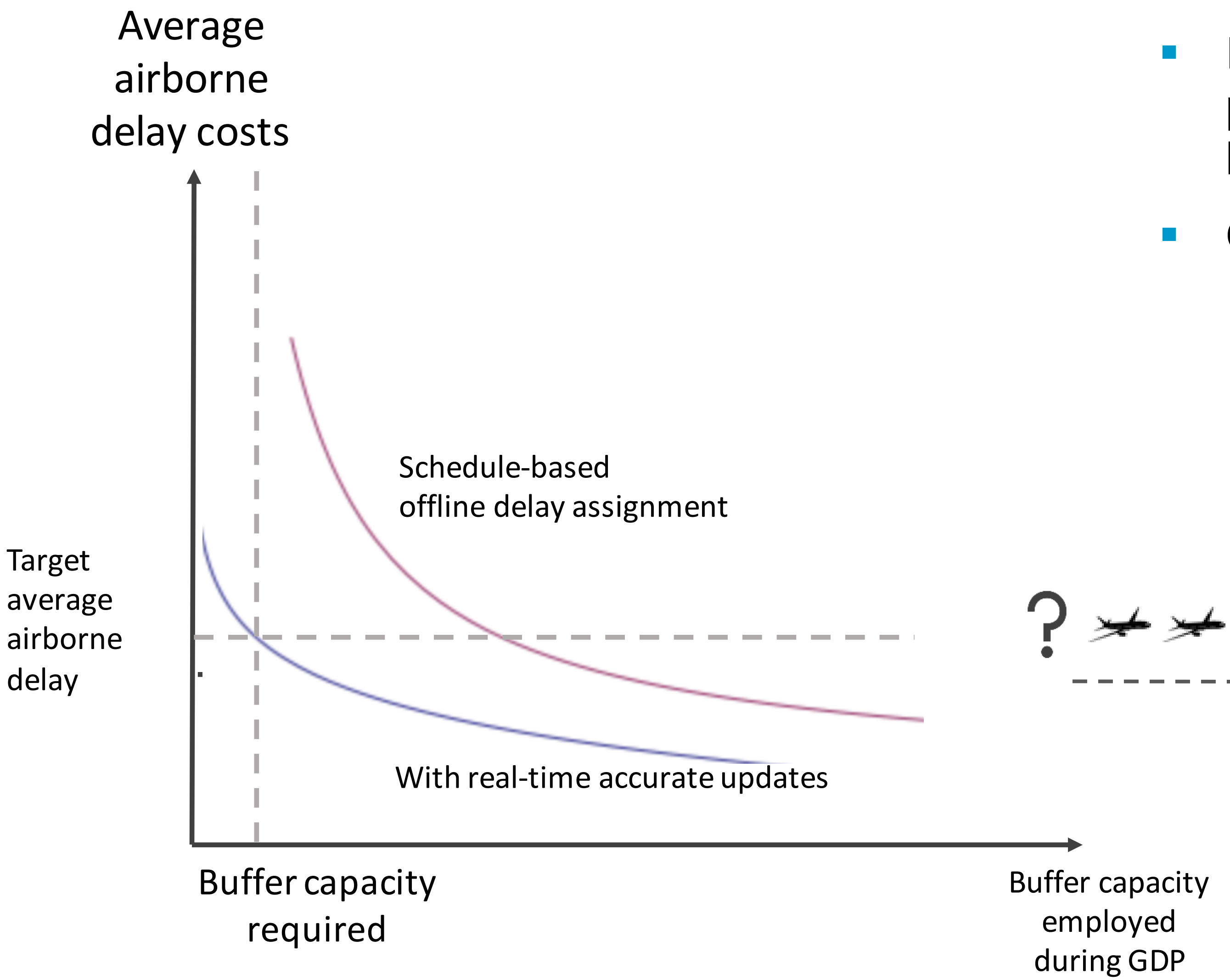
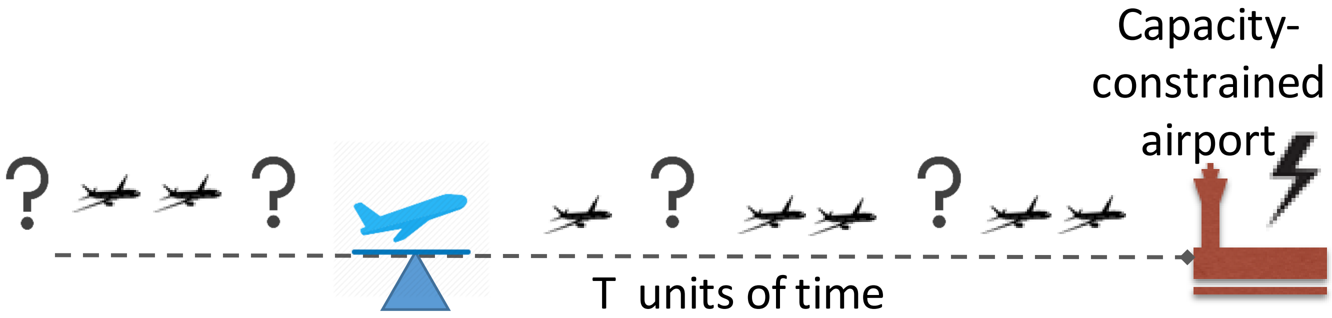
Airborne delay: Dynamic assignment with accurate arrival profiles



- In the presence of SWIM, it is realistic to have arrival profile predictions available for a longer horizon, with higher fidelity prediction if closer in time.
- Greater the collaboration, higher is the accuracy



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Q1. How to perform ATFM differently in the presence of SWIM?

At any given time-step,

Observe state variables:

1) # flights in airborne and ground queues

2) future arrival profile estimates

Decide the # flights which need not be held anymore on ground

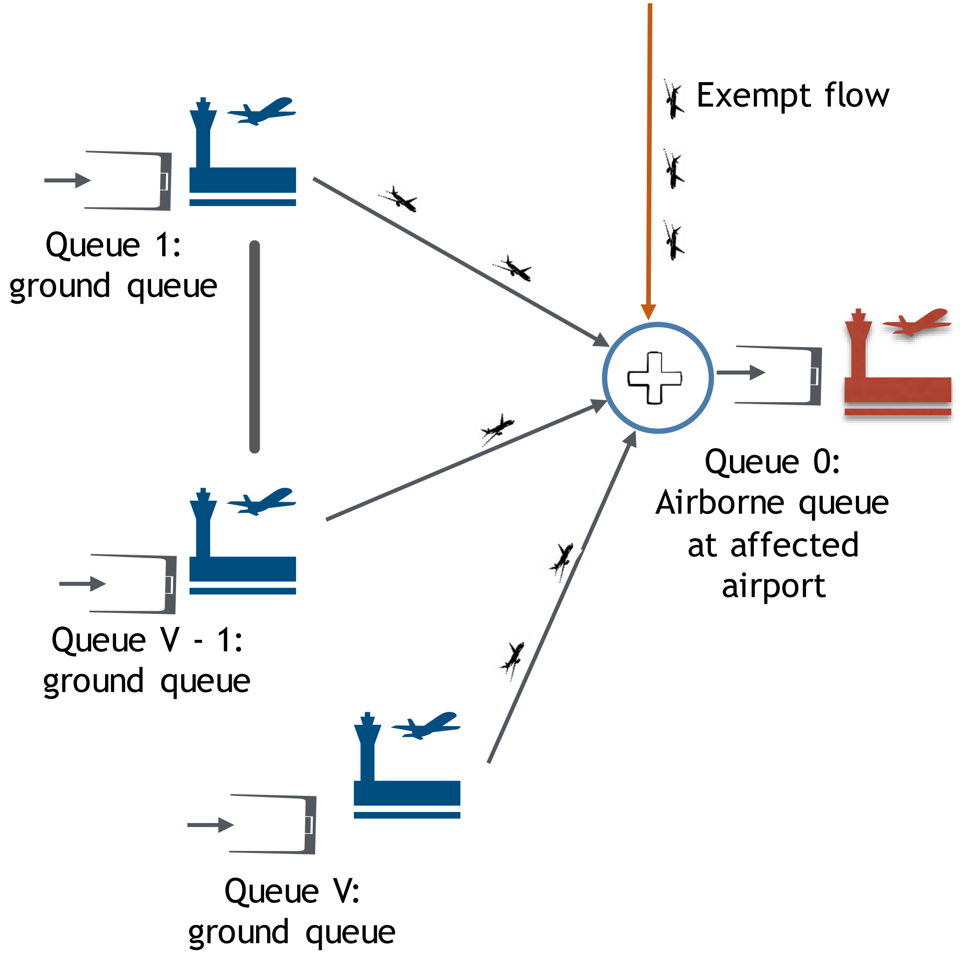
based on a suitable criterion

referred as "ground holding policy"

Time-step elapse

Observe updates to state variables resulting from flight movements in the elapsed time

Cost at the time-step determined by the #flights held in air and ground



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A high-level description of the ground holding prescription

A simple anticipatory prescription for ground holding:
Release a flight from the ground queue only if, upon its arrival,

1. the projected # flights in the airborne queue is below an acceptable threshold, and
2. is projected to return below the pre-arrival level within a fixed window of time

Figure: Illustration of the policy's decision criterion for releasing a flight from ground holding

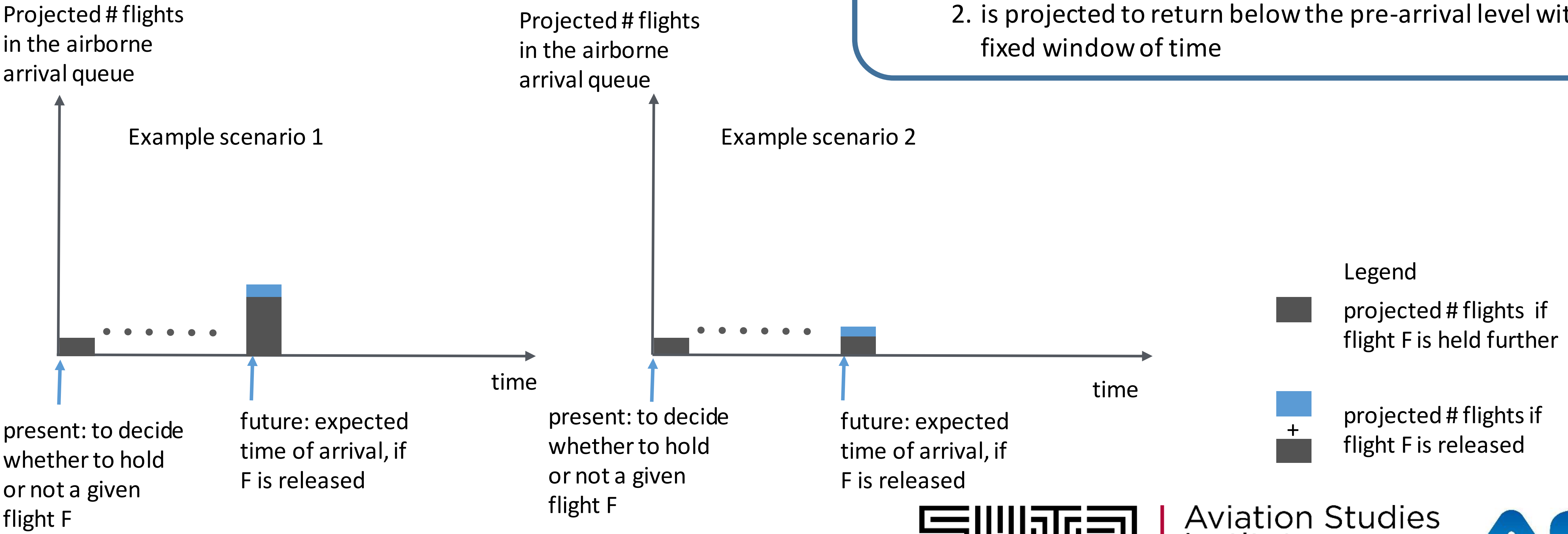

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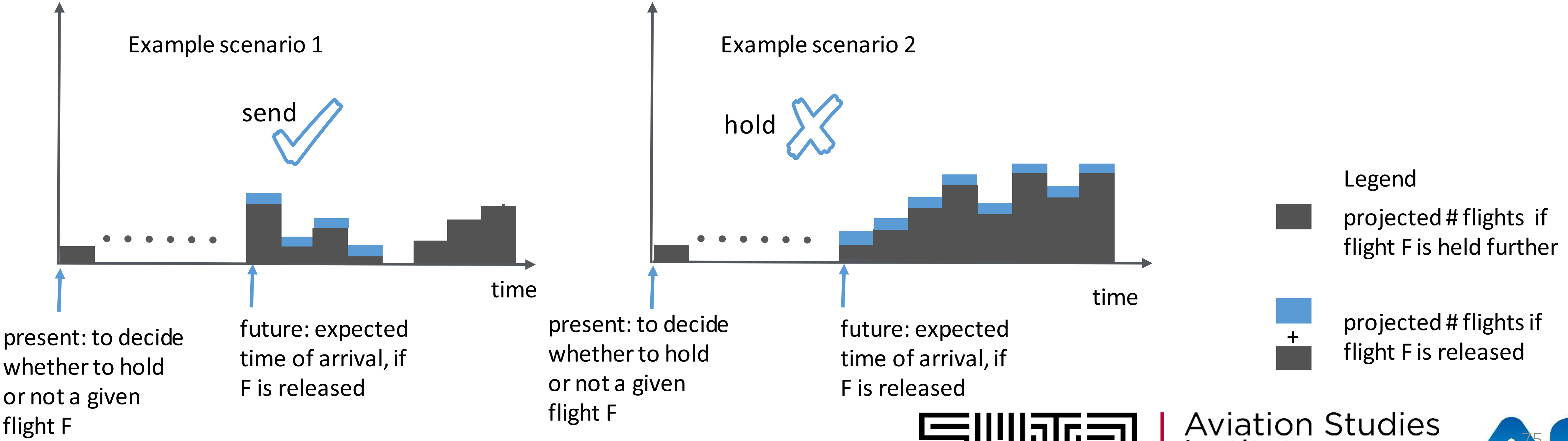
Figure: Illustration of the policy's decision criterion for releasing a flight from ground holding

Projected # flights in the airborne arrival queue

Projected # flights in the airborne arrival queue



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Q2. On assessing the delay-costs of SWIM and non-SWIM GDP

- A network simulation model for yielding delay estimates for the ground delay prescriptions in SWIM and non-SWIM settings
- Data is crucial in equipping the models with a sensible picture of the traffic supported by the network.
- As examples, we use data to create the network, identify the average volume of traffic via each link, capacity constraints, etc.

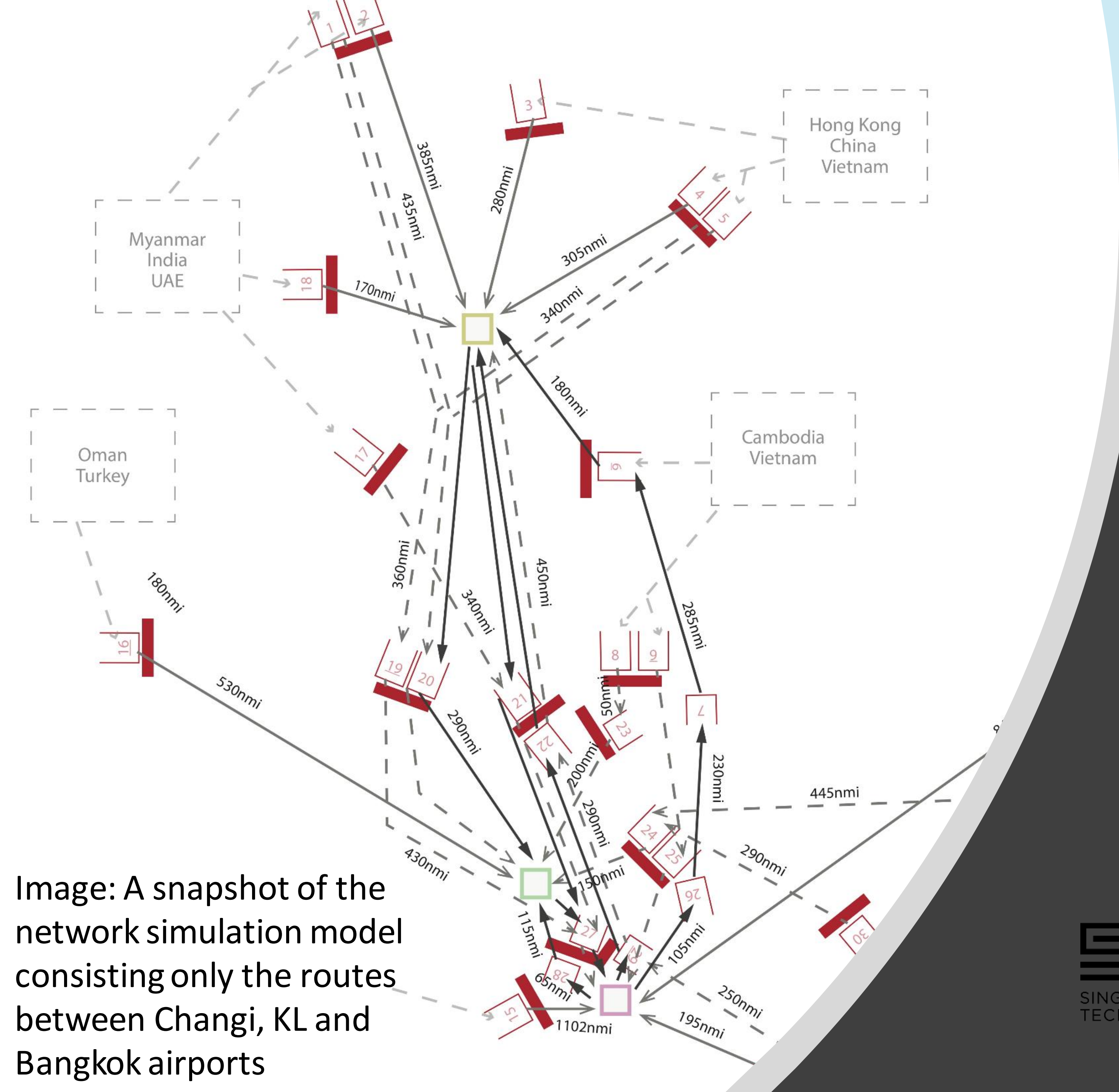

Image: A snapshot of the network simulation model consisting only the routes between Changi, KL and Bangkok airports

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In summary: Information sharing and CDM for managing ground delays

- The primary objective of the tool is to provide an understanding of how increased collaboration in information sharing and decision-making translates to decreased delays (costs)
- Quantitative models bring out how superior ATFM strategies can be devised in the presence of real-time updates in future data-rich environments
- The fully developed tool will additionally allow users to inform various capacity reduction scenarios, airport acceptance rates and gain an understanding on resulting airborne and ground delays in ground delay programs

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Thank you

A BETTER WORLD BY DESIGN

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Institute

Regional Focus

Advancing ATM Research & Development in the Asia Pacific

Spotlight on ASI

Peter Jackson

Professor, Head of Pillar (ESD) and Director of Aviation Studies Institute (ASI), SUTD

Nuno Ribeiro

Assistant Professor, Engineering Systems and Design, SUTD

Understanding Convective Weather events and their Impact on Air Traffic Management

Peter Jackson, Director, Aviation Studies Institute, SUTD

Nuno Ribeiro, Assistant Professor

CAAS
Civil Aviation Authority of Singapore
Enabling opportunities through aviation

VAISALA

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ASI

Outline

- Predicting Lightning Strikes at Airports
- Impact of Lightning Strikes on Aircraft Routes
- Impact of Lightning Strikes on Airport Delays

Research Problem

- The aim is to develop data-driven models to predict weather events and estimate their impacts on air traffic operations at Changi Airport.
- The impact on air traffic operations can be evaluated in terms of local delays and/or additional travel times to go from the FIR entry points and the airport of destination.
- The predictors may be the geographical location of the lightning strikes, the frequency and number of events, the lightning warnings (ground crew are asked to seek shelter when warnings are activated), aircraft type, FIR entry point, SID/STAR route used, wind and visibility conditions, time of the day, number of flights scheduled, runway assigned, etc.

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Predicting Lightning Strikes at Airports

- Starting point: data set provided by Vaisala Corp.
  - All recorded lightning strikes in Southeast Asia
  - Sept.-Dec. 2019
- Initial study: (student project) predict occurrence of lightning strikes at Changi airport
  - Two teams, both achieving similar results
  - Repeat the analysis here with finer grid and time intervals
  - Conclusion: not sufficiently reliable… yet

VAISALA

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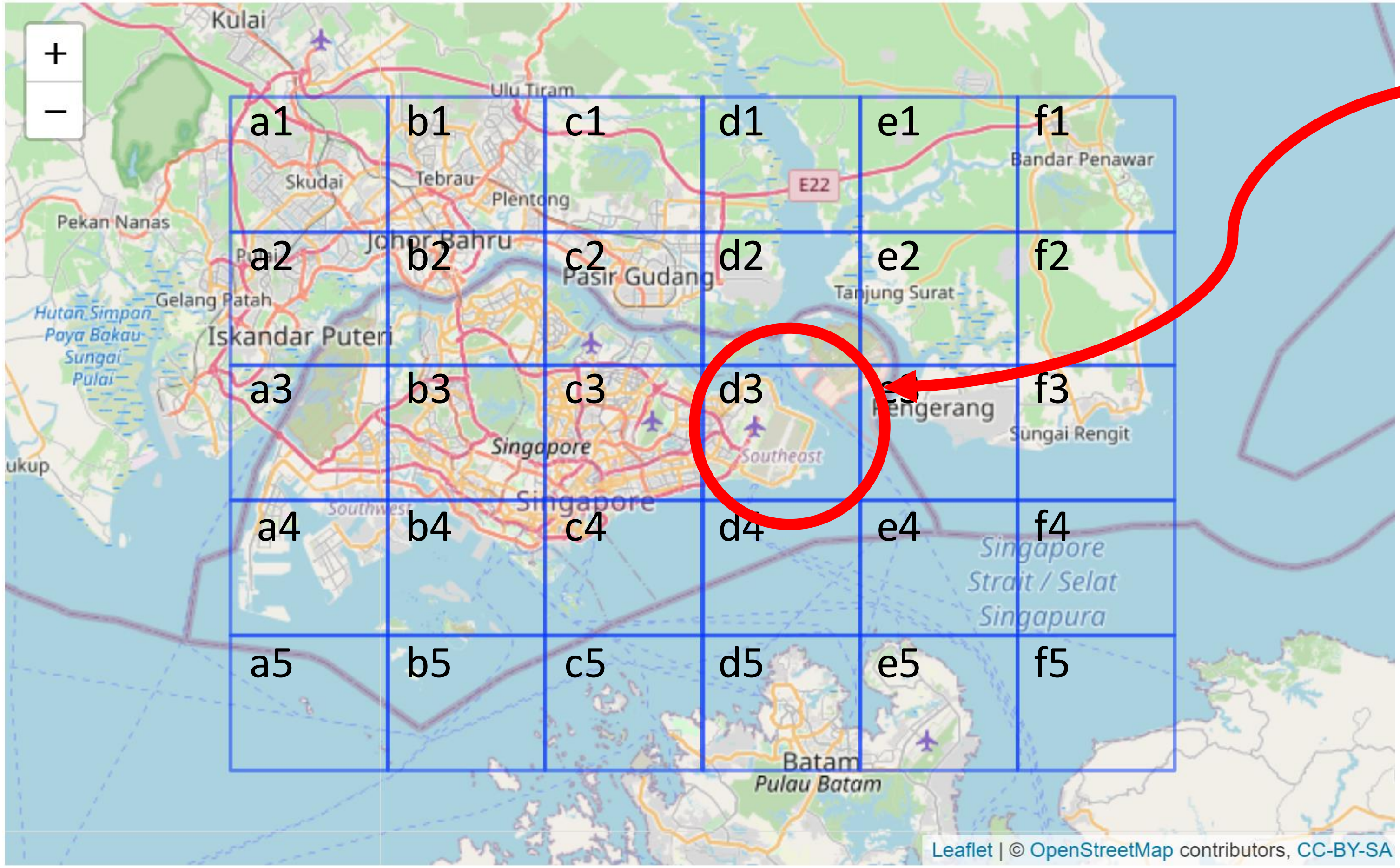
Superimpose Grid on Changi Airport



- Cell d3 covers Changi International Airport

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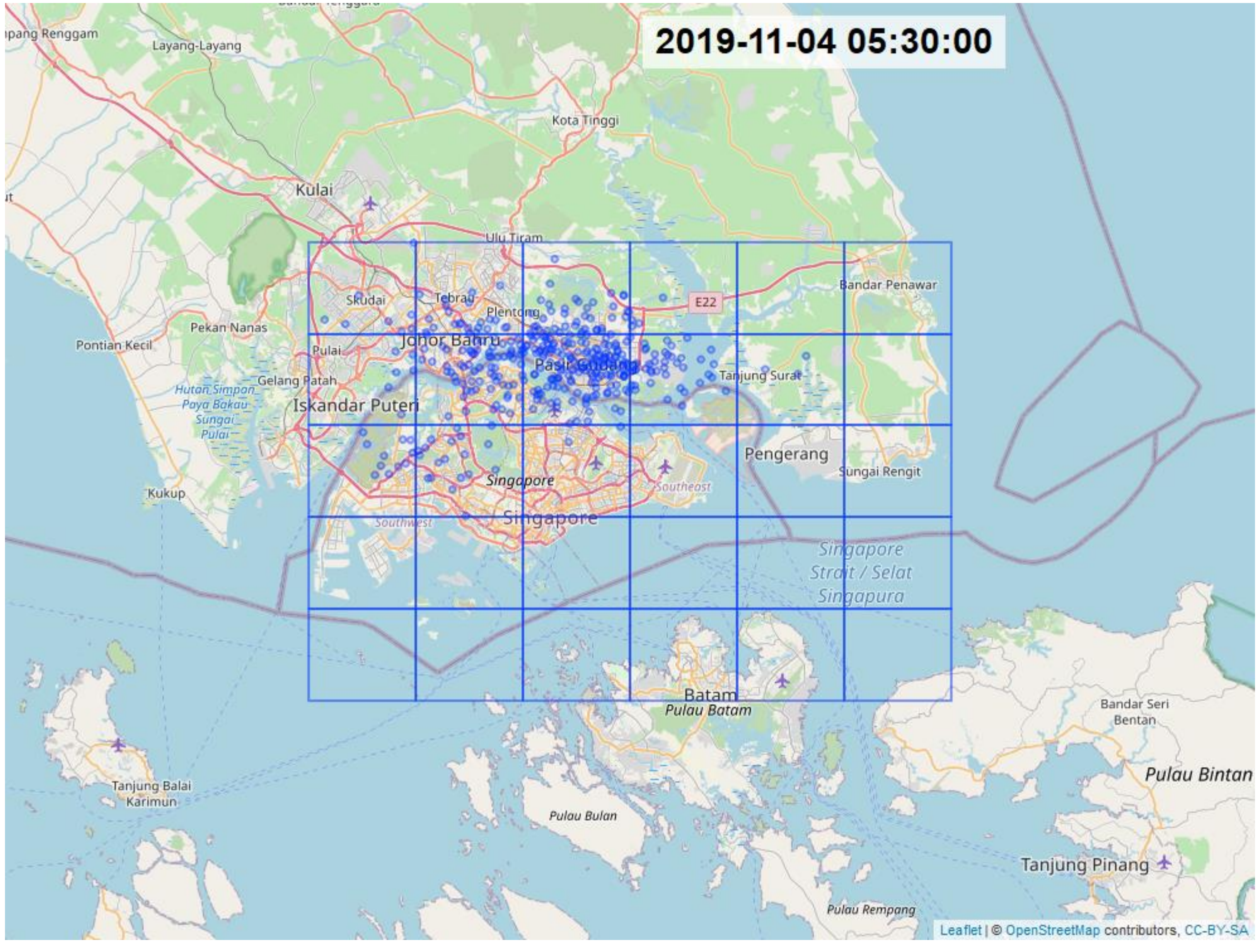
Capture Data In 15-Minute Intervals



- Count lightning strikes in each cell for each 15 minute interval

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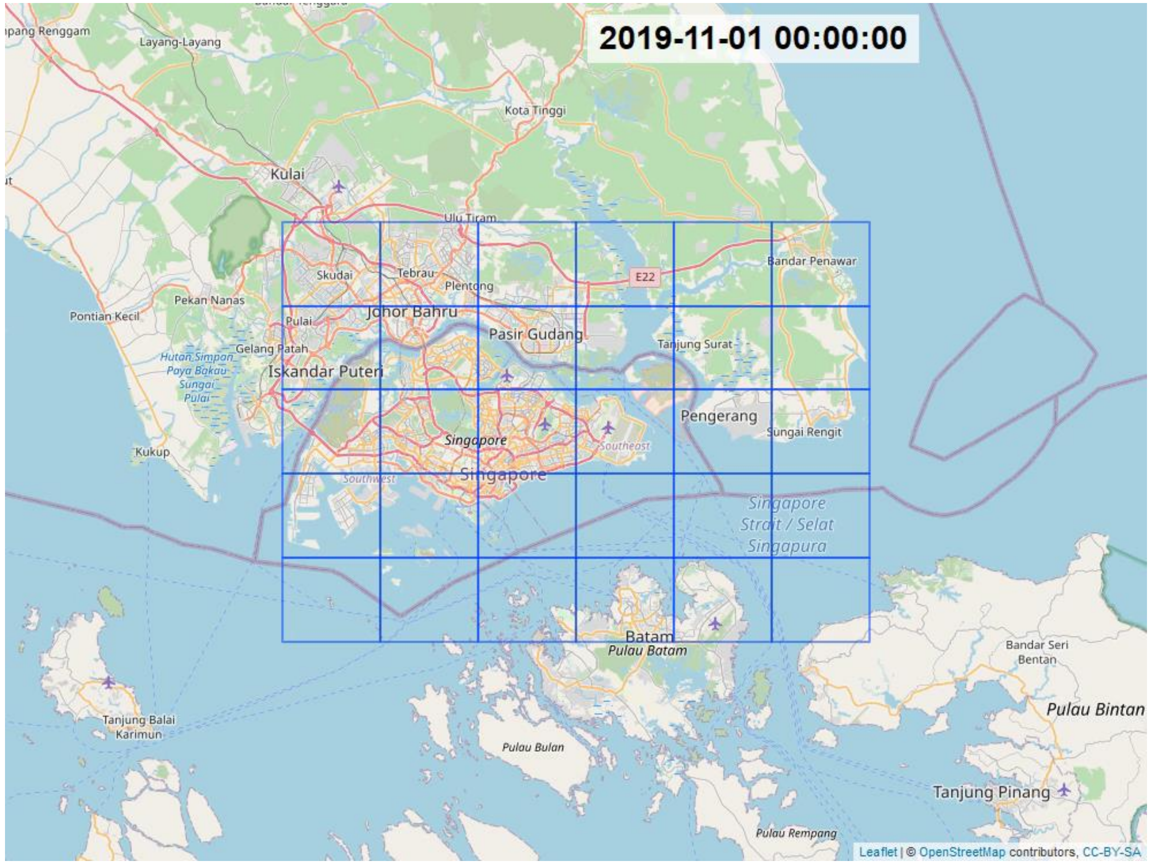
Animation (for live presentation only)



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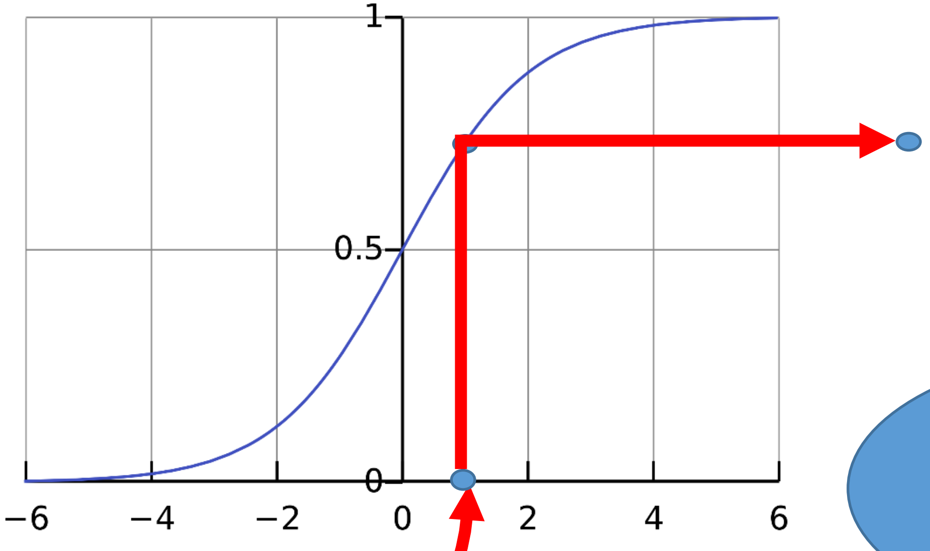
From Data to Probability: Logistic Regression



Convert score to probability

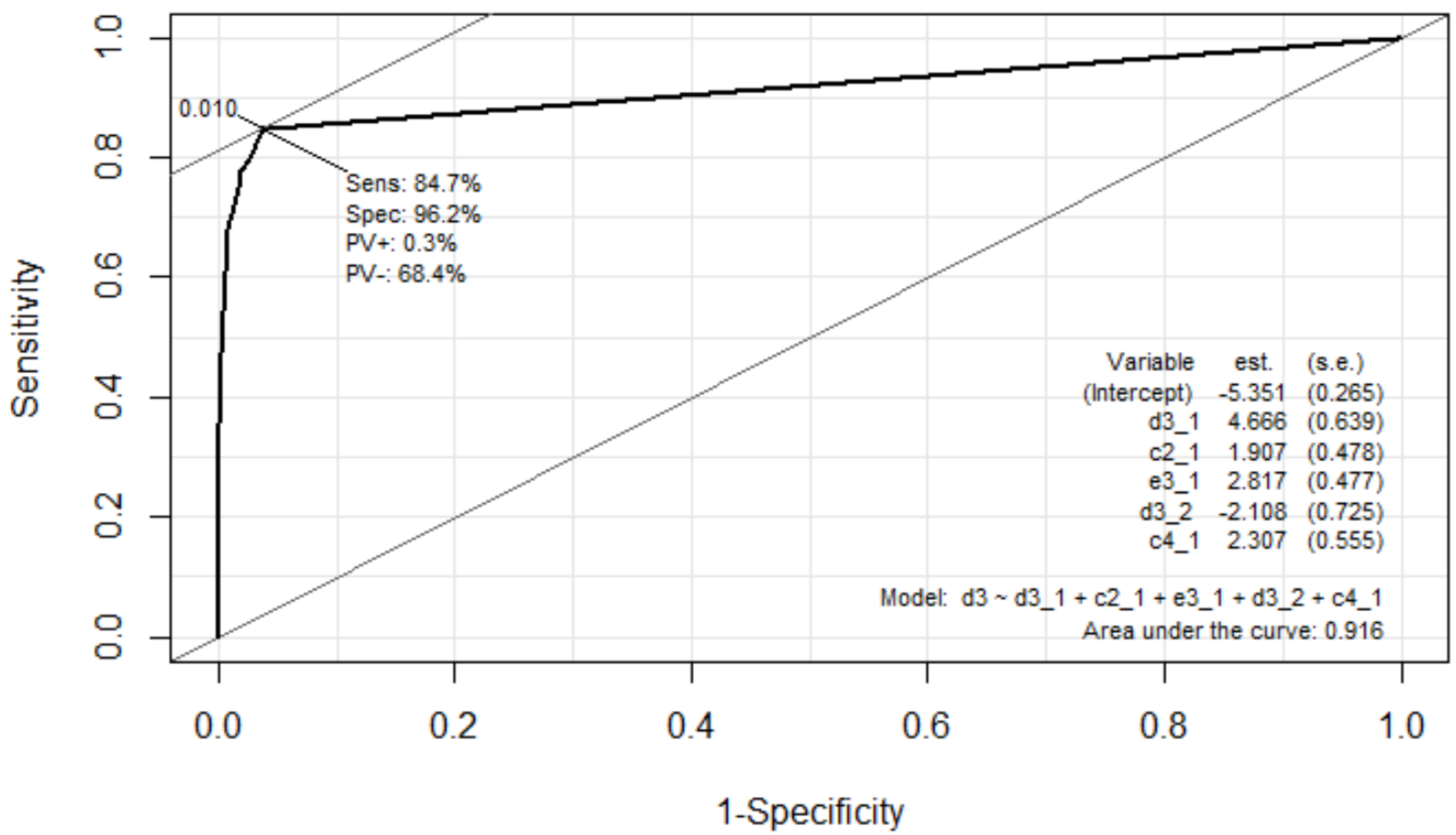
Optimization: find best weights

intervalID <int>	a1 <dbl>	b1 <dbl>	c1 <dbl>	d1 <dbl>	e1 <dbl>	f1 <dbl>	a2 <dbl>	b2 <dbl>	c2 <dbl>
311	8	23	39	4	0	0	6	69	161
312	0	13	11	1	1	0	1	11	17
313	1	21	24	0	1	0	0	5	10
314	0	11	27	0	0	0	0	0	0
315	0	0	0	0	0	0	0	0	0
316	0	0	0	0	0	0	0	0	0
317	0	0	0	0	0	0	0	0	0
318	0	0	0	0	0	0	0	0	0
319	0	0	0	0	0	0	0	0	0
320	0	0	0	0	0	0	0	0	0

Convert data to weighted score

https://en.wikipedia.org/wiki/Sigmoid_function#/media/File:Logistic-curve.svg

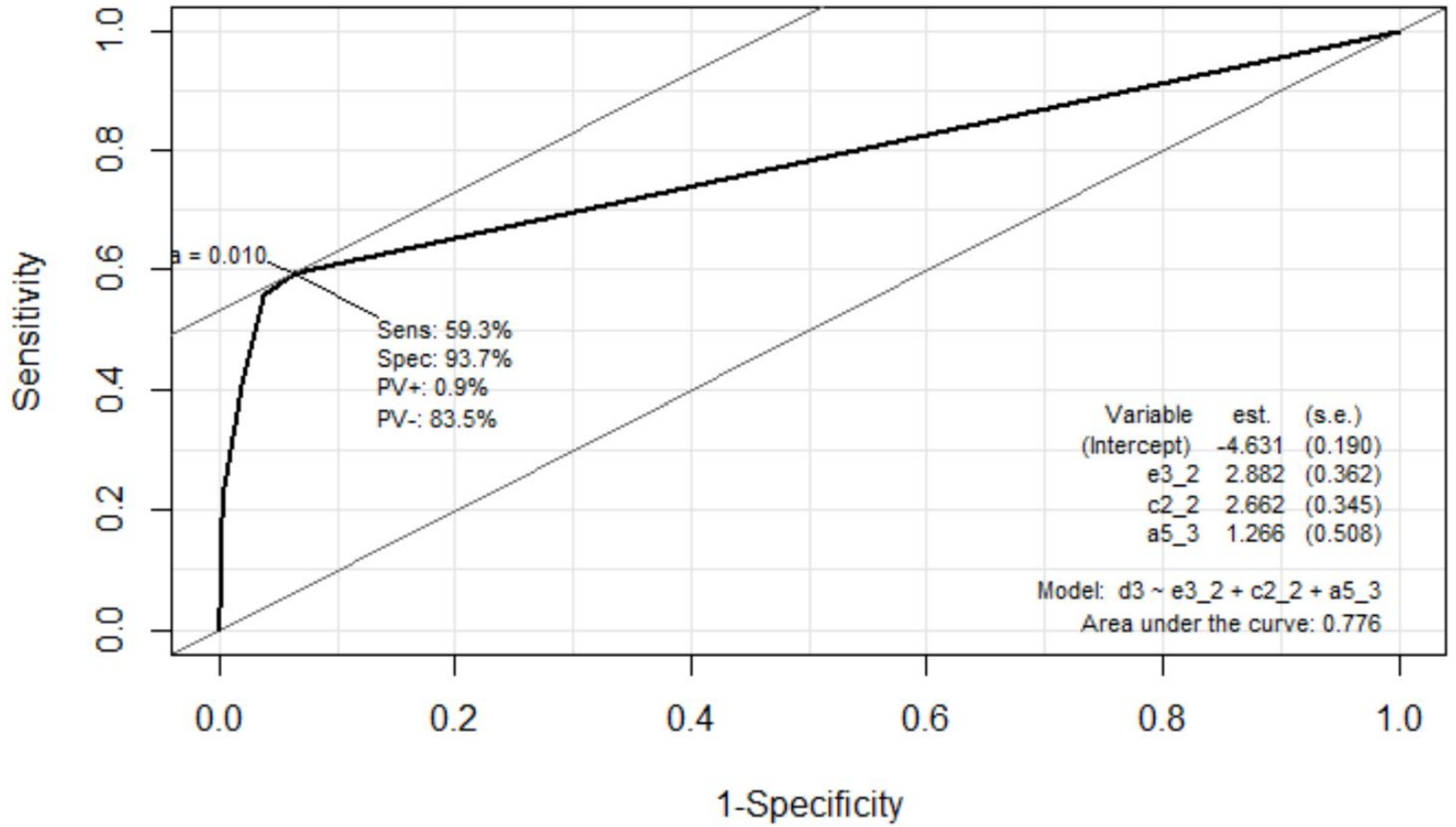
The Best Model (for instantaneous prediction)



- Cells c2, c4, d3 and e3 are most useful for prediction

But this gives almost no warning time. Suppose we want at least 15 minutes warning…

Best Model (for 15 minute warning)



- Cells c2, e3, and a5 are most useful

But performance is much worse.

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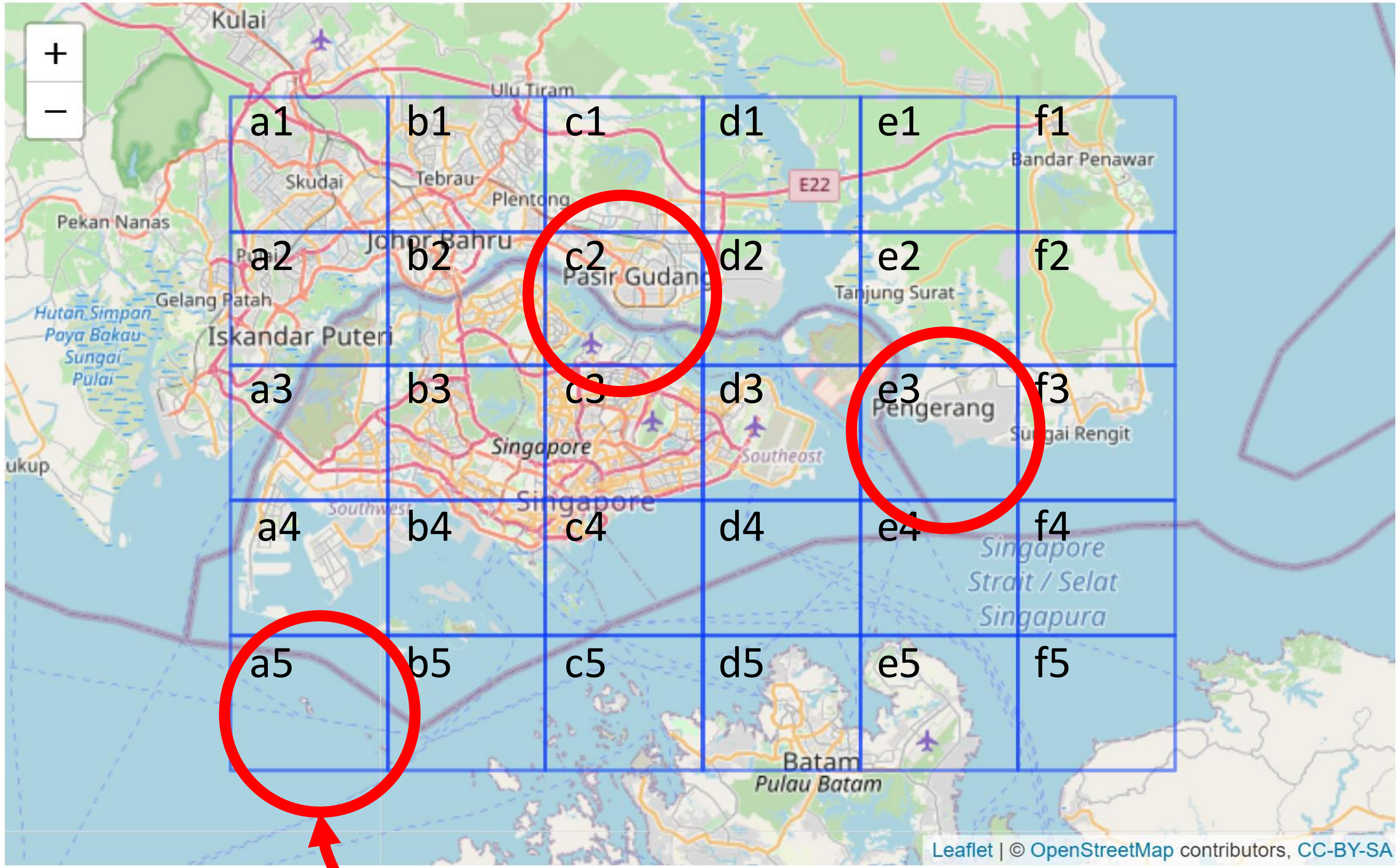
Cells With Best Predictive Power



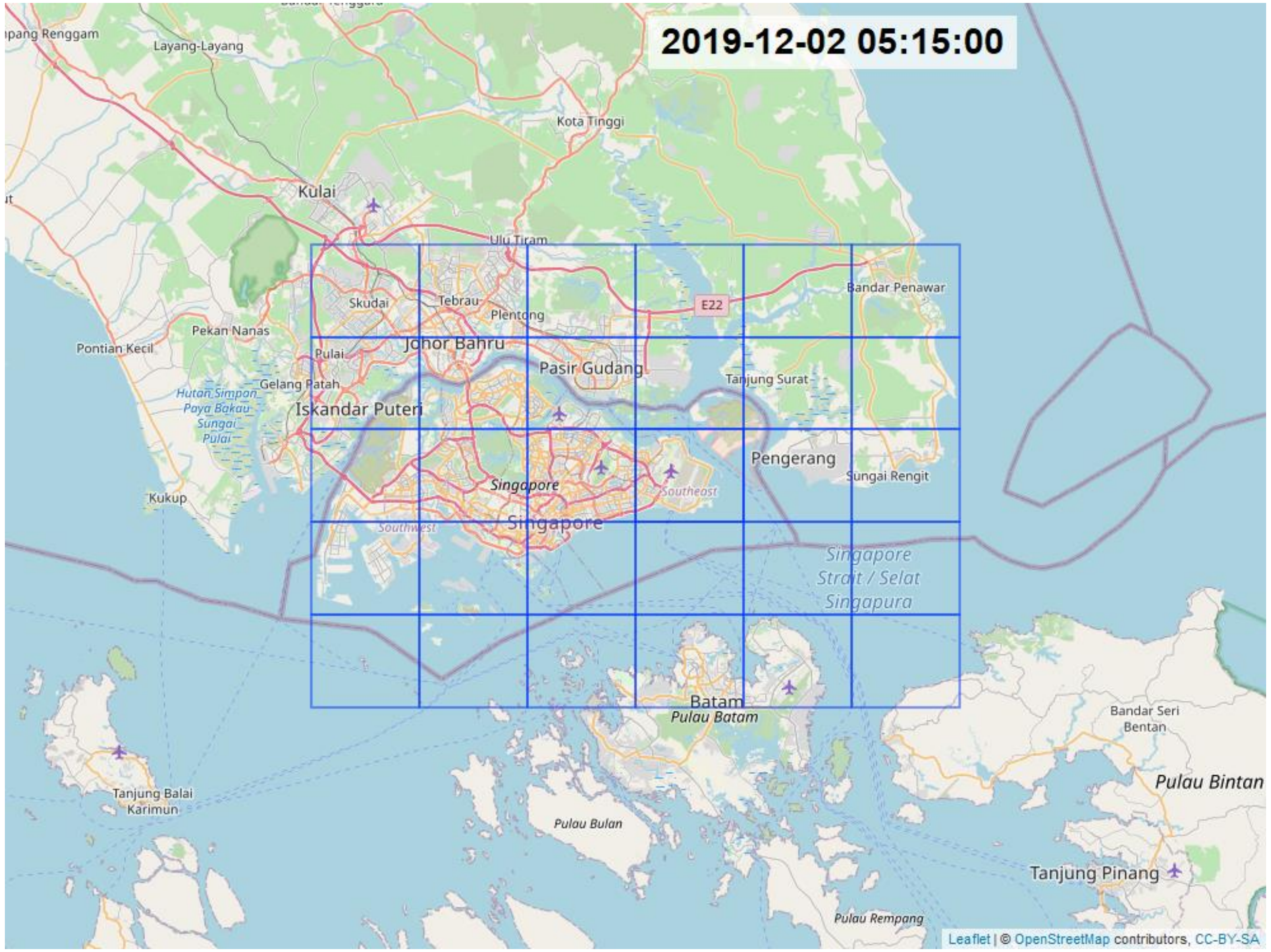
(with extra 15 min. lag)

Tested with December 2019 Data

Interval Count	Predict No Lightning	Predict Lightning
Actual No Lightning	2942	19
Actual Lightning	7	5

Not sufficiently reliable…yet

All is Quiet



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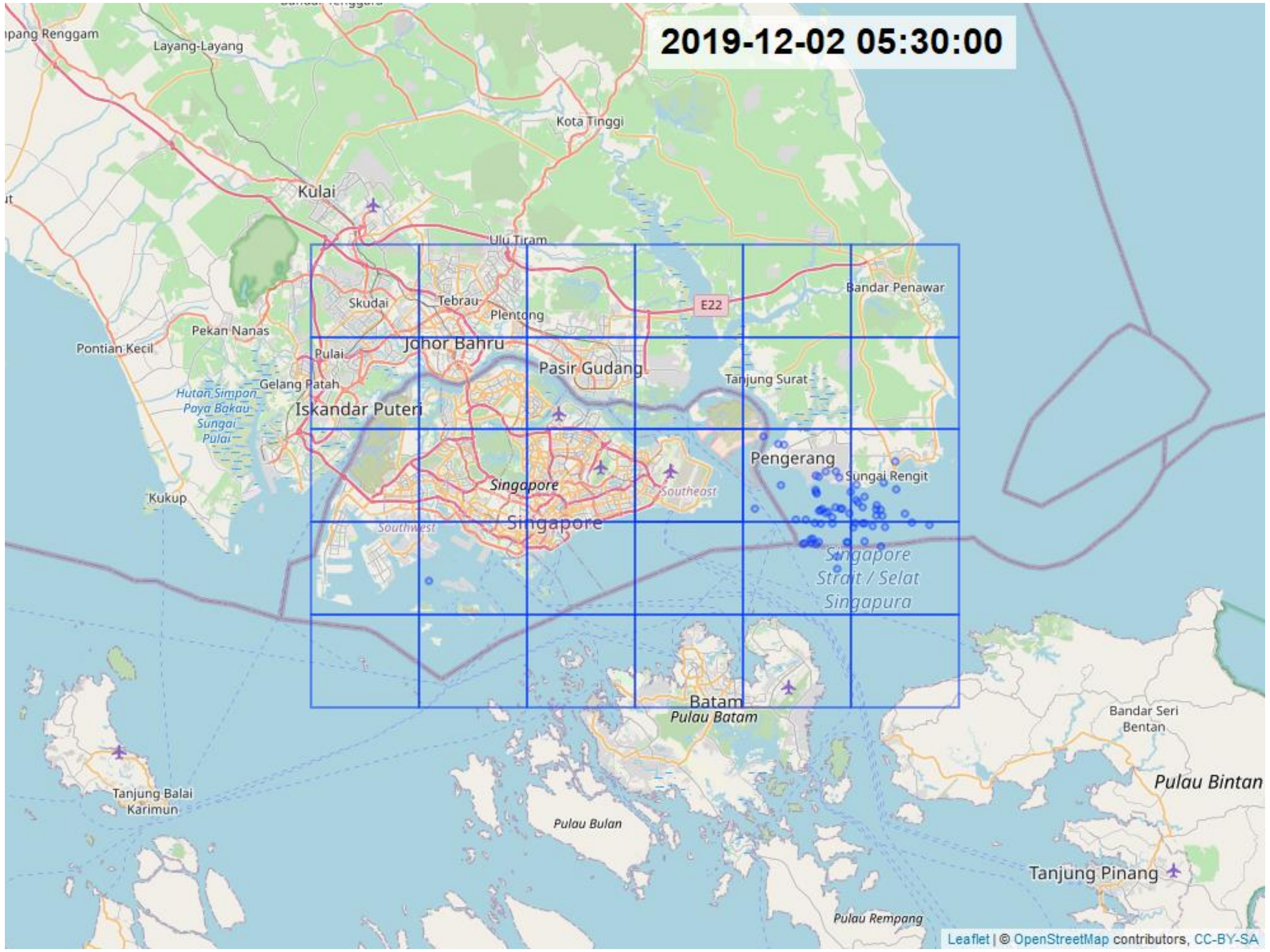
Activity in E3: We Predict Lightning for 6:00 a.m.-6:15 a.m.



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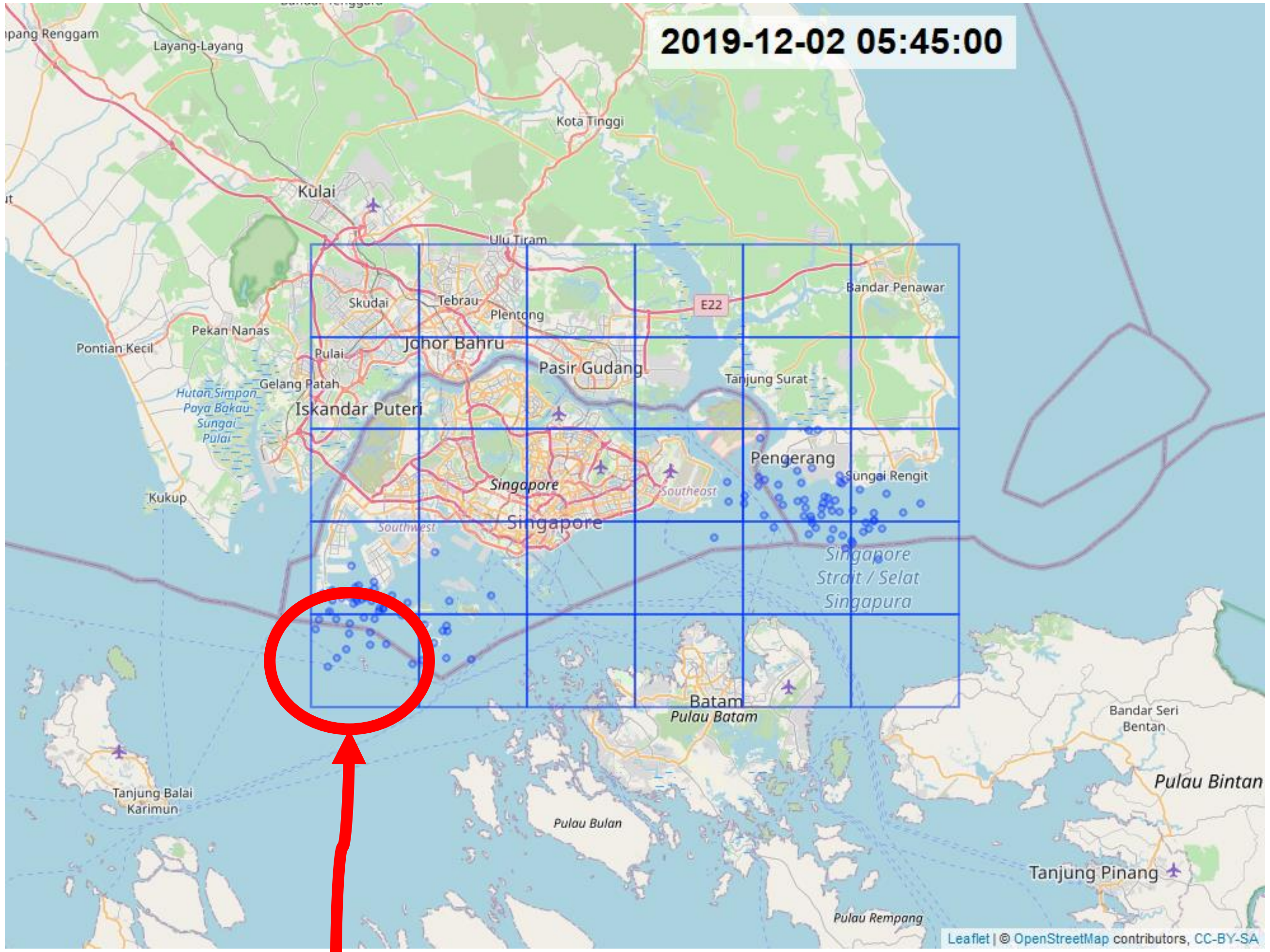
False Negative: Lightning Shows Up in 5:45-6:00 a.m. Interval



Activity in a5 drives prediction for 6:30-6:45 a.m.

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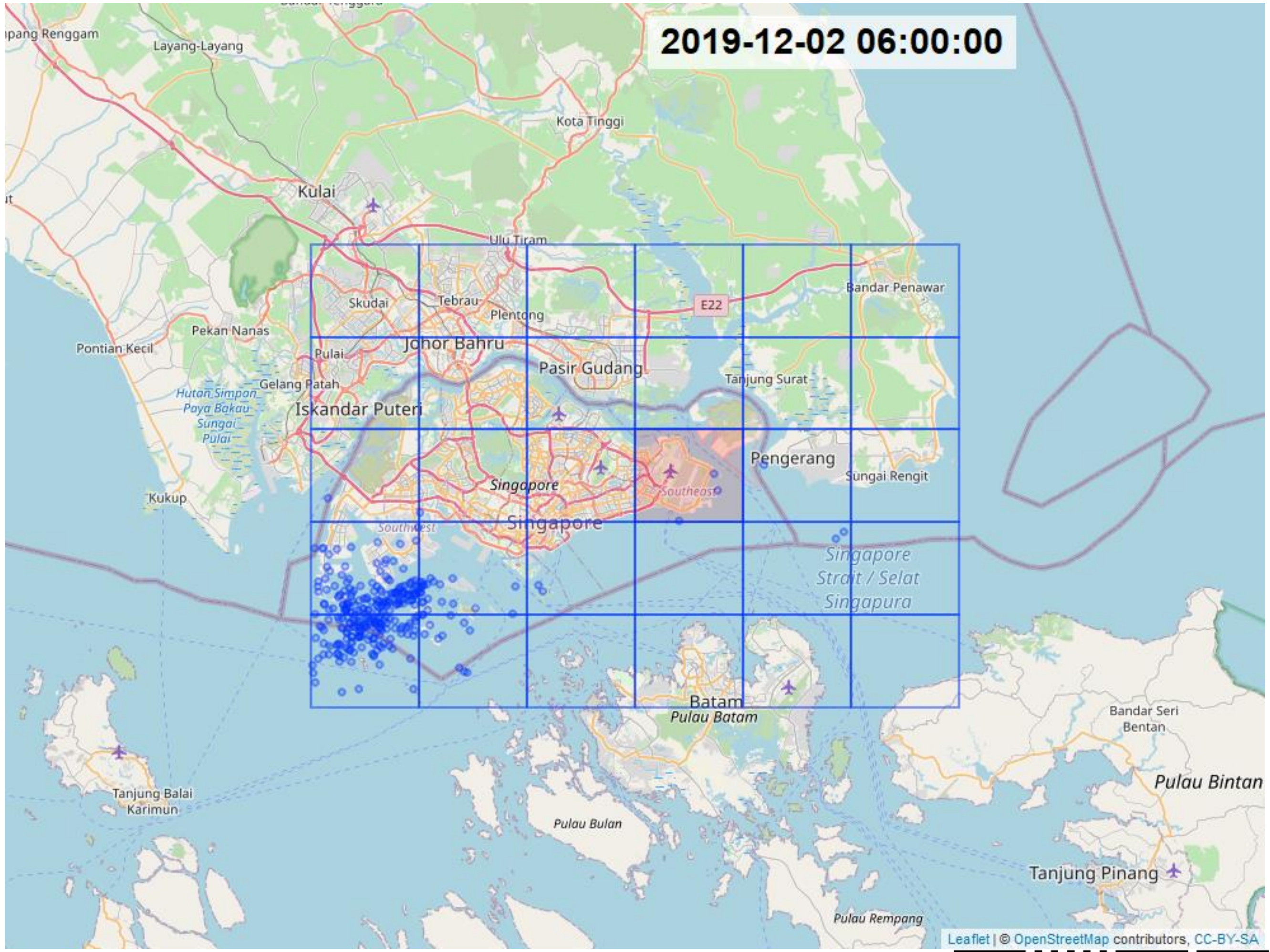
True Positive: We Predicted This



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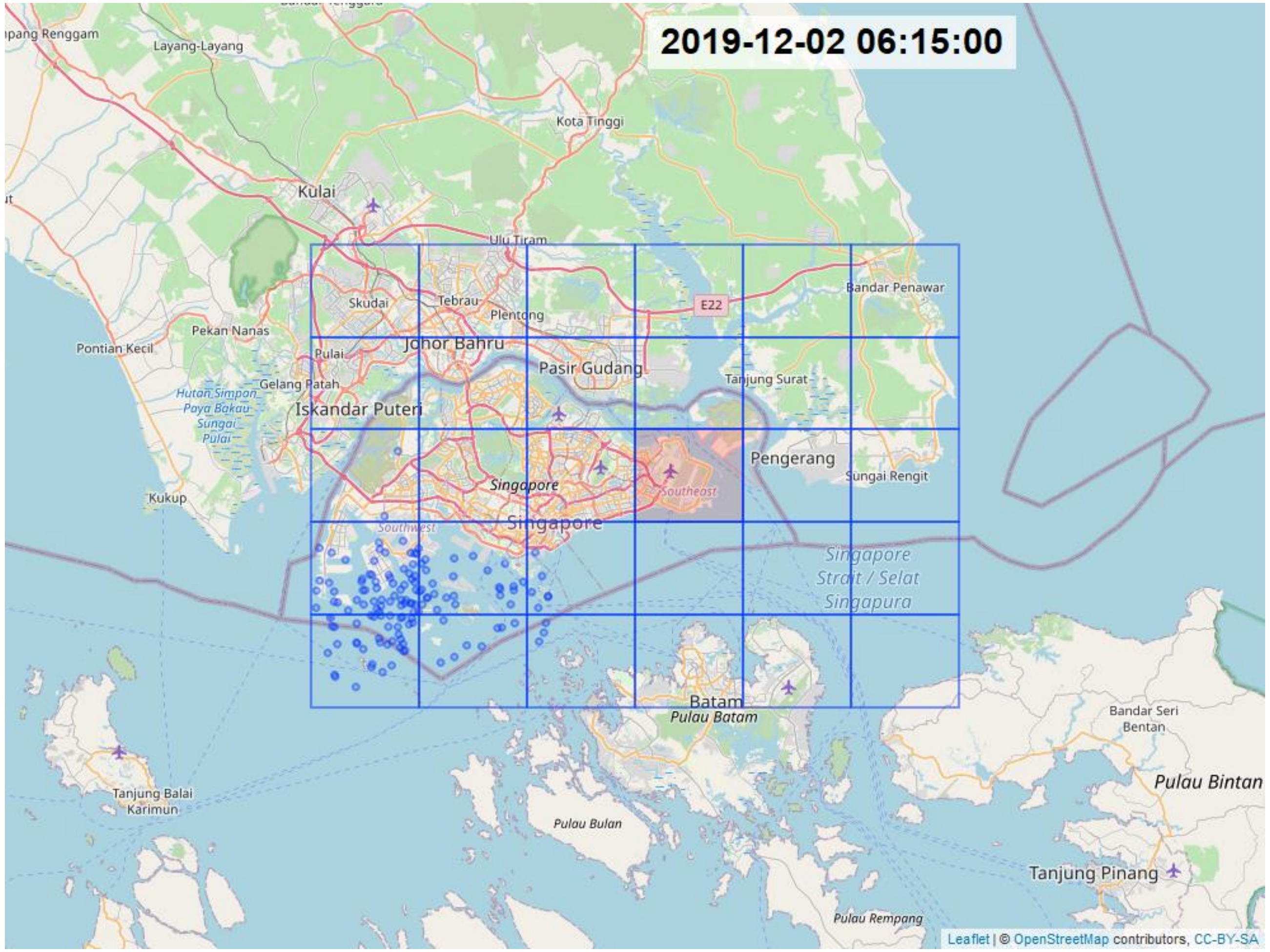
False Positive: We Predicted Strikes But They Didn't Happen



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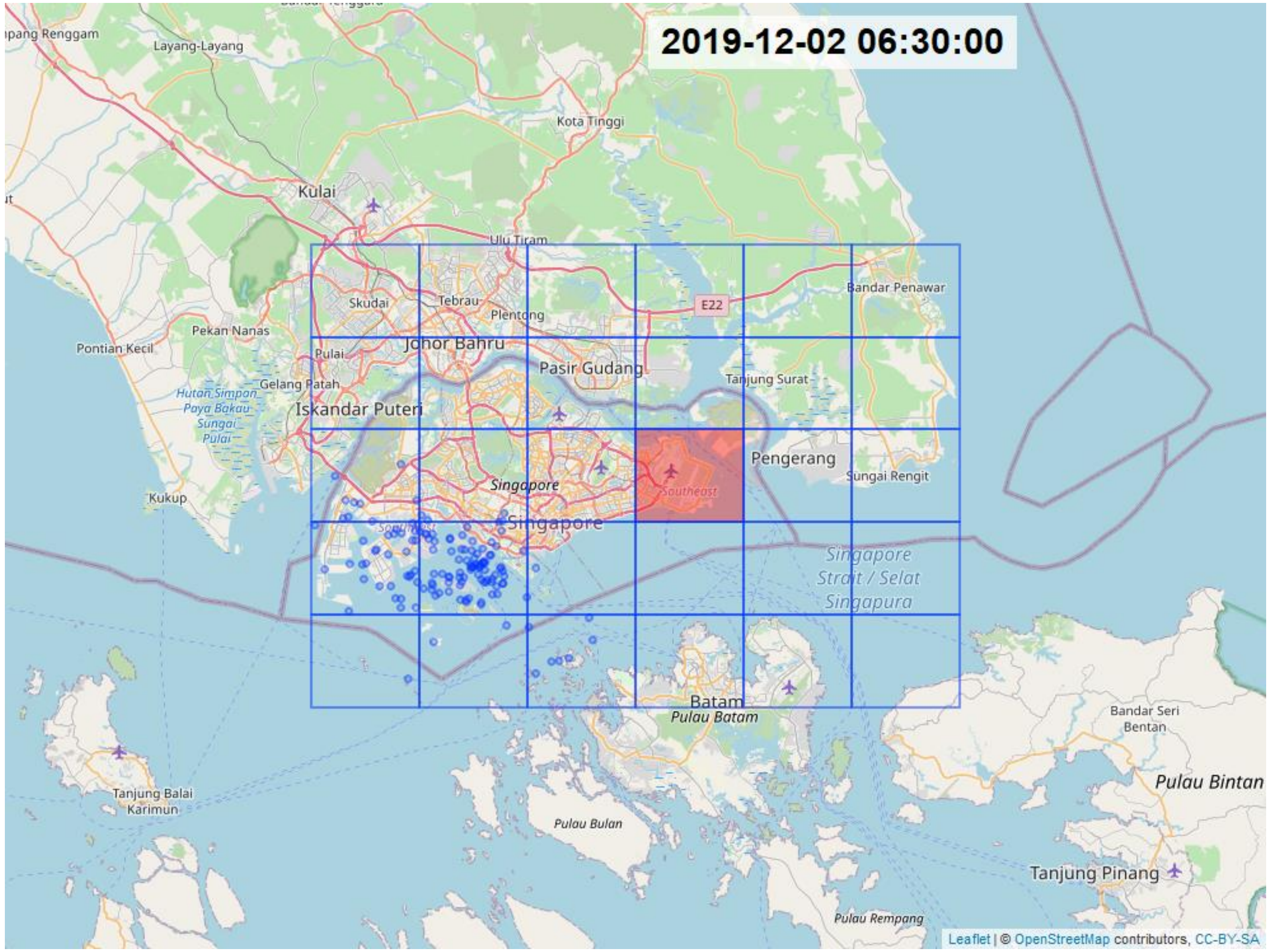
False Positive Again for 6:30-6:45 a.m.



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Next Steps

- We are just beginning our meteorological studies: more to come…
- Seeking wind shear and other data to supplement lightning strike data
- More sophisticated machine learning tools are available – logistic regression is the starting point

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Outline

- Predicting Lightning Strikes at Airports
- Impact of Lightning Strikes on Aircraft Routes
- Impact of Lightning Strikes on Airport Delays

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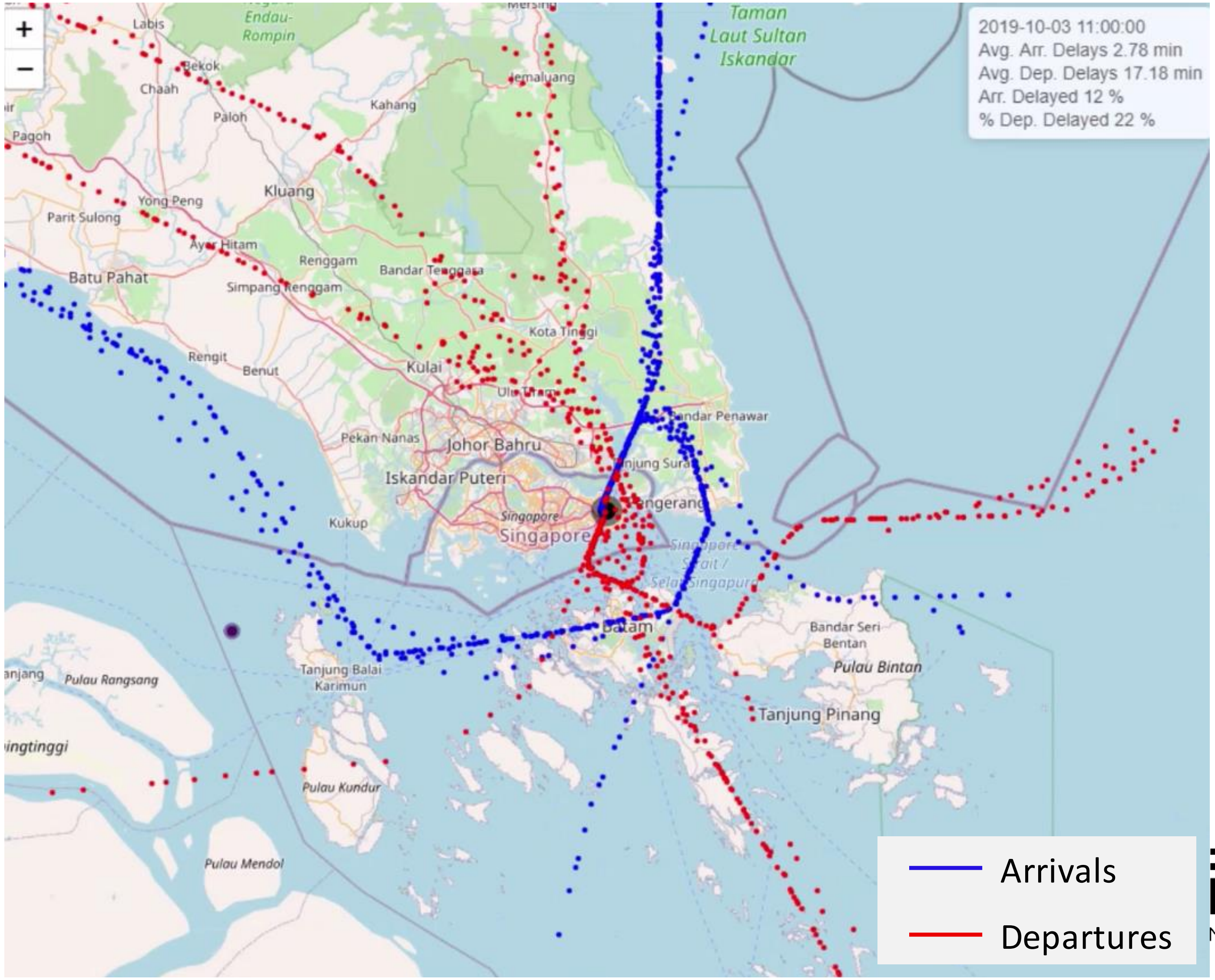
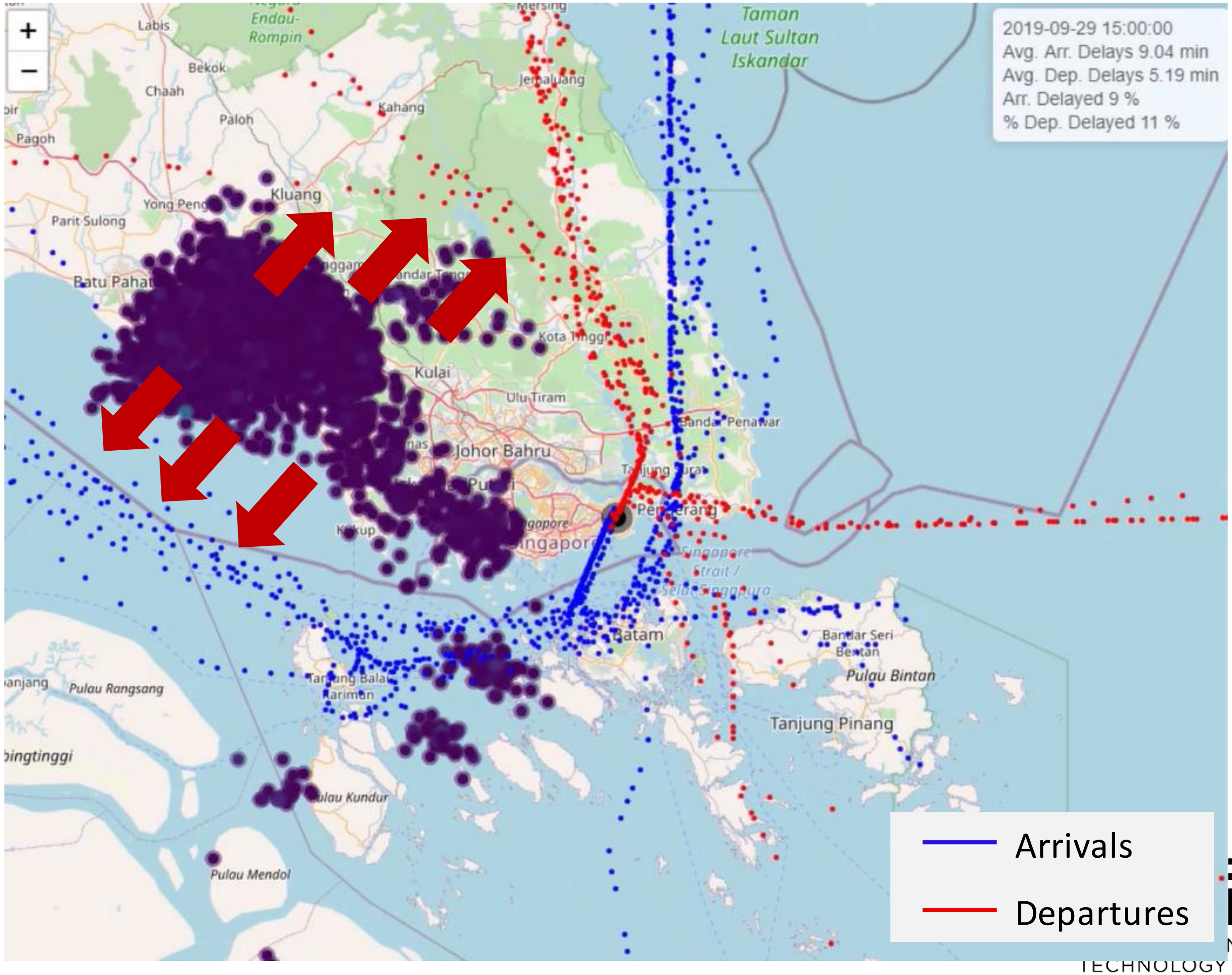
Impact of Lightning Strikes on Aircraft Routes



Normal hour of operations;
No lightning events.

Aviation Studies Institute

Impact of Lightning Strikes on Aircraft Routes



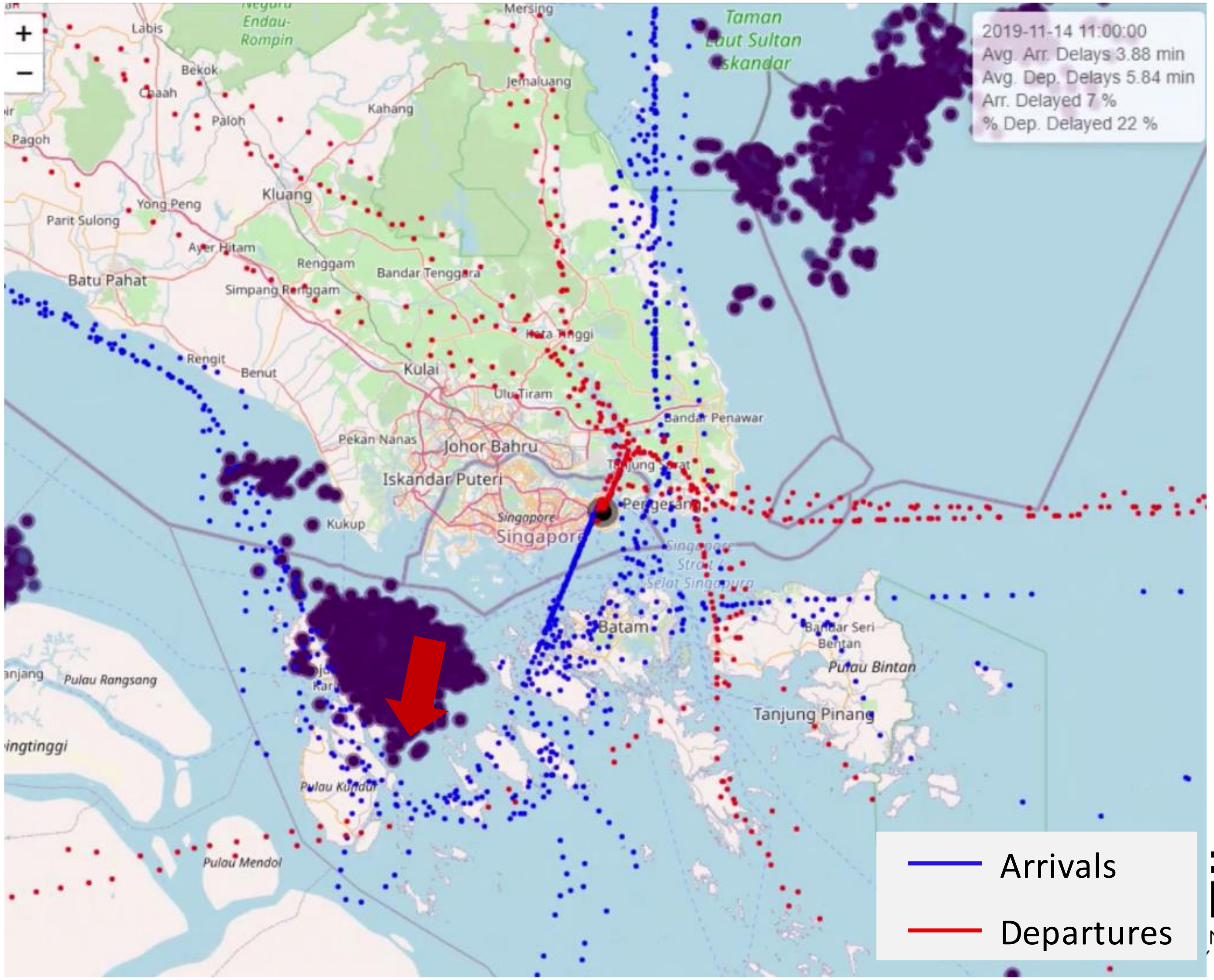
Lightning events over the west coast of Malaysia;

Arrivals and departures from the west are diverted.

Singapore University of Technology and Design | Aviation Studies Institute

ASI

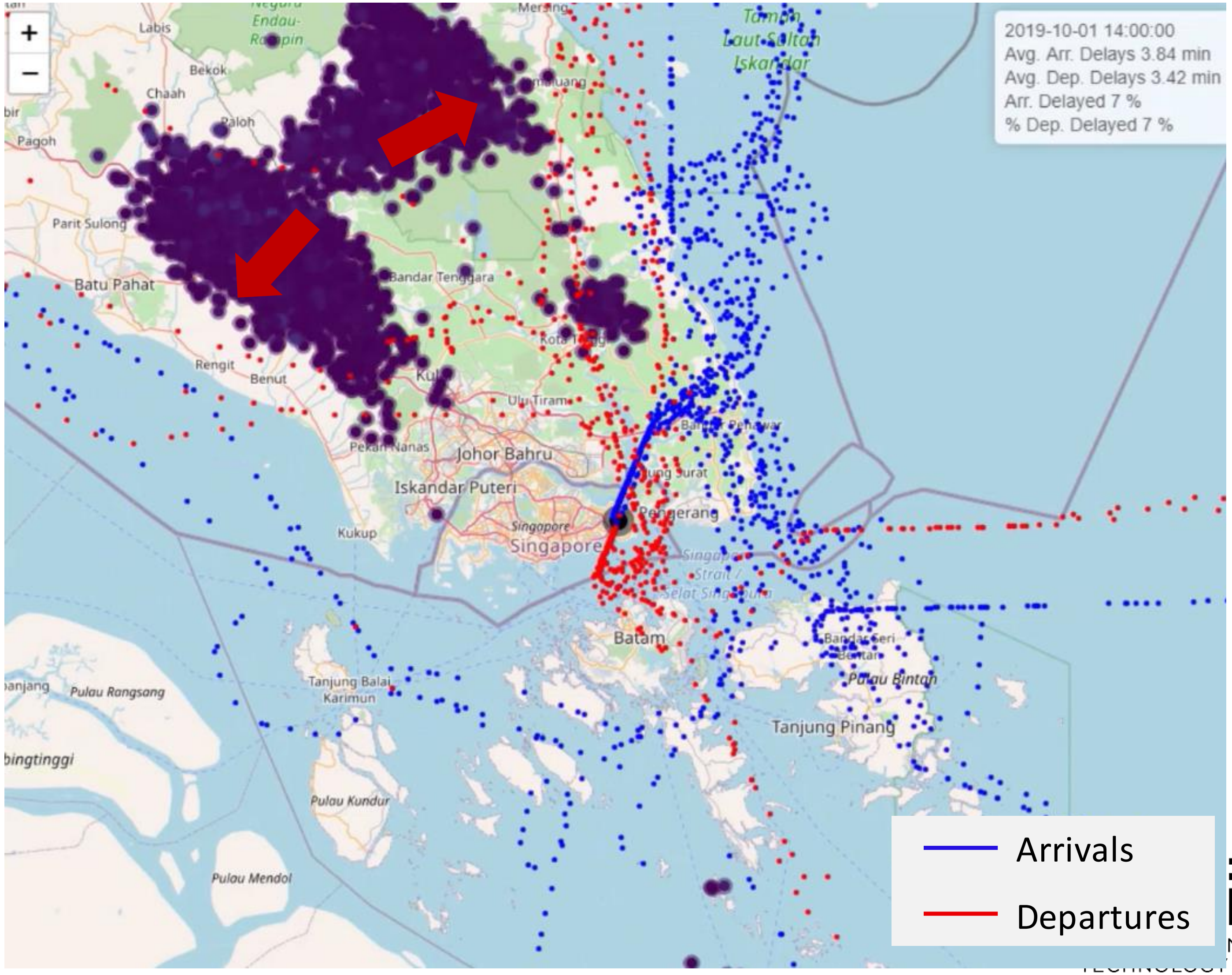
Impact of Lightning Strikes on Aircraft Routes



Lightning events over the South of Singapore;

Arrivals from the west are diverted.

Impact of Lightning Strikes on Aircraft Routes



Lightning events over Malaysia;

Departures are diverted;

Arrivals from the north are diverted to avoid conflicts with the departure flights.

UNIVERSITY OF TECHNOLOGY AND DESIGN
Aviation Studies Institute

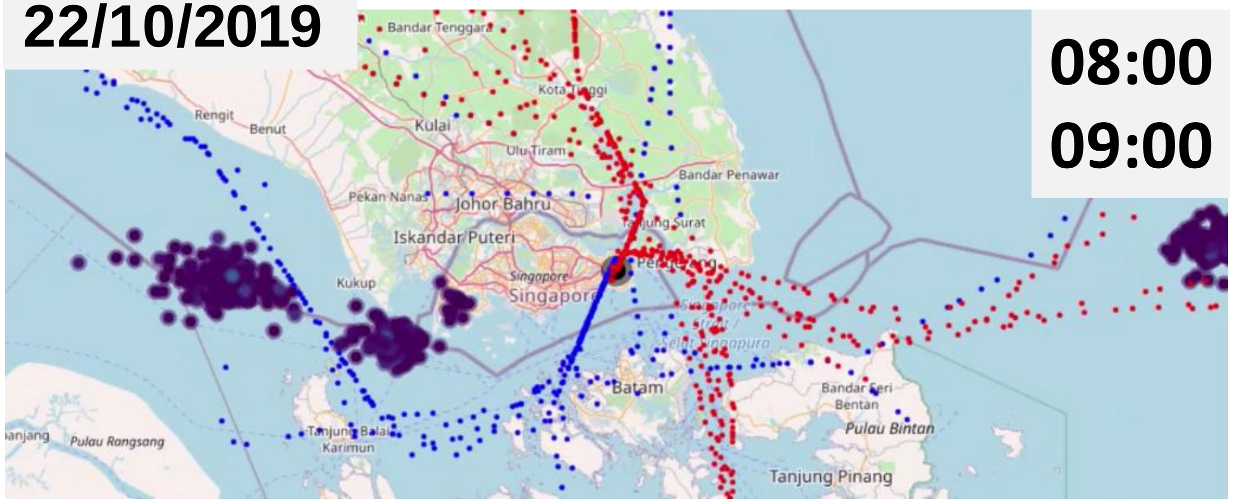
Outline

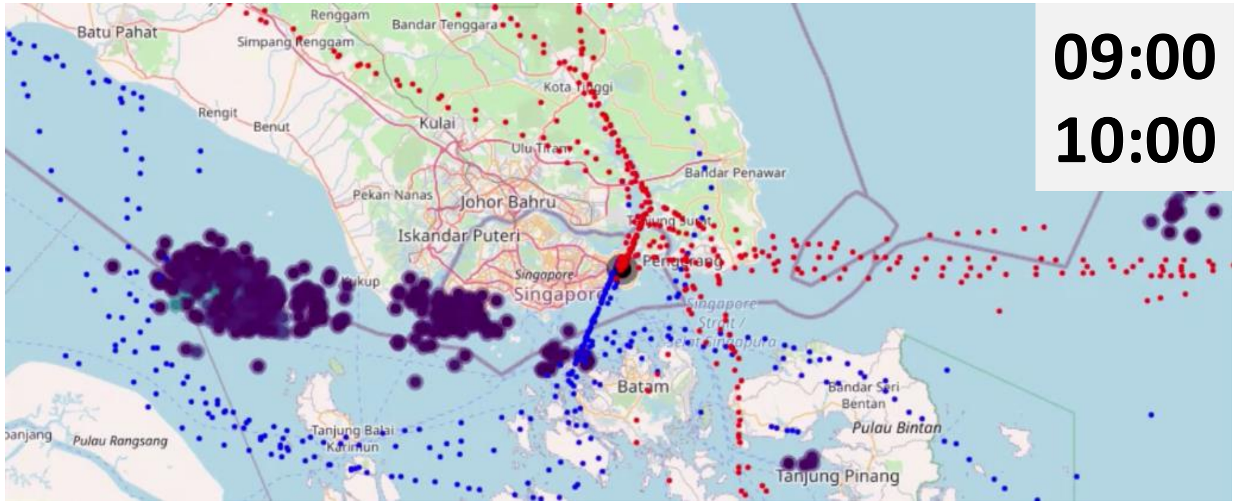
- Predicting Lightning Strikes at Airports
- Impact of Lightning Strikes on Aircraft Routes
- Impact of Lightning Strikes on Airport Delays

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
Aviation Studies Institute

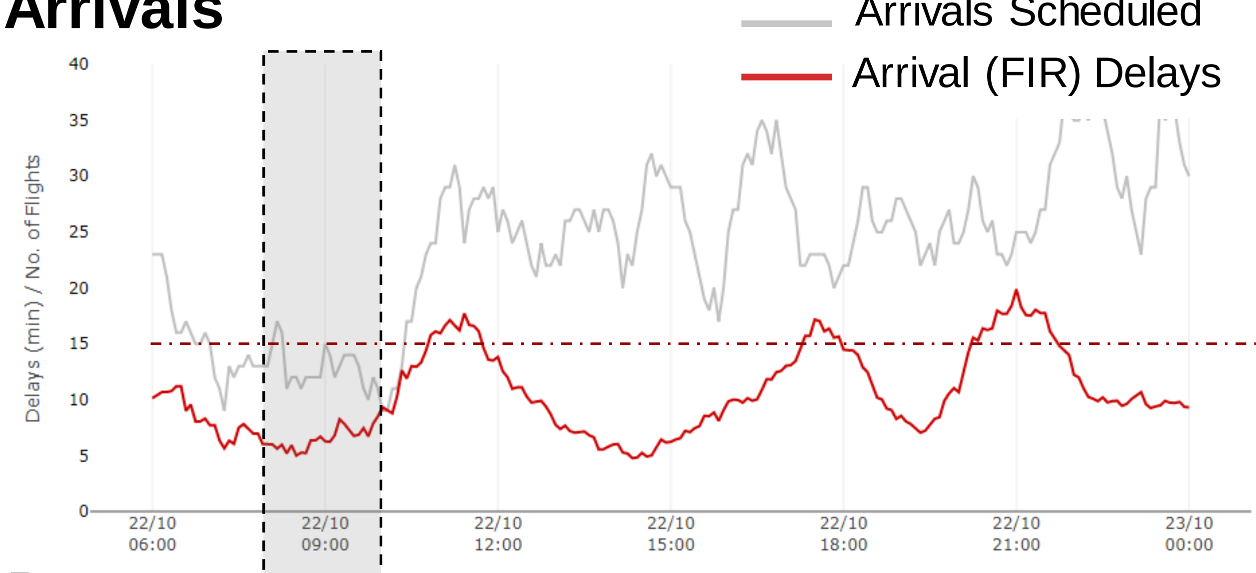
Impact of Lightning Strikes on Airport Delays

22/10/2019

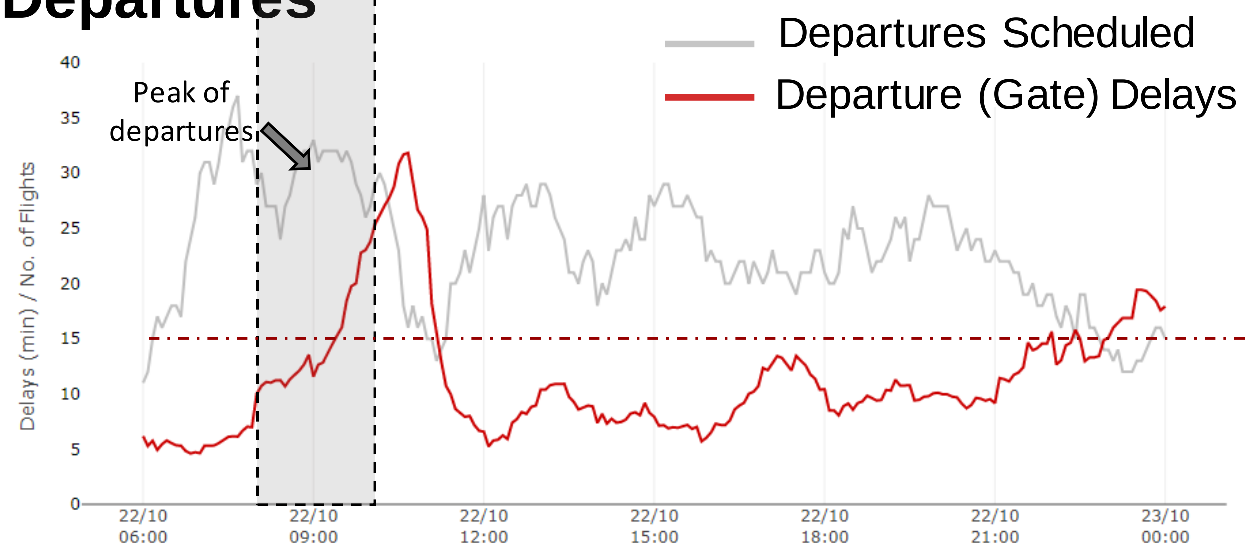




Arrivals



Departures



Impact of Lightning Strikes on Airport Delays

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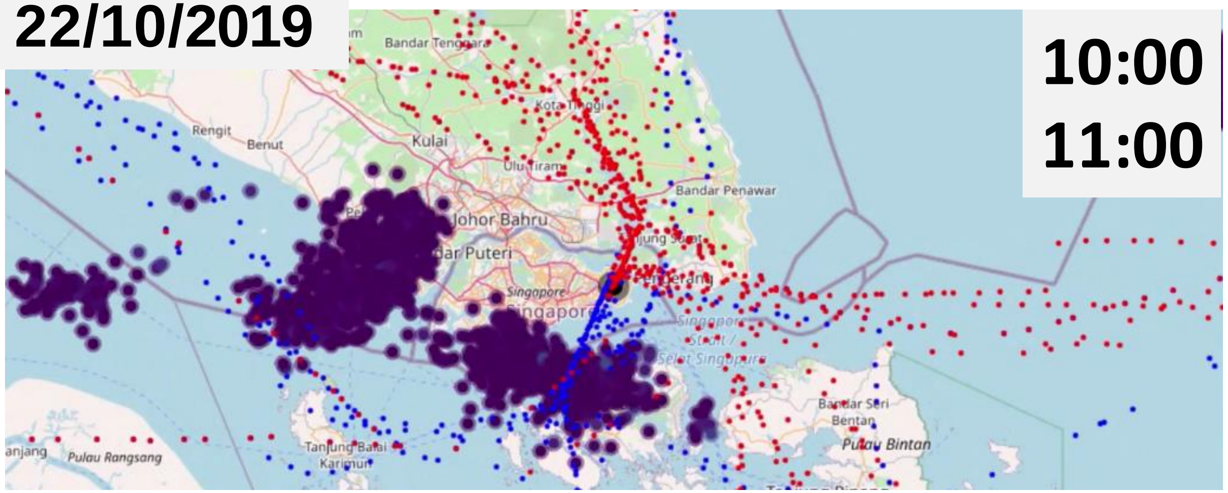
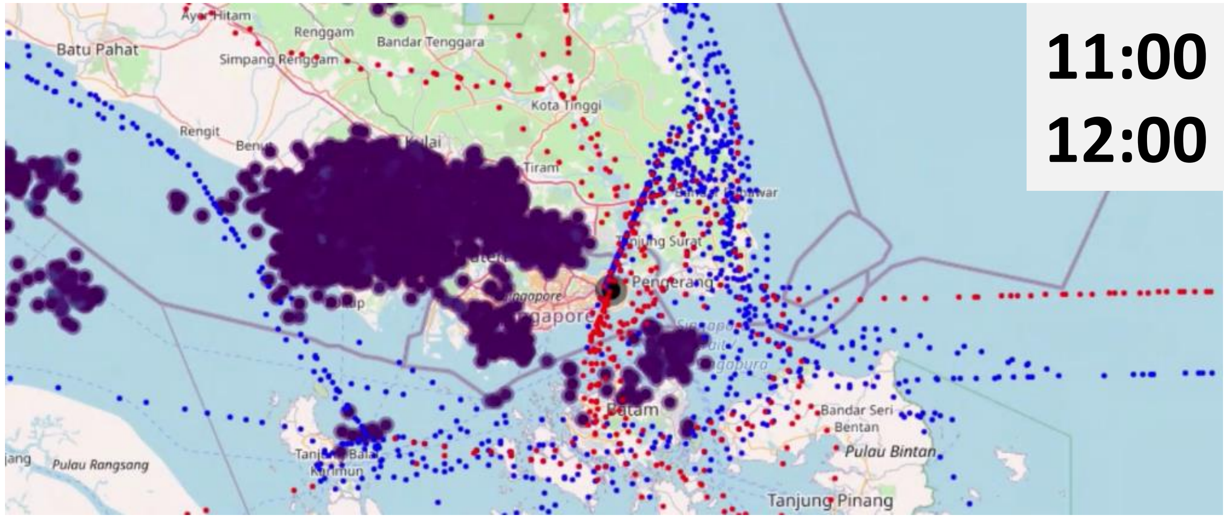
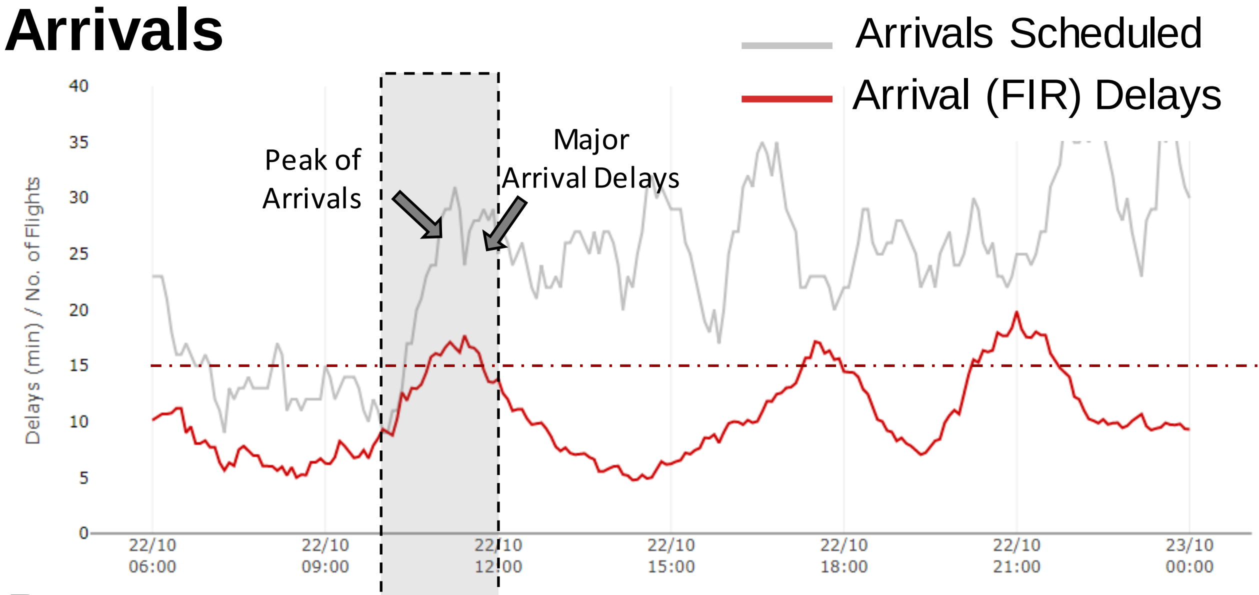
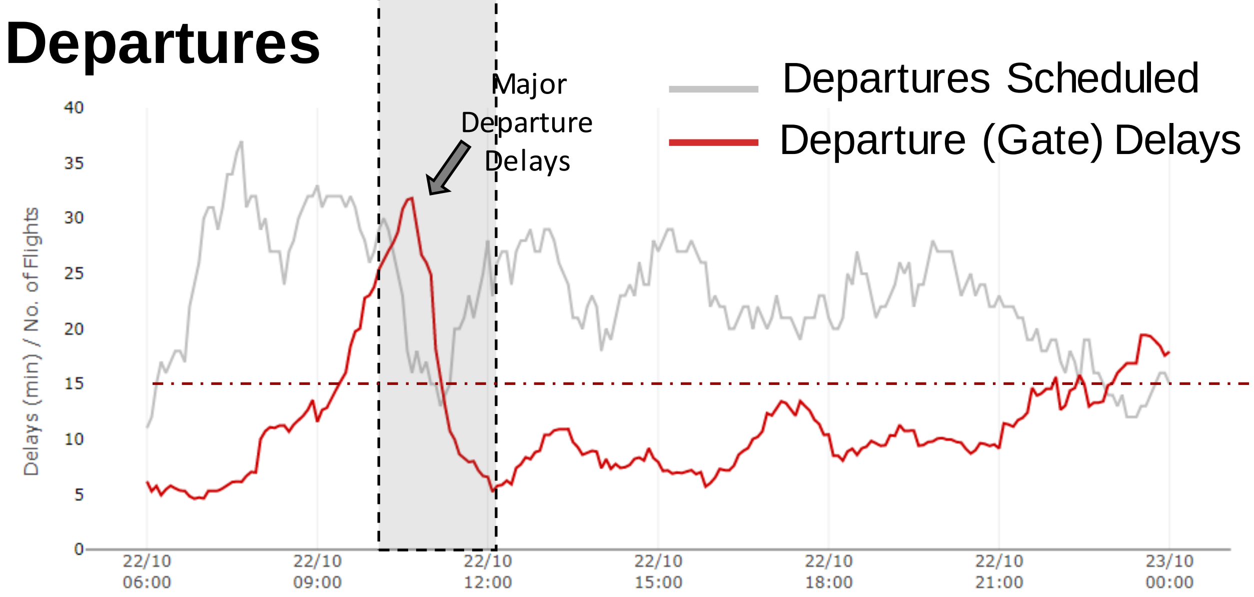




Change of runway operating direction





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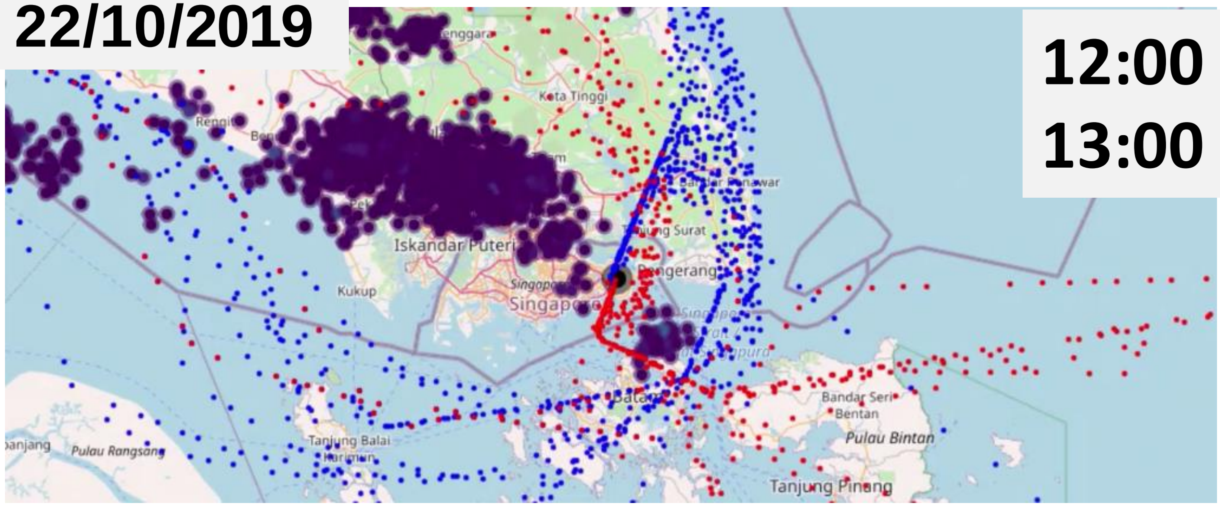
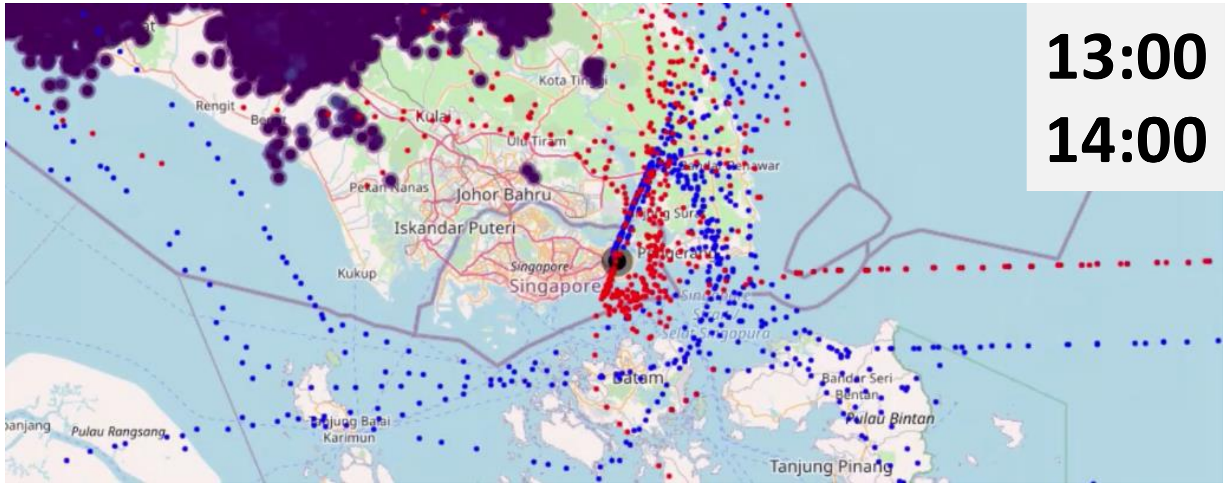
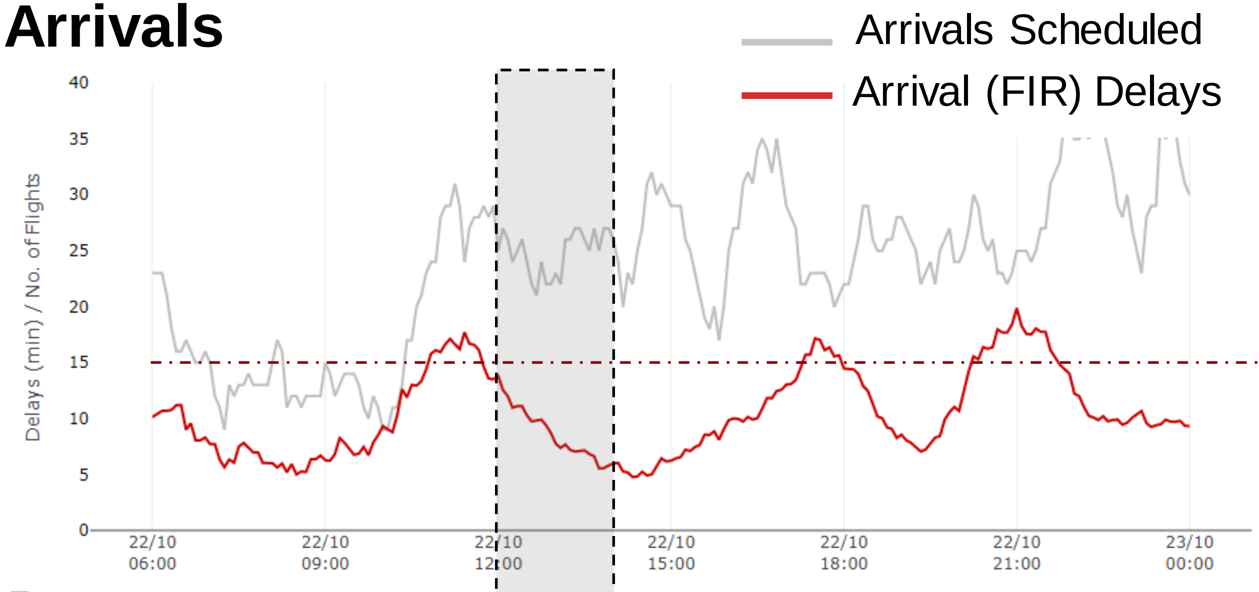
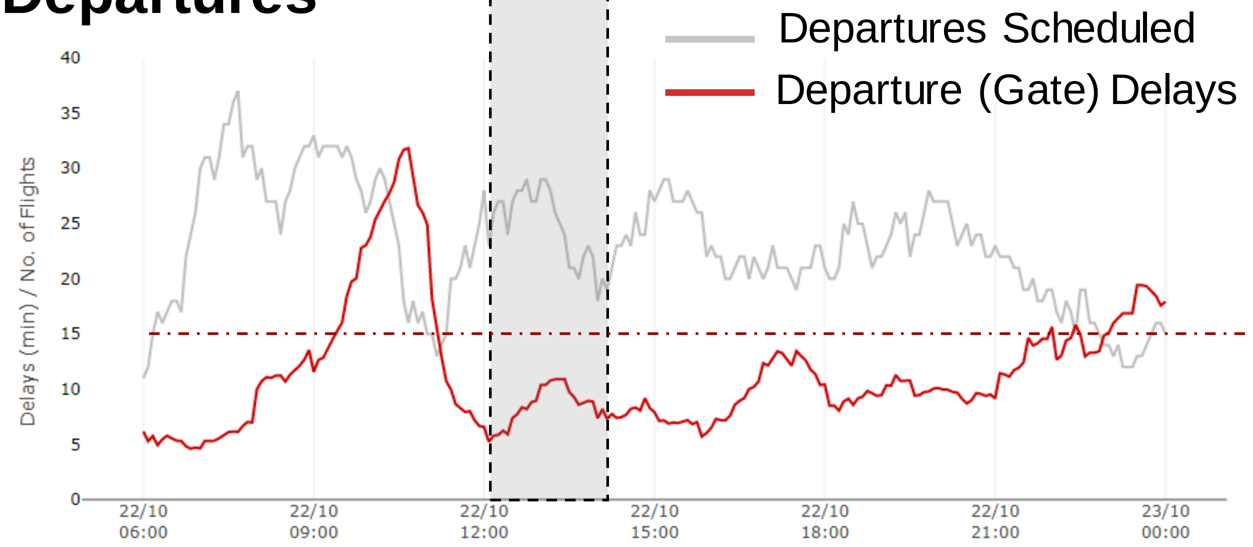




Arrivals



Departures



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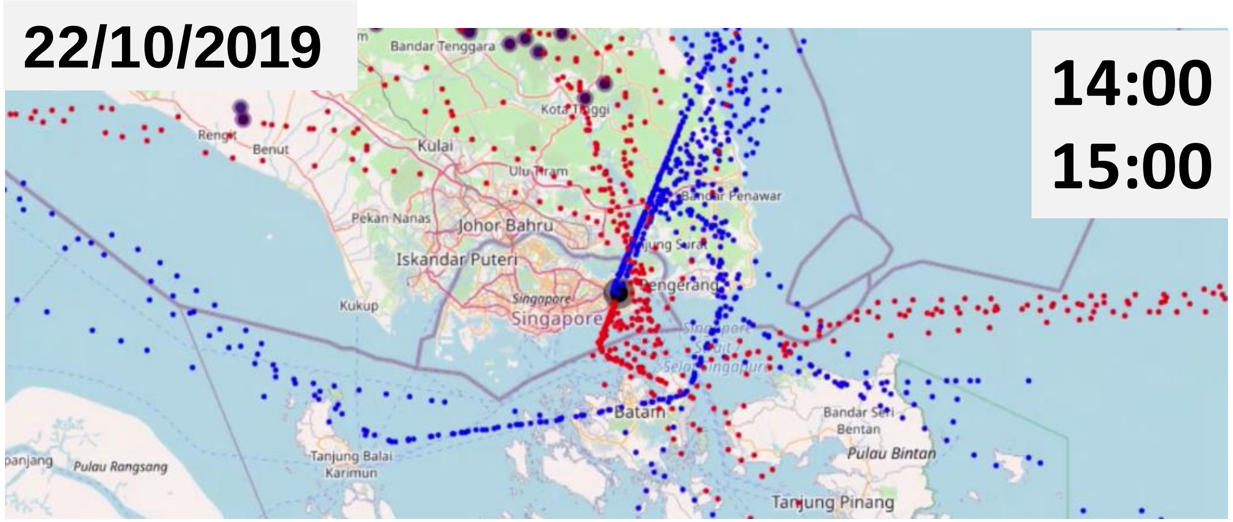

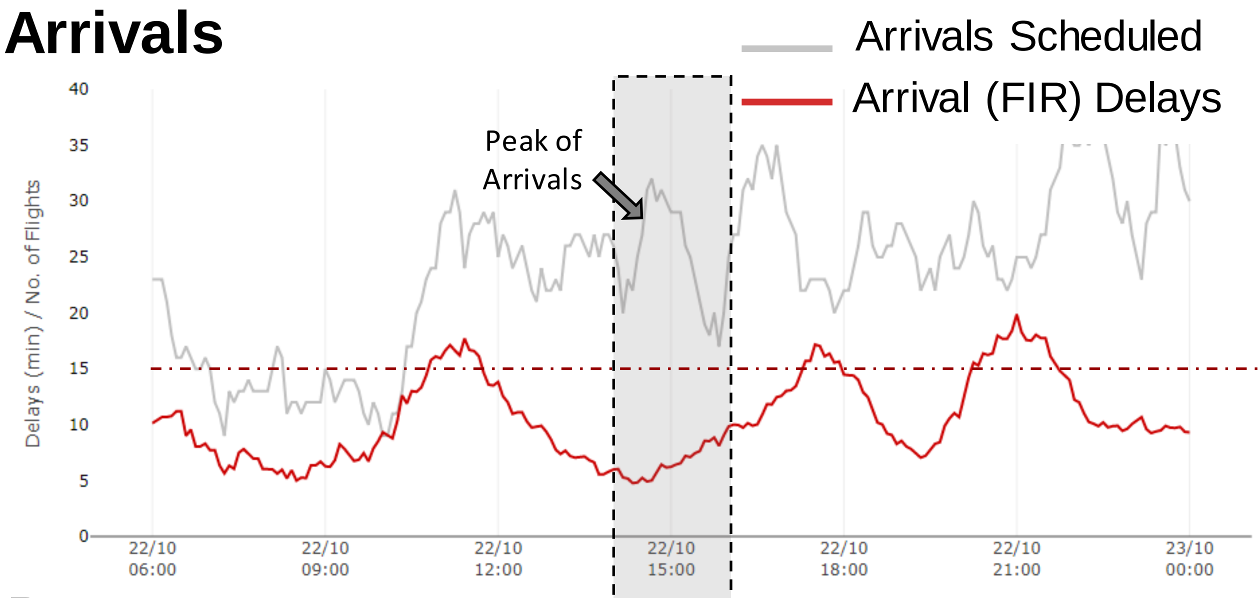

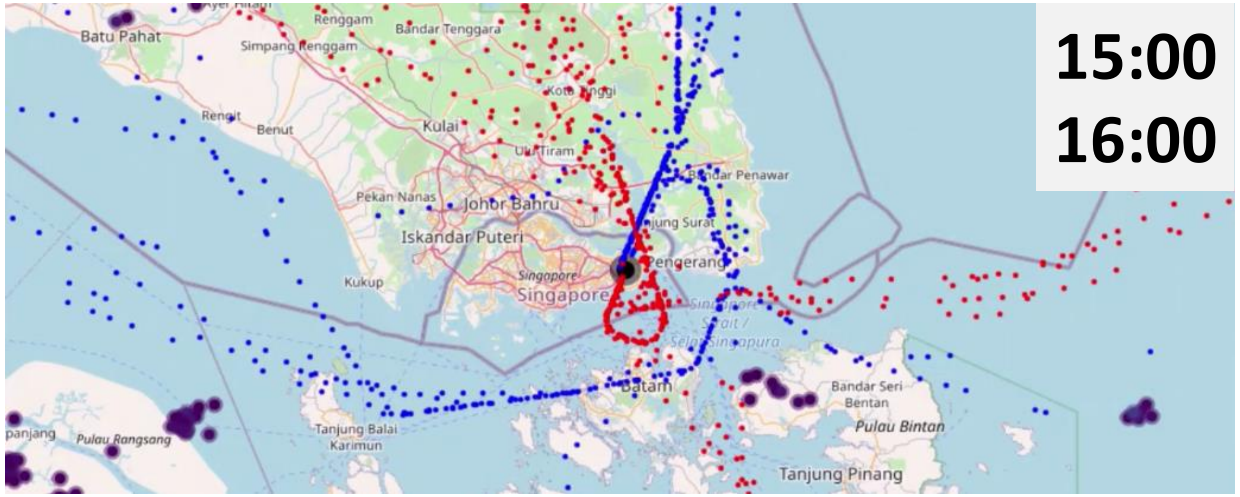

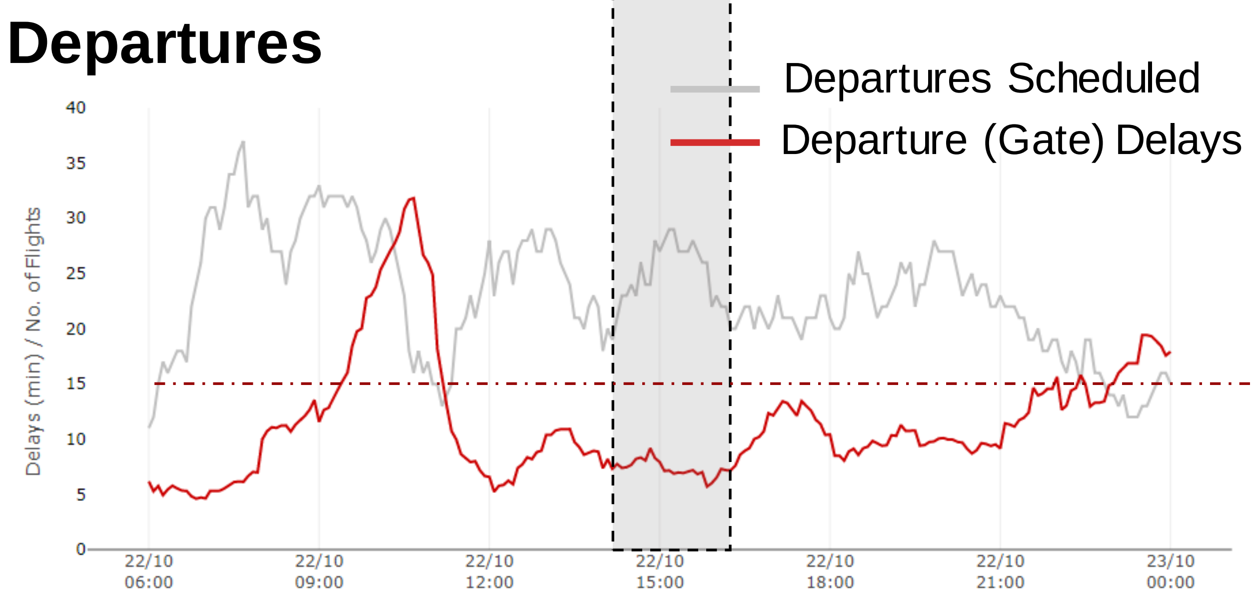

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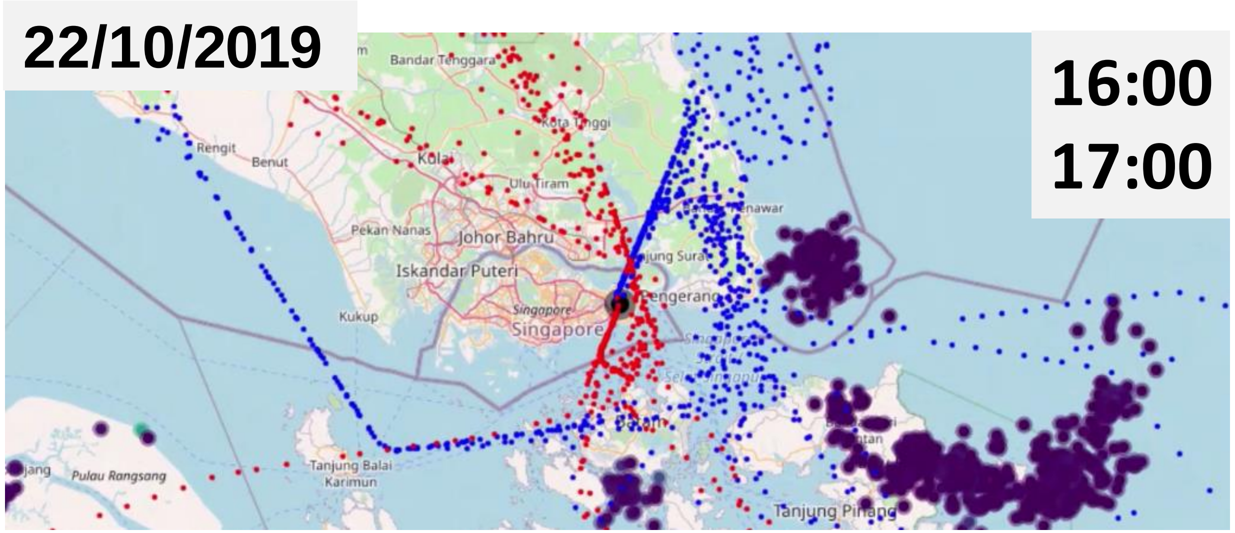

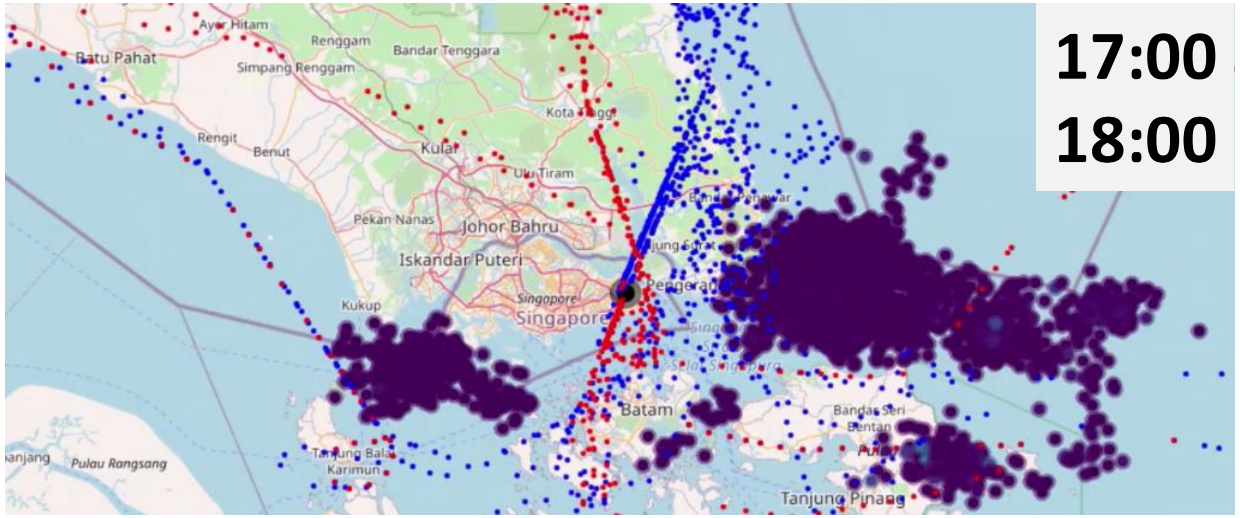

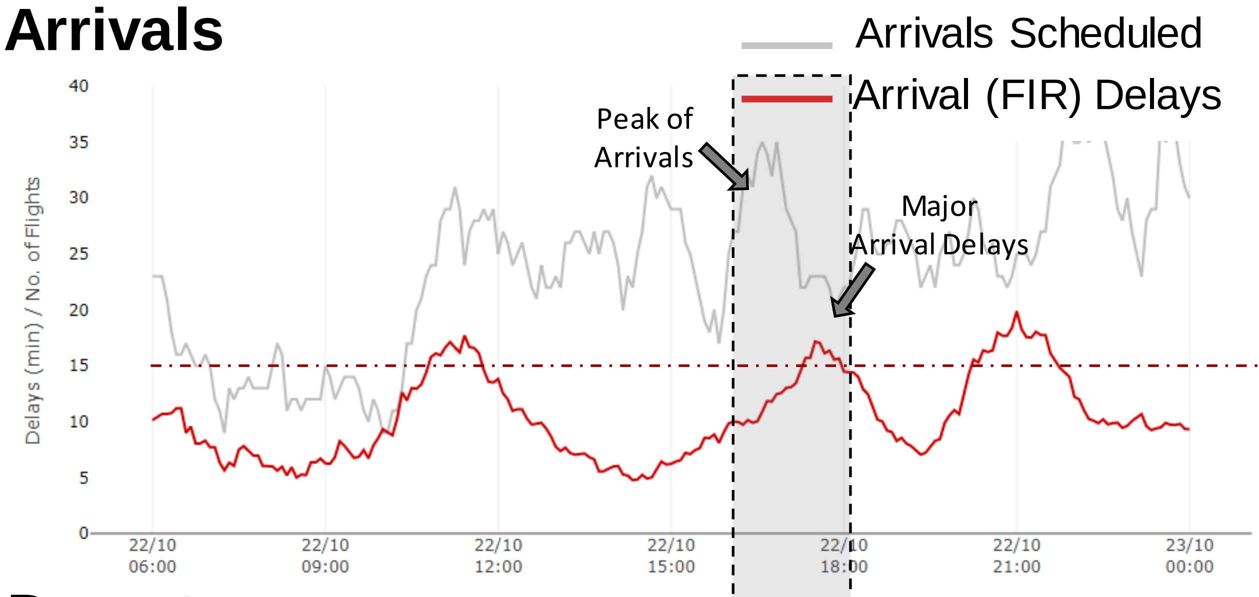

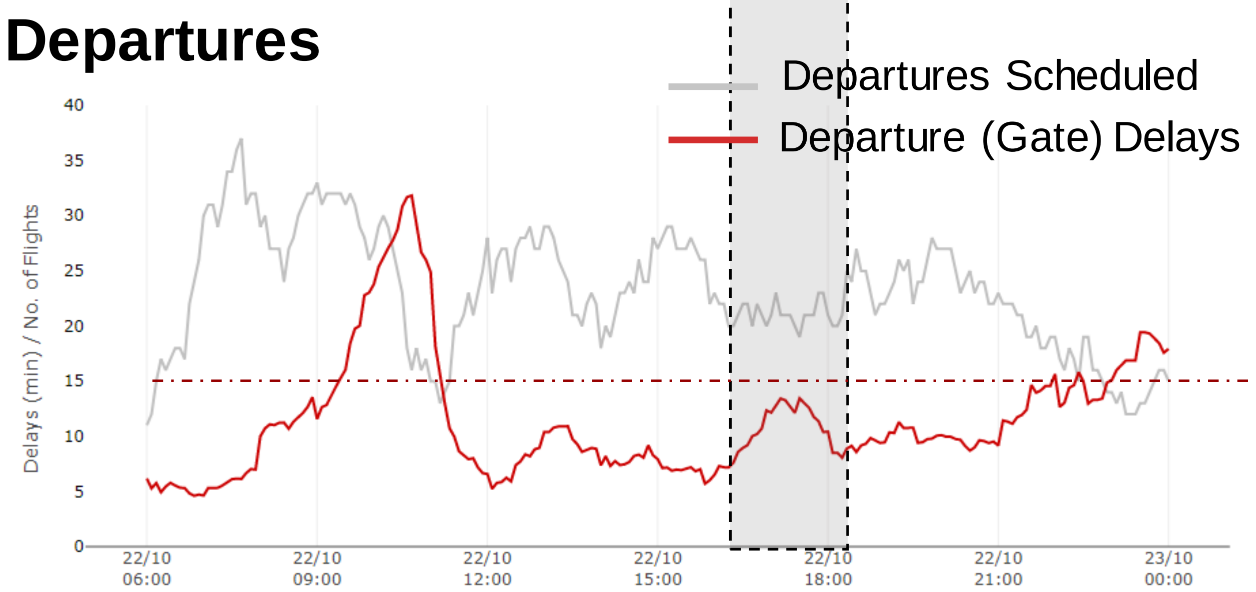

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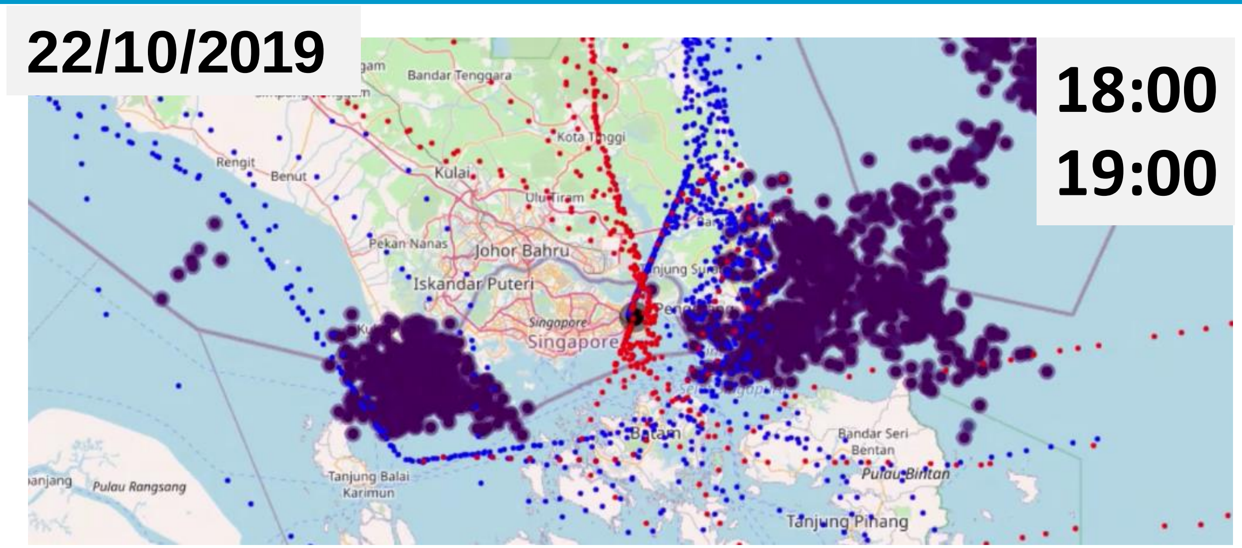
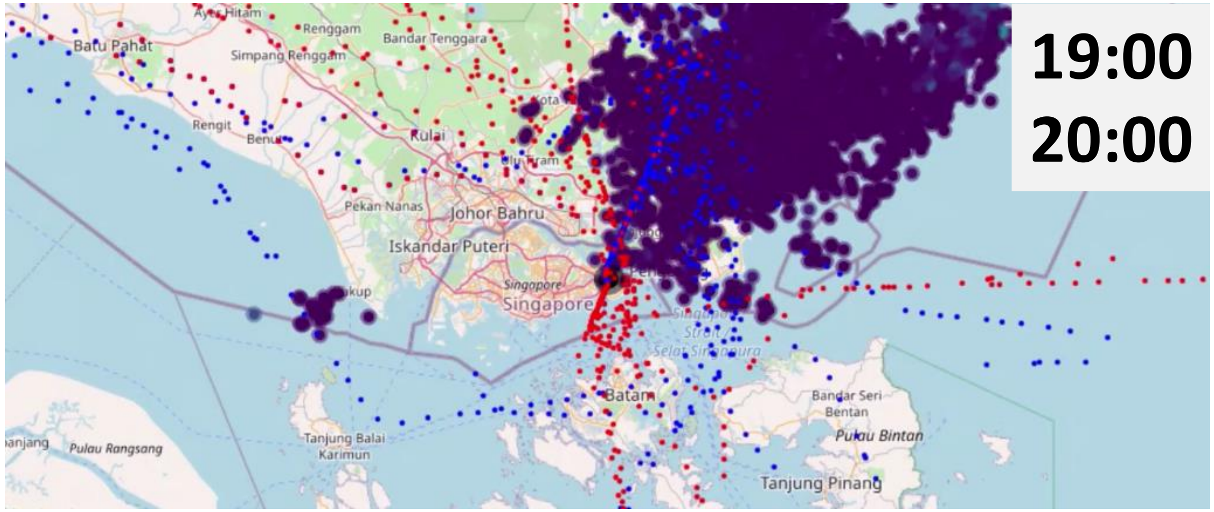
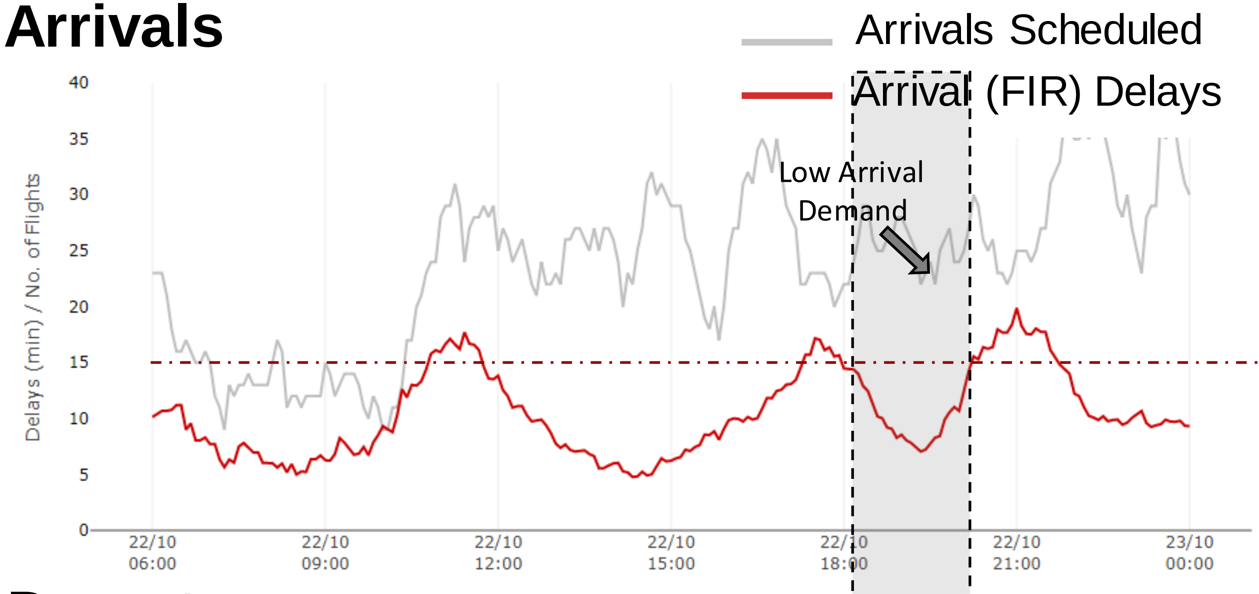
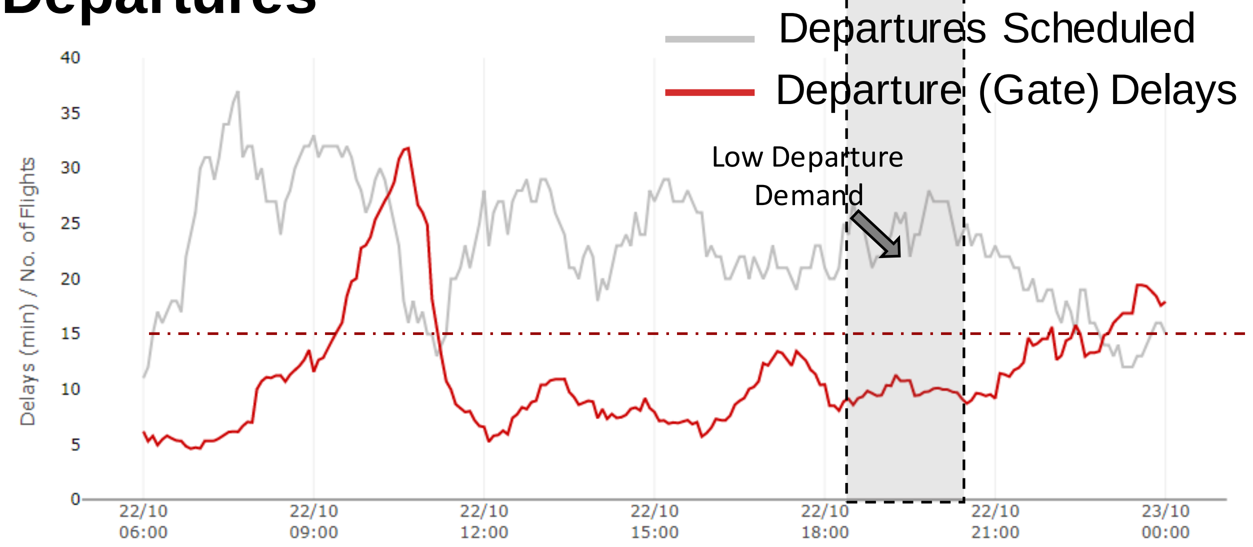




Arrivals



Departures



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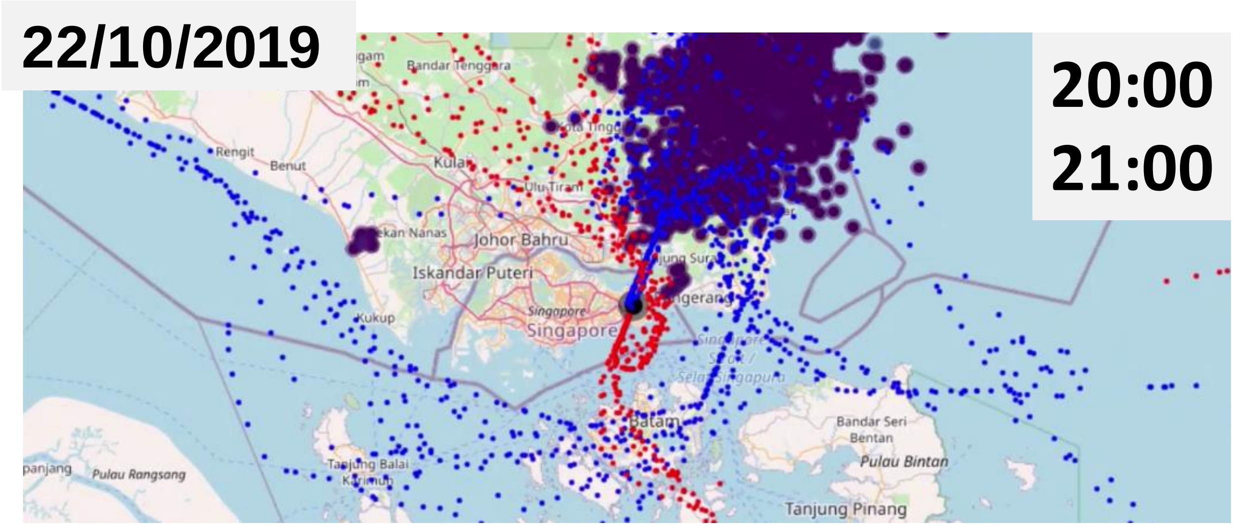

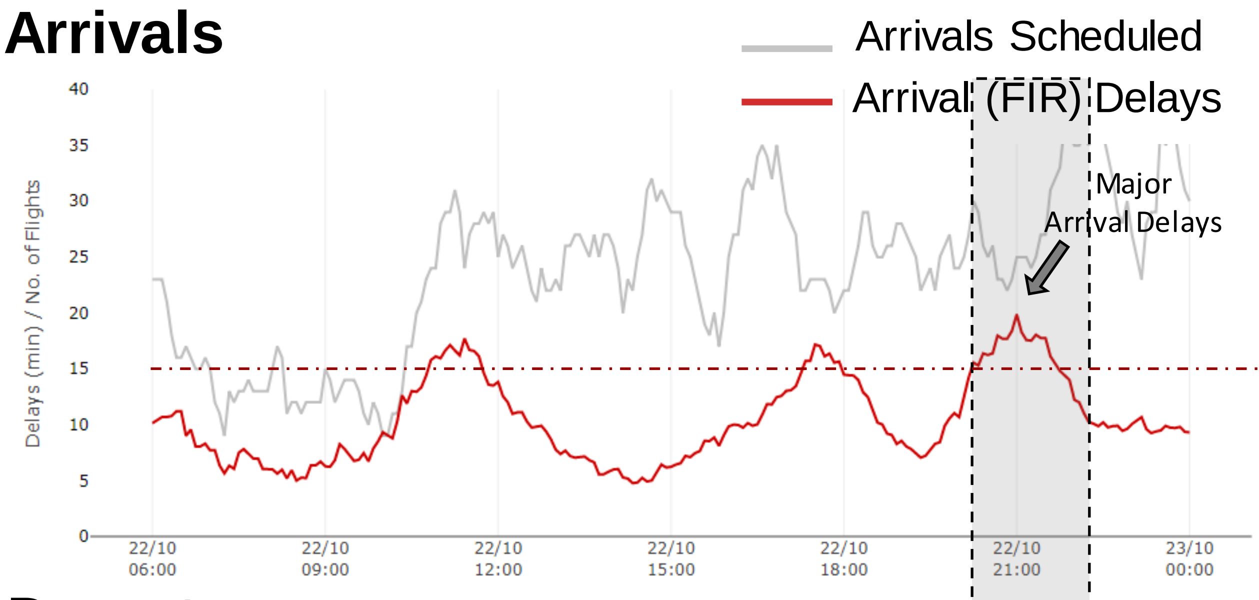

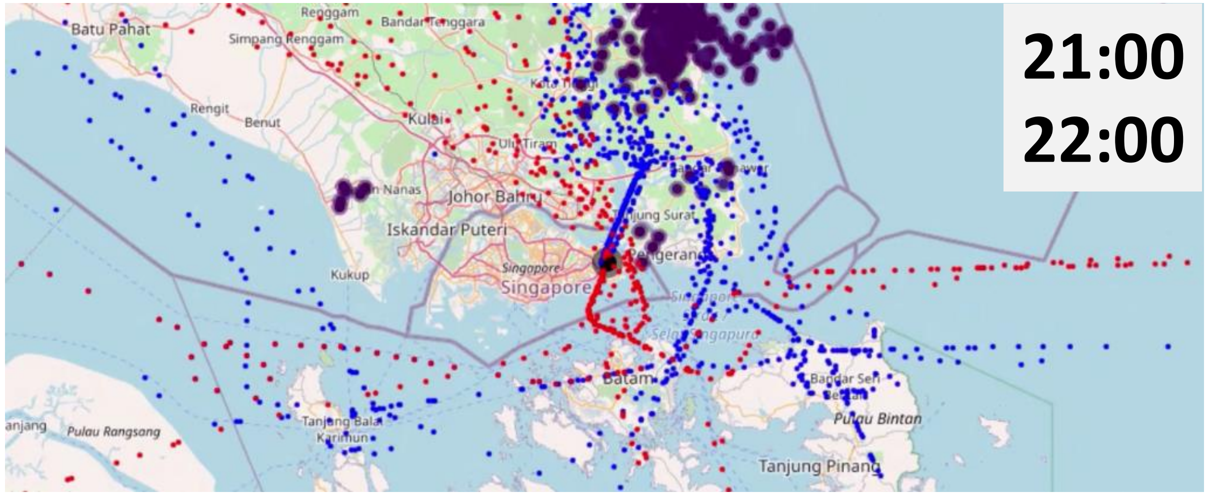

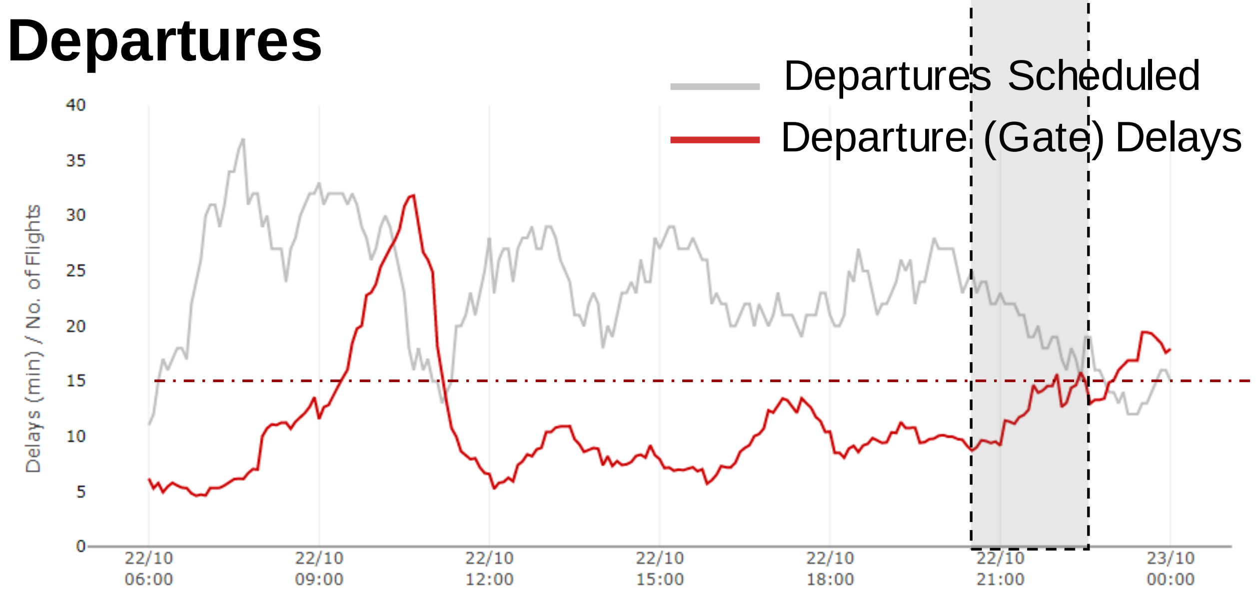

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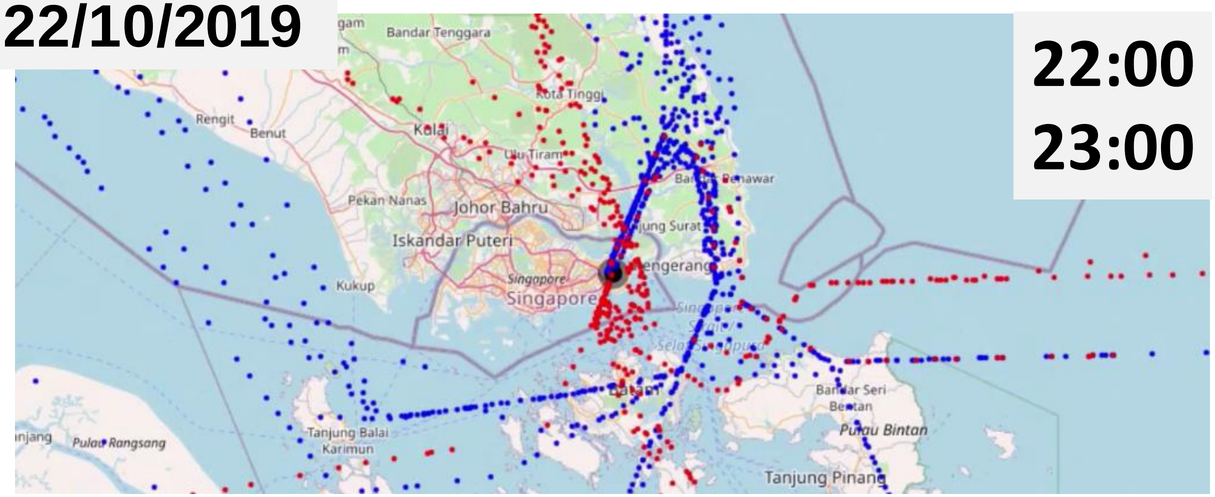

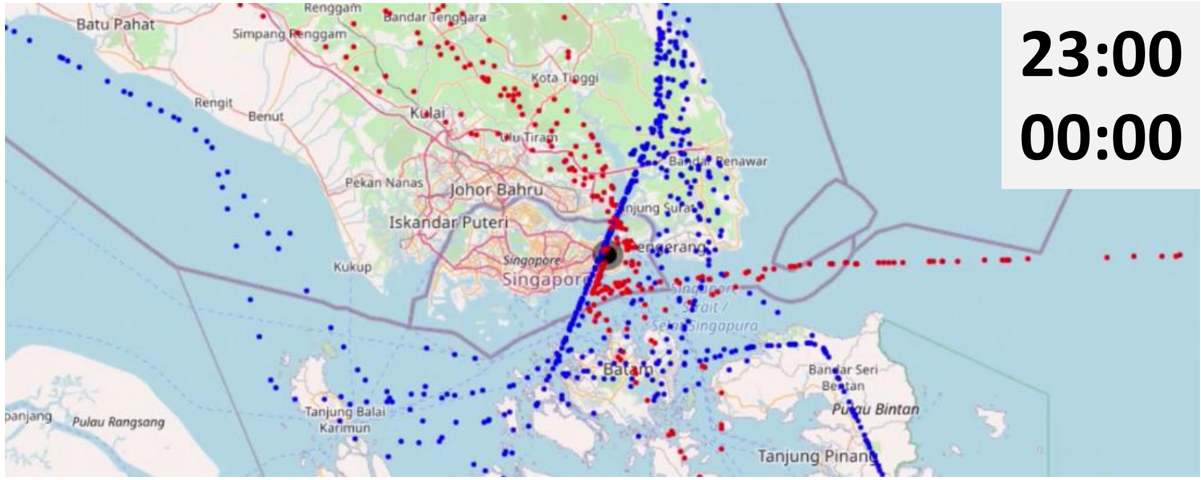

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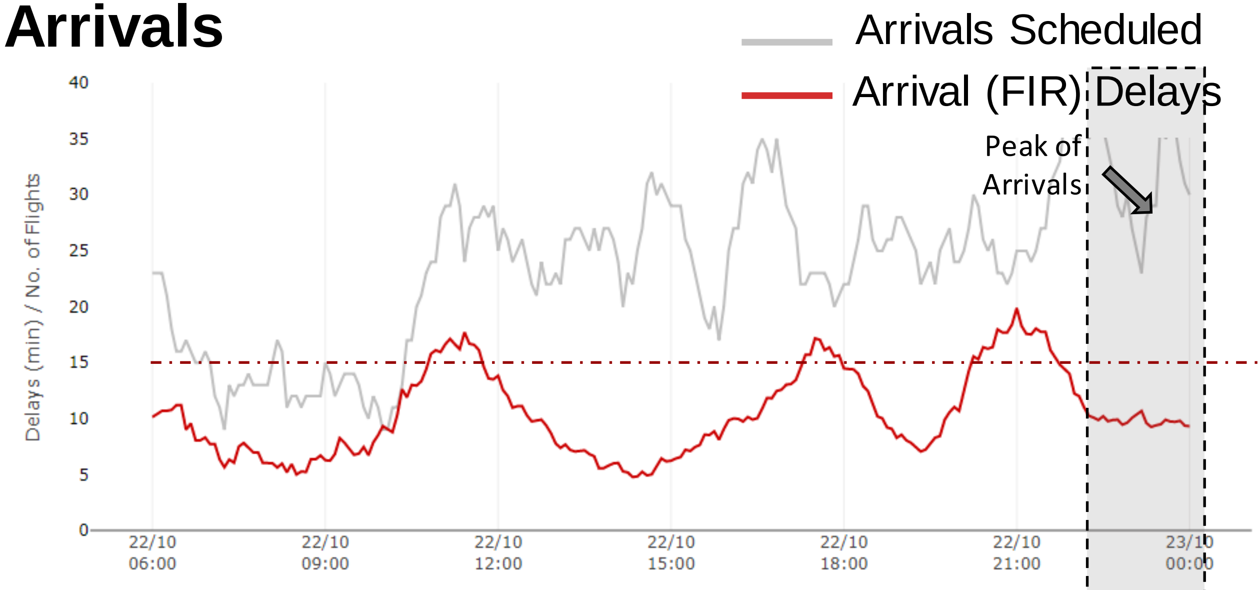

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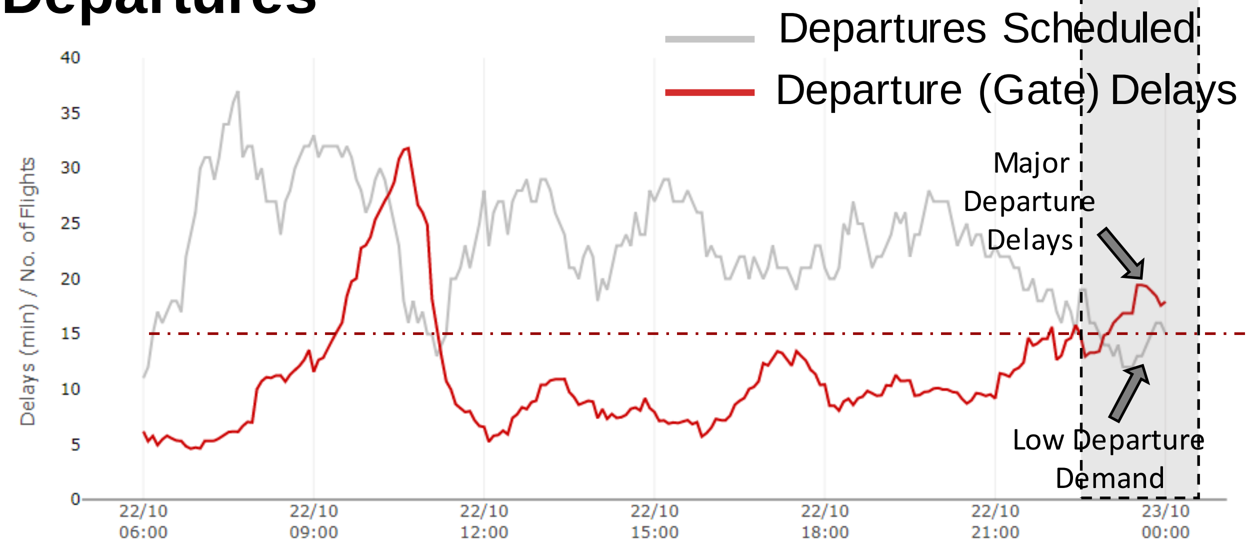

In Summary

- Data fusion: merging meteorological data with ADSB data
- Machine learning and AI: derive insights and develop prediction methods
- Apply to airport operations and air traffic management

Regional Focus

Advancing ATM Research & Development in the Asia Pacific

Spotlight on ASI

Questions

and

Answers

Thank you

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