

Heathrow Airport R3 NW MDL W TAAM Modelling

Modelling Assumptions and Results

Version 2.0

13 June 2014

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Version History:

Version 1.0	Original Document (26 th February 2014)
Version 1.1	Runway exits (slide 14) added, SID separations (slide 17) updated, 570K schedule analysis (slides 28-34) added, 740K schedule results updated (slides 40-57) 570K schedule results added (slides 58 onwards)
Version 1.2	740K schedule results updated (slides 7-8, 37-38, 40-57)
Version 1.3	Slides 12-14, 46, 48, 62 and 64 updated renamed aprons
Version 2.0	All results updated following simulation re-runs with revised apron allocations

Contents

- Executive Summary
- Modelling Configuration
- Results
 - Results – 740K Schedule
 - Results – 570K Schedule

Caveats

- Simulation tools offer a 'first cut' assessment of operational scenarios. Changes to operations must not be implemented without first completing all appropriate actions, which may include further analytical assessment, real-time simulation, operational trials, safety assessment and obtaining regulatory approval
- When interpreting results from simulation models, please note that models generally present an optimistic view of operations because events such as aircraft technical problems, pilot-ATC communication errors, variation in pilot performance, weather and slot compliance are not modelled
- It should be noted that whilst every effort has been made to ensure that the modelled scenarios are as representative of real life as is possible, fast-time computer simulations can never predict future ATM operations with 100% certainty. Any business decisions made based on the outputs of such modelling need to take these uncertainties into account as well as all assumptions made during the modelling process

Executive Summary

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Executive Summary (1)

- > This study was carried out to investigate Heathrow operations with a 3rd runway located to the North-West in Westerly MDL mode
- > Two schedules were modelled (740K movements per year and 570K movements per year)
- > The key preliminary findings of this study are:
- > For the 740K schedule:
 - > Runway throughput rates consistently over 120 movements per hour were achieved, averaging 127 per hour between 07:00 and 21:59
 - > In order to achieve these levels of throughput, runway balancing and demand smoothing measures were applied to the schedule:
 - > Almost all Super and many Heavy departures were moved from 27C to 27R in order to reduce the number of wake turbulence separations applied
 - > In hour smoothing was applied to 27C and 27R departures in order to ensure an even level of demand in each half hour and in each ten minute period
 - > Arrival and departure taxi times varied widely depending on the terminal and runway combination. There may be opportunities to change runway assignments to reduce taxi times
 - > Traffic generally flowed well around the layout, but a number of areas that showed relatively high interaction counts and high delays have been identified
 - > In this configuration (MDL, W) it is important to manage traffic in the 27C Runway Hold Zone (RHZ) in order not to delay other aircraft, particularly arrivals from 27R to T2

Executive Summary (2)

- For the 570K schedule:
 - The runways comfortably met the level of demand and delivered a peak throughput of 108 movements per hour
 - As a result of the lower levels of traffic, delays were substantially lower than for the 740K schedule
 - Taxi times were similar to those for the 740K schedule and varied widely depending on the terminal and runway combination. There may be opportunities to change runway assignments to reduce taxi times
 - Traffic generally flowed well around the layout with the only notable area of concern being the area around the 27C Runway Hold Zone (RHZ)
 - The increase in traffic from 570K to 740K movements caused an increase in delay, most notably to departures

Modelling Configuration

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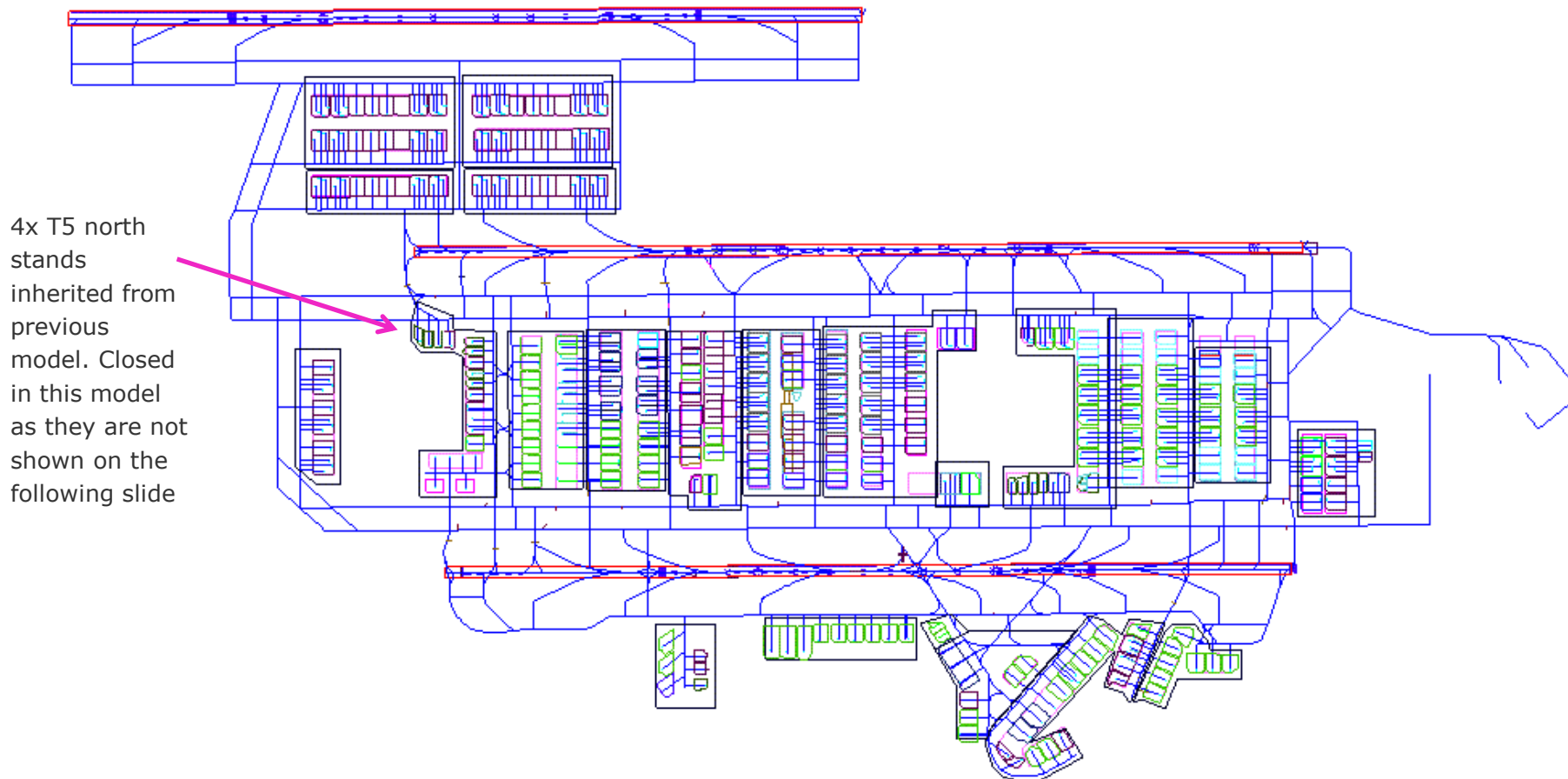
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R3 NW Layout

Taken from "3R Masterplan North West V3.1.dxf"

Stand positions for new stands (T6) are approximate. T6 stands were drawn using information for the number of stands of each size in each apron.



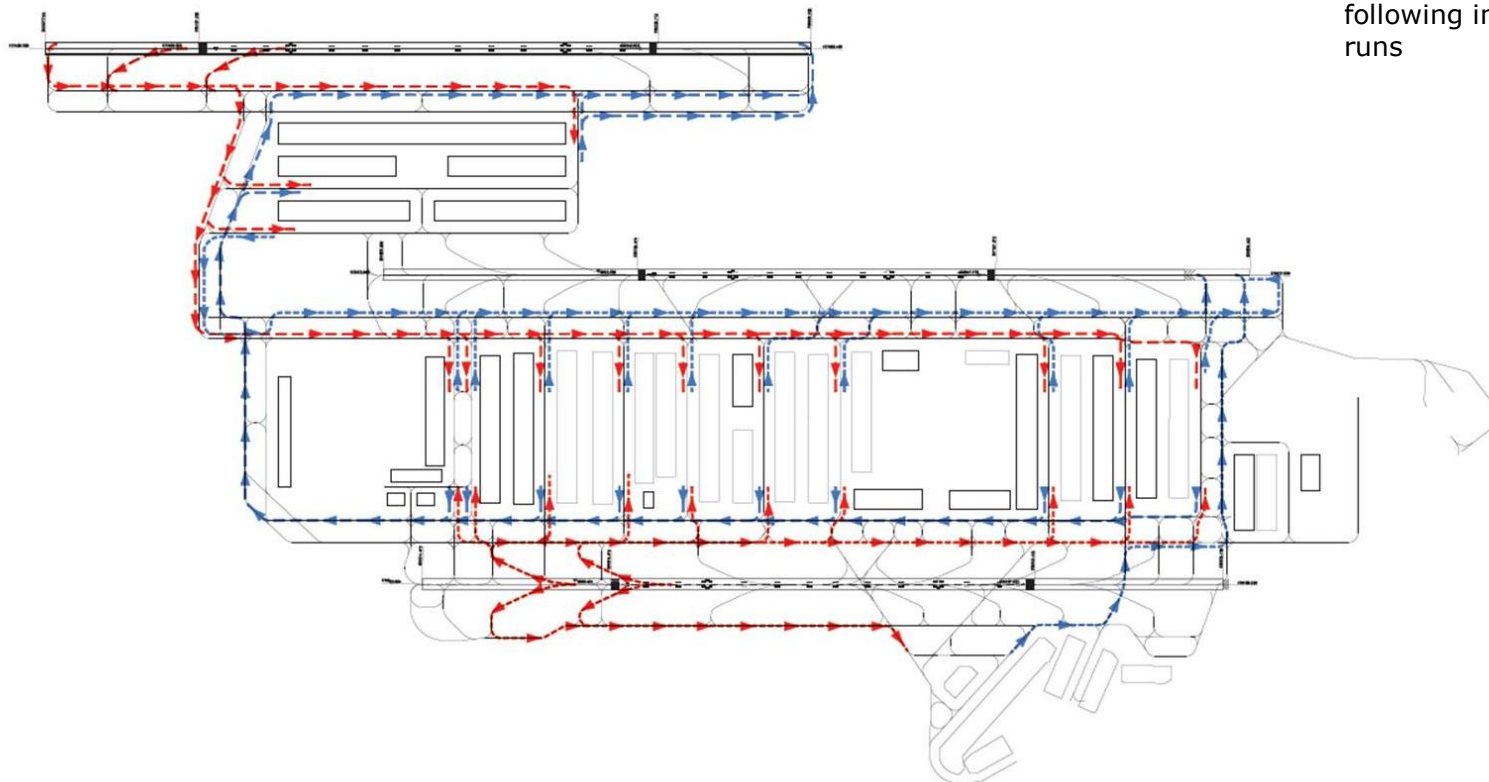
Expected Taxiway Flows

Diagram supplied by Mott MacDonald

Departures (Blue)

Arrivals (Red)

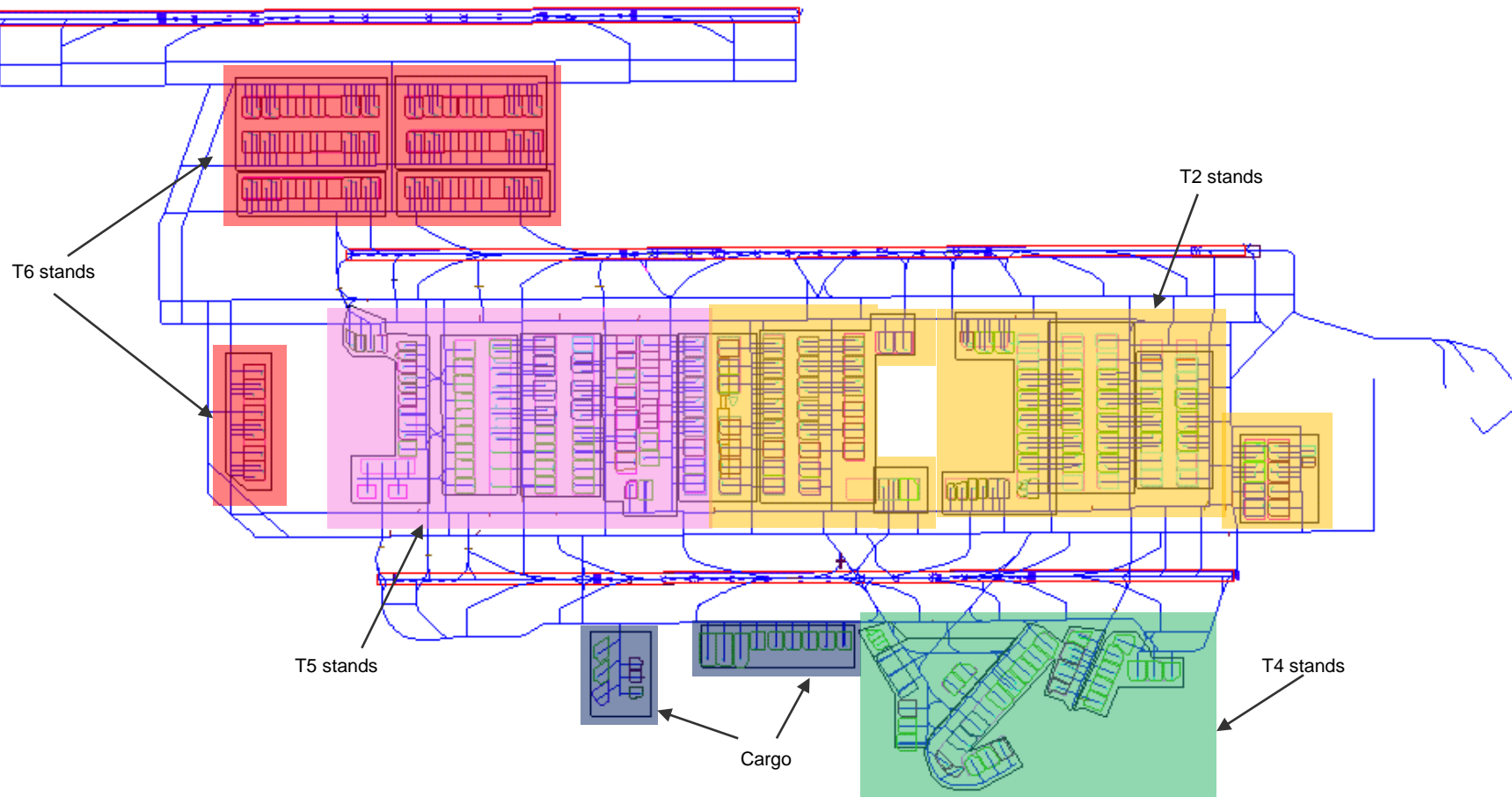
Taxiway flows may be modified if necessary following initial simulation runs



LHR 3R Northwest V3 Taxiway
Flow Diagram - MDL Westerlies

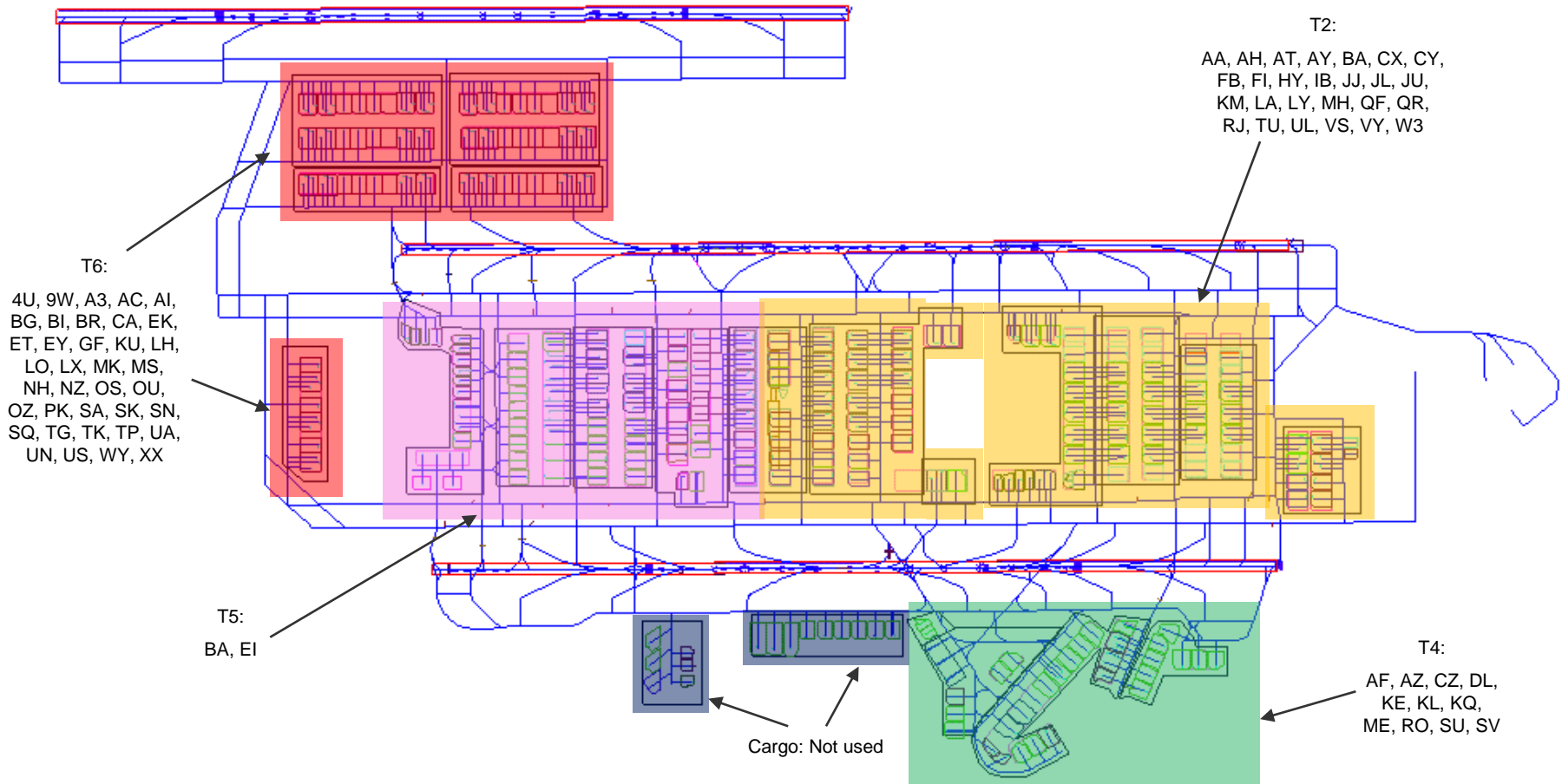
Layout - Terminals

The terminal definitions shown here are used by the model to find an alternative stand if the stand specified in the stand plan is not available. The schedule allocates each flight to a terminal (T2, T4, T5, T6)



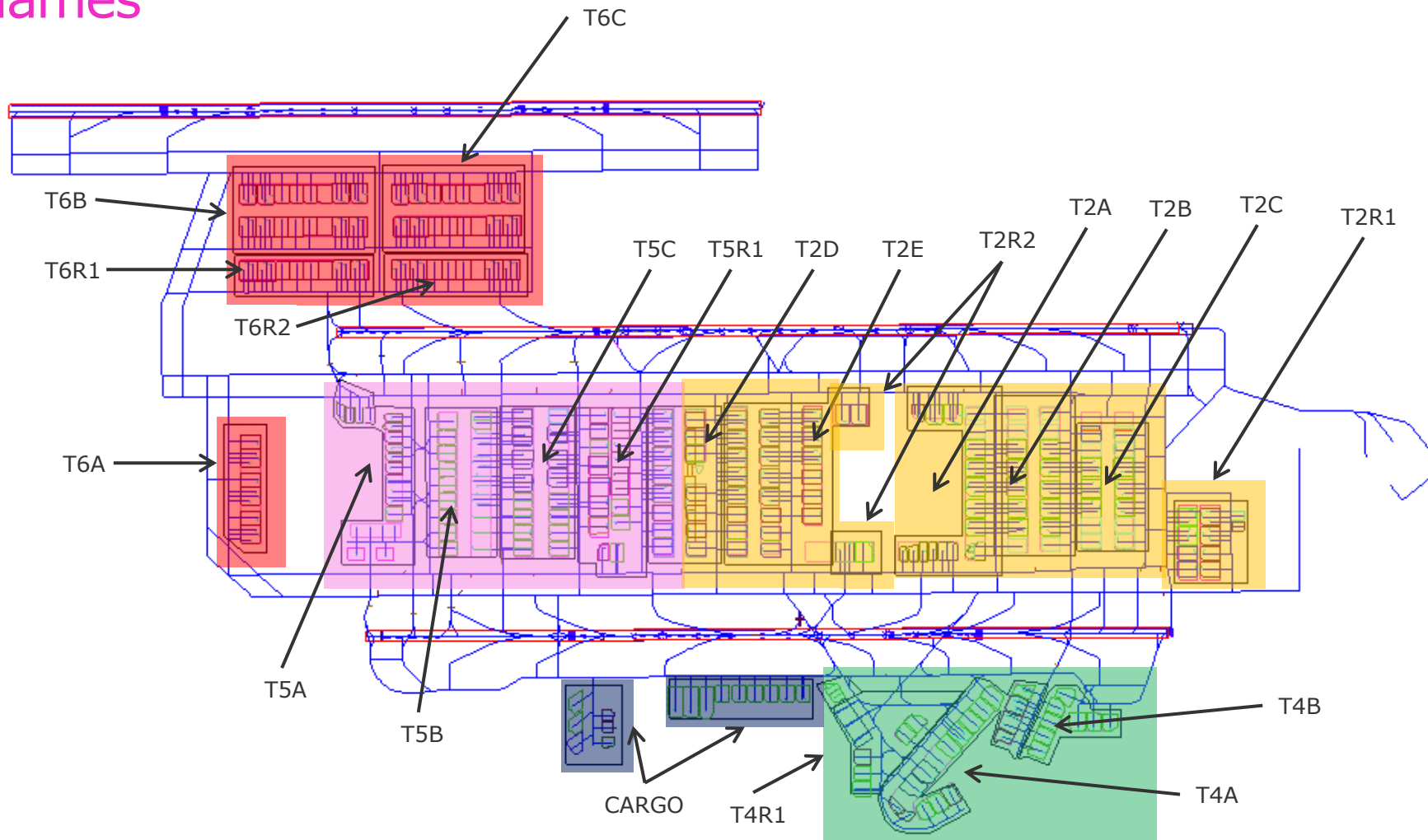
Layout – Carrier occupancy of terminals

Data from extracted from 740k schedule, using terminal definitions from previous slide

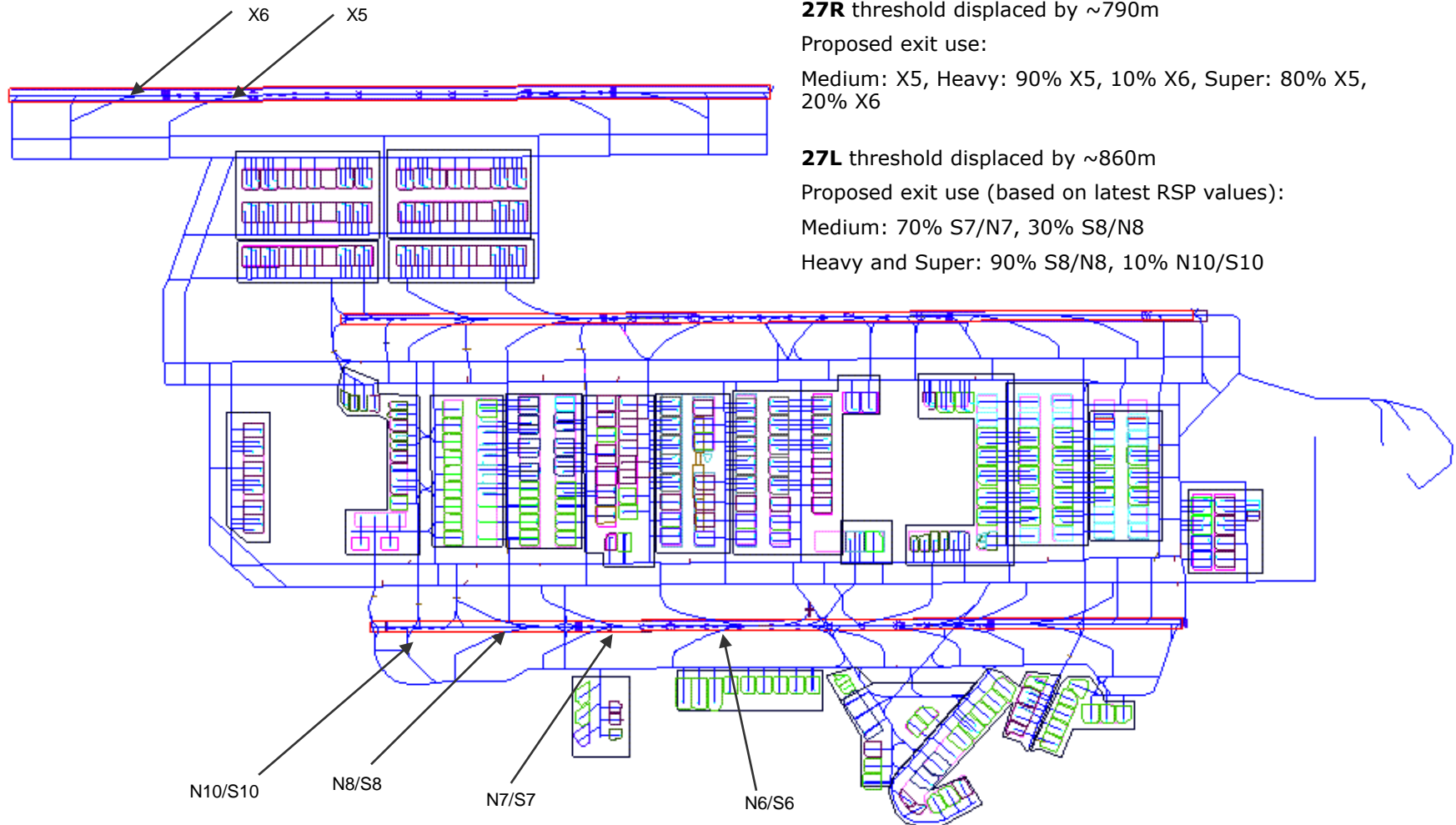


Layout – Apron Names

The apron names below will be used in the analysis when reporting taxi times and delays by apron



Runways: Displaced Thresholds and Exit Use



Configuration

- > The model will be developed from the most recent EGLL R3 model (September 2010: MDL, Westerly, NE runway)
- > The assumptions listed here are consistent with previous R3 modelling:
 - > Maximum number of aircraft taxiing for departure at any one time set to unlimited
 - > Arrival sequence optimisation will be applied to the arrival runway
 - > Stand size rules will be inherited from the most recent R3 model. New rules will be applied for stands that did not previously exist, based on stand size information provided with the layout
 - > Use of the ATET is fully independent of the centre runway
 - > Multiple runs will be carried out for each simulation scenario. Randomisation will be applied to scheduled times (up to + / - 4 mins)

To expedite the completion of the model, the following simplifications will be made (also consistent with previous R3 modelling):

- > Airframe linking between arrivals and departures will not be modelled
- > Towing of aircraft will not be modelled
- > It is assumed that sufficient stands will be available to support the 740k and 570k levels of traffic. Therefore arrival aircraft waiting for stand will not be modelled and aircraft will be removed from the simulation if no stand is available
- > A "stand plan" (a schedule with stands allocated for each flight) will not be modelled. Instead, aircraft will be allocated to stands using apron preferences for each carrier

Configuration

Taxi speeds

- > General = 15 kts
- > In apron = 10 kts
- > Pushback = 3 kts

Airspace

- > Arriving traffic is fed to the ground model from a source 25 NM from the airport
- > Departures are also removed from the model 25 NM from the airport
- > The model assumes that the surrounding airspace is not a constraint upon airport operations. En-route delays and slot delays are not applied to aircraft in the model
- > Airspace considerations (arrival and departure spacing) are modelled to reflect the published spacing standards
- > Departure routes (SIDs) are discussed on the next slide

Slide 17

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Slide 17

Departure Separations

Minimum departure separations

- > SIDs provided by Heathrow Airport (via Anderson Acoustics)
- > The SID and runway allocations provided in the schedule assume that the following combinations will be available:
 - > 27C: BPK-South, CPT, DVR, MID, SAM, WOB-West
 - > 27R: BPK, CPT-North, DVR-North, SAM-North, WOB
 - > No consideration has been given to the airspace structure required to support these routes
 - > Please note that the London Airspace Management Programme (LAMP) assumes no new runway development
 - > Implementation of Departure Enhancement Project (DEP) has not been assumed
- > 27R - 2 mins (or wake turbulence minima if greater)
- > 27C – Matrix of SID separations (separation times in seconds):

27C SID Separation Matrix – provided by NATS ATC

Lead	BPK-S	DVR	MID	SAM	CPT	WOB-W
Follower						
BPK-S	120	120	60	60	60	60
DVR	120	120	60	60	60	60
MID	60	60	120	75	75	75
SAM	60	60	75	120	90	90
CPT	60	60	75	90	120	90
WOB-W	60	60	75	90	90	120

Slide 18

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Slide 18

Arrival Separations Minimum arrival separations

- > 27R – 6NM, but reduce to 3NM when there is no departure queue (pack and gap on mixed mode runway)
- > 27L – 3NM (or wake turbulence minima if greater)
- > Time Based Separation (TBS) has not been assumed

Traffic

740K Schedule

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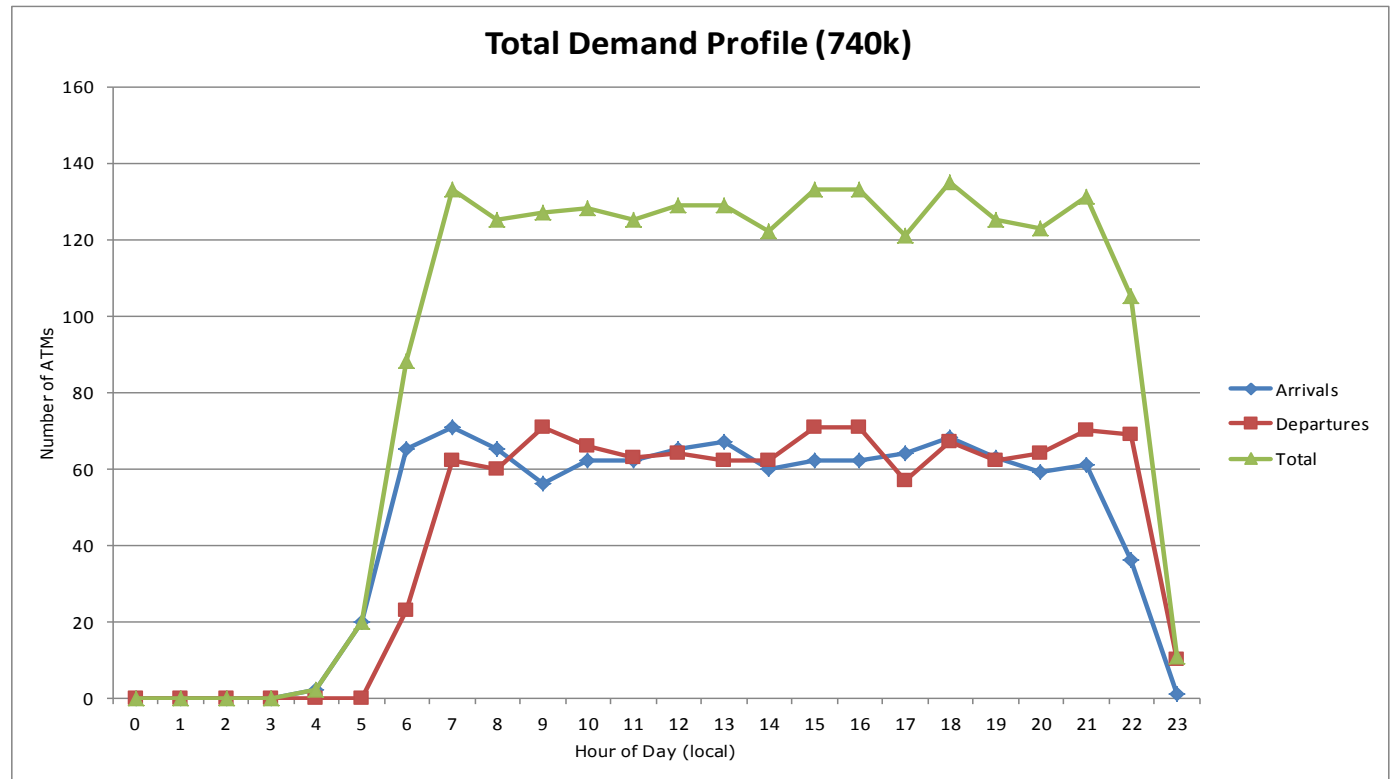
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Traffic – 740k Schedule

- > Source: "Sch_2025_3RLong_Max_740K_AA-v4_forAMECv6.xlsx"
- > Schedule times taken to be on/off stand times
- > The runway to be used is specified in the schedule for each flight
- > Note that no T4 arrivals were allocated to Runway 27R. 21 T4 departures use 27R

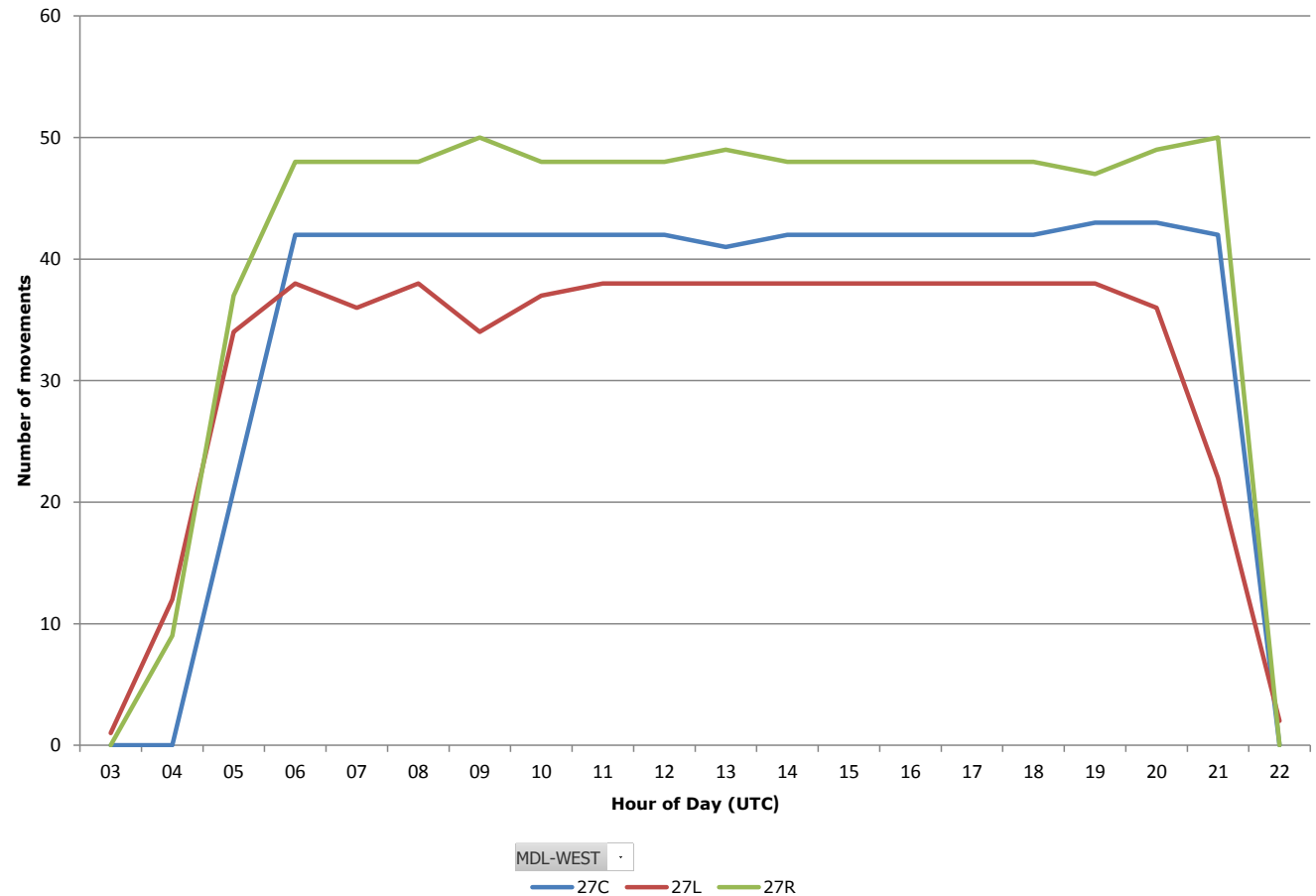
Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Sum
Arrivals	0	0	0	0	2	20	65	71	65	56	62	62	65	67	60	62	62	64	68	63	59	61	36	1	1071
Departures	0	0	0	0	0	0	23	62	60	71	66	63	64	62	62	71	71	57	67	62	64	70	69	10	1074
Total	0	0	0	0	2	20	88	133	125	127	128	125	129	129	122	133	133	121	135	125	123	131	105	11	2145



Traffic – 740k Schedule

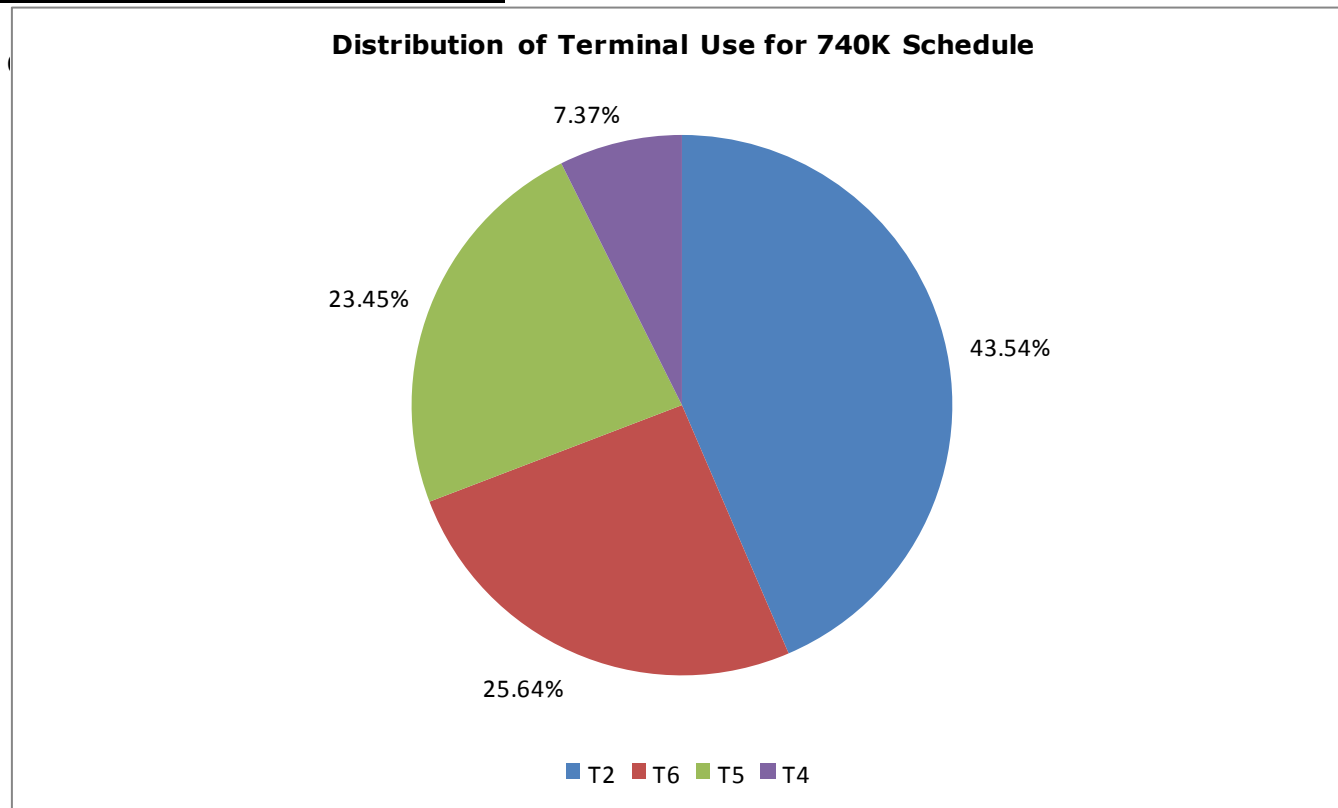
- > Analysis of the schedule shows that movements have been allocated to runways such that hourly demand for 27L does not exceed 38, demand for 27C does not exceed 43 (42 in most hours) and demand for 27R does not exceed 50 (48 in most hours)
- > Note that this profile uses the scheduled on/off stand times and therefore the demand profiles for the runways (i.e. taking into account taxi times) are unlikely to be as smooth. This could cause peaks and troughs in delay

Number of movements allocated to each runway by hour, using scheduled on/off stand times (740k)



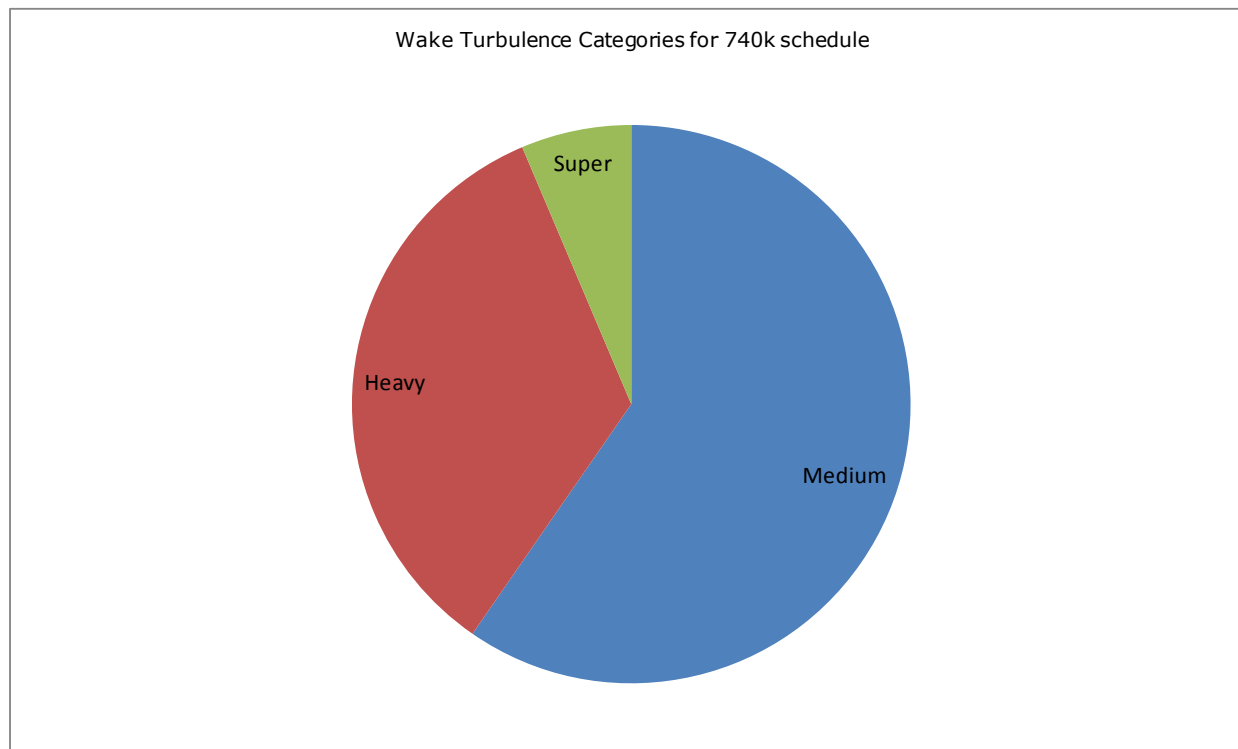
Traffic – 740k Schedule – Terminal Use

Terminal	Count	Percentage
T2	934	43.54%
T6	550	25.64%
T5	503	23.45%
T4	158	7.37%
Total	2145	100.00%



Traffic – 740k Schedule – Wake Turbulence Categories

Wake Turbulence	Count	Percentage
Medium	1279	59.63%
Heavy	729	33.99%
Super	137	6.39%
Total	2145	100.00%

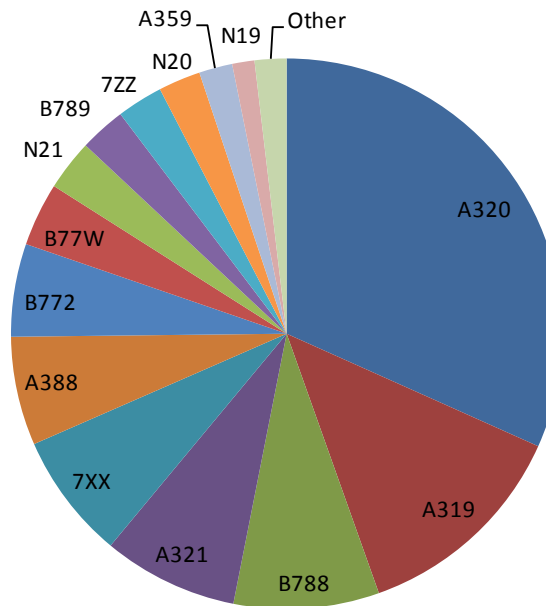


Traffic – 740k Schedule – Aircraft Types

Aircraft Type	Count	Percentage
A320	680	31.70%
A319	276	12.87%
B788	183	8.53%
A321	170	7.93%
7XX	159	7.41%
A388	137	6.39%
B772	117	5.45%
B77W	80	3.73%
N21	64	2.98%
B789	58	2.70%
7ZZ	58	2.70%
N20	53	2.47%
A359	42	1.96%
N19	28	1.31%
Other	40	1.86%
Total	2145	100.00%

Other = categories that contributed < 1% each

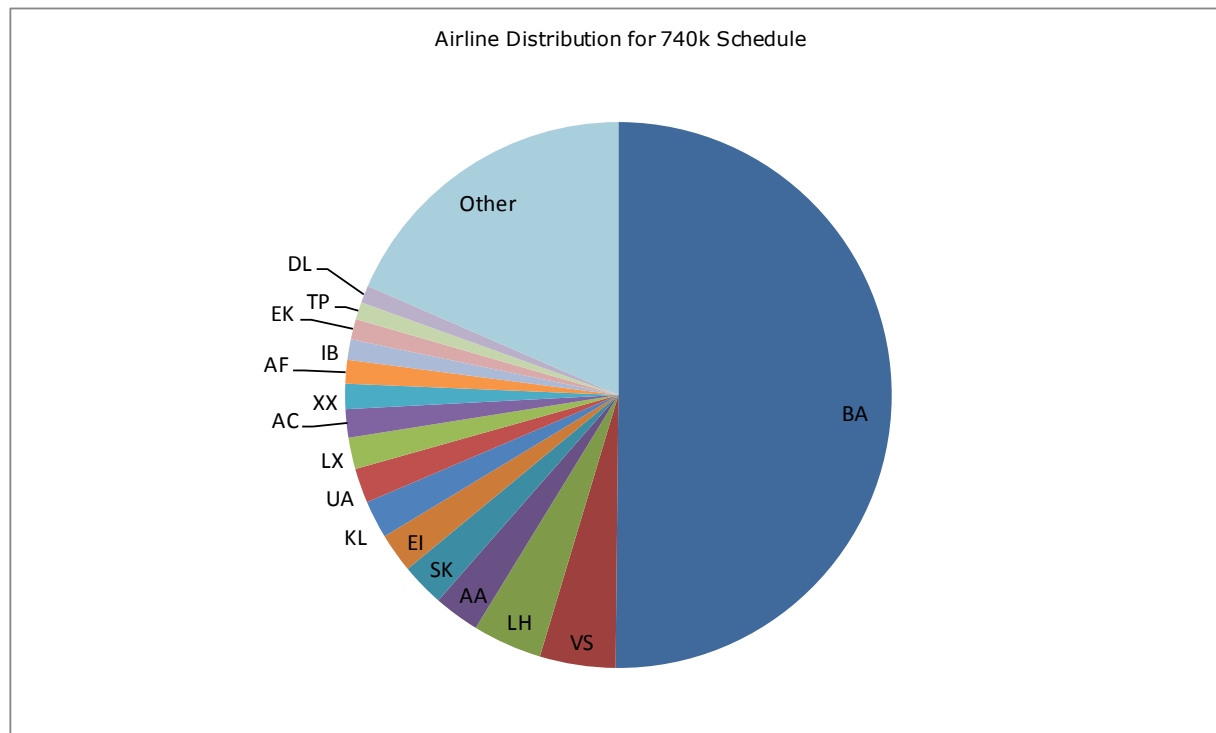
Aircraft Type Distribution for 740k Schedule



Traffic – 740k Schedule – Airlines

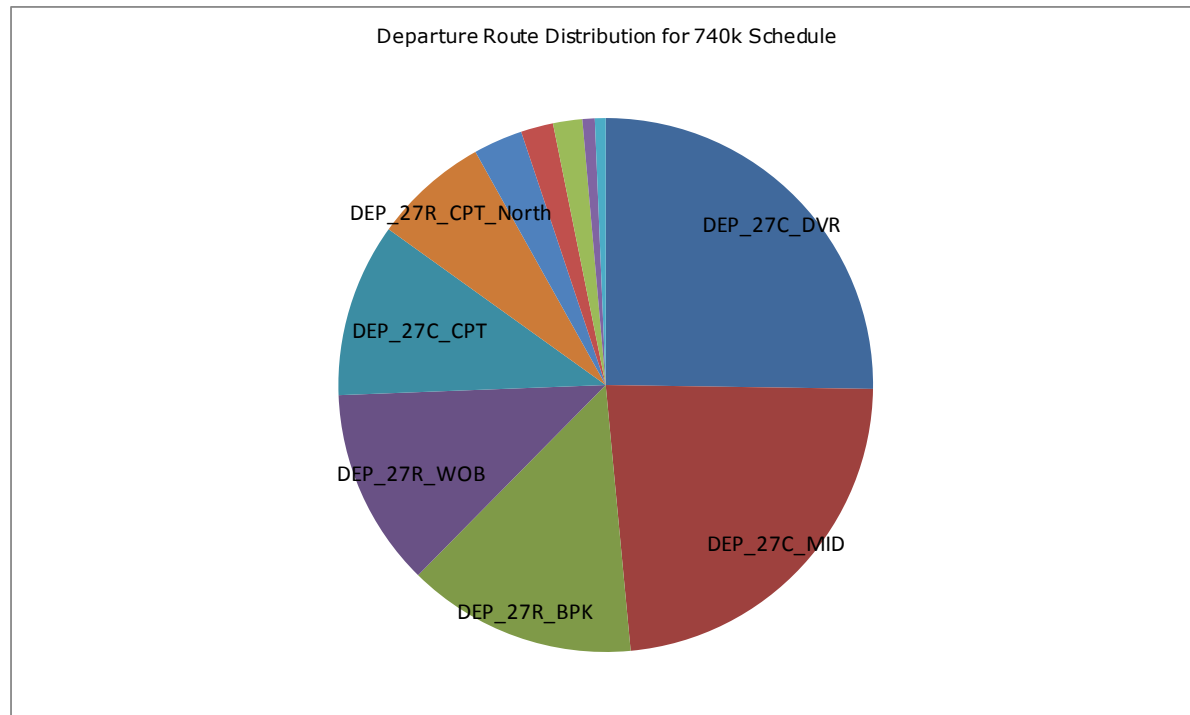
Airline	Count	Percentage
BA	1076	50.16%
VS	96	4.48%
LH	88	4.10%
AA	58	2.70%
SK	55	2.56%
EI	50	2.33%
KL	48	2.24%
UA	44	2.05%
LX	40	1.86%
AC	36	1.68%
XX	32	1.49%
AF	30	1.40%
IB	26	1.21%
EK	26	1.21%
TP	22	1.03%
DL	22	1.03%
Other	396	18.46%
Total	2145	100.00%

Other = categories that contributed < 1% each



Traffic – 740k Schedule – Departure Routes

Route	Count	Percentage
DEP_27C_DVR	271	25.23%
DEP_27C_MID	250	23.28%
DEP_27R_BPK	149	13.87%
DEP_27R_WOB	129	12.01%
DEP_27C_CPT	113	10.52%
DEP_27R_CPT_North	75	6.98%
DEP_27C_BPK-S	32	2.98%
DEP_27C_SAM	21	1.96%
DEP_27R_SAM_North	19	1.77%
DEP_27R_DVR-N	8	0.74%
DEP_27C_WOB-W	7	0.65%
Total	1074	100.00%



Traffic

570K Schedule

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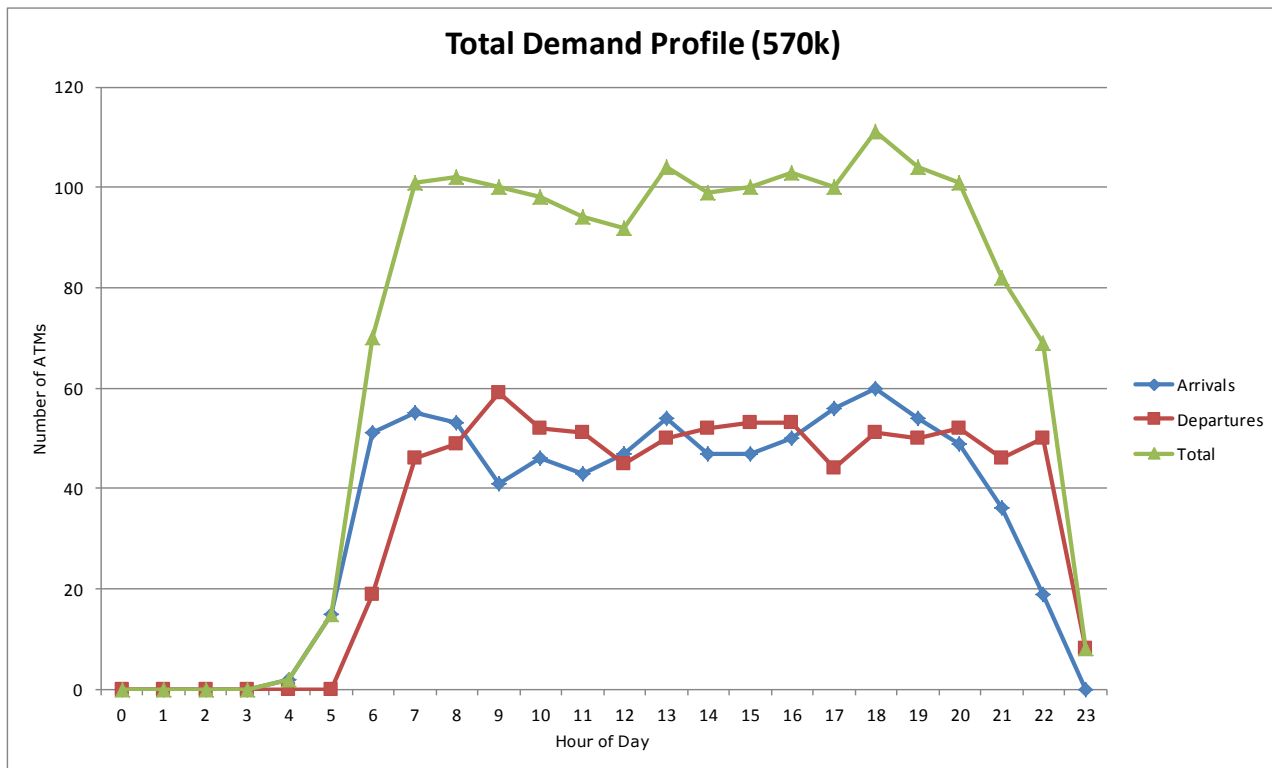
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Traffic – 570k Schedule

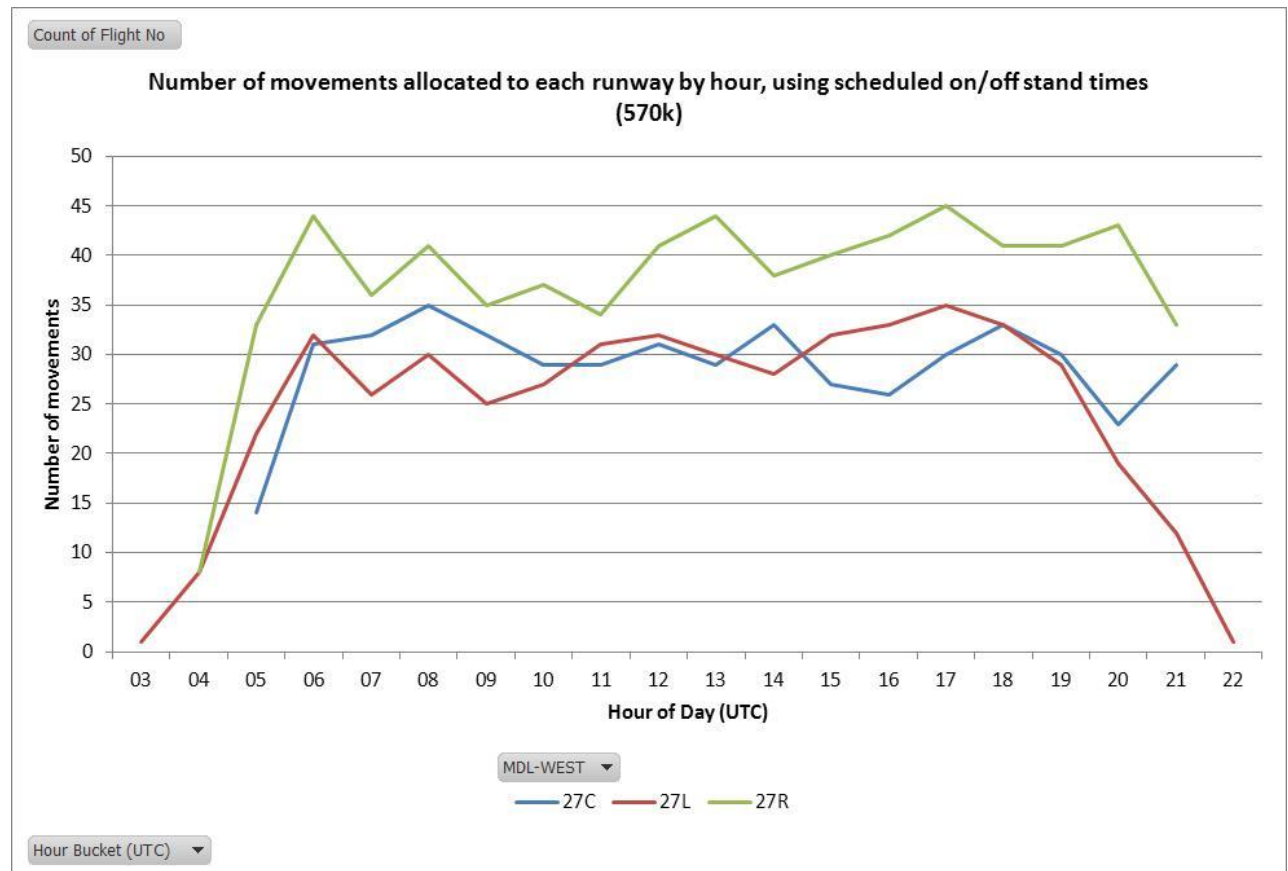
- > Source: "2276_3RSchedules_Master_V5.xlsm", "570K-AA" sheet
- > Schedule times taken to be on/off stand times
- > The runway to be used is specified in the schedule for each flight
- > Note that no T4 arrivals were allocated to Runway 27R. 19 T4 departures use 27R

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Sum
Arrivals	0	0	0	0	2	15	51	55	53	41	46	43	47	54	47	47	50	56	60	54	49	36	19	0	825
Departures	0	0	0	0	0	0	19	46	49	59	52	51	45	50	52	53	53	44	51	50	52	46	50	8	830
Total	0	0	0	0	2	15	70	101	102	100	98	94	92	104	99	100	103	100	111	104	101	82	69	8	1655



Traffic – 570k Schedule

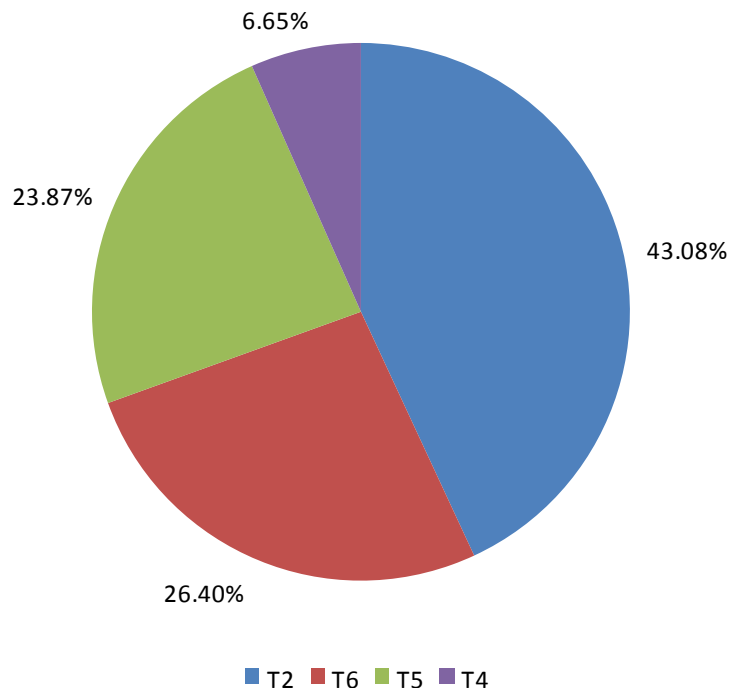
- > Analysis of the schedule shows that movements have been allocated to runways such that hourly demand for 27L does not exceed 35, demand for 27C does not exceed 35 and demand for 27R does not exceed 45
- > Note that this profile uses the scheduled on/off stand times and therefore the demand profiles for the runways (i.e. taking into account taxi times) will differ



Traffic – 570k Schedule – Terminal Use

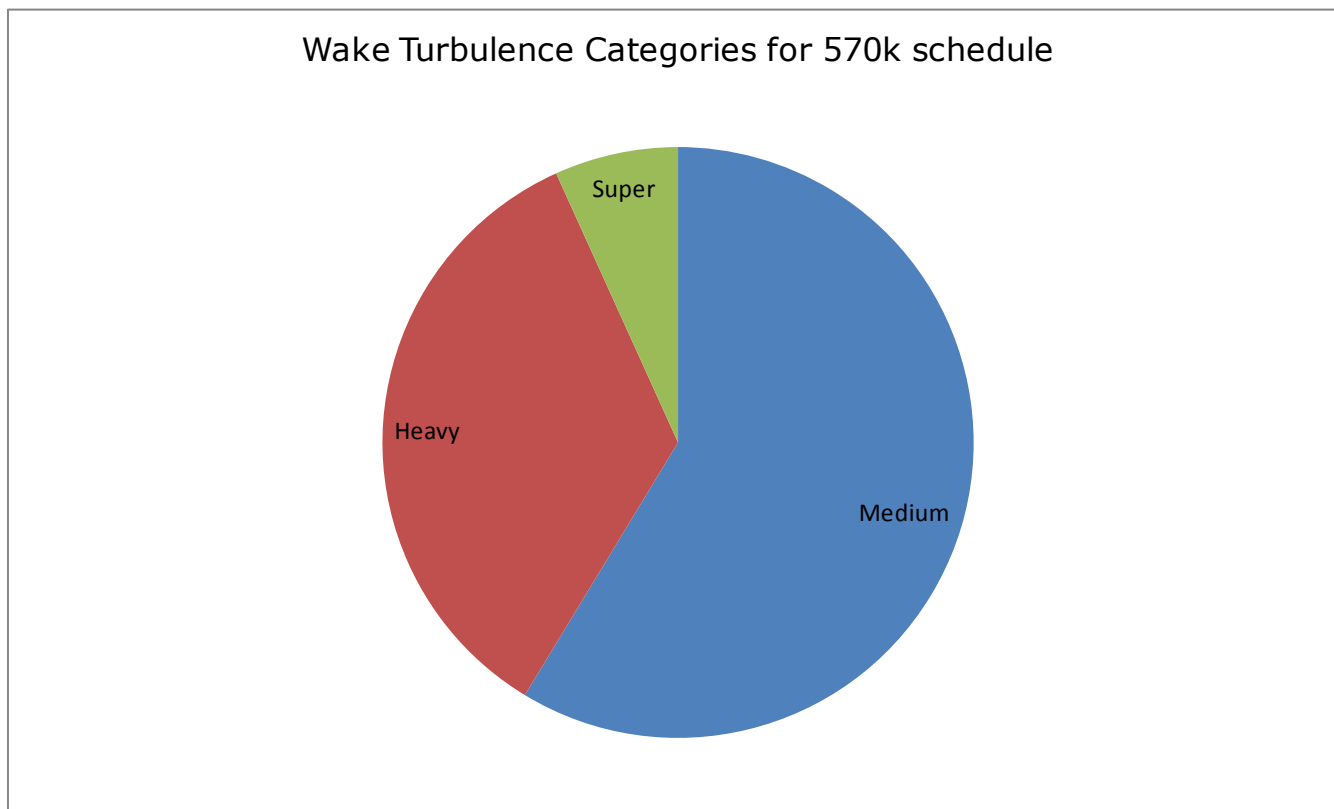
Terminal	Count	Percentage
T2	713	43.08%
T6	437	26.40%
T5	395	23.87%
T4	110	6.65%
Total	1655	100.00%

Distribution of Terminal Use for 570K Schedule



Traffic – 570k Schedule – Wake Turbulence Categories

Wake Turbulence	Count	Percentage
Medium	971	58.67%
Heavy	572	34.56%
Super	112	6.77%
Total	1655	100.00%

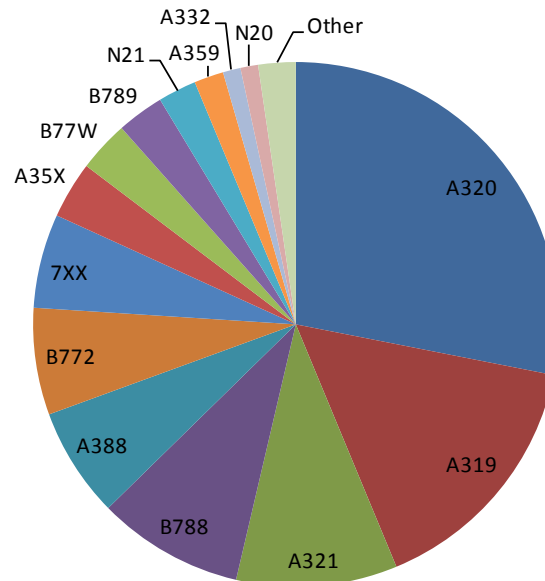


Traffic – 570k Schedule – Aircraft Types

Aircraft Type	Count	Percentage
A320	465	28.10%
A319	259	15.65%
A321	164	9.91%
B788	149	9.00%
A388	112	6.77%
B772	109	6.59%
7XX	96	5.80%
A35X	58	3.50%
B77W	52	3.14%
B789	48	2.90%
N21	39	2.36%
A359	30	1.81%
A332	18	1.09%
N20	18	1.09%
Other	38	2.30%
Total	1655	100.00%

Other = categories that contributed < 1% each

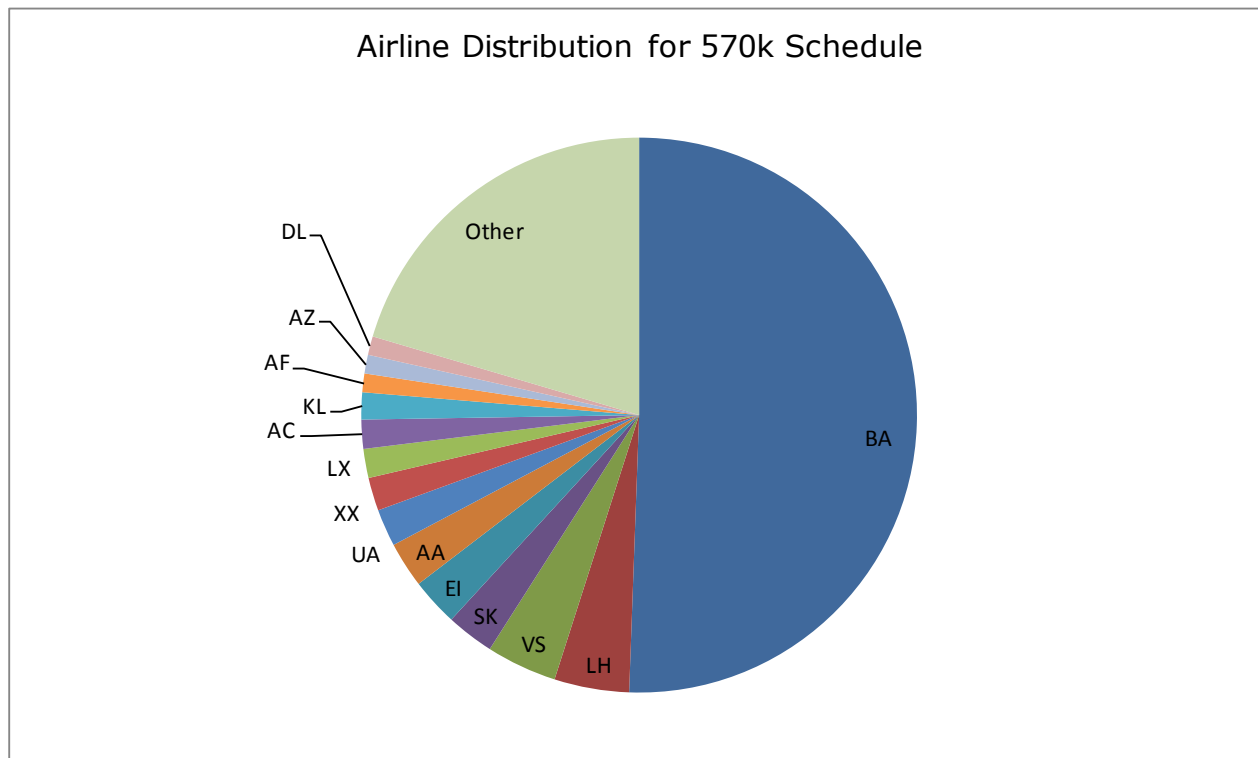
Aircraft Type Distribution for 570k schedule



Traffic – 570k Schedule – Airlines

Airline	Count	Percentage
BA	837	50.57%
LH	72	4.35%
VS	68	4.11%
SK	46	2.78%
EI	46	2.78%
AA	44	2.66%
UA	36	2.18%
XX	32	1.93%
LX	28	1.69%
AC	28	1.69%
KL	26	1.57%
AF	18	1.09%
AZ	18	1.09%
DL	18	1.09%
Other	338	20.42%
Total	1655	100.00%

Other = categories that contributed < 1% each



Results

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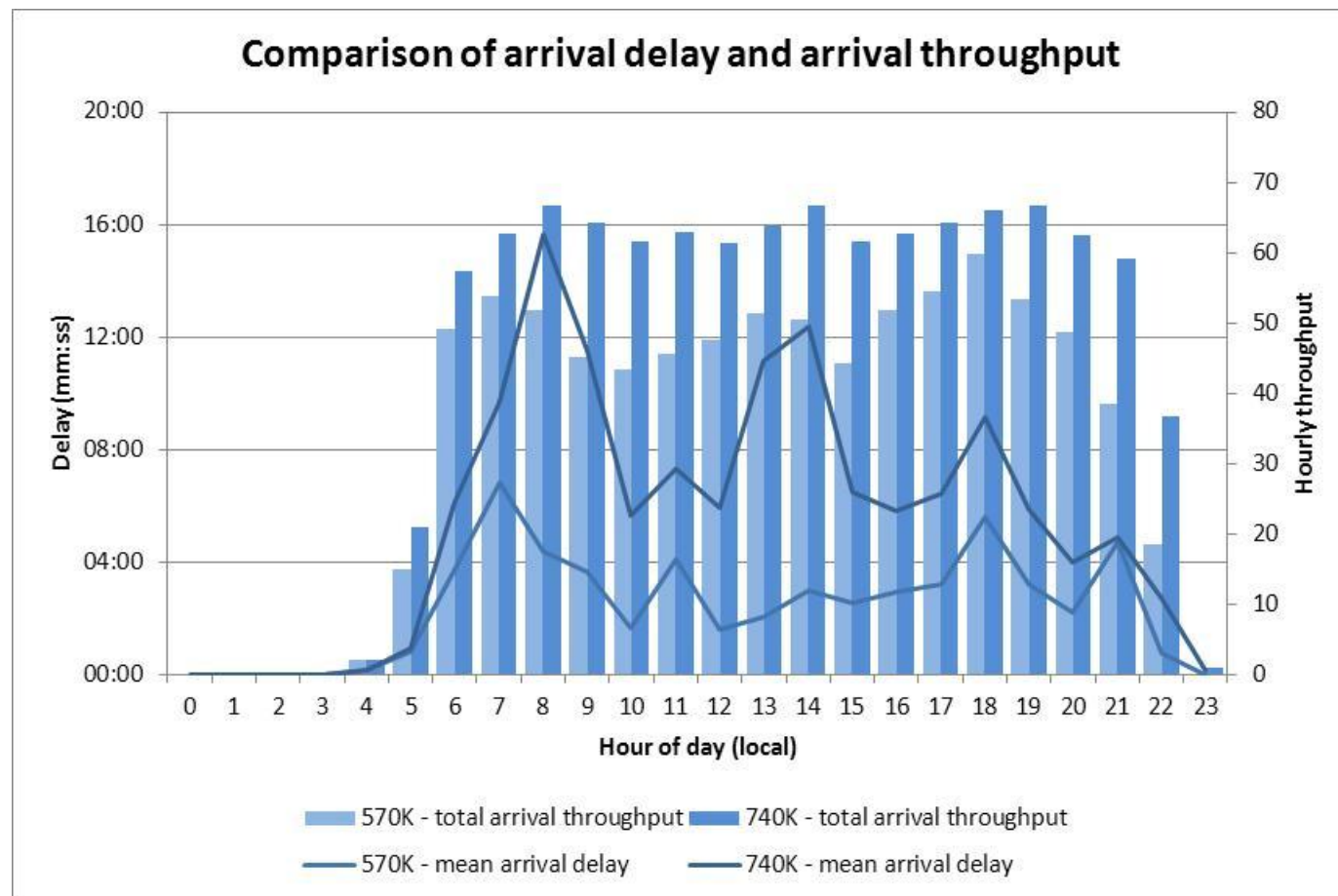
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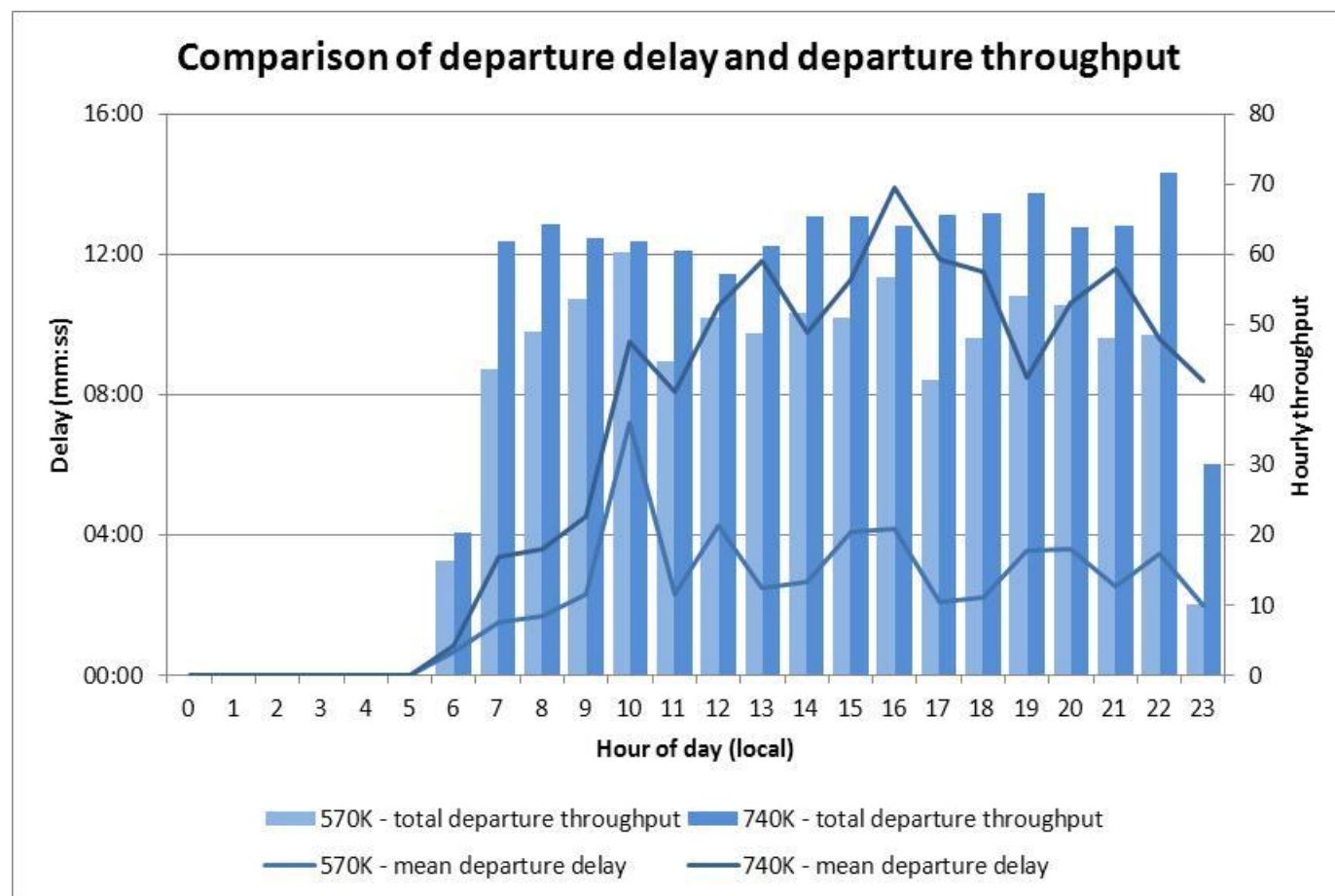
Results

- The simulation results are presented in three sections:
 1. High level comparison of results for 740K and 570K schedules
 2. Results for the 740K schedule
 3. Results for the 570K schedule

High level comparison of results for 740K and 570K schedules



High level comparison of results for 740K and 570K schedules



High level comparison of results for 740K and 570K schedules

Comparison of overall mean values (mm:ss):

	740K Schedule	570K Schedule	Difference (mm:ss)
Arrival Delay	07:44	03:23	04:21
Departure Delay	09:12	03:10	06:02
Arrival Taxi Time	07:37	07:35	00:02
Departure Taxi Time	16:01	15:47	00:14
Departure Gate Delay	04:11	01:07	03:04

- > Delays were substantially lower for the 570K schedule, whilst taxi times slightly lower

Results – 740K Schedule

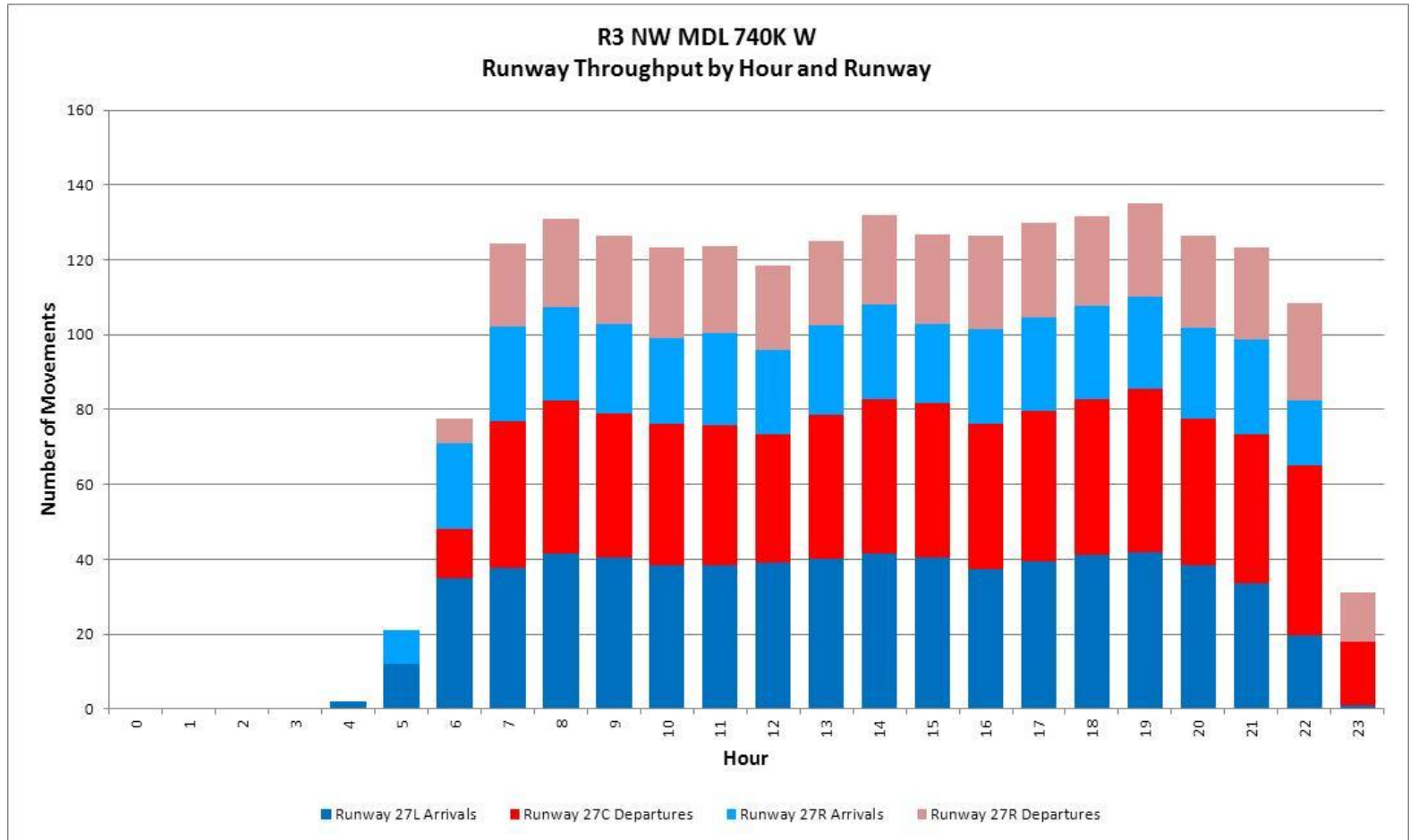
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Runway Throughput

- Achieved runway throughput consistently over 120 movements per hour, averaged 127 per hour between 07:00 and 21:59
- Achieved throughput peaked at 135 movements at 19:00



Runway Throughput

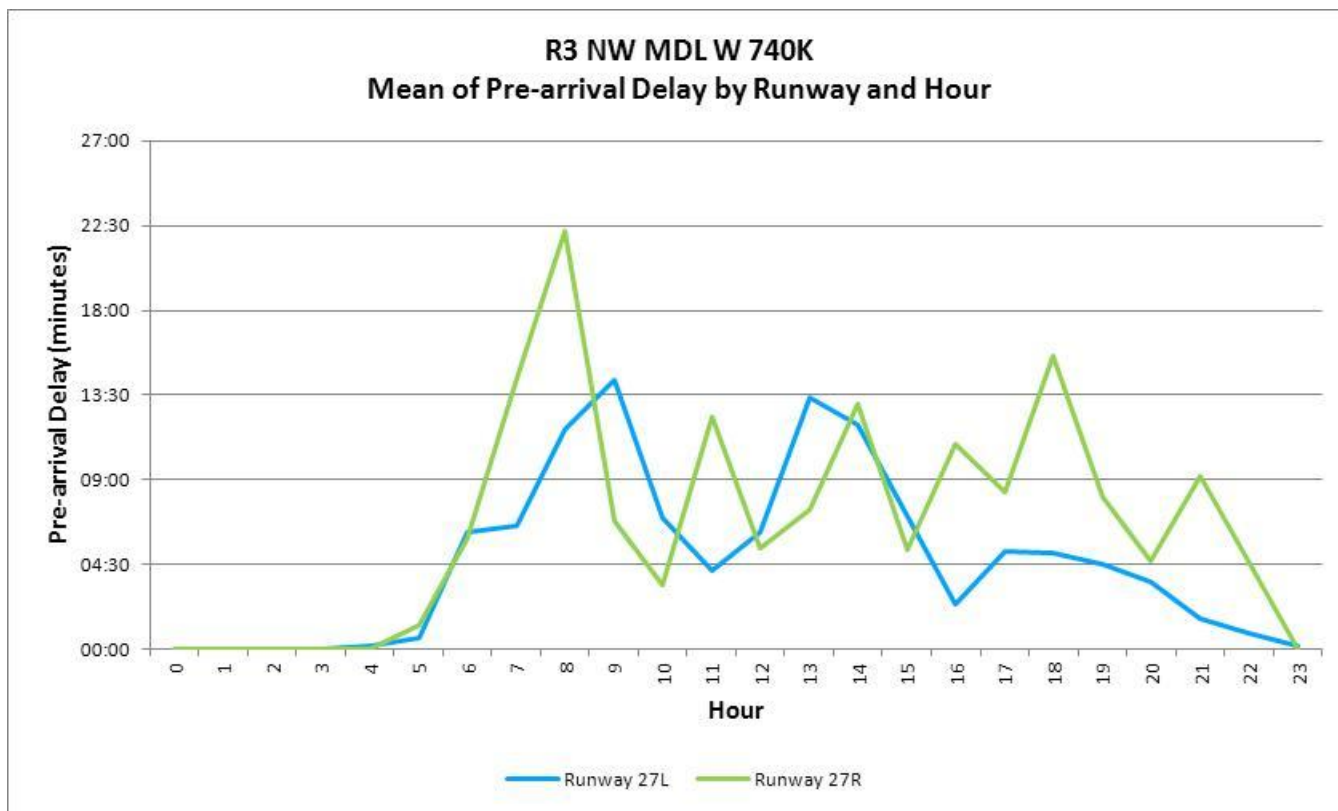
- > Consistently achieving the runway service rate (in this case 128 movements per hour) can be challenging for the following reasons:
 - > Arrival wake turbulence mix can vary
 - > Departure wake turbulence mix and SID mix can vary
 - > In-hour profiles can vary and may not be smooth
 - > Interactions on the taxiway network will often mean that departing traffic does not arrive at the Runway Hold Zone (RHZ) in the scheduled order
- > If the runway throughput does not keep up with the demand, the level of delay will increase
- > The schedule coordination process often adds 'fire breaks' to allow the recovery from delay

Runway Throughput and delay

- > In initial simulation runs the 27C Runway Hold Zone (RHZ) was frequently congested. There is a need to keep the inner taxiway (B) clear for arrivals, but with the volume of traffic this was not always possible
- > Solutions implemented:
 - > 19 departures were moved from 27C to 27R (all T5/T6 flights)
 - > The number of departures taxiing for 27C was capped at 20 and number of departures taxiing for 27R capped at 15. This reduces pressure on the RHZ but increases gate delay
- > Further measures were then taken to increase runway throughput and reduce delays:
 - > Some arrivals moved from 27R to 27L in order to ensure an even mix of arrivals and departures on 27R
 - > Almost all Super (A380) departures and a large number of Heavy departures moved from 27C to 27R in order to reduce the number of wake turbulence separations applied
 - > In hour smoothing applied to 27C and 27R departures in order to ensure an even level of demand in each half hour and in each ten minute period

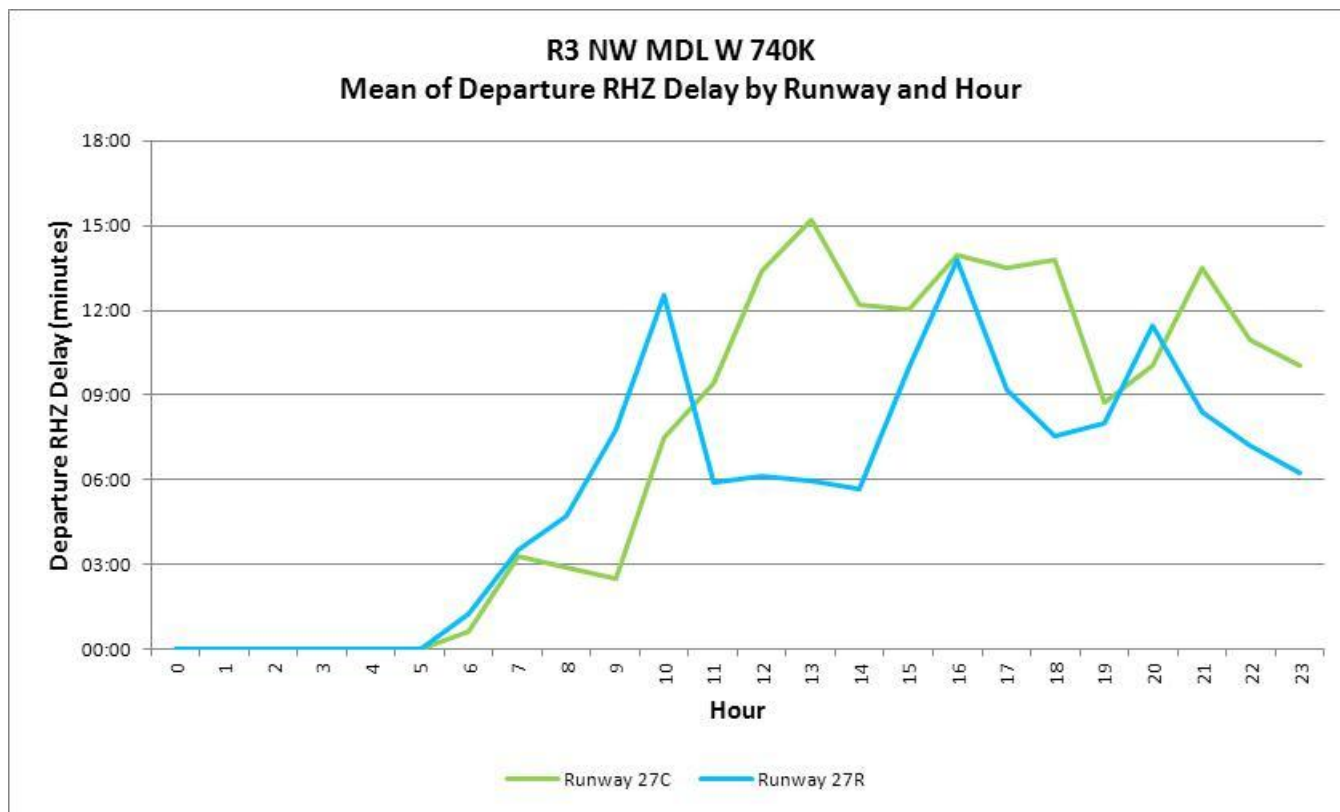
Arrival Delays

- Mean arrival delay is 7 minutes 44 seconds
- Peaks and troughs suggest that runway balancing and demand smoothing could be applied to the schedule to achieve a more even delay profile



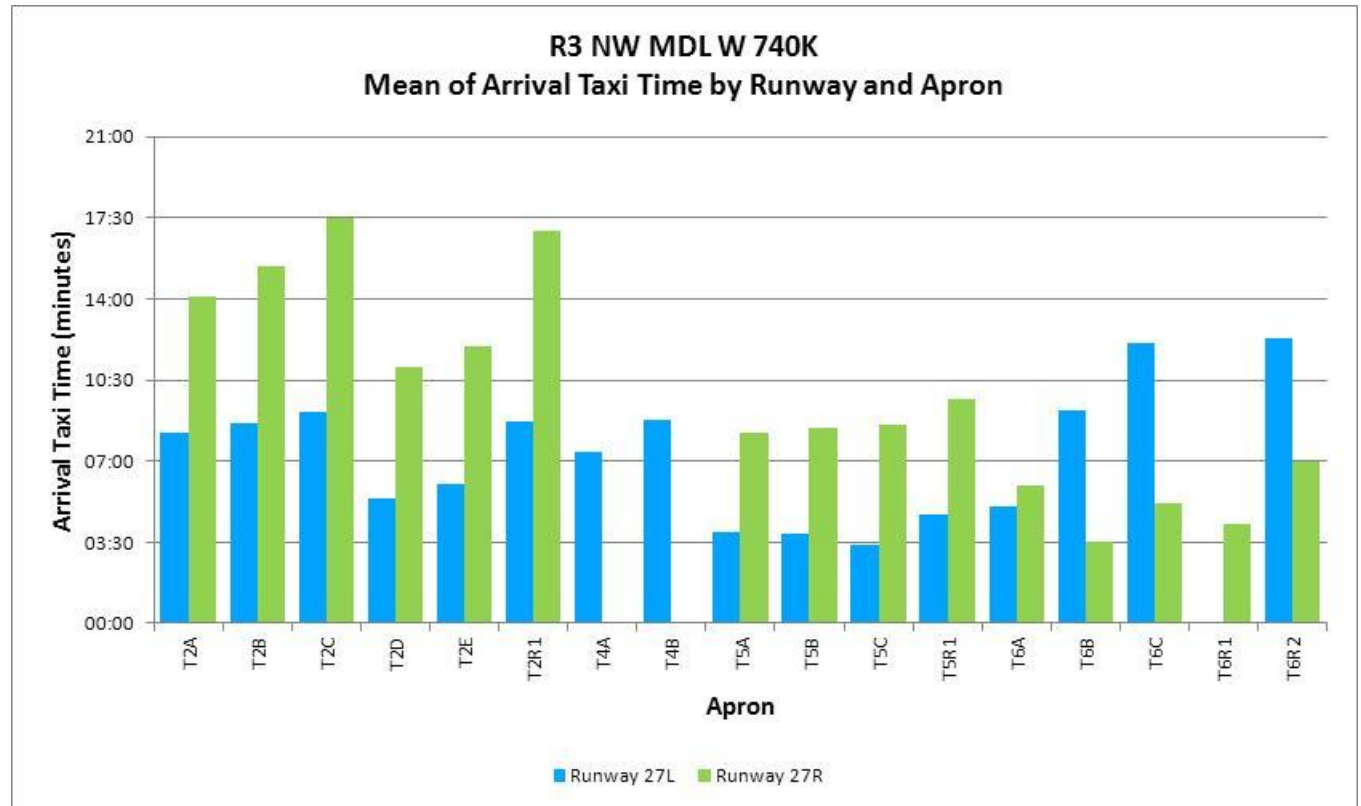
Departure Delays

- Peaks in departure delay reach 12-15 minutes, although overall daily average is 9 minutes 12 seconds



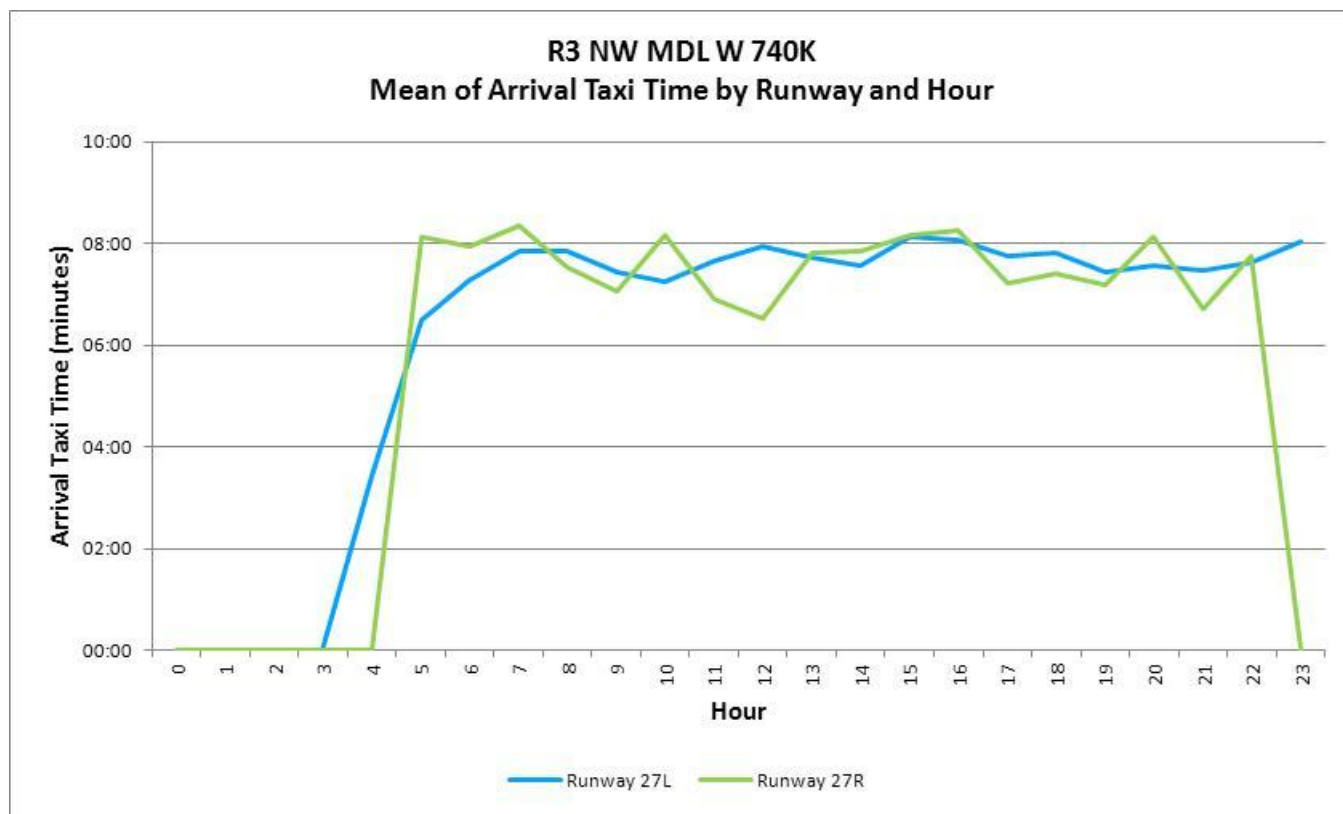
Arrival Taxi times – by Runway and Apron

- > This is the taxi time from the runway exit to stand
- > Overall mean arrival taxi time is ~8 minutes, but varies widely. E.g. 27L to T2R1 ~8 minutes, 27R to T2R1 can take twice as long
- > Similar situation in reverse for T6
- > Note that almost all T2 arrivals use 27L (short taxi), most T6 arrivals use 27R (short taxi) and most T5 arrivals use 27R (long taxi)



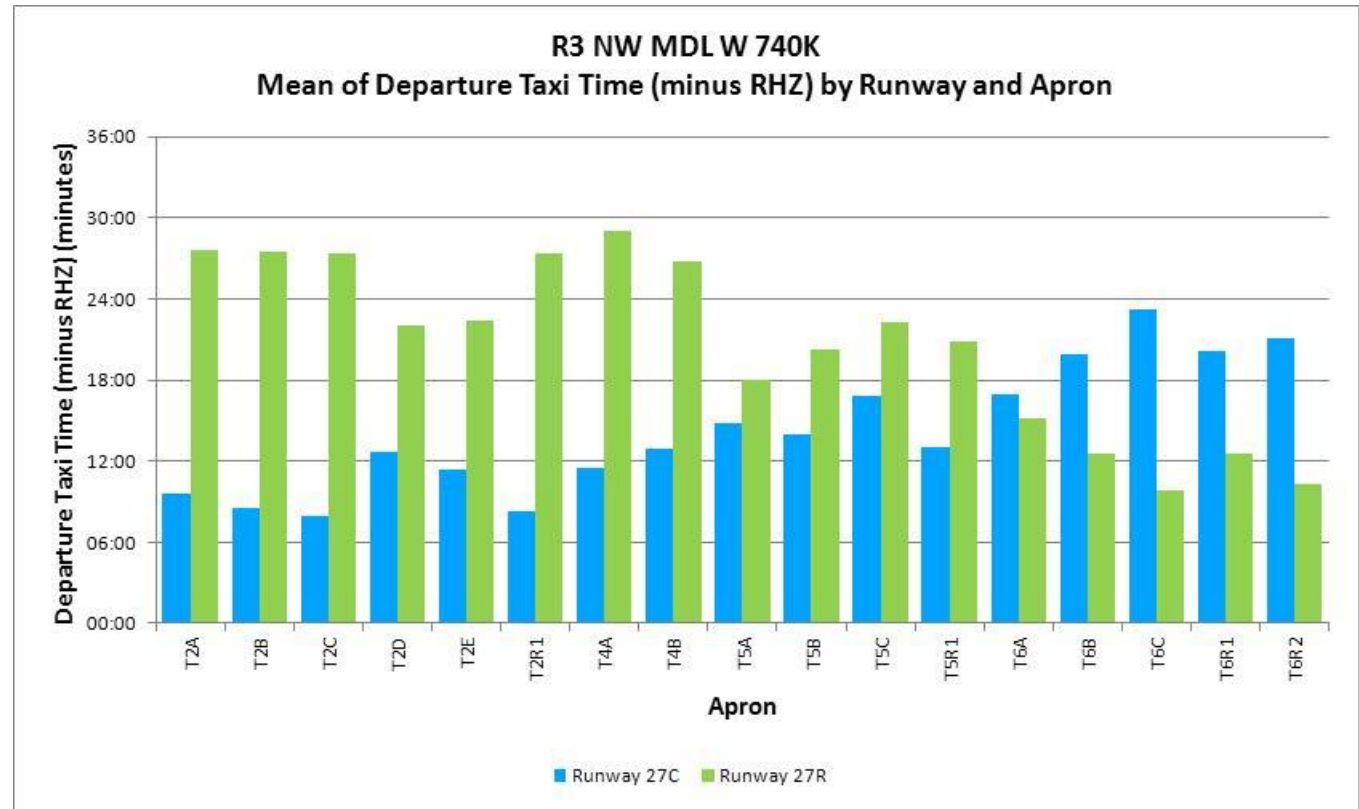
Arrival Taxi times – by hour of day

- › This is the taxi time from the runway exit to stand
- › Average arrival taxi times are broadly consistent across the day



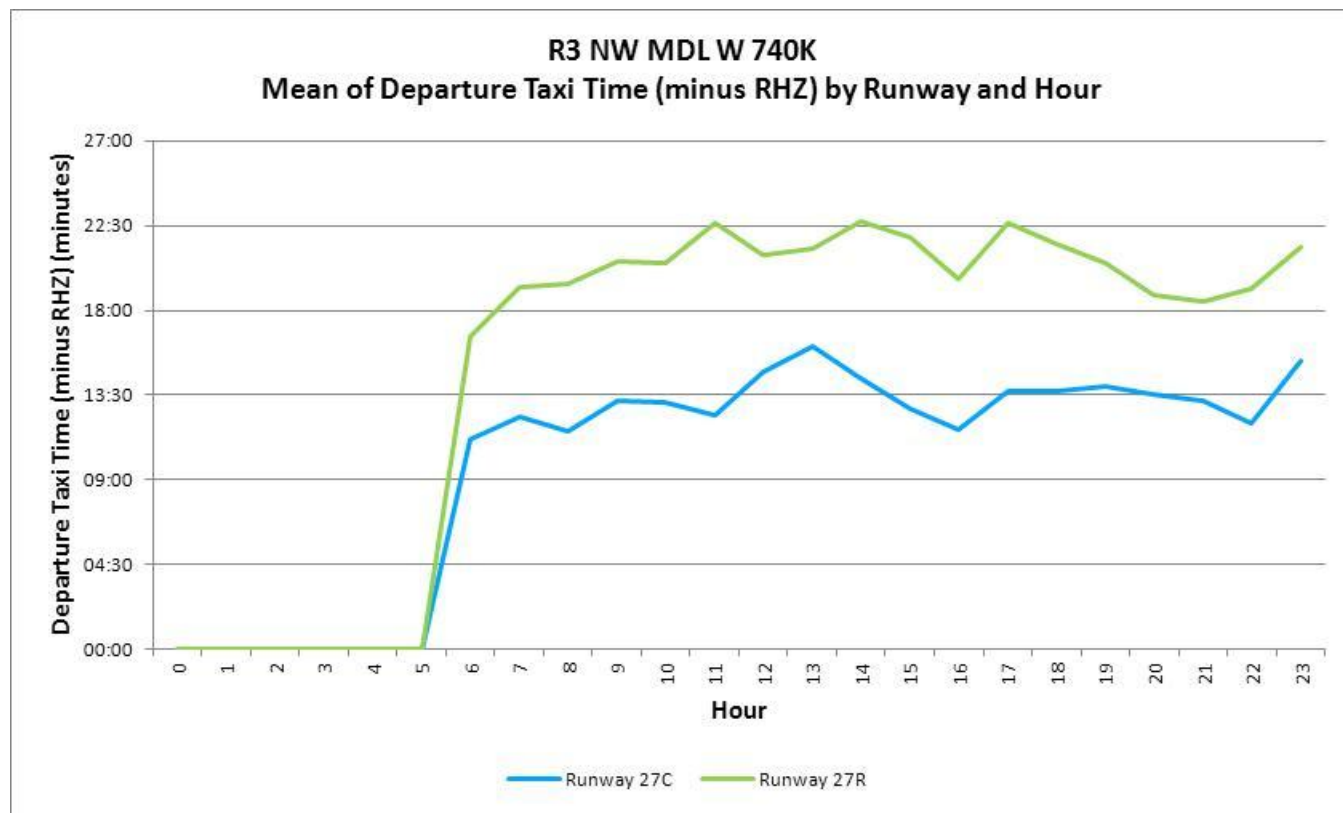
Departure Taxi times – by Runway and Apron

- › Departure Taxi Time is the time from an aircraft leaving the stand to reaching the Runway Hold Zone (RHZ). It includes the pushback pause
- › Overall mean departure taxi time is 16 minutes, but varies widely. E.g. T2 to 27C ~8 minutes, T2 to 27R ~25 minutes



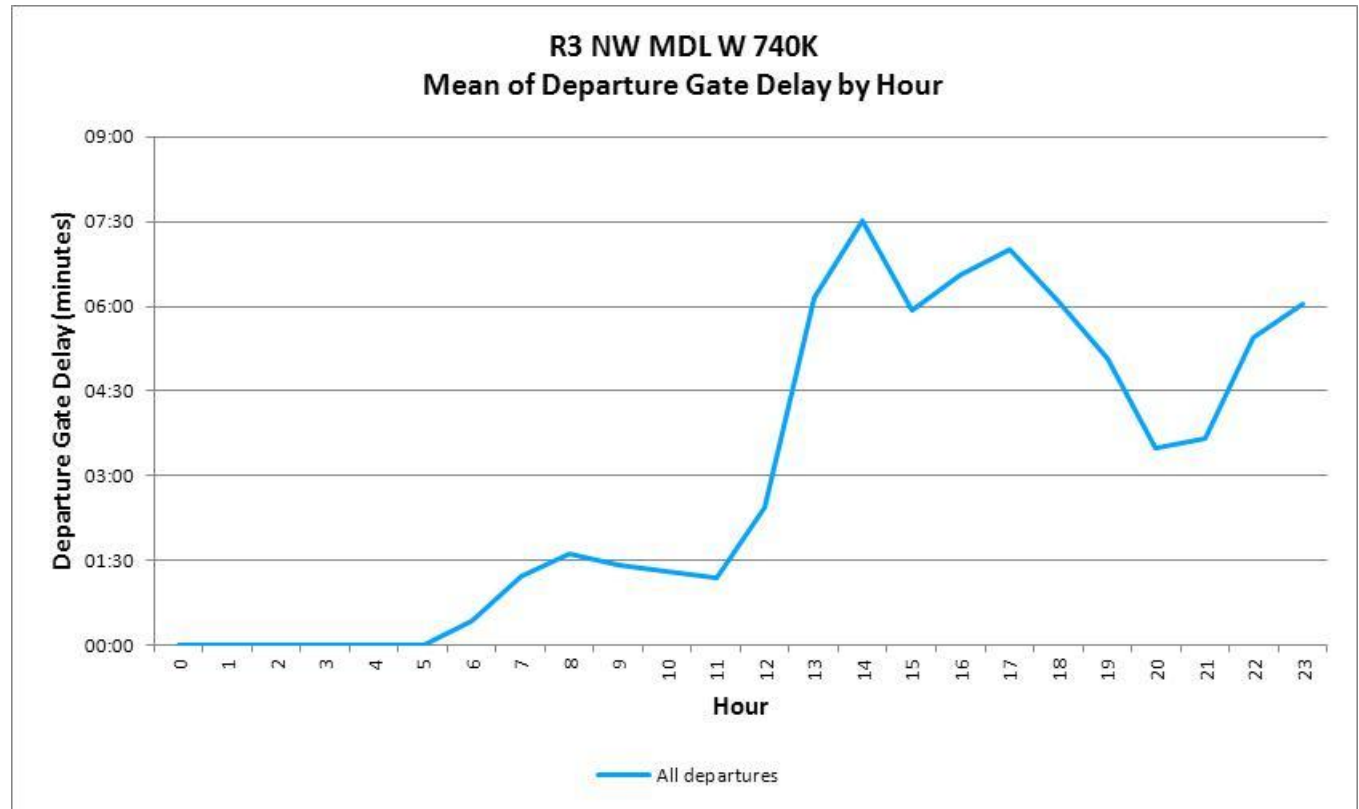
Departure Taxi times – by hour of day

- › Departure Taxi Time is the time from an aircraft leaving the stand to reaching the Runway Hold Zone (RHZ). It includes the pushback pause
- › Departure taxi times are broadly consistent over the day



Average Departure Gate Delay – All Aircraft by Hour

- > This is the delay prior to pushback due to taxiway congestion, the maximum number of aircraft taxiing for departure at any one time having been reached, or a late inbound aircraft
- > Gate delay peaks at 7.5 minutes, but does not continue to rise throughout the day



Runway Crossings

- > Arrivals to T4: 0
- > Departures from T4: All cross 27L (79 flights per day)
- > Current number of runway crossings (2013-14 mean) is 46 flights per day

Ground Interaction and Taxiway Delay Plots

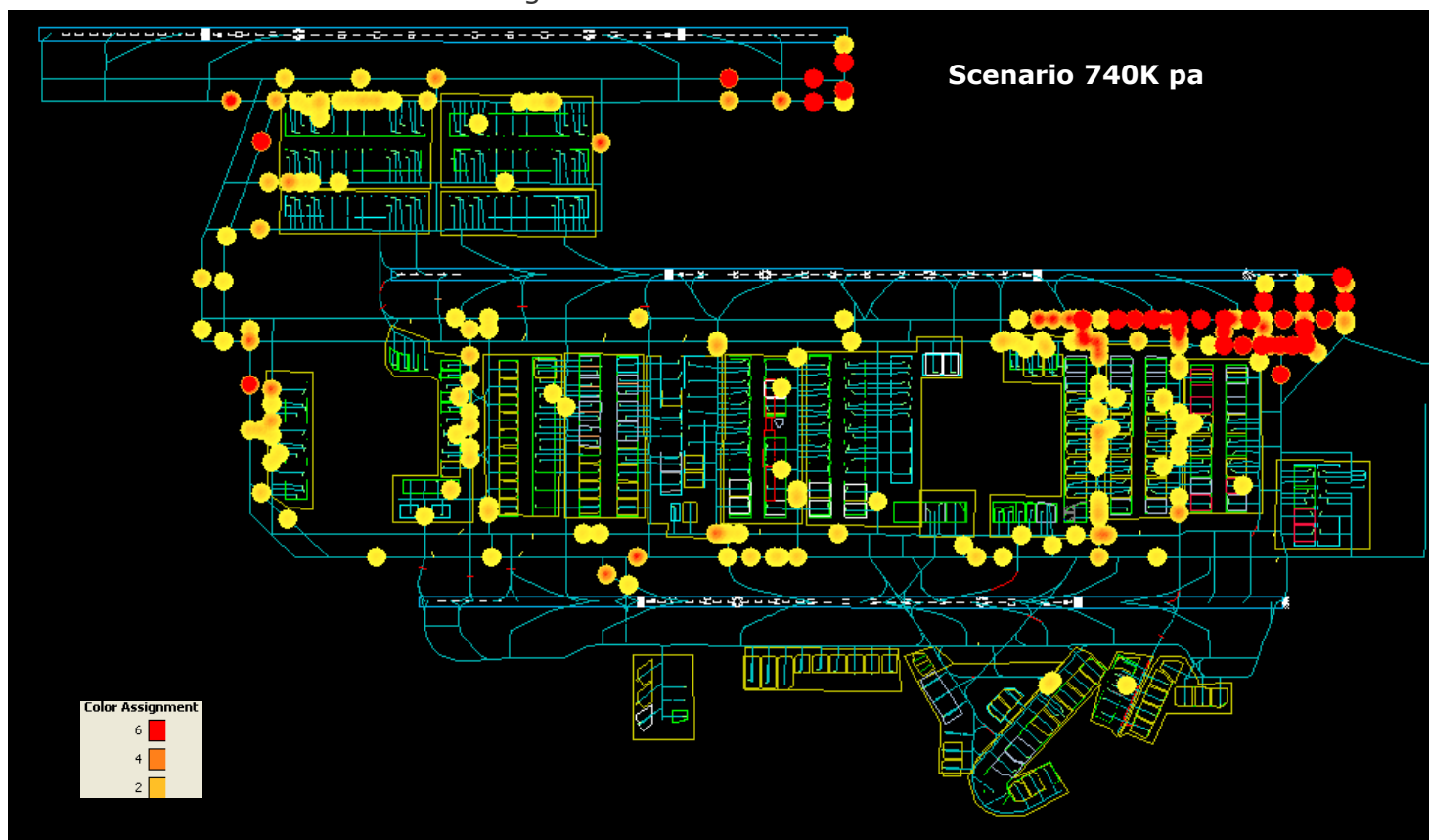
- The ground interaction and taxiway delay plots on the following slides show the effects of the 740K pa traffic schedule on the layout
- It should be noted that the models do not test resilience of the layout (i.e. the effect of taxiway closures)

Ground Interactions

A ground interaction is recorded in TAAM whenever an aircraft is required to wait for another, or when the speed of an aircraft is reduced to allow for another

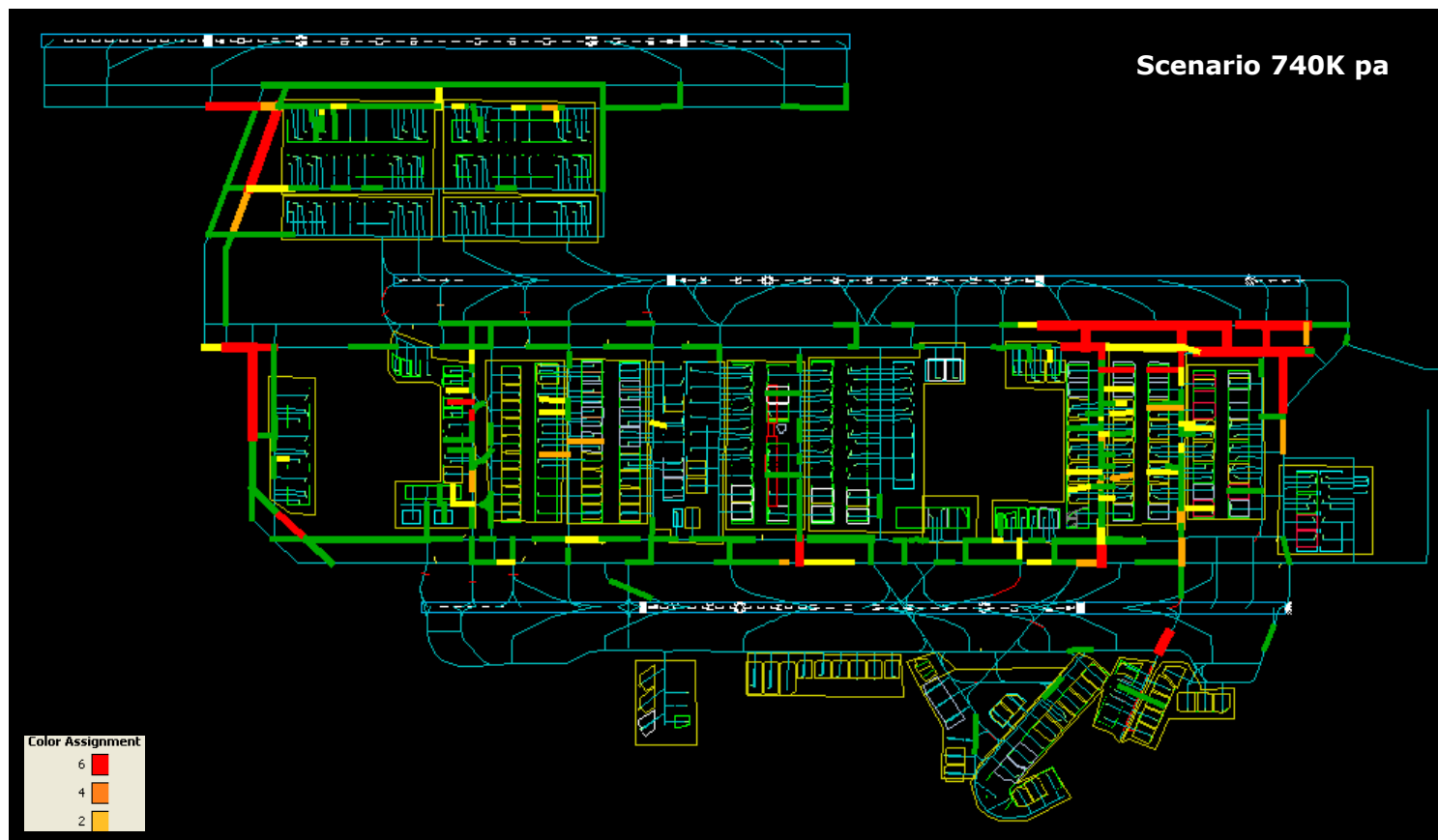
Colour (yellow, orange, red) shows an increasing number of interactions

The plots are indicative and highlight potential hotspots that can occur across the infrastructure. The plots presented show all recorded interactions from a single simulated run for each scenario



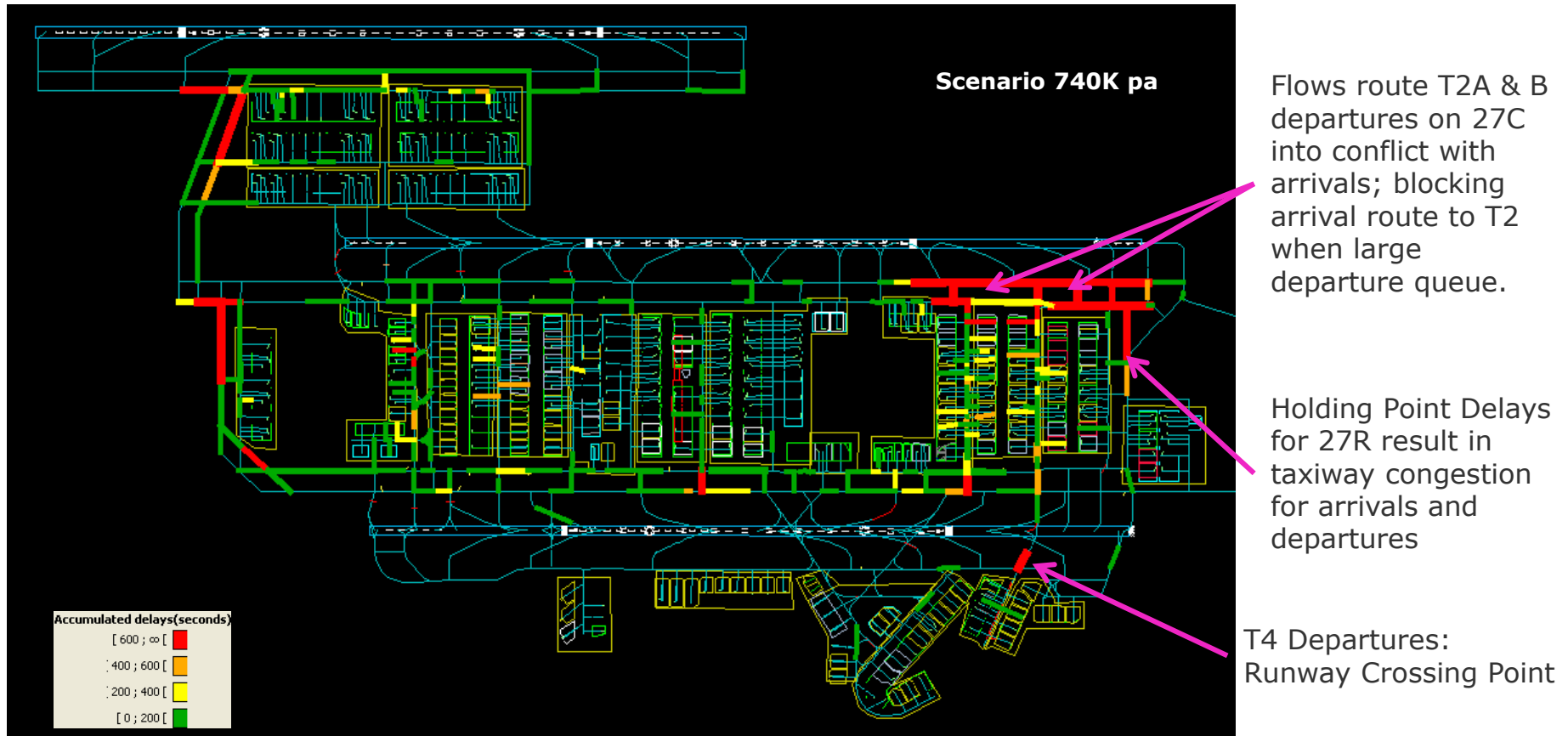
Taxiway Delays

The plots show all recorded taxiway delays from a single simulated run for each scenario. Colour (green, yellow, orange, red) shows increasing taxiway delays. The thickness of the line increases with the number of aircraft affected.



Taxiway Delays

The plots show all recorded taxiway delays from a single simulated run for each scenario
 Colour (green, yellow, orange, red) shows increasing taxiway delays. The thickness of the line increases with the number of aircraft affected

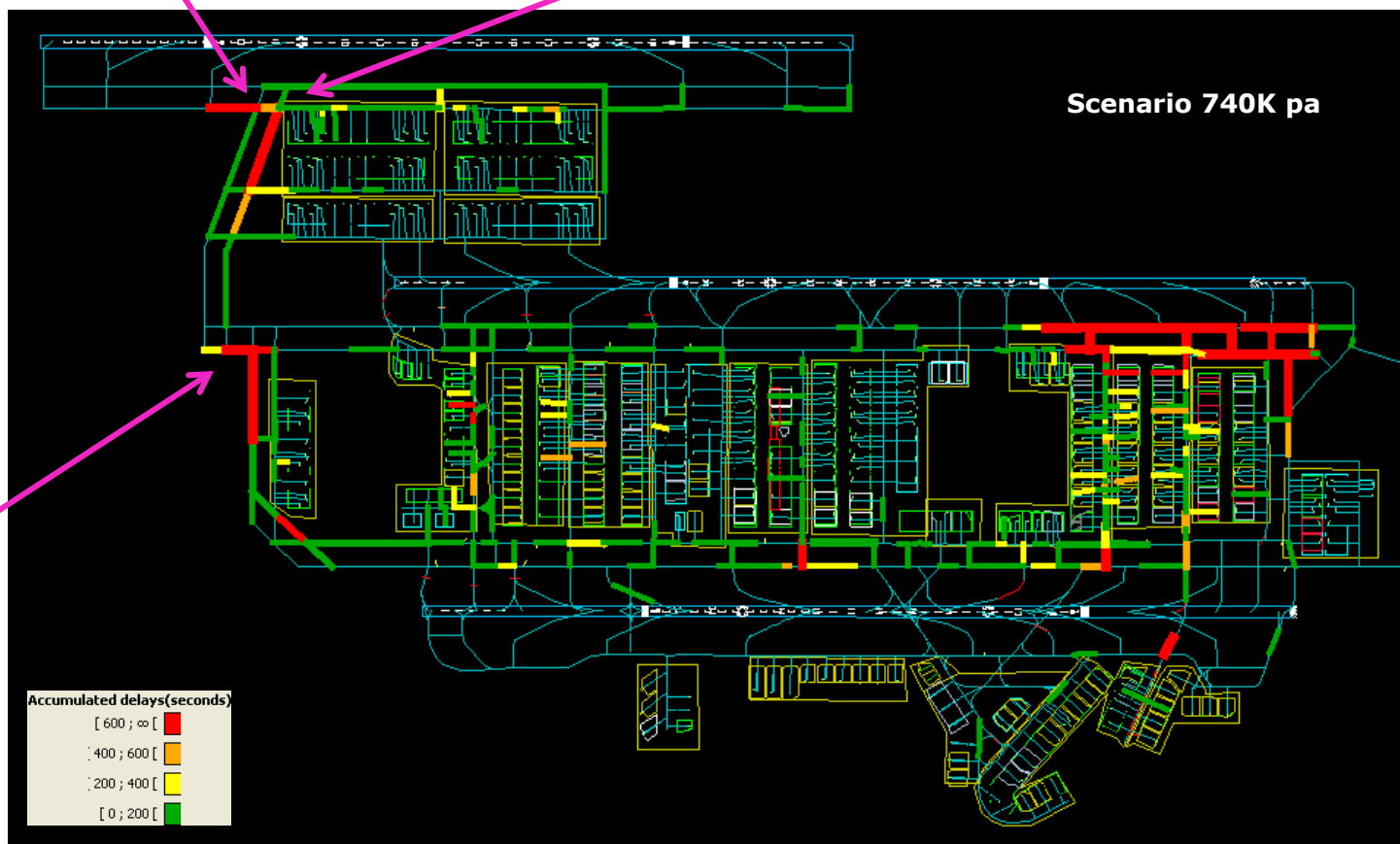


Taxiway Delays

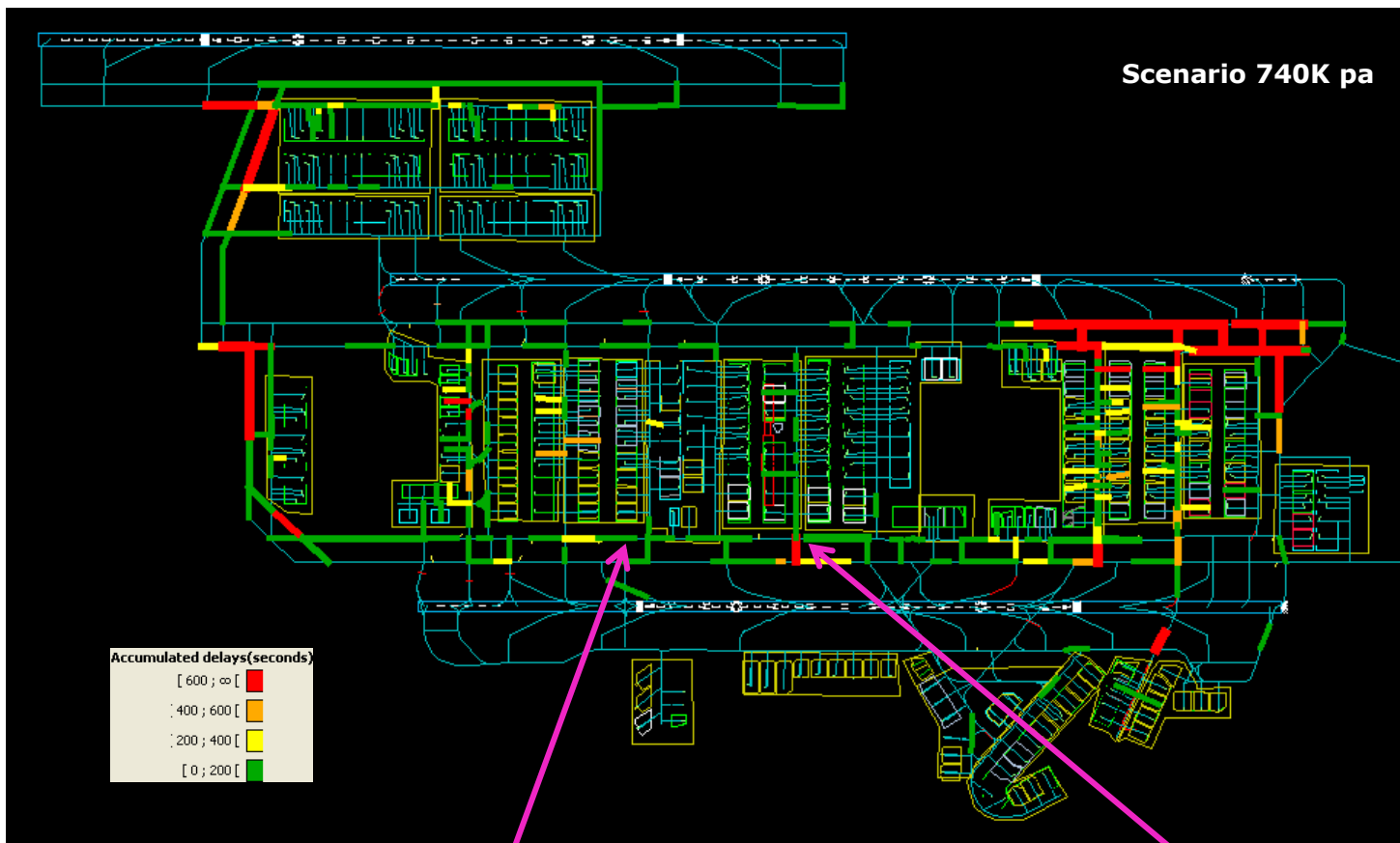
Merging Flows:
27R Arrivals +
T6B & T6D Departures
from 27C

Crossing Point:
T6B & T6D Departures on 27C +
27R Departures +
some T6B & T6D arrivals

Crossing Point:
27R & 27C
Departures
+
T6 B-E deps on
27C
+
27R arrivals



Taxiway Delays



Crossing Point:
27R & 27C Departures +
T6 B-E deps on 27C +
27L arrivals

Combination of 27L arrivals
+
departures taxiing to 27R

Results – 570K Schedule

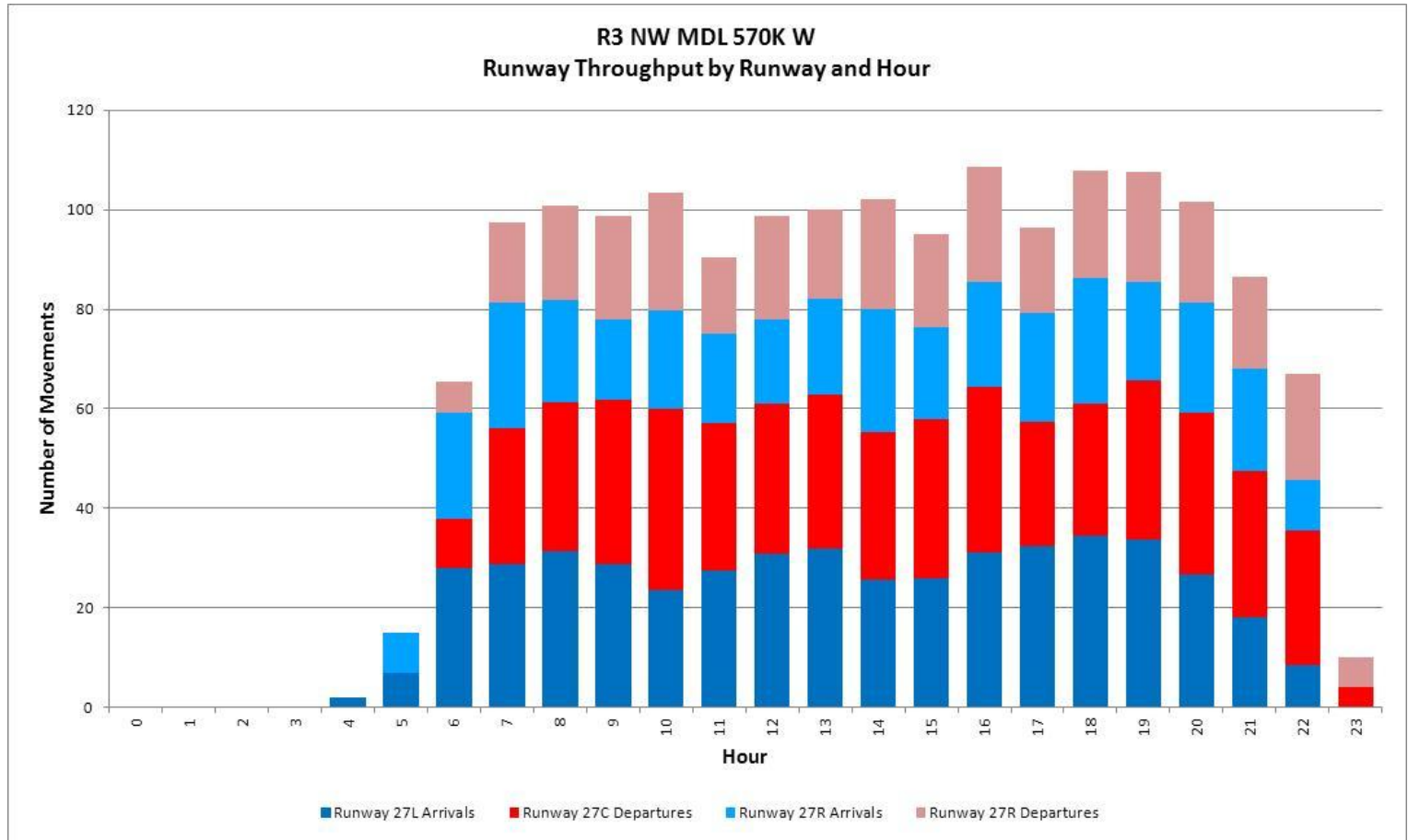
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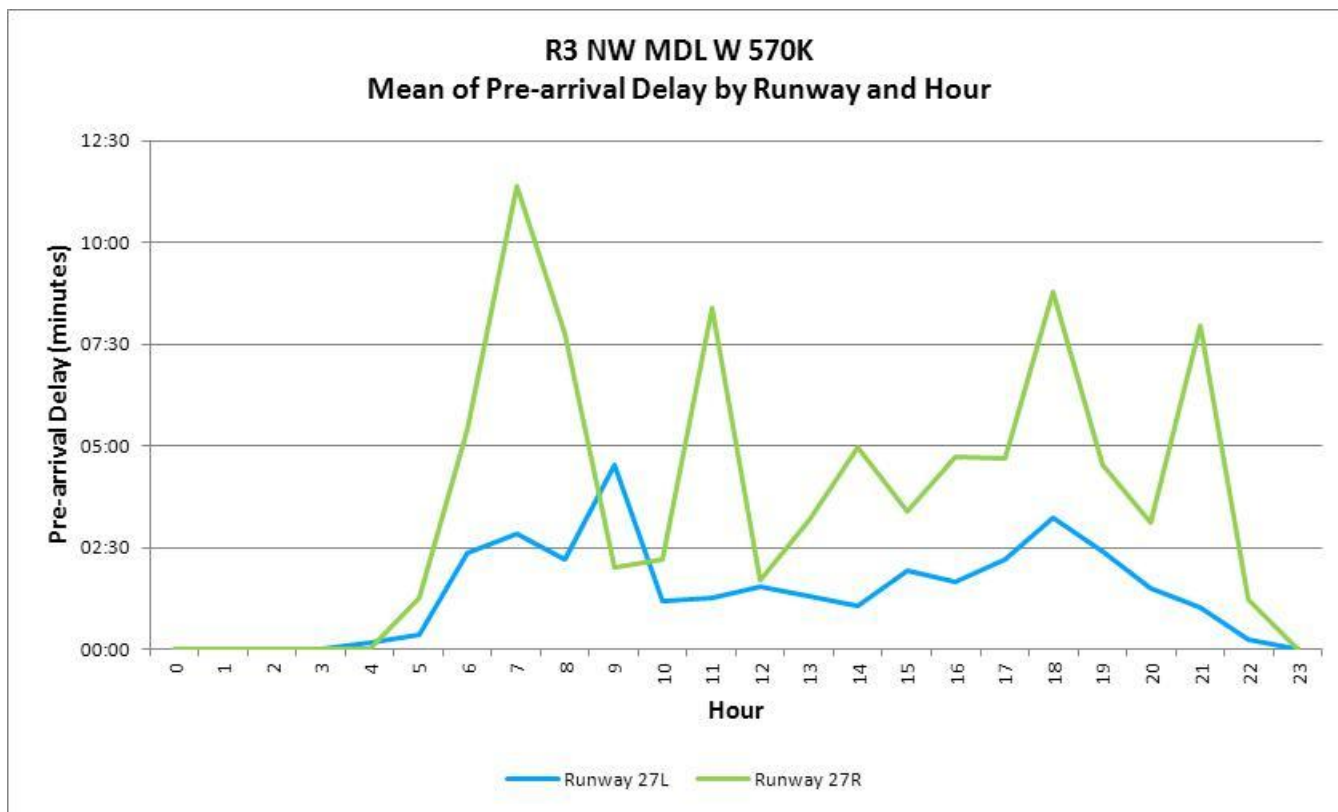
Runway Throughput

- The runways comfortably serve the level of demand
- Achieved throughput peaked at 108 at 16:00



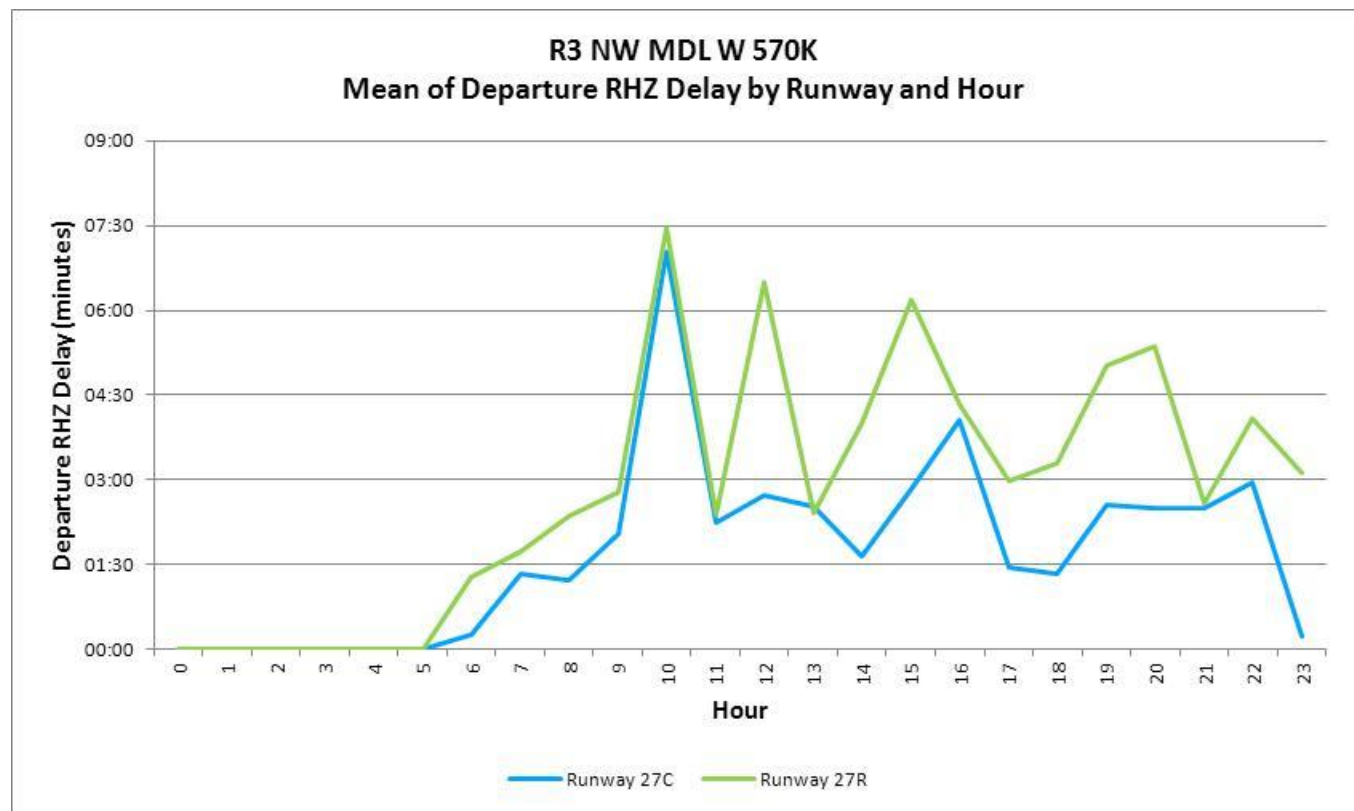
Arrival Delays

- Arrival delay on the mixed mode runway (27R) is mostly below 10 minutes (peak is 11 minutes at 07:00)
- Arrival delay on the landing (27L) is consistently below 5 minutes all day



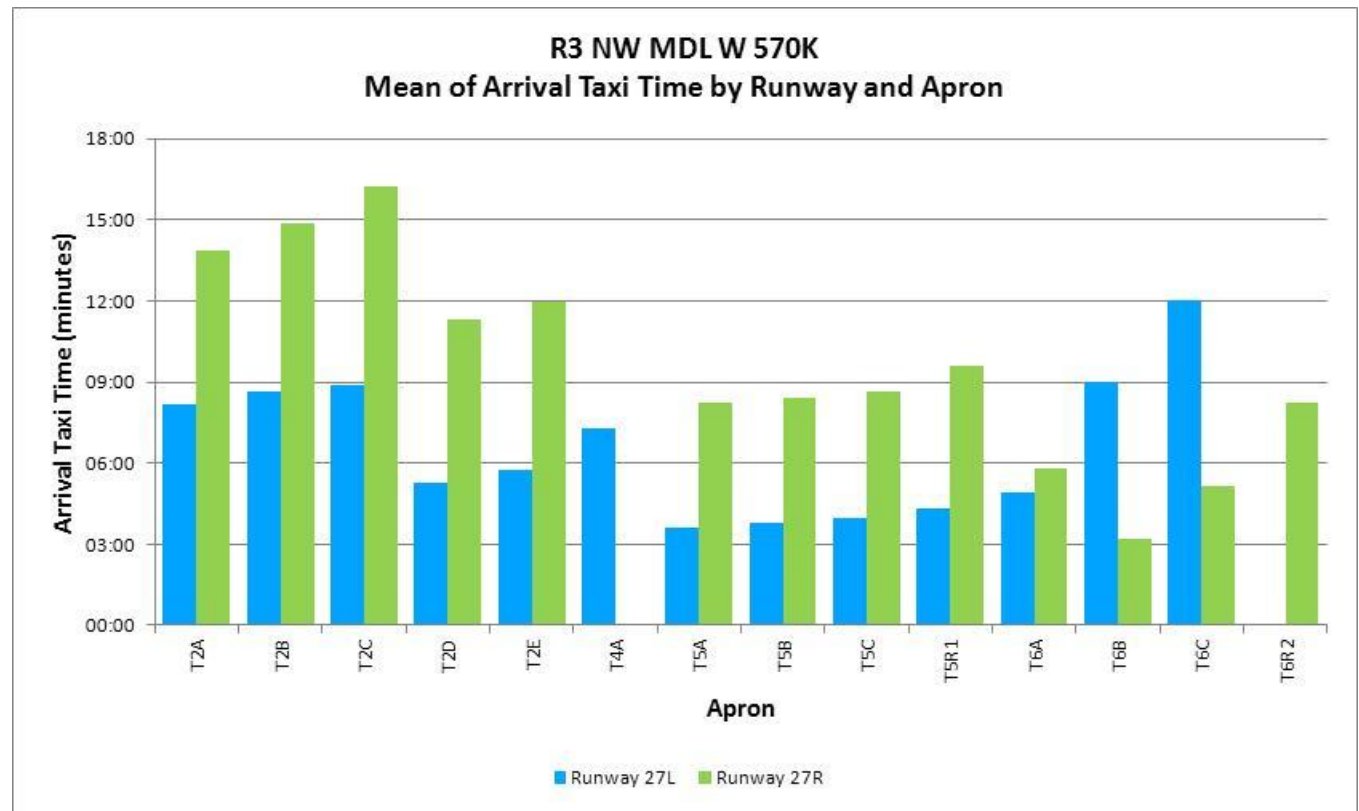
Departure Delays

- Departure delay on both landing runways is consistently below 10 minutes



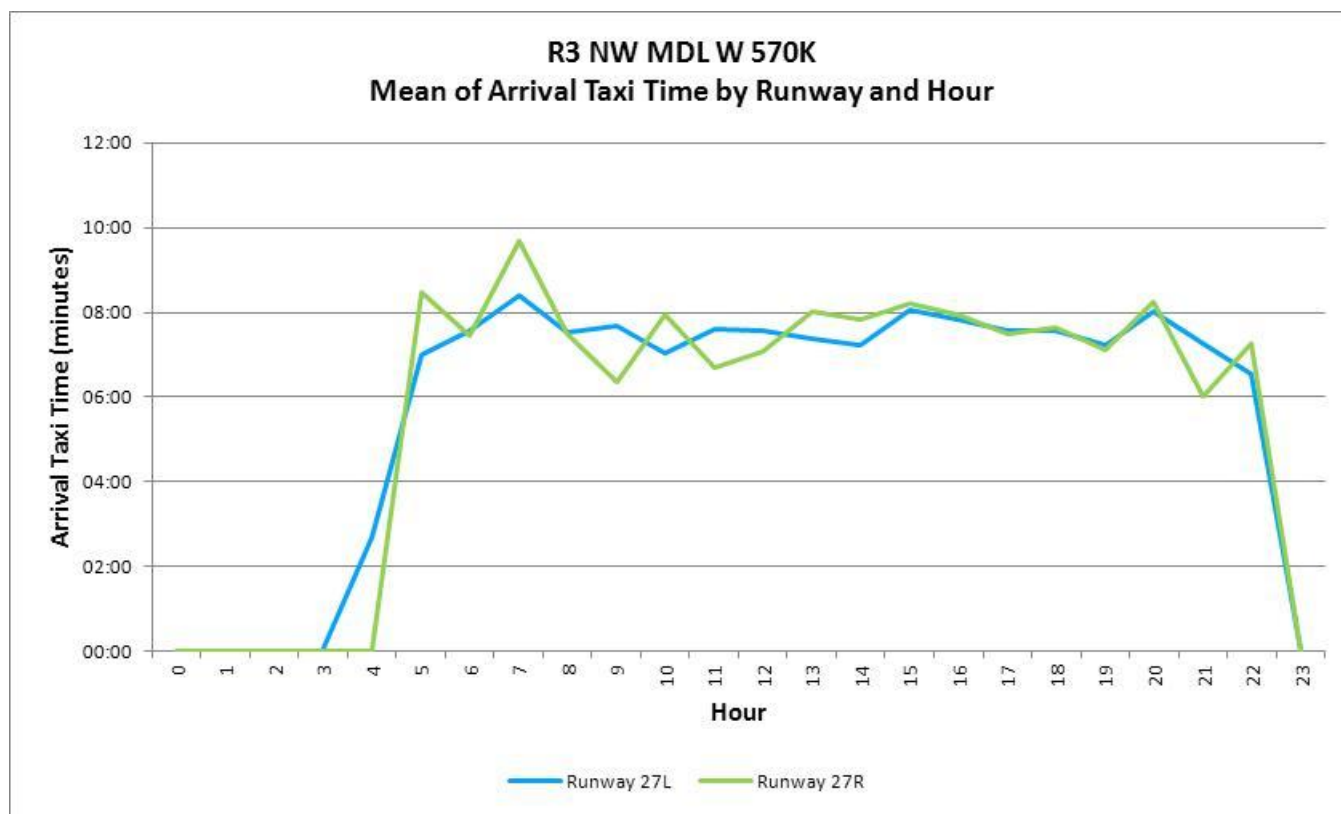
Arrival Taxi times – by Runway and Apron

- > This is the taxi time from the runway exit to stand
- > Overall mean arrival taxi time is ~7.5 minutes, but varies widely
- > E.g. 27L to T2D/E ~6 minutes, 27R to T2D/E can take twice as long
- > Similar situation in reverse for T6B/C
- > Note that almost all T2 arrivals use 27L (short taxi), most T6 arrivals use 27R (short taxi) and most T5 arrivals use 27R (long taxi)



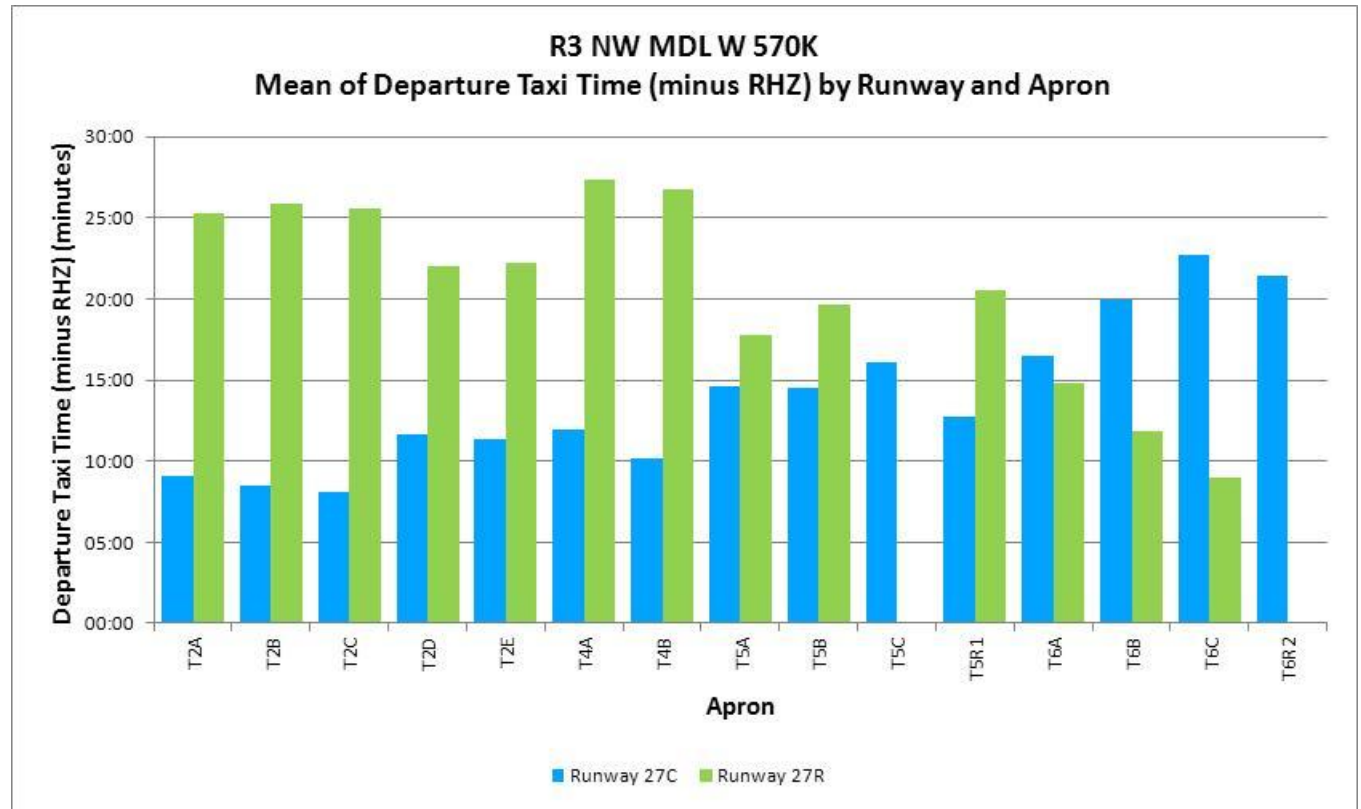
Arrival Taxi times – by hour of day

- This is the taxi time from the runway exit to stand
- Average arrival taxi times are broadly consistent across the day



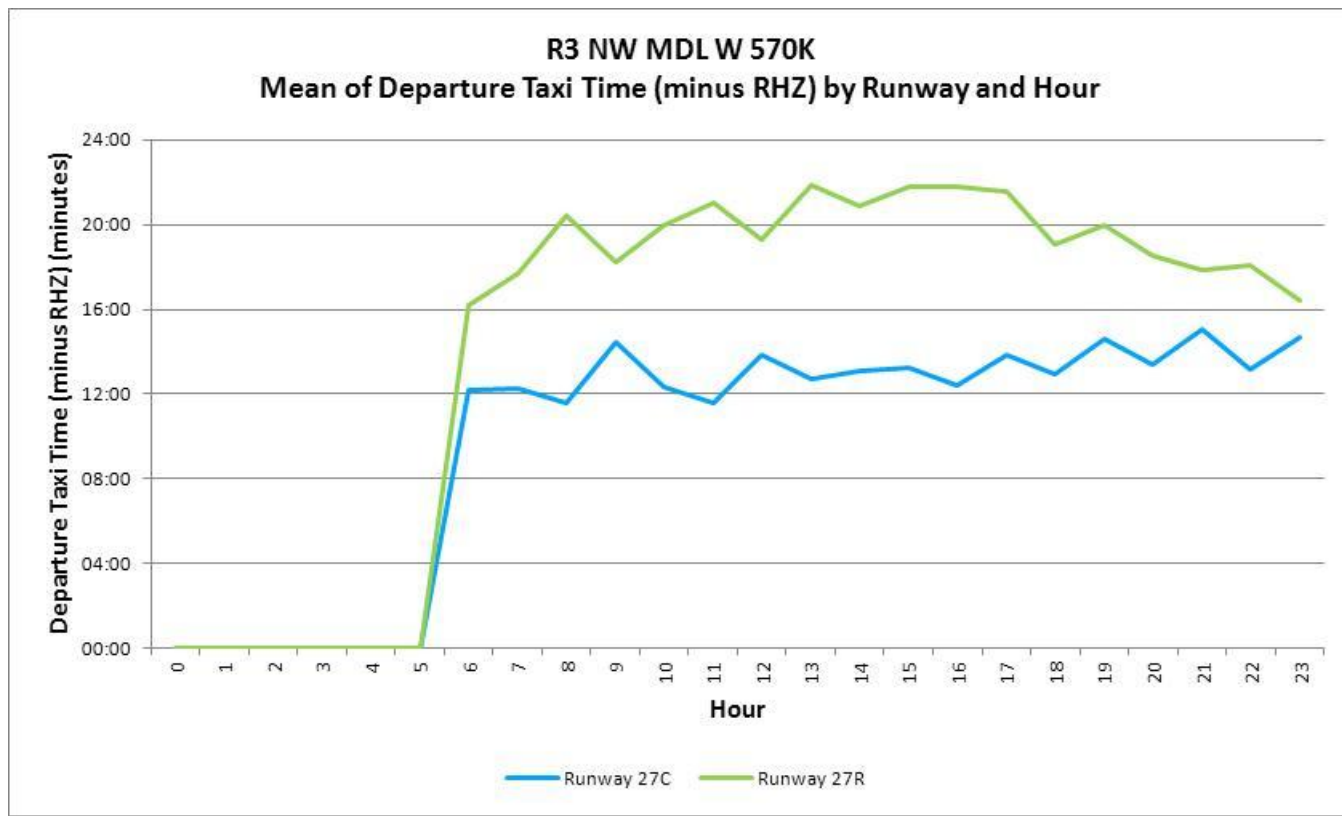
Departure Taxi times – by Runway and Apron

- › Departure Taxi Time is the time from an aircraft leaving the stand to reaching the Runway Hold Zone (RHZ). It includes the pushback pause
- › Overall mean arrival taxi time is ~17 minutes, but varies widely
- › E.g. T2A-C to 27C ~10 minutes, T2A-C to 27R ~25 minutes
- › There may be opportunities to re-assign departure runways to reduce taxi times (e.g. more than 60% of T6 departures assigned to 27C)



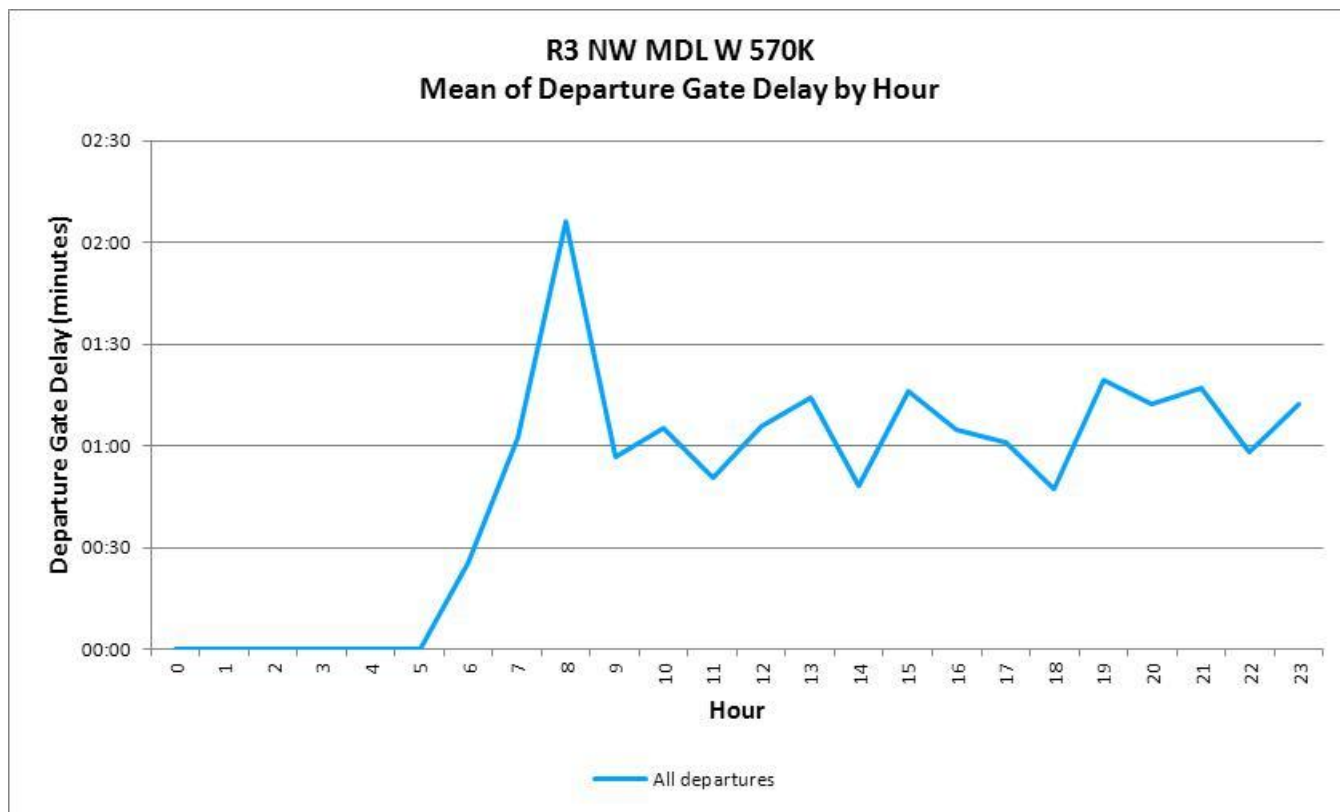
Departure Taxi times – by hour of day

- > Departure Taxi Time is the time from an aircraft leaving the stand to reaching the Runway Hold Zone (RHZ). It includes the pushback pause
- > Departure taxi times are broadly consistent over the day on each runway



Average Departure Gate Delay – All Aircraft by Hour

- > This is the delay prior to pushback due to taxiway congestion, the maximum number of aircraft taxiing for departure at any one time having been reached, or a late inbound aircraft
- > After a peak of around 2 minutes at 08:00, gate delay remains low throughout the day



Runway Crossings

- Arrivals to T4: 0
- Departures from T4: All cross 27L (55 flights per day)
- Current number of runway crossings (2013-14 mean) is 46 flights per day

Ground Interaction and Taxiway Delay Plots

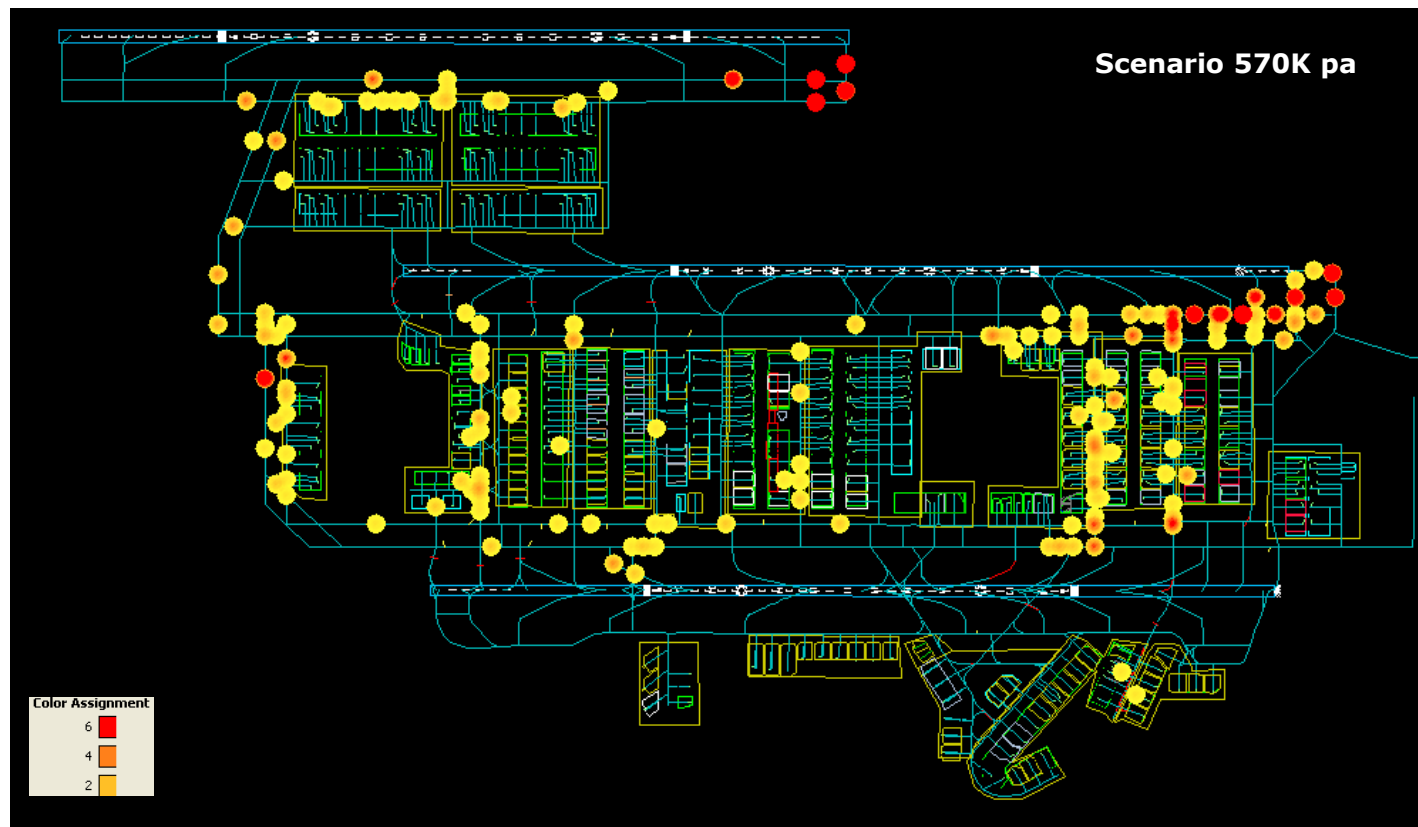
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Ground Interactions

A ground interaction is recorded in TAAM whenever an aircraft is required to wait for another, or when the speed of an aircraft is reduced to allow for another

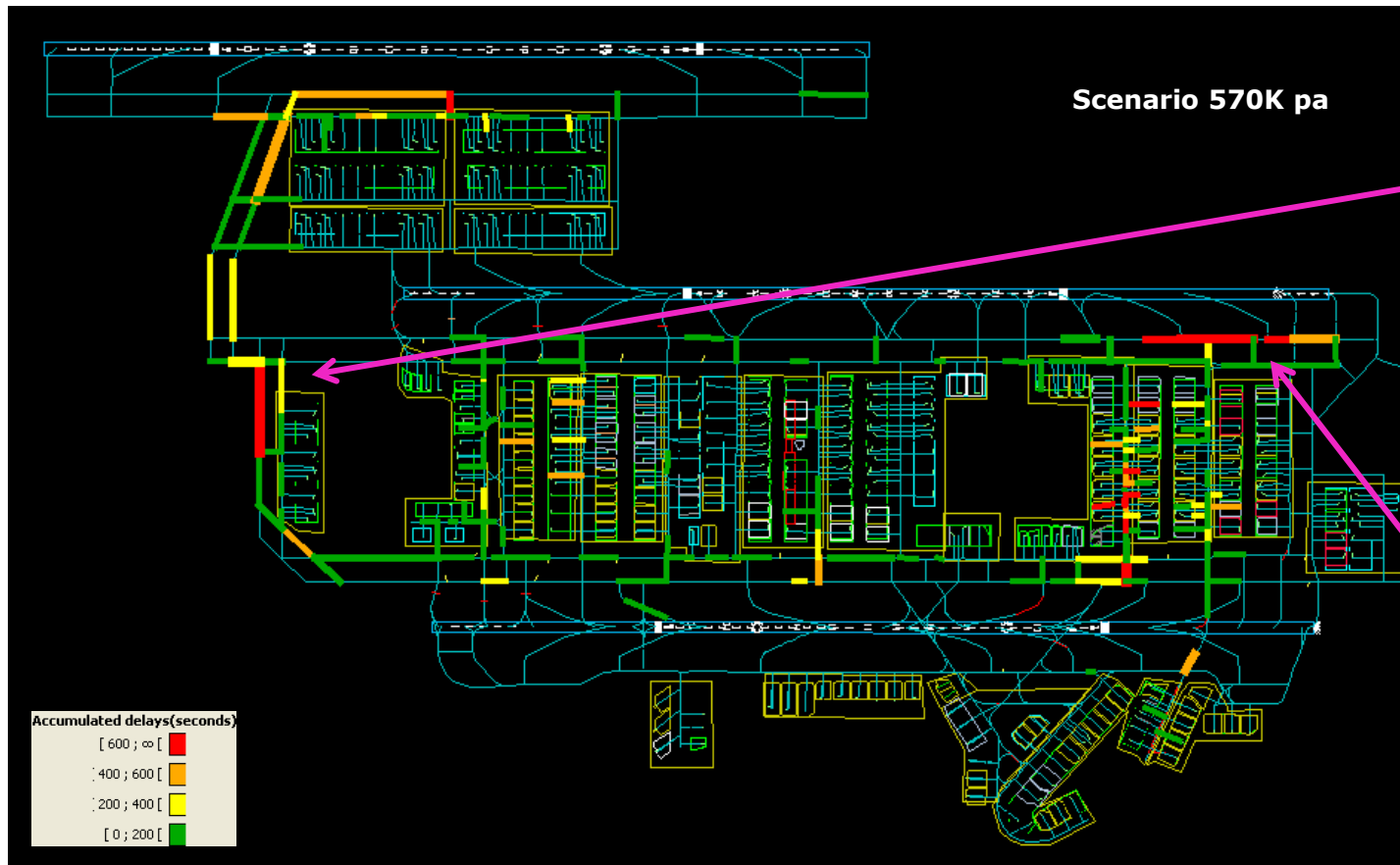
Colour (yellow, orange, red) shows an increasing number of interactions

The plots are indicative and highlight potential hotspots that can occur across the infrastructure. The plots presented show all recorded interactions from a single simulated run for each scenario



Taxiway Delays

The plots show all recorded taxiway delays from a single simulated run for each scenario
 Colour (green, yellow, orange, red) shows increasing taxiway delays. The thickness of the line increases with the number of aircraft affected



Crossing Point:
 27R & 27C
 Departures
 +
 T6 B-E deps on
 27C
 +
 27R arrivals

Holding Point Delays
 for 27R result in
 taxiway congestion
 for arrivals and
 departures