Dynamic Scheduling

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AGIFORS SSP, May 2021

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Speakers

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Agenda

Dynamic Scheduling

Schedule Feasibility

Schedule Reliability

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DYNAMIC SCHEDULING

Key Challenges for Airlines

Schedule Development

- ✓ Centerpiece of airline resource planning
- ✓ Requires input from all stakeholders
- ✓ Rigid processes, various tech platforms
- ✓ Time consuming

Demand vs Capacity

- ✓ Unmatched supply and demand result in lost revenue, pax turned away, or financial loss due to low fares

External Factors

- ✓ Slow reaction to external factors (COVID-19)

Addressing these challenges require airlines to be flexible with their scheduling practices!

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Dynamic Scheduling

	Long-Term Planning	Medium-Term Planning And Scheduling	Short-Term Scheduling	Operations Interval Day of Departure
Traditional Scheduling	Evaluate 10 -12 major scenarios each taking several days	Creates feasible monthly schedules (3w), limited time for schedule optimization (1w)	Feedback from Ops, Crew, Res, Airport, Maintenance takes days. Manual alignments, few minor modifications are possible	Only small and quick changes possible, any fix for feasibility is done at extra cost (cancels, spare aircrafts, etc.). Most revenue generating opportunities are missed
Dynamic Scheduling	Evaluate 100 -120 major scenarios each taking few hours	Creates feasible monthly schedules (1w), enough time for schedule optimization (3w)	Feedback from Ops, Crew, Res, Airport, Maintenance takes minutes. Automated checks and alignments, many modifications with various complexities are possible	Changes can be evaluated and executed very fast, hence opportunities to capture extra demand can be taken advantage of. In case of infeasibility the least costly fix can be found.

Timeline

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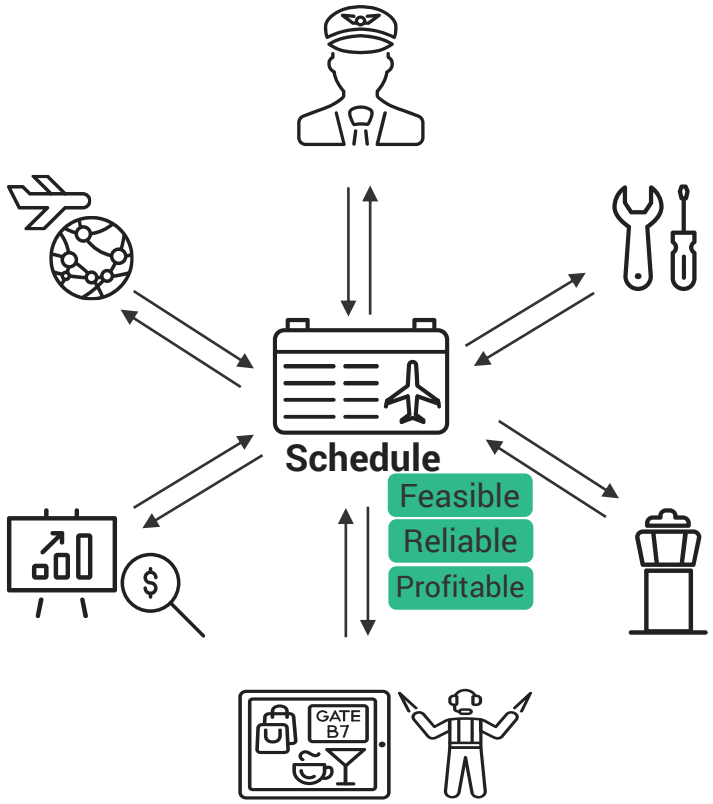
Dynamic Scheduling

Dynamic scheduling empowers airlines to *respond quickly* to *market changes* such that the modified schedule is

feasible to operate,

executable as planned,

and *profitable*!



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SCHEDULE FEASIBILITY

Ground Resources - Gates

Schedule Feasibility – Gate Planning

- Gate planning ensures that there are enough gates available to serve scheduled flights
- Critical at hubs and busy airports

Gate rules

- Event: arrival, departure
- Configuration: domestic, international
- Equipment
- Effective dates, times, frequency
- Occupancy factor
- Set up, tows, stands

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Is Schedule Feasible for Gating?

Gate Rules								
Airport	Eqp Level	Eqp.	Eff Time	Disc Time	# of GATES	Terminal	Occu. Factor	Set up Time
ZRH	Sub-fleet	330	00:00	23:59	1	A	1	10

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Case 1 - Schedule Feasibility

Switching Mode

ZRH
A 330
Capacity = 1

Flight cannot be gated. Infeasible Analysis!

Reduction Mode

ZRH
A 330
Capacity = 1

Two flights are canceled!

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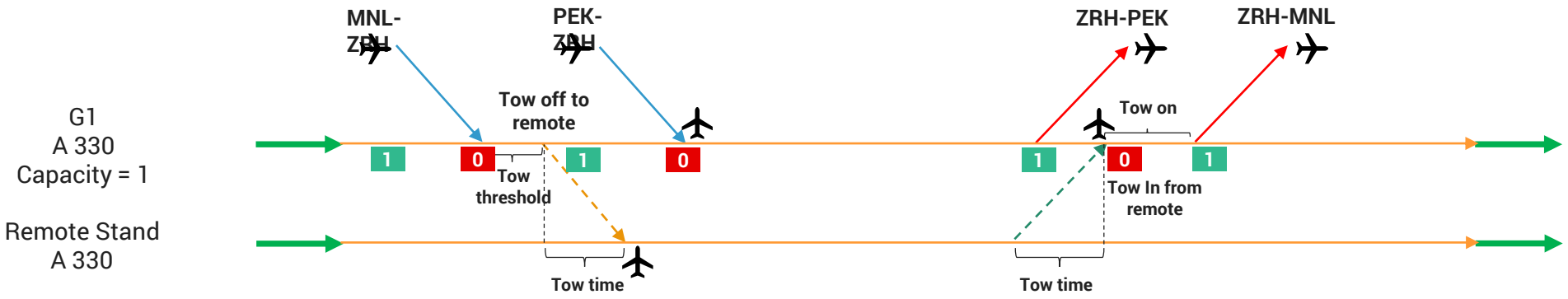
Case 1 - Schedule Feasibility



All flights served. Schedule is feasible for gating!

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Is Schedule Feasible for Gating?

Gate Rules													
Gate Definition	ARP	Eqp Level	Eqp	Eff Date	Disc Date	FRQ	Eff Time	Disc Time	# of GATES	Terminal	Occu. Factor	FLT Type	Event Type
G1	ZRH	Eqp Group	33A, 33C	12/12/2016	12/13/2016	1357	00:00	23:59	2	A	1	INTL DOM	ARR DEP
G2	ZRH	Eqp Group	33A, 33C	12/12/2016	12/13/2016	1234567	00:00	23:59	2	A	1	INTL DOM	DEP

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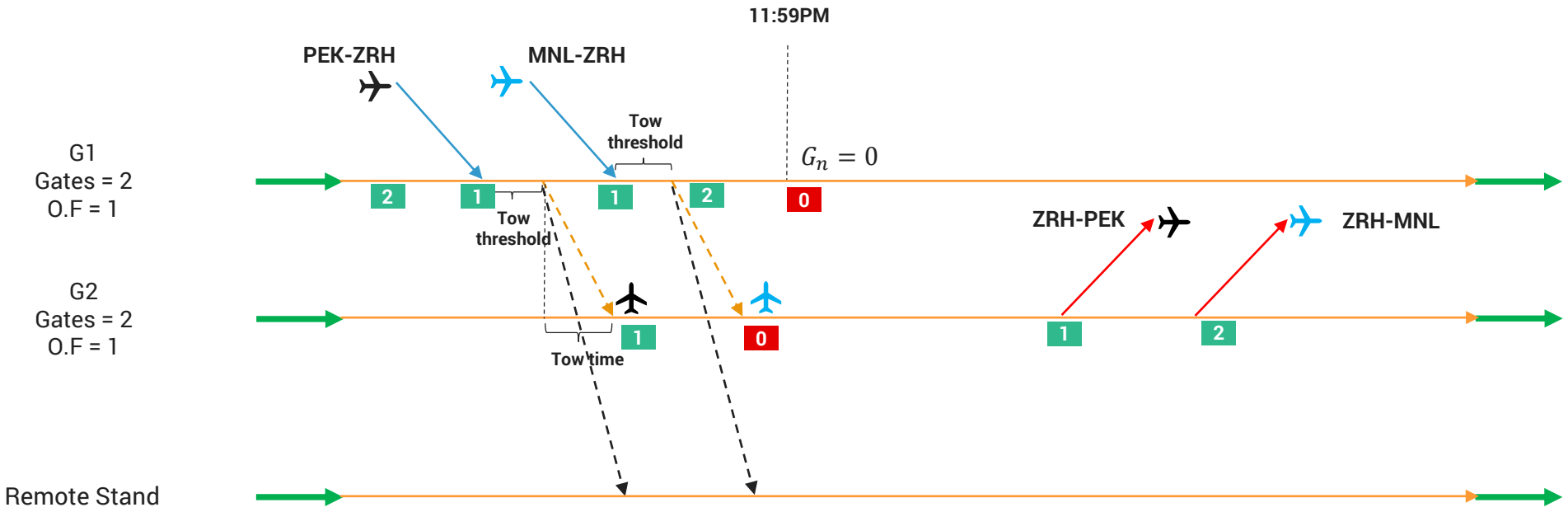
Case 2 – Schedule Feasibility



Gate Rules													
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G2	ZRH	Eqp Group	33A, 33C	12/12/2016	12/12/2016	1234567	00:00	23:59	2	A	1	INTL DOM	DEP

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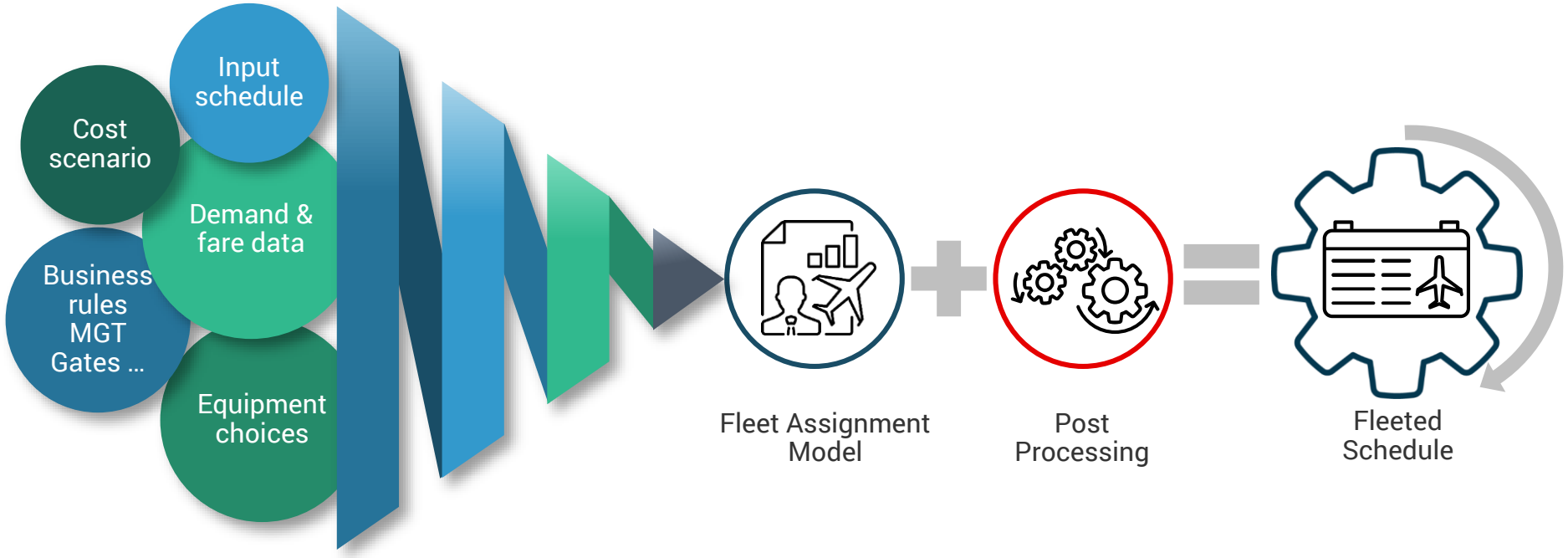
Fleet Assignment + Gate Planning



Fleet assignment is to find the optimal allocation of seat capacity to market demand given the business rules

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Fleet Assignment + Gate Planning

$$\max \sum_{j \in J} \sum_{i \in F} (R_{ij} - C_{ij}) x_{ij}$$

$s.t.$

Flight coverage $\sum_{i \in F} x_{ij} = 1 \quad \forall j \in J$

Aircraft count $\sum_{j \in M(i)} x_{ij} + \sum_{s \in S} G_{iso^-} \leq N_i \quad \forall i \in F$

Flow conservation $G_{ist^-} - G_{ist^+} + \sum_{j \in IN(i,s,t)} x_{ij} - \sum_{j \in OUT(i,s,t)} x_{ij} = 0 \quad \forall i \in F, s \in S, t \in T$

Gate flow conservation $K_{isht^-} - K_{isht^+} + \sum_{j \in IN(i,s,t)} z_{ijh} - \sum_{j \in OUT(i,s,t)} z_{ijh} = 0 \quad \forall i \in F, s \in S, h \in H, t \in T$

Gate coverage $\sum_{h \in H} z_{ijh} = x_{ij} \quad \forall j \in J, i \in F$

Gate capacity $\sum_{i \in F} K_{isht^+} \leq M_h \quad \forall s \in S, h \in H, t \in T$

$x_{ij}, z_{ijh} \in \{0,1\} \quad \forall i \in F, j \in J, h \in H$

$G_{ist}, K_{isht} \geq 0 \quad \forall i \in F, s \in S, t \in T$

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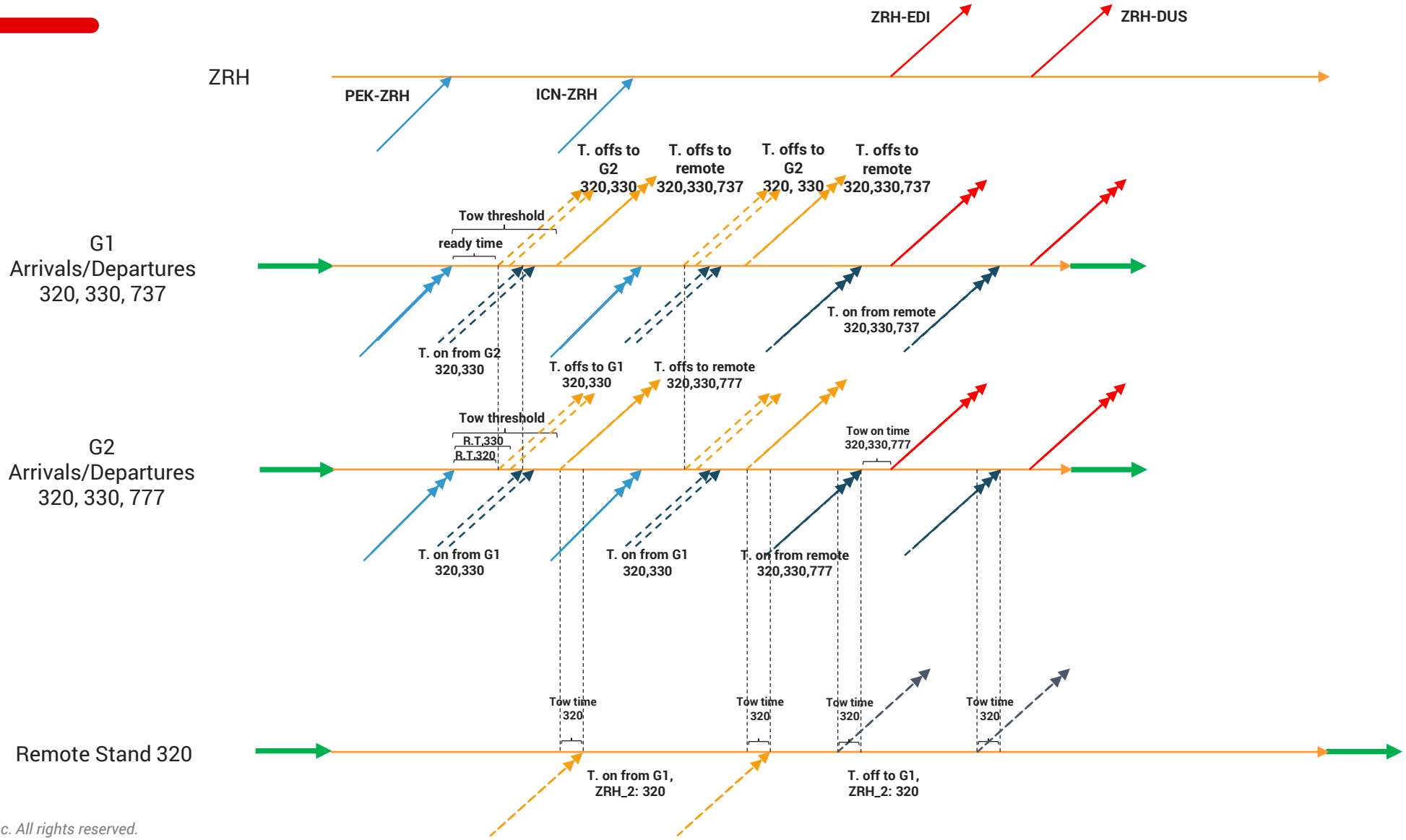
Gate Timeline



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Benchmarks

Weekly Schedule	Number of gate violations	Airport/day gate violation*
Prior to enhancement	974	144
After enhancement	553	109
Improvement (%)	43%	24%

*Airport/day gate violation is sum over all violations throughout the week for all airports.

Weekly scenario	
Flights	3,394
Sub-fleets	3
Airports with gate limit	103

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Conclusions

Given input schedule:

- Provides feedback on availability of gates for scheduled flights in all stations
- Flags gate capacity violations
- Generates and evaluates aircraft tow opportunities to reduce input schedule violations and improve gate utilization
- Optimizes and provides the least costly solution for fleet assignment along with gate operations and aircraft tows

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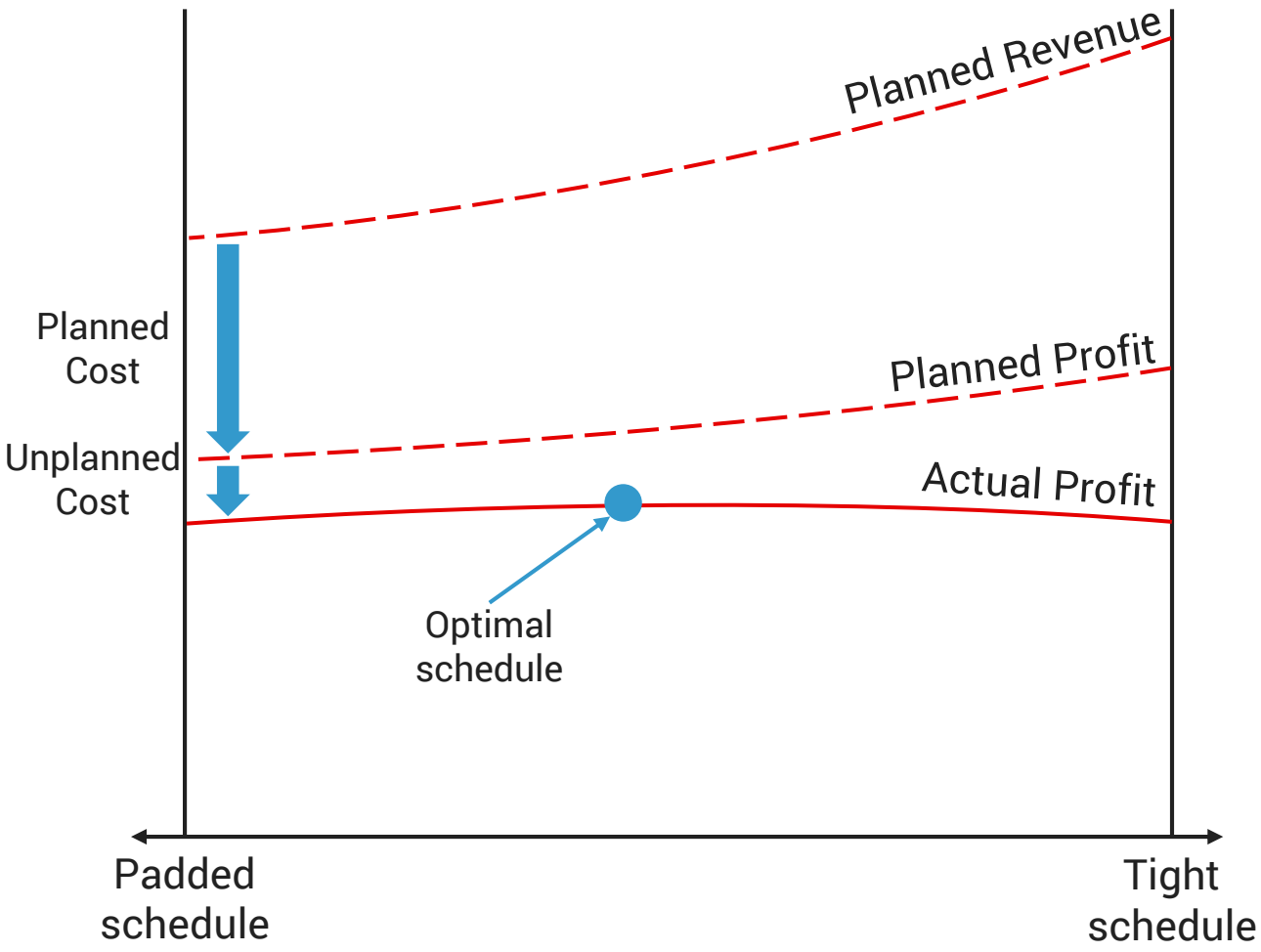
SCHEDULE RELIABILITY

Schedule Development – Balance Robustness & Profitability

- **Robustness**
  - Schedule resilient to disruptions and transferring passengers with minimum delays
- **Business Problem**
  - Improve Reliability – identify and fix potential reliability issues to improve OTP in long-term planning phase
  - Improve Profitability – increase aircraft utilization and reduce operations cost while limiting risk of disruptions
- **Solution**
  - Reliability Forecasting - use historic on-time performance to predict OTP of the future schedule and detect high-risk flights and connections.
  - Robustness Optimization - adjust block time, departure time, turn time, subfleet swaps and aircraft routings to improve OTP.
  - Visualization - Expected arrival and expected departure time in flight display and aircraft flow. Identify critical spots in the schedule that are most likely to be affected by disruptions



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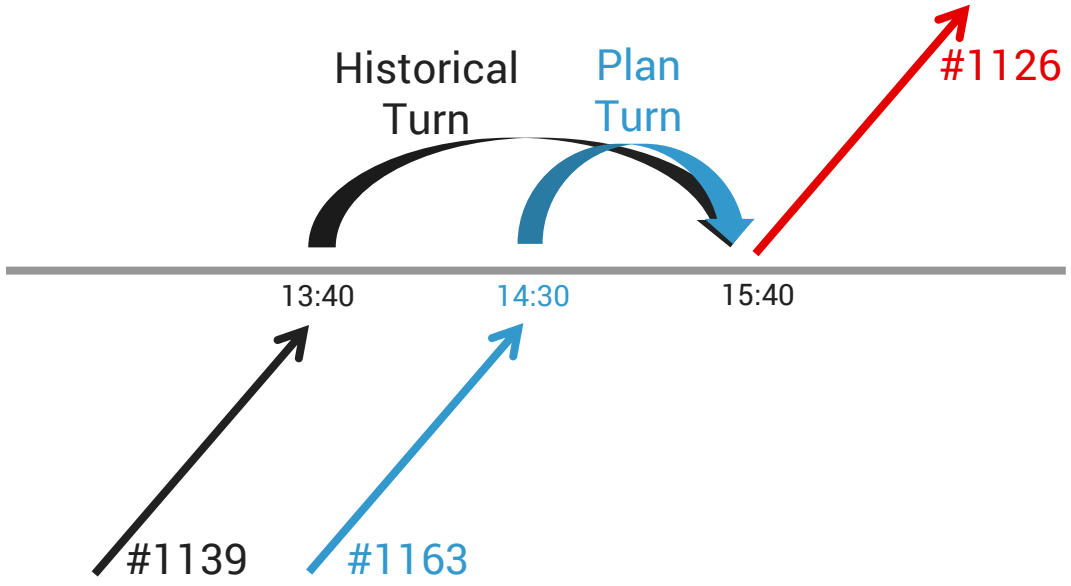
Reliability Forecasting

Report for the whole schedule

Flight	# Historical Flights	Historical OTP	# Forecast Flights	Forecast OTP
1126	150	80.33%	28	53.59%
2206	151	76.85%	28	50.19%
2428	138	70.11%	28	56.49%
2313	139	78.31%	28	62.64%
1460	151	71.72%	28	60.31%
507	146	79.28%	28	66.42%
1893	149	75.91%	28	67.84%
504	148	83.92%	28	60.01%
1360	144	80.10%	28	59.95%
1228	137	80.91%	28	58.15%
…	…	…	…	…

Individual flight analysis



Delay Reason:

- MGT: 70 min
- Historical Turn: 120 min
- Plan Turn: 80 min

Improvement Opportunities:

- Add ground time
- Consider re-routing
- Improve turn management
- Pad block time

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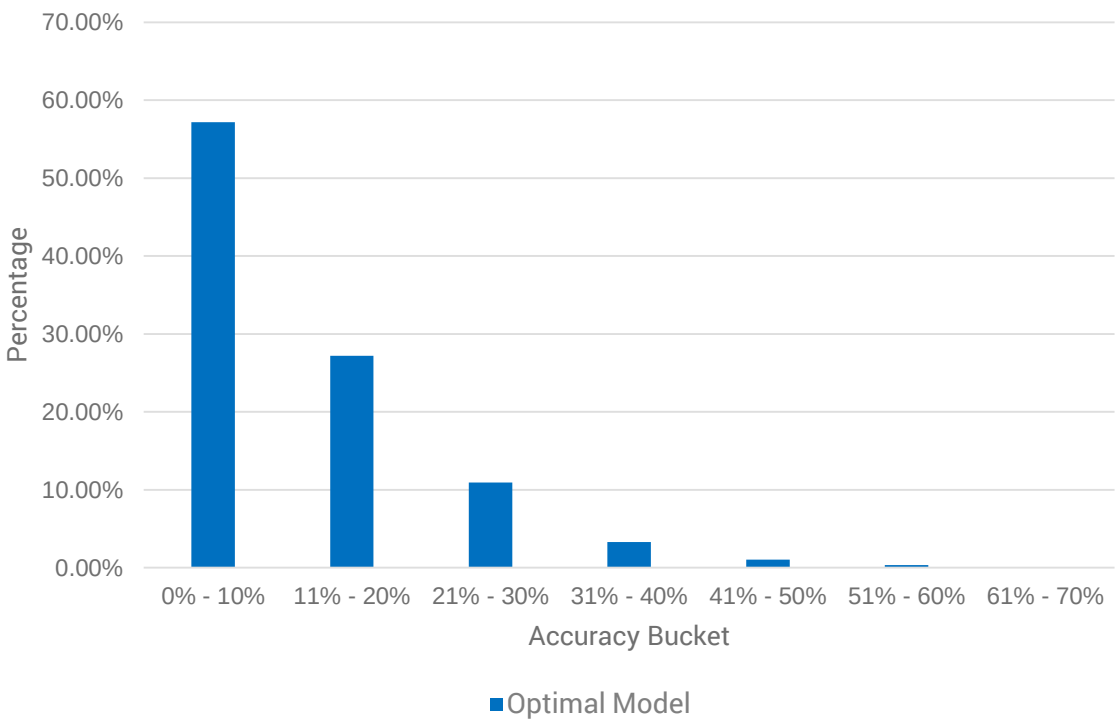
Forecast Accuracy – Validation

Network Level Error

Model	A15 OTP
Simple Average	86.95%
Accurate Model	70.86%
Actual	70.82%

Flight Level Error



Optimal Model is very close on the Network Level and accurately predicts over 85% of the individual Flights

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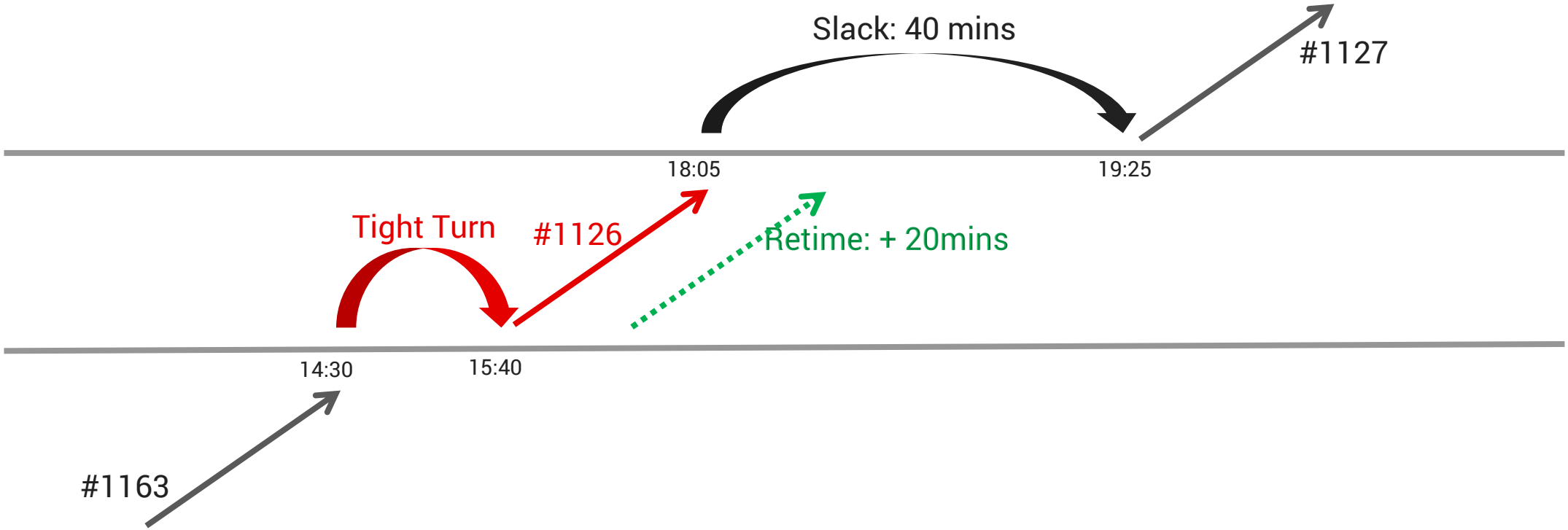
Recommendations

Flight	Historical OTP	Forecast OTP	Forecast OTP New
#1126	80.33%	53.59%	74.64% ↑



Adding Ground Time results in improved OTP for #1126 with no affect on #1127

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Reliability Objectives

Achieve the right balance between OTP and costs.

- Predict the OTP of future schedules and associated operating and delay costs.
- Create an optimized robust future schedule more resilient to disruptions and capable of transferring passengers with minimum delays.

Expected results:

- Reduce delays and unplanned delay costs.
- Increase revenue through more efficient aircraft utilization.
- Identifiable, measurable cost savings and revenue gains.
- Improve customer satisfaction, raise Net Promoter Score and re-attract customers lost to poor historical performance.

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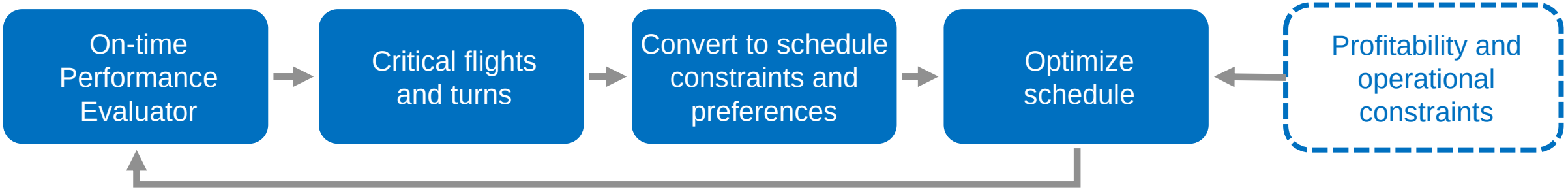
Reliability for Current Schedule

Iterate between OTP Evaluator and Schedule Optimizer until target Reliability-Profitability balance is achieved



- Robust Retiming - allocate schedule slack to the most critical turns
- Block Time Optimization - select optimal scheduled block time values to balance multiple KPIs
- Robust Aircraft Routing - schedule that can be easily recovered in case of disruption

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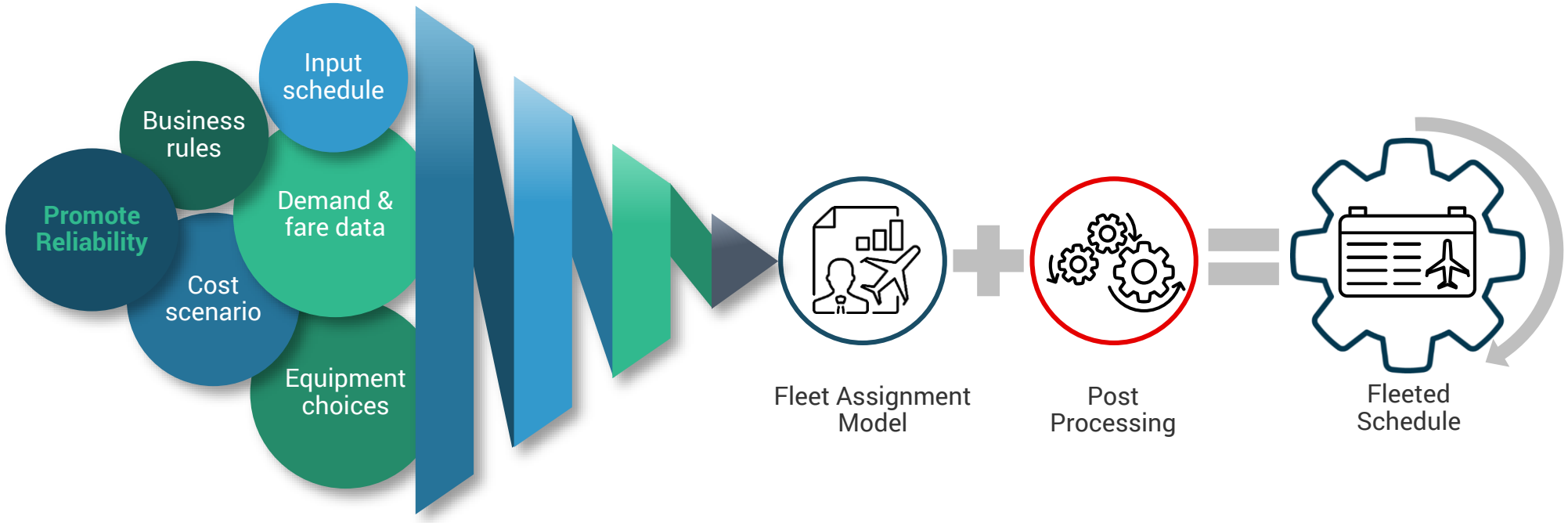
Fleet Assignment + Reliability



Fleet assignment is to find the optimal allocation of seat capacity to market demand given the business rules

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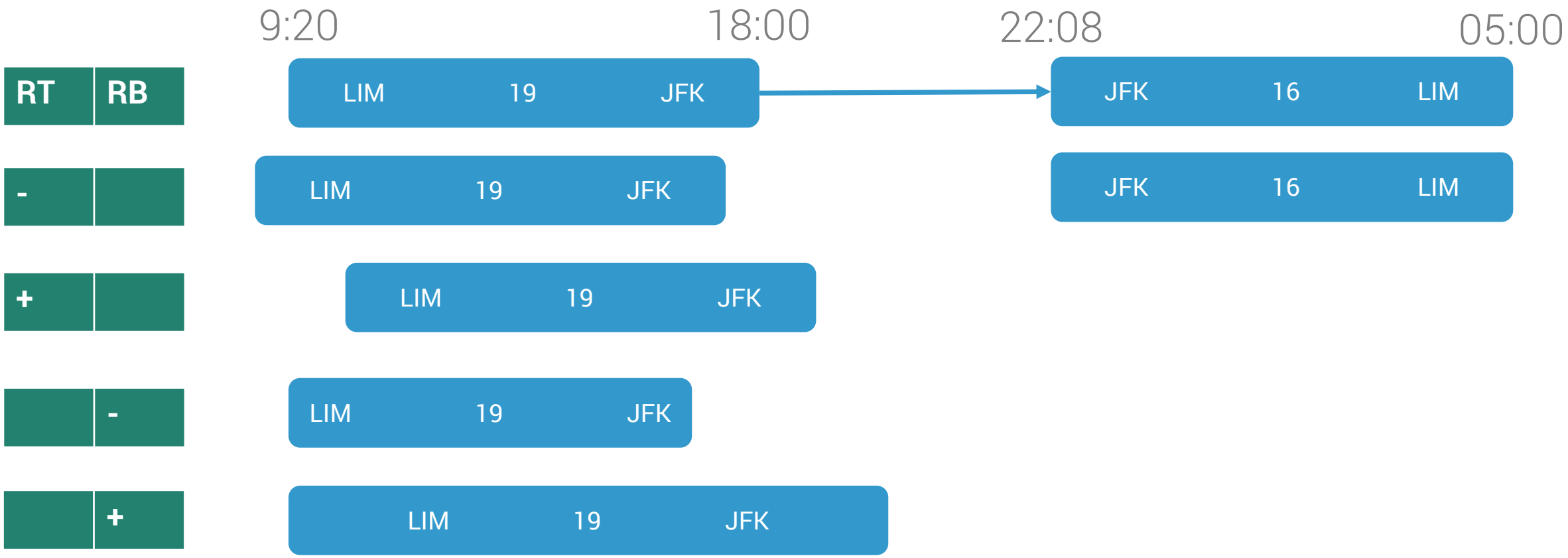
Retime or Reblock



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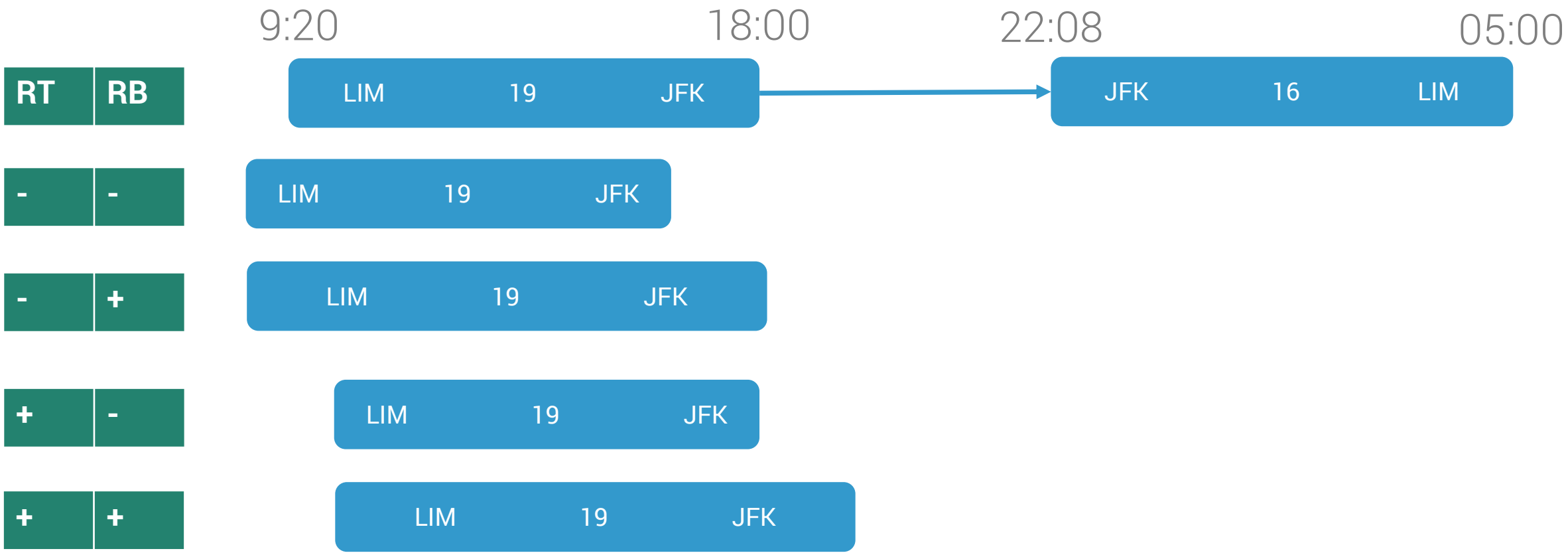
Retime and Reblock



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Flight Copies

- Retime
- Controlled by step size and pre, post time limits.
- For -10, +10 with step of 5 there can be 5 retime values -10,-5,0,+5,+10
- Reblock
- Controlled by block reliability constraints.
- For -15, +15 with step of 5 there can be 7 reblock values -15,-10,-5,0,+5,+10,+15
- Combinations:
- In this example there can be 5 times 7 = 35 flight copies each starting at different time with different block time. (r,b) denotes the change. Only (0,0) is in original problem. We add 34 copies – not all will be feasible due to MGT. We add all and let model pick one that is feasible.
-

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Fleet Assignment + Reliability

$$\max \sum_{k \in J} \sum_{i \in F} (R_{ik} - C_{ik}) x_{ik} + \alpha * Network\ OTP$$

$s.t.$

Flight coverage $\quad \sum_{k \in copies(j)} \sum_{i \in F} x_{ik} = 1 \qquad \forall j \in J$

Aircraft count $\quad \sum_{k \in M(i)} x_{ij} + \sum_{s \in S} G_{iso^-} \leq N_i \quad \forall i \in F$

Flow conservation $\quad G_{ist^-} - G_{ist^+} + \sum_{k \in IN(i,s,t)} x_{ik} - \sum_{k \in OUT(i,s,t)} x_{ij} = 0 \quad \forall i \in F, s \in S, t \in T$

Network OTP $\quad \sum_{k \in J} \sum_{i \in F} otp_{ik} * x_{ik} = Network\ OTP$

Block time budget $\quad \sum_{k \in J} \sum_{i \in F} Block_Delta_{ik} * x_{ik} \leq Block\ time\ budget$

For each flight copy k we know parent flight j

$x_{ik} \in \{0,1\} \quad \forall i \in F, j \in J, k \in copies(j)$

$G_{ist} \geq 0 \qquad \forall i \in F, s \in S, t \in T$

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Results

Run	Block Time	A0	B0
Baseline	0	74.3	74.6
Unconstrained	+6.2%	84.5	84.9
No Budget for block time	0%	77.4	75.3

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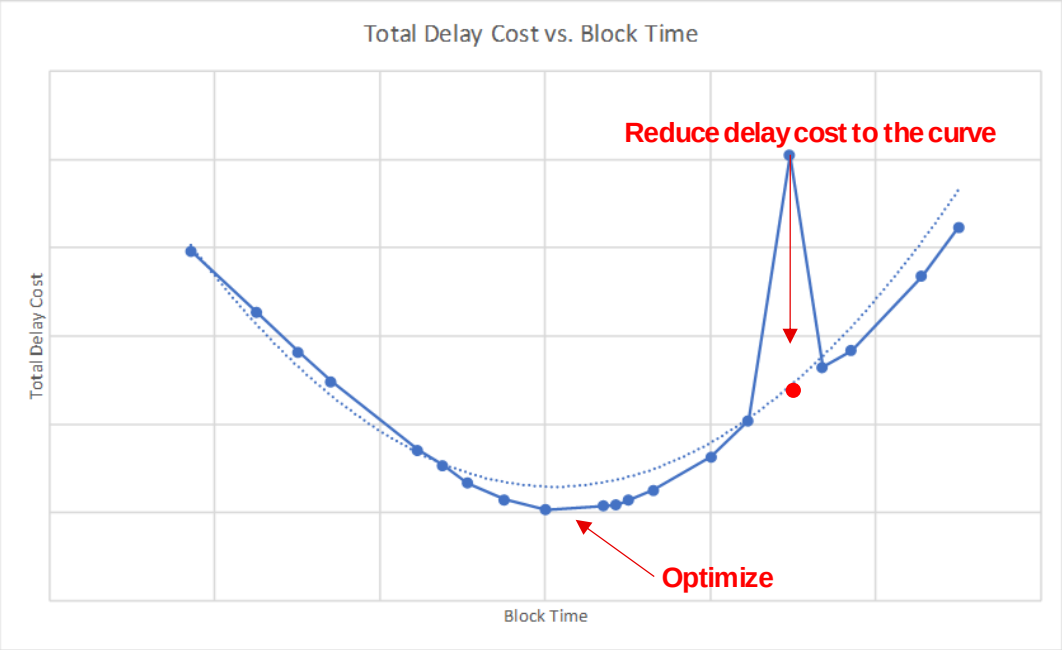
Results

Recommendation	Annual Cost Savings	OTP Impact	Annual Block Time Impact
Reduce delay cost to the curve	$2 to $6 Million	+0.9 to 2.4 OTP point increase	No change
Optimize to reduce delay costs	$9 to $19 Million	+0.3 to +1.3 OTP point increase	Block hour reduction 3% to 7%



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Conclusion

- Reliability of current schedule
  - Forecast KPIs
  - Inspect schedule for critical flights and turns
  - Improve reliability along with profitability and feasibility
- Reliability of future schedule
  - Balance profit and reliability
  - Redistribute buffers to gain OTP with no additional cost
  - Block time optimization
  - Ground time buffers

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