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Integrated Analysis of Airportal Capacity and Environmental Constraints

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Task Description

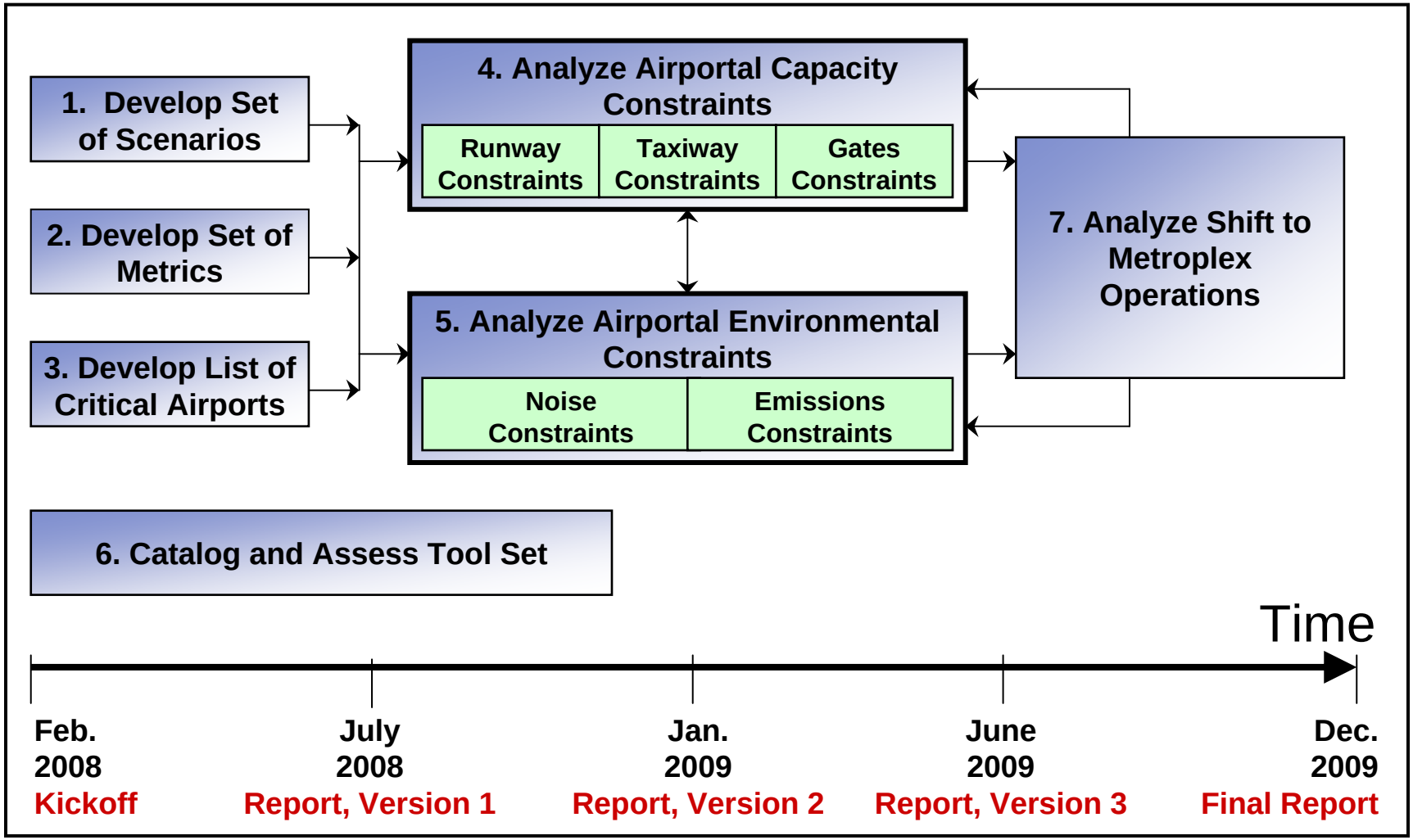
- Objective:
  - Identify and rank the key factors limiting the achievement of the capacity goals of NextGen
  - Identify gaps in available tools for conducting system-level trade and benefit studies
  - Results will help prioritize NASA's research to enable NextGen

- Outcomes:
  1. Define a set of critical airports and the most significant limitations to airport capacity at those airports
  2. Define the relevant environmental constraints that limit Airportal capacity growth
  3. Catalog the available tool set for analysis and modeling, assess gaps
  4. Estimate the point of diminishing returns for hub capacity increases vs. shifting to metroplex operations

Notional Mock-up of Key Results

			VMC Airport Constraints					
			Runway		Surface		Environment	
ID	Apt	Rank	R.O.T.	Spacing	Gates	Taxi	Noise	Emissions
1	ABQ	29	-	-	-	-	1	2
2	ALB	47	-	-	-	-	1	2
3	ANC	74	-	-	-	-	2	1
4	ATL	3	1	2	-	-	-	-
5	AUS	44	-	-	-	-	1	2
6	BDL	85	-	-	-	-	1	2
7	BFL	92	-	-	-	-	1	2
8	BHM	55	-	-	-	-	1	2
9	BNA	83	-	-	-	-	1	2
10	BOI	64	-	-	-	-	1	2
11	BOS	9	2	1	-	-	-	-
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Overview of Subtasks and Schedule



Subtasks Completed

- Subtask 1: Develop Set of Scenarios
  - 2007, 2015, and 2025 demand
  - Capacity per JPDO NextGen deployment schedule
- Subtask 2: Develop Set of Metrics
  - Primary metric for this study is “projected throughput”
  - Recommended rich set of metrics for use by NASA Airportal project
- Subtask 3: Develop Set of Critical Airports
  - Set of 310 airports which cover 98.6 percent of all air carrier operations and 99.8 percent of air carrier enplanements
- Subtask 6: Catalog and Assess Tool Set
  - Final comprehensive report and database tool

Subtasks In Progress

- Subtask 4: Analyze Airportal Capacity Constraints
  - Developed the runway capacities and have done initial constraint analysis
  - Completed initial gate constraint modeling and analysis
  - Started the detailed taxiway modeling of a few airports
- Subtask 5: Analyze Airportal Environmental Constraints
  - 2025 fleet forecast augmented to use FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) and N+1 Subsonic Fixed Wing projections with a 2016 insertion
- Subtask 7: Analyze Shift to Metroplex Operations
  - Started to brainstorm technical approach but have not begun analysis

Subtask 4.1: Analyze Airportal Capacity Constraints (Runways)

Runway Capacity Analysis at 310 Critical Airports

- We assume no change to the airport capacities at the smaller 200 airports
  - Likely cost prohibitive to deploy NextGen technologies so widely
- For the 110 larger airports, their capacities can be increased by
  - New runways
  - NextGen technologies
- One primary airport runway configuration for each meteorological operating condition
- Airport runway configurations based on analysis of FACT2 and FAA configurations, airport diagrams, capacity data, procedure charts, and knowledge from prior tasks

Projected Throughput Based on Runway Capacity

- Only the runway capacities are considered
  - There is no other constraint assumed
- Capacities are allocated along the Pareto curve to give the best balance between the arrival and departure capacities
- Extra demand is removed from the schedule (trimmed) according to rules enforced by our model for demand/capacity (D/C) ratios
  - The process is done for every epoch of 15 minutes
- The rules for D/C ratios
  - Cannot exceed 1.2 for every 15-minute epoch
  - Cannot exceed 0.9 for every rolling hour
  - Same ratios as used for JPDO studies
  - Allows for short-term spikes but also the need for recovery
  - Targets a relatively high level of service (low delay)

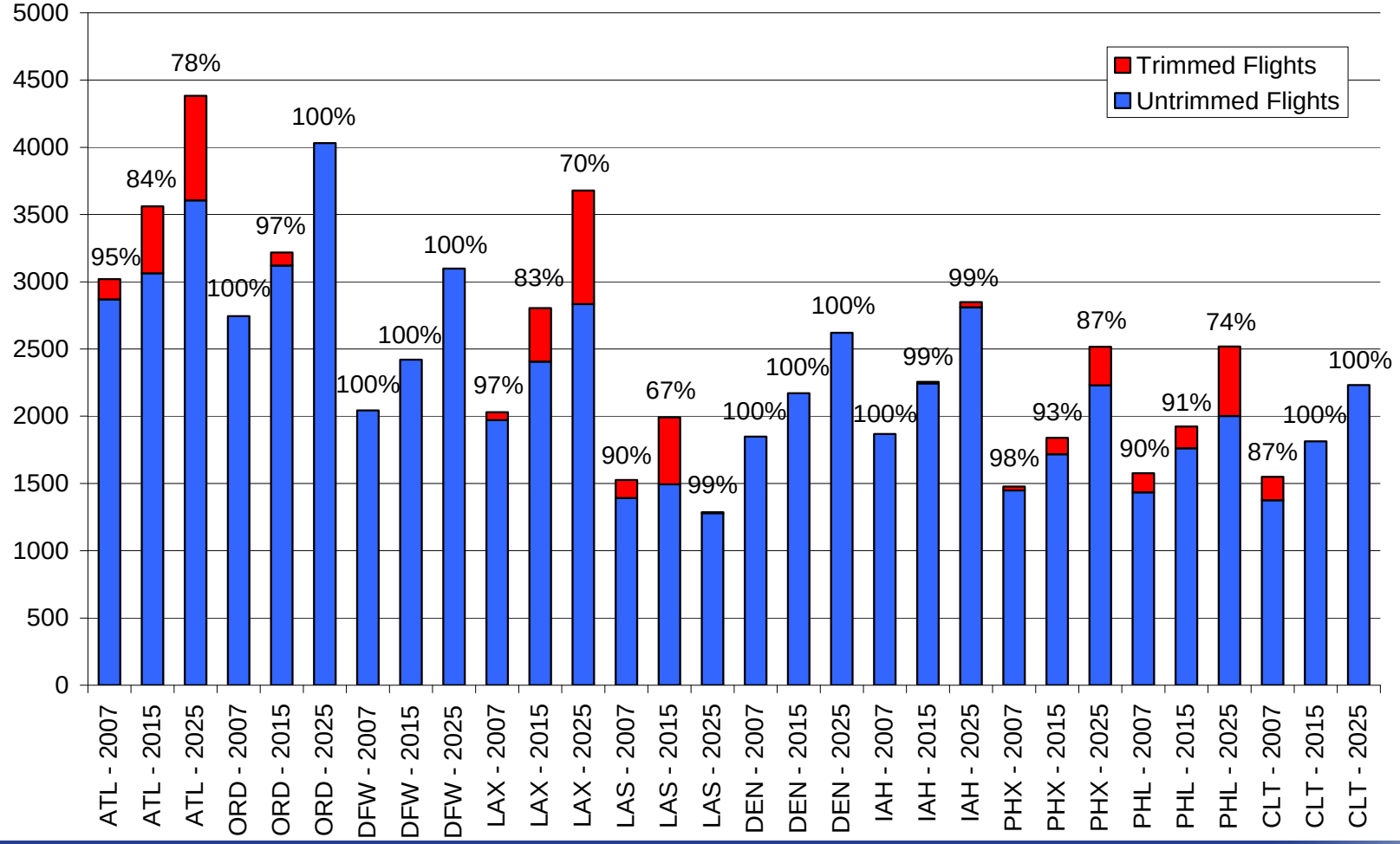
Projected Throughput Results: Overview

- Significant flight reductions (unsatisfied demand) at the busiest hub airports
- Flight reductions in later years grow at some major airports, as demand increases at a rate faster than some of the NextGen improvements
- However, flight reductions at many airports decrease or are eliminated in future years, as capacity enhancement from new runways and NextGen improvements outpace demand growth (e.g., ORD in 2025)

Subtask 4.1: Analyze Airportal Capacity Constraints (Runways)

Projected Throughput Results: Top 10 Airports

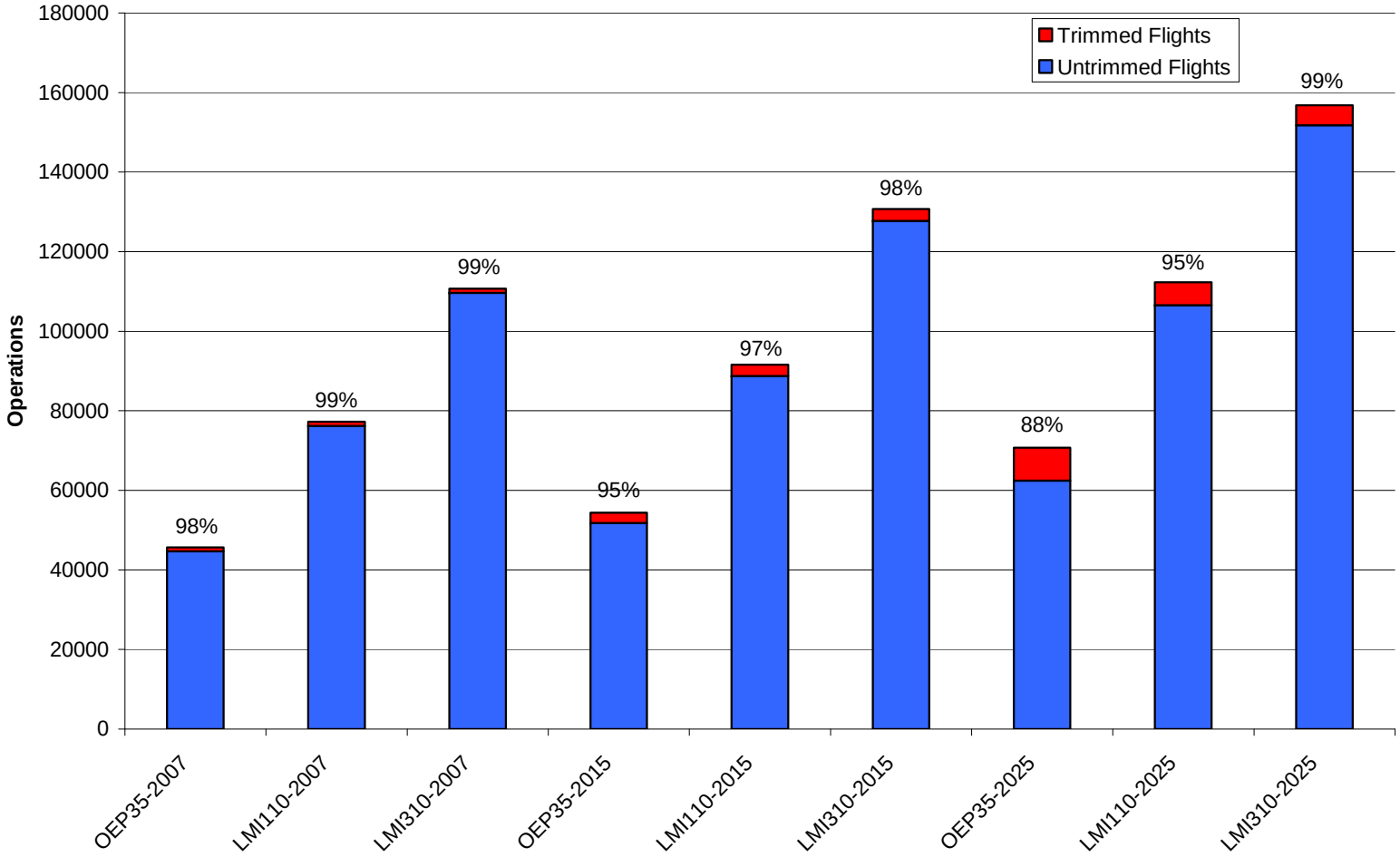
The percentage = projected throughput / unconstrained throughput



Subtask 4.1: Analyze Airportal Capacity Constraints (Runways)

Projected Throughput Results: Comparison

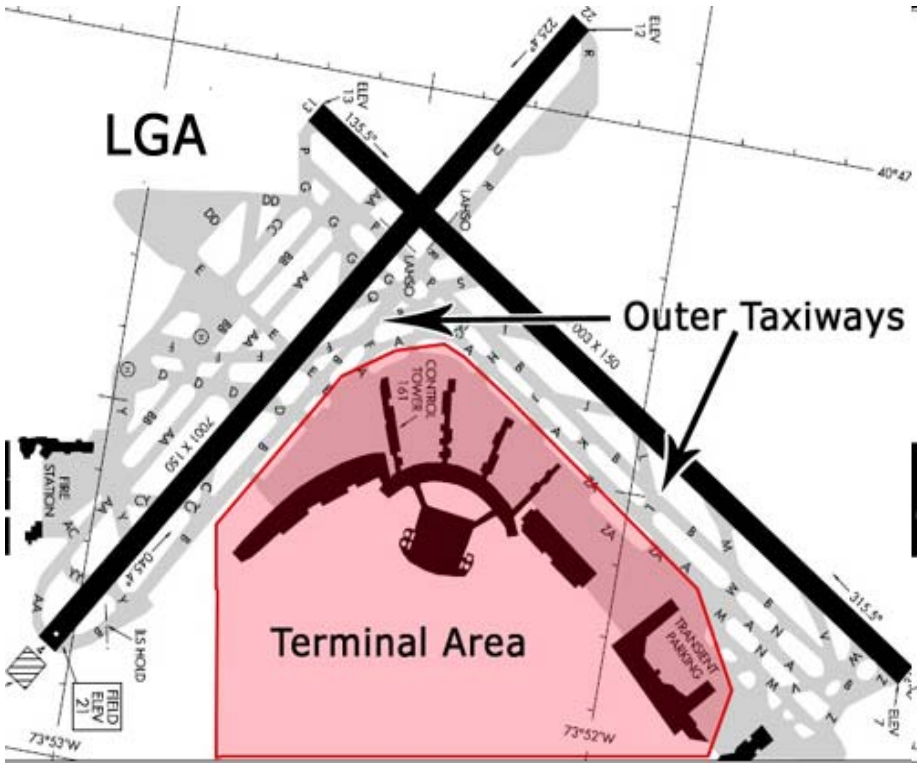
The percentage = projected throughput / unconstrained throughput



Subtask 4.2: Analyze Airportal Capacity Constraints (Taxiways)

Approach to Developing Taxiway Capacity Model

- Divided the airport surface into two regions: terminal area, and outer taxiways
- Focused on the outer taxiways; for the majority of the airports in this study, congestion in the terminal area is not a concern
- Flag airports with characteristics that typically lead to terminal area congestion (narrow alleyways, aircraft pushback into taxiways, etc.) and adjust expected taxi delays appropriately



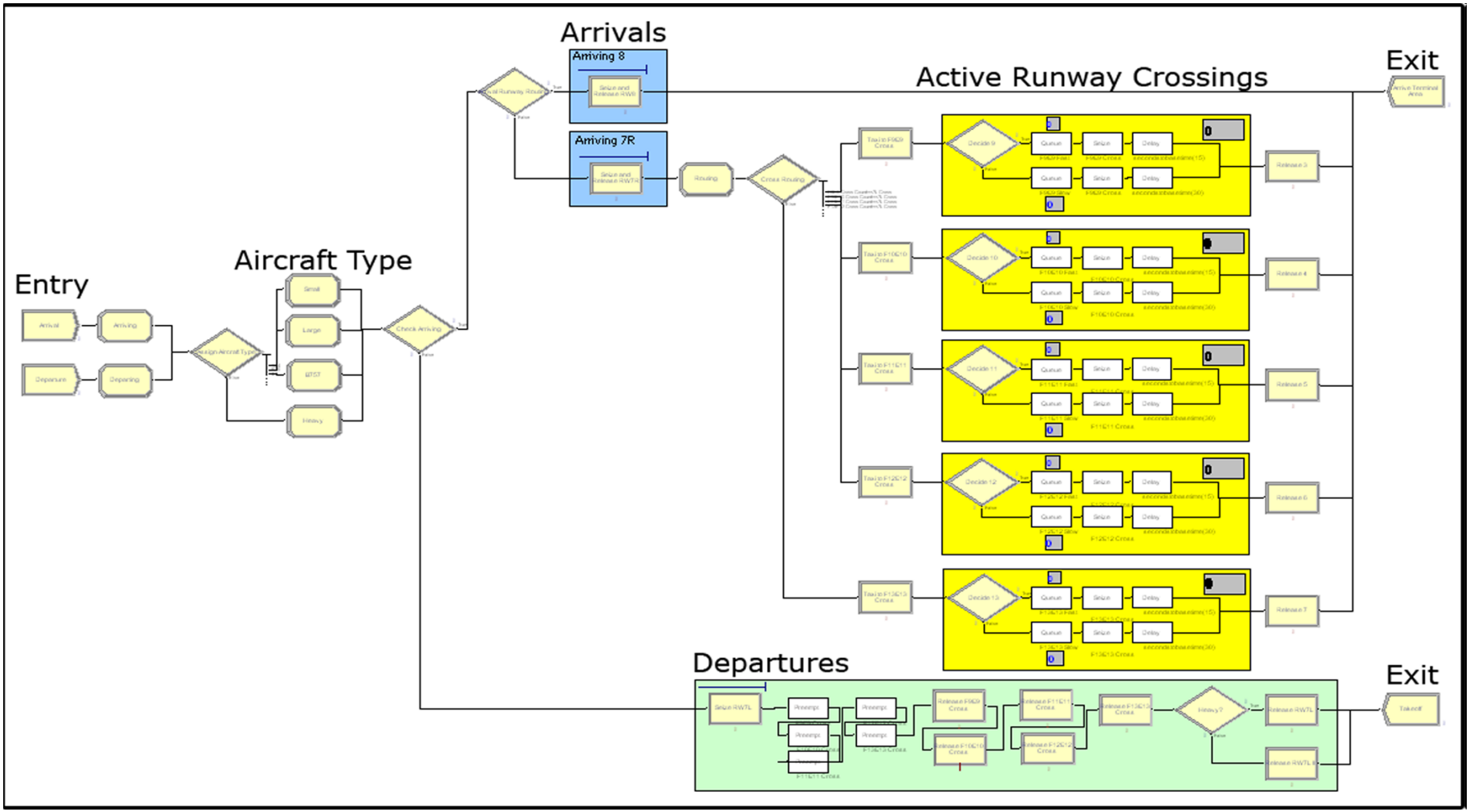
Subtask 4.2: Analyze Airportal Capacity Constraints (Taxiways)

Approach to Developing Taxiway Capacity Model

- Used off the shelf simulation software (Rockwell's Arena)
- Focused only on bottlenecks formed by active runway/taxiway interaction
- Runways and runway crossings modeled as resources
- Taxiing aircraft can be preempted from runway crossings by landing or departing (high priority) aircraft
- Delays take place as aircraft wait for runway crossings to become available
- Delays can be calculated by comparing high demand taxi times to those of very low demand

Subtask 4.2: Analyze Airportal Capacity Constraints (Taxiways)

Taxiway Capacity Model Example: PHX



Taxiway Capacity Model: Progress to date

- Taxiway capacity models have been built for:
  - SAN (1 active runway without active runway crossings)
  - LGA (2 non-parallel active runways with active runway crossings)
  - PHX (2 parallel active runways with active runway crossings)
  - SEA (3 parallel active runways with active runway crossings)
- Analysis for these models has not yet been conducted
- Next up: ATL, DFW, ORD

Determining Airports' Gate Capacity

- An airport's gate capacity is determined by many complex interrelated factors
- No centralized source for data on gate capacity
  - We collected gate count data for the top 310 airports from a wide variety of sources
  - No data on which gates can serve which types of aircraft
- The data that are available are unreliable and follow many different definitions for a "Gate"
  - We focused on gates with passenger bridges
    - Adding additional space for ground-loading aircraft is relatively easy compared with adding additional passenger bridge-equipped gates
    - Airlines increasingly prefer to use passenger bridges

Gate Capacity: Important Assumptions

- All airlines have equal access to all gates, regardless of current gate-access leasing agreements
- Due to the shortage of airport-specific information, we have also assumed that all gates can service all aircraft types
  - This ignores aircraft spacing requirements
  - Unfortunately there is no information available on what types of aircraft a given gate at a given airport can accommodate
  - We developed a supplementary tool to track growth in the maximum required terminal frontage for each airport (more on this later)

Developing the Gate Capacity Model

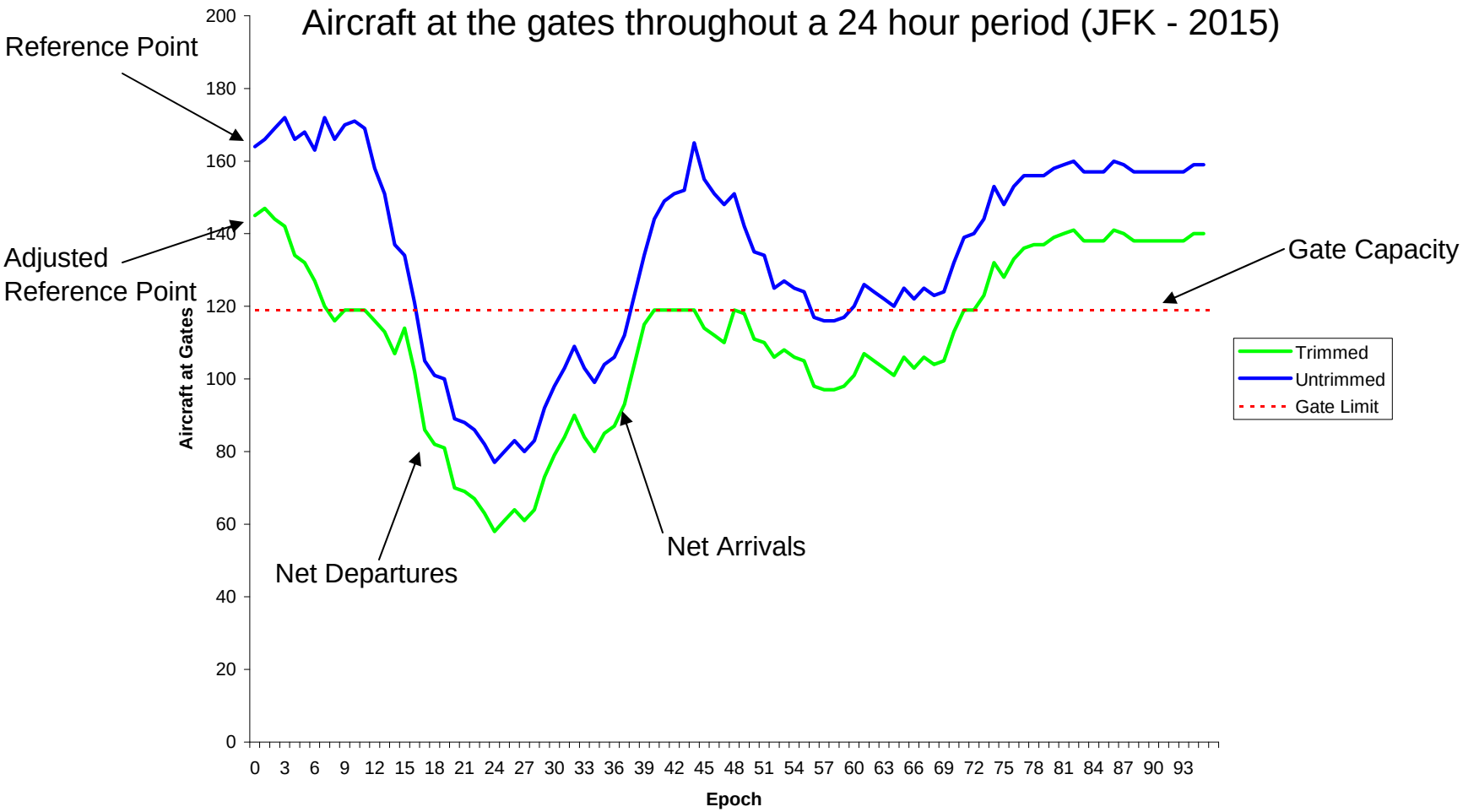
- Basic steps of the model
  1. Use FAA-provided schedules to estimate the number of aircraft on the ground at the beginning of the day for each airport
  2. Use this reference point and the same schedules to track the number of aircraft at the gates throughout a 24 hour period
  3. When gate capacity is exceeded, trim arrivals (and departures) from the schedule
  4. Adjust the estimate for the number of aircraft on the ground at the beginning of the day to reflect schedule trimming
  5. Repeat steps 3 and 4 until the reduction in operations is proportional to the reduction in the number of aircraft on the ground at the beginning of the day

Model Execution: Terminal Frontage Requirements

- The model also calculates and compares current and future terminal frontage requirements to help identify aircraft spacing problems
  - We categorized aircraft according to the FAA's gate-group categorization system
  - Space requirements were defined as each category's maximum wingspan plus the FAA's suggested wingtip-to-wingtip gate spacing
  - We cycle through the arrival and departure schedules to calculate the change in the terminal frontage requirement throughout the day
  - We can get an estimate of each airport’s growth in this requirement by comparing the 2007, 2015, and 2025 maxima

Subtask 4.3: Analyze Airportal Capacity Constraints (Gates)

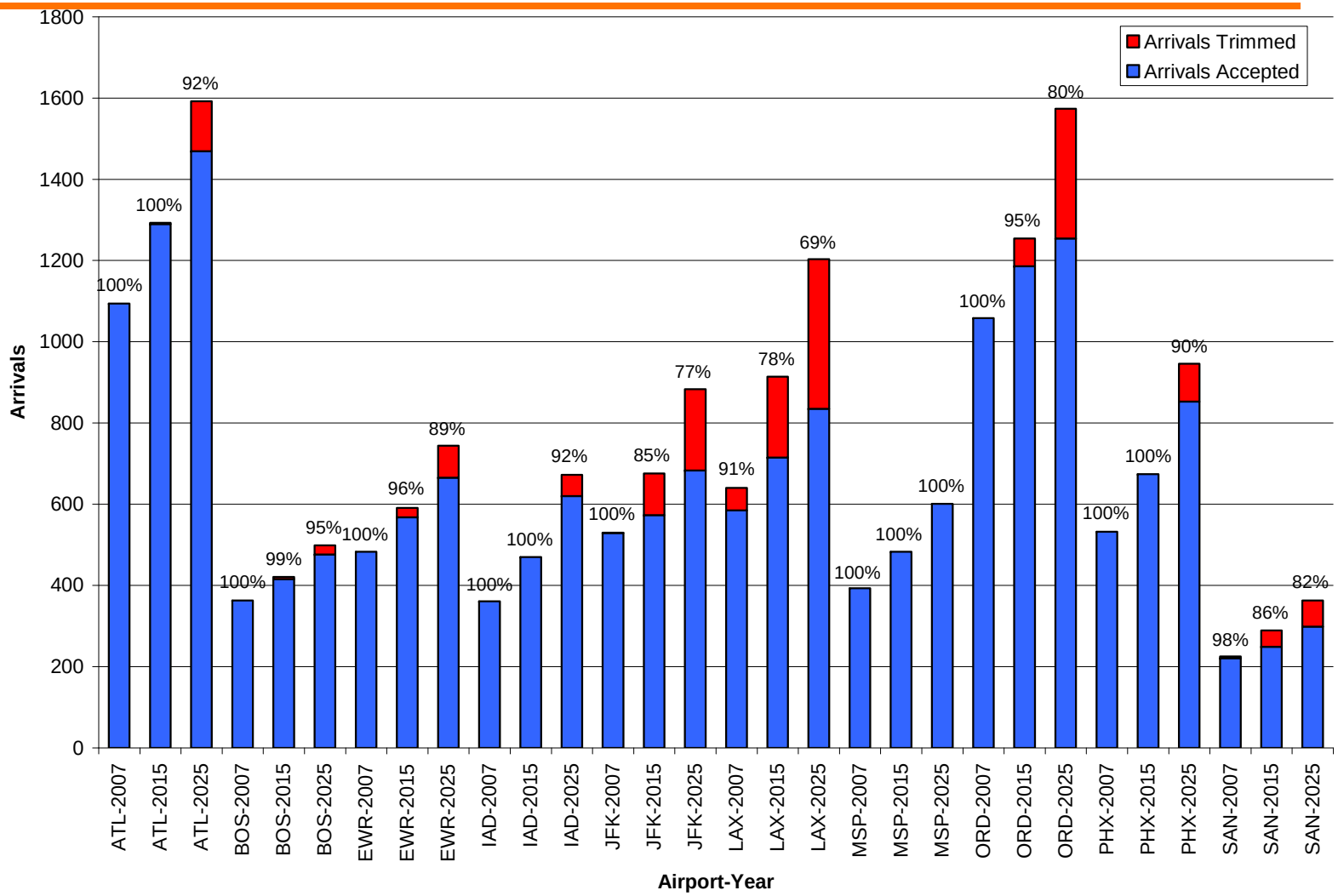
Model Execution Example: JFK Int'l Airport (JFK)



Note: Epoch 0 corresponds to 9:00 AM GMT

Subtask 4.3: Analyze Airportal Capacity Constraints (Gates)

Preliminary Results for a Sample of Large Airports



Remaining Work

- We are on schedule
- Subtask 4: Analyze Airportal Capacity Constraints
  - Complete the constraint analysis under the hypothetical scenarios when the ROT or MIT are not binding, respectively
  - Update gate constraint analyses
  - Continue the detailed taxiway modeling of airports
- Subtask 5: Analyze Airportal Environmental Constraints
  - Airport modeling and environmental constraint modeling
- Subtask 7: Analyze Shift to Metroplex Operations
  - Outline the approach and start the modeling
- Results synthesis
  - Compile and identify the primary and secondary airportal constraints

Backup Material

Subtask 4:
Analyze Airportal Capacity Constraints

- Along with the analysis of environmental constraints, this is (half of) the heart of the work
- We will rely on the approach we have developed and refined over several years of NASA and JPDO work which estimates a metric called “projected throughput”
- Use of this metric allows for an analytical “common currency” to evaluate the Airportal constraints
  - Runways
  - Taxiways
  - Gates
  - (as well as the environmental constraints)

Motivation for Using Projected Throughput as a Metric ("schedule trimming")

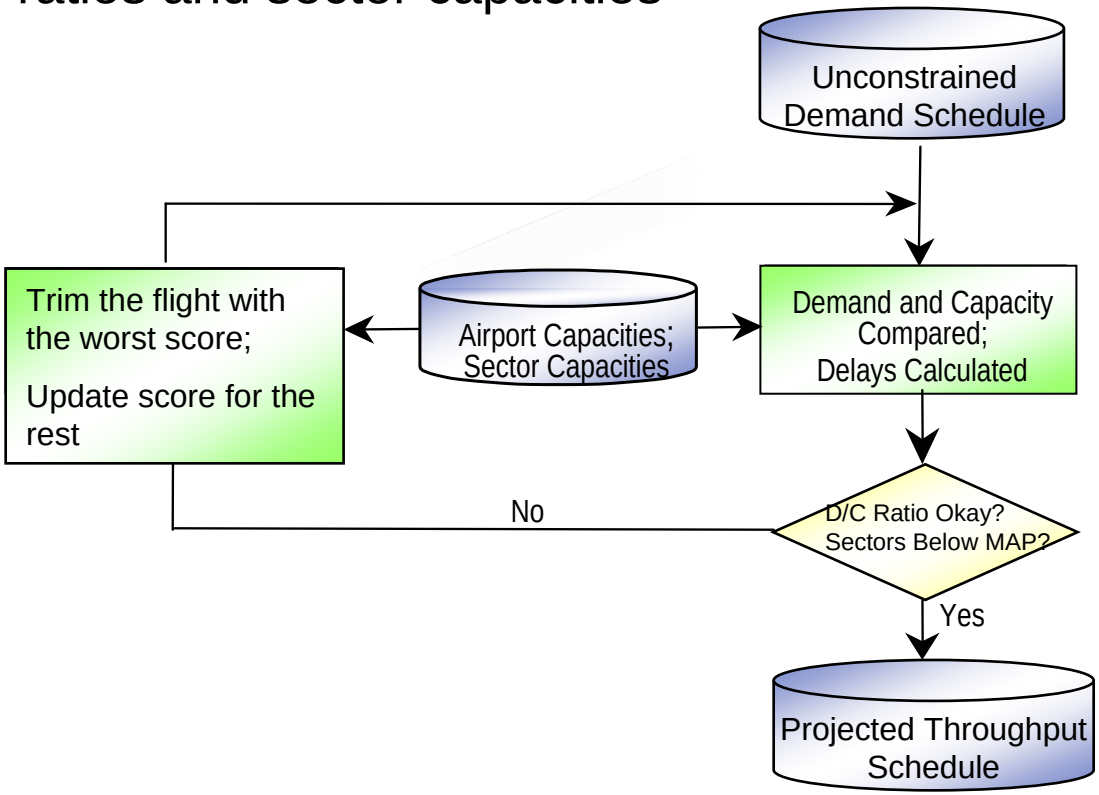
- "Unconstrained demand" (e.g., the FAA's Terminal Area Forecast) represents the public's desire for air transportation regardless of whether sufficient future NAS capacity will exist
- Without sufficient capacity, future flight schedules would incur unrealistically large delays if all the flights in the unconstrained schedule were actually flown
  - Traditional valuation methods based on delay reduction may not be appropriate for far-term states of the system
  - While it's easy to mathematically compute the DOC and passenger value of time benefits for a hypothetical case of reducing delay from 500 minutes to 300 minutes, what is the interpretation?

Motivation for Using Projected Throughput as a Metric ("schedule trimming")

- At some point, capacity constraints would lead schedule-conscious airlines to cease adding additional flights to the schedule, even though the demand would exist; to represent this, we analytically remove flights from future flight schedules according to specified airport delay tolerances or demand/capacity ratios and sector capacities
  - This can also reflect service provider policies such as slot controls
- We call this consolidated capacity metric **"*projected throughput*"** which estimates the number of flights that could be scheduled and flown for a given level of system capacity
- Airline coping strategies such as using larger aircraft, shifting flights to other times of the day or other airports, etc., are all possible but all have their own ramifications and costs
- Projected throughput thus measures the effect of insufficient capacity and estimates the benefit of additional system capacity

Process for Going from Unconstrained Demand to Projected Throughput

- To represent this behavior, we analytically remove flights from the future flight schedule according to specified airport demand/capcity ratios and sector capacities



Objective:

Trim the flights to satisfy the D/C rules and ATC sector capacities while maintaining maximum system throughput

Airport Taxiway Constraints Analysis

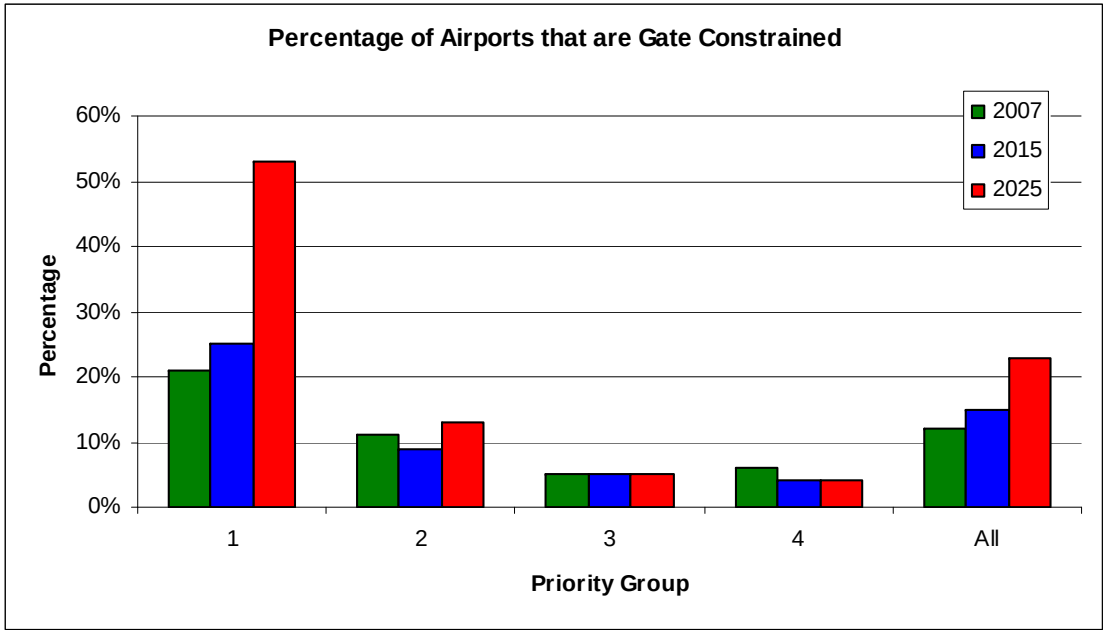
- **Approach 1:** Use queuing theory to construct a taxi model:
  - Most previous studies have focused on runways-not applicable here
  - We analyzed average taxi-in time as a function of demand for 70 airports:
    - Generally linear functions, and often with near-zero slope
    - Taxi time is a flat function of demand if the arrivals do not cross an active runway → active runway/taxiway interaction is the main driver of extra taxi time
  - The linear relationship of the empirical functions cannot be explained by the standard queuing models:
    - Model suggests exponential growth while observed behavior is linear
    - → Taxi time cannot be successfully modeled with queuing theory

Approach 2: Develop a physics-based model

- **Approach 2:** Build physics-based model of taxiway operations at airports:
  - Use simulation to determine taxi-time as a function of demand
  - Model a small subset of airports from the OEP35 that together represent the majority of common airport layouts
  - Identify problematic airport layout/demand level combinations
  - Extend findings to similar airports
- Challenges:
  - Limited data available, especially pathway data
  - Taxiway interaction with other airport elements (gates, apron areas, service equipment) complicates analysis
  - **Building accurate physics-based simulations of taxiway operations is highly labor intensive and time consuming**

Subtask 4.3: Analyze Airportal Capacity Constraints (Gates)

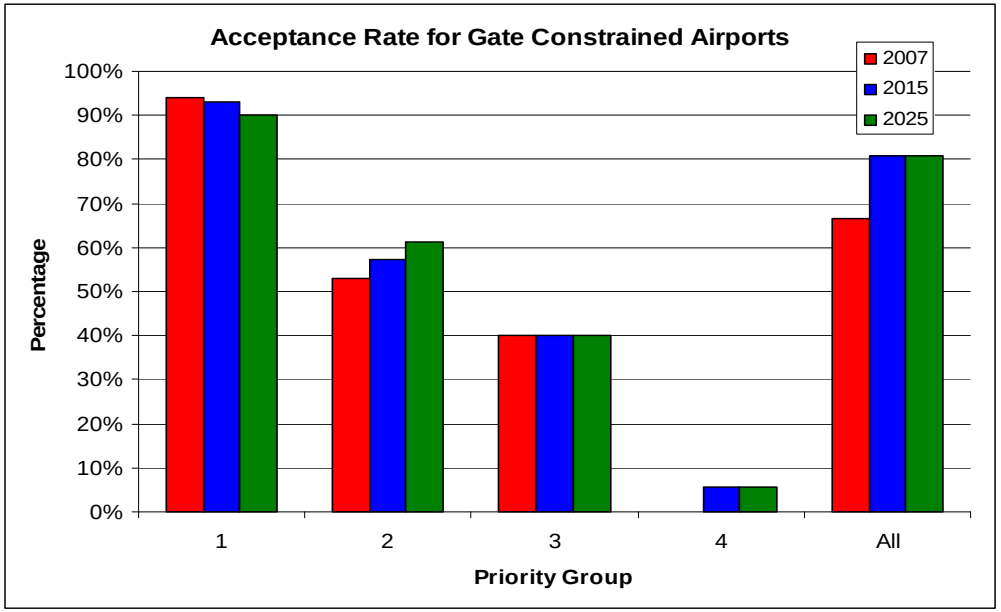
Preliminary Results: Overview



- More priority 1 airports are gate-constrained than any other priority group
- The percentage of airports that are gate-constrained stays relatively stable from 2007 to 2025 in low priority airports
- There is a dramatic increase in the percentage of gate-constrained airports in priority 1, from 21% in 2007 to 25% in 2015, to 53% in 2025

Subtask 4.3: Analyze Airportal Capacity Constraints (Gates)

Preliminary Results: Overview



- Most priority 1 airports have acceptance rates in the 90-100% range
  - This corresponds to some small amount of gate-related delays at peak operating periods
- The average acceptance rate for gate-constrained priority 1 airports steadily declines over time
- Demand will surpass capacity at a greater number of priority 1 airports by a greater amount in the future