Regional GDP – Extending Ground Delay Program to Regional Airport Systems

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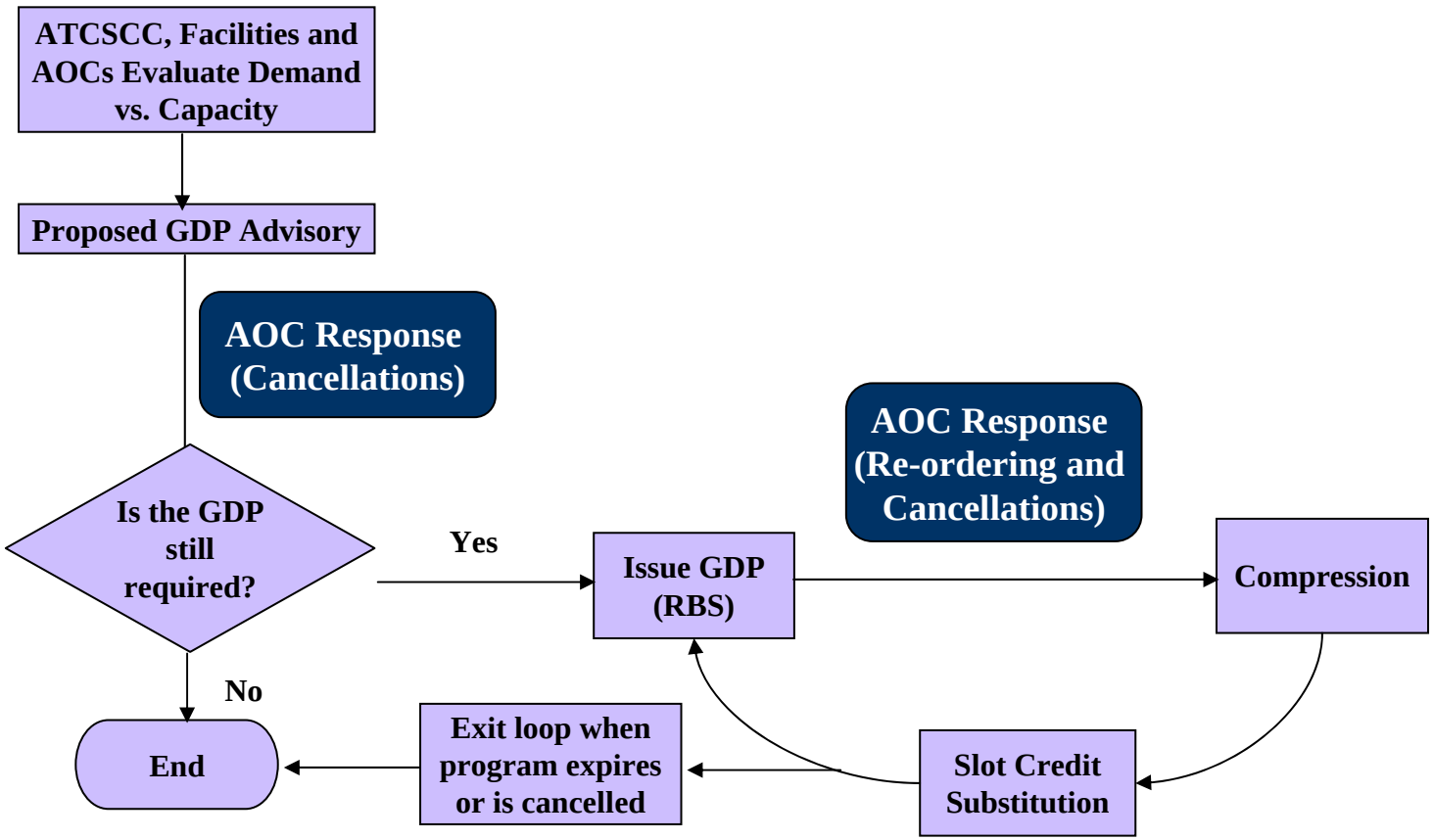
Roadmap

- Introduction
- Proposed extension of CDM with Regional GDP
- Decision support for initiating a Regional GDP
- A case study
- Conclusions

Flow Chart of Existing Collaborative Decision Making (CDM)



1. With adjustments based on Metron Aviation, 2004

Rationale

- Marginal benefit of GDP decreases with the increase of severity of demand-capacity imbalance.
- Excess capacity at secondary or regional airports in regional airport systems.
- Observed phenomena of diverting flights and utilizing ground transport.
- In the operational concept for the NextGen, regional system planning and operations are highlighted.

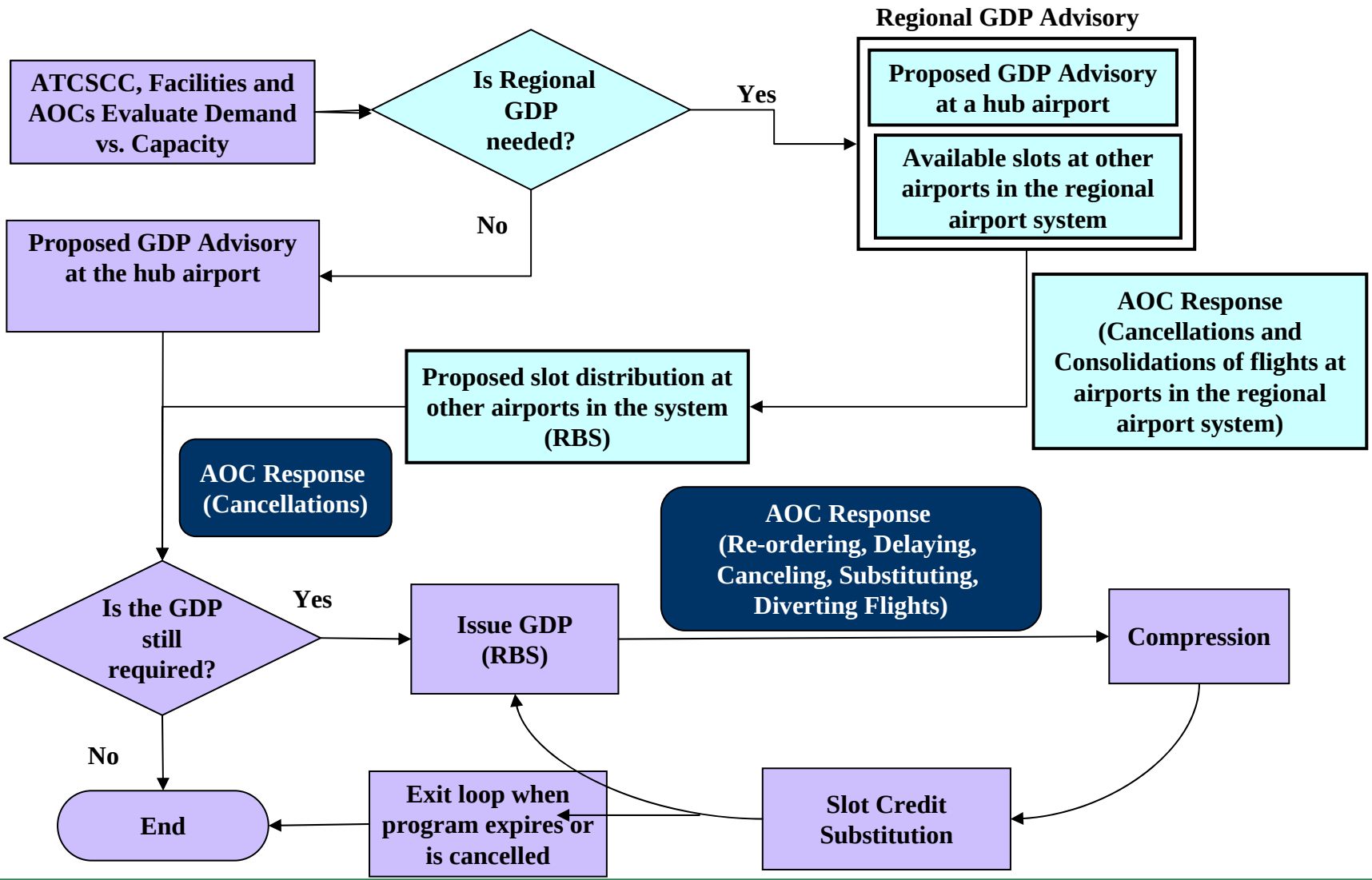
  --“If there are multiple airports within a system, they need to designed as one system to avoid system imbalances, bottlenecks, and associated congestion and delay. Intermodal transportation links are an important component in making regional airport systems viable.” [1]

1. Operational Concept for the Next Generation Air Transportation System (NextGen), page 3-14

Regional GDP

- Regional GDP advisory:
  - A GDP advisory at the hub airport with demand-capacity imbalance
  - Information regarding available slots at other airports in the regional airport system.
- Given the feedback from airlines, slots at other airports would be distributed according to ration-by-schedule (RBS) or other mutually agreed algorithms.

Proposed extension of CDM with Regional GDP



Calling a redundant Regional GDP will cause unnecessary cost

- Cost of extending system users to airports and ground transportation providers
- Extra operational management efforts at Airline Operations Centers (AOCs)

Decision Support for Initiating a Regional GDP

Decision

- Initiating Regional GDP ? → Is flight diversion and alternative hub cost-effective?

Objective

- Minimize passenger disruption cost, airlines' disruption cost, and regional system cost if a Regional GDP was initiated

Constraints

- Runway length at alternative hub
- Alternative hub excess capacity

Decision Variables

$$x_{i,j} = \begin{cases} 1 \text{ if flight } i \text{ is landed at alternative hub } j \\ 0 \text{ otherwise} \end{cases}$$

$$y_j = \begin{cases} 1 \text{ if airport } j \text{ is utilized as an alternative hub} \\ 0 \text{ otherwise} \end{cases}$$

Objective Function

Passenger delay

Passenger ground transportation time

Passenger misconnection penalty time

Passenger Value of Time (VOT)

$$Min \left(\sum_k w_k \cdot P_k + \sum_i \sum_j x_{i,j} \cdot BT_{i,j} \cdot Pax_i + \sum_i \sum_j x_{i,j} \cdot TPax_i \cdot Mis_i \right) \cdot C^P + \sum_k w_k \cdot F_k \cdot C^F + \sum_i \sum_j x_{i,j} \cdot C_{i,j}^D + \sum_j C_j^A y_j$$

Flight delay Cost

Flight diversion Cost

Alternative hub utilization cost

Objective Function

$$Min \quad \left(\sum_k w_k \cdot P_k + \sum_i \sum_j x_{i,j} \cdot BT_{i,j} \cdot Pax_i + \sum_i \sum_j x_{i,j} \cdot TPax_i \cdot Mis_i \right) \cdot C^P$$
$$+ \sum_k w_k \cdot F_k \cdot C^F + \sum_i \sum_j x_{i,j} \cdot C^D_{i,j} + \sum_j C^A_j y_j$$

$$w_k = \min\left(\max\left(0, \frac{D_k}{c_I} - t_k\right), \max\left(0, \frac{D_k - c_I T_I}{c_V} - (t_k - T_I)\right)\right) \qquad 0 < t_k \le T_I$$

$$= \max\left(0, \frac{D_k - c_I T_I}{c_V} - (t_k - T_I)\right) \qquad t_k > T_I$$

$$D_k = \sum_{i \in \{i | HSA_i < t_k\}} \left(1 - \sum_j x_{i,j}\right) \qquad \forall k \in \mathrm{K}$$

$$P_k = \sum_{i \in \{i | t_{k-1} \le HSA_i < t_k\}} \left(1 - \sum_j x_{i,j}\right) \cdot Pax_i \qquad \forall k \in \{1..K\}$$

$$F_k = \sum_{i \in \{i | t_{k-1} \le HSA_i < t_k\}} \left(1 - \sum_j x_{ij}\right) \qquad \forall k \in \{1..K\}$$

Average delay during time period k

Cumulative number of arrivals at original hub

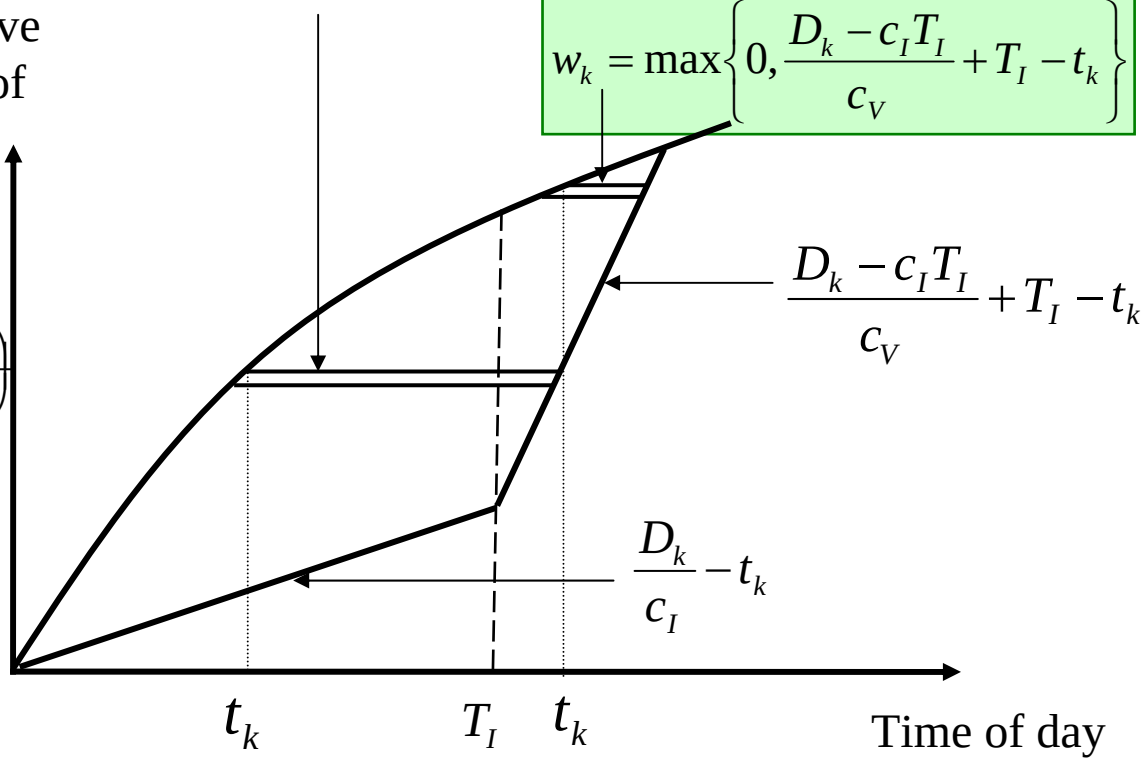
Passengers arrival at original hub airport during time period *k*

Flights landed at original hub airport during time period *k*

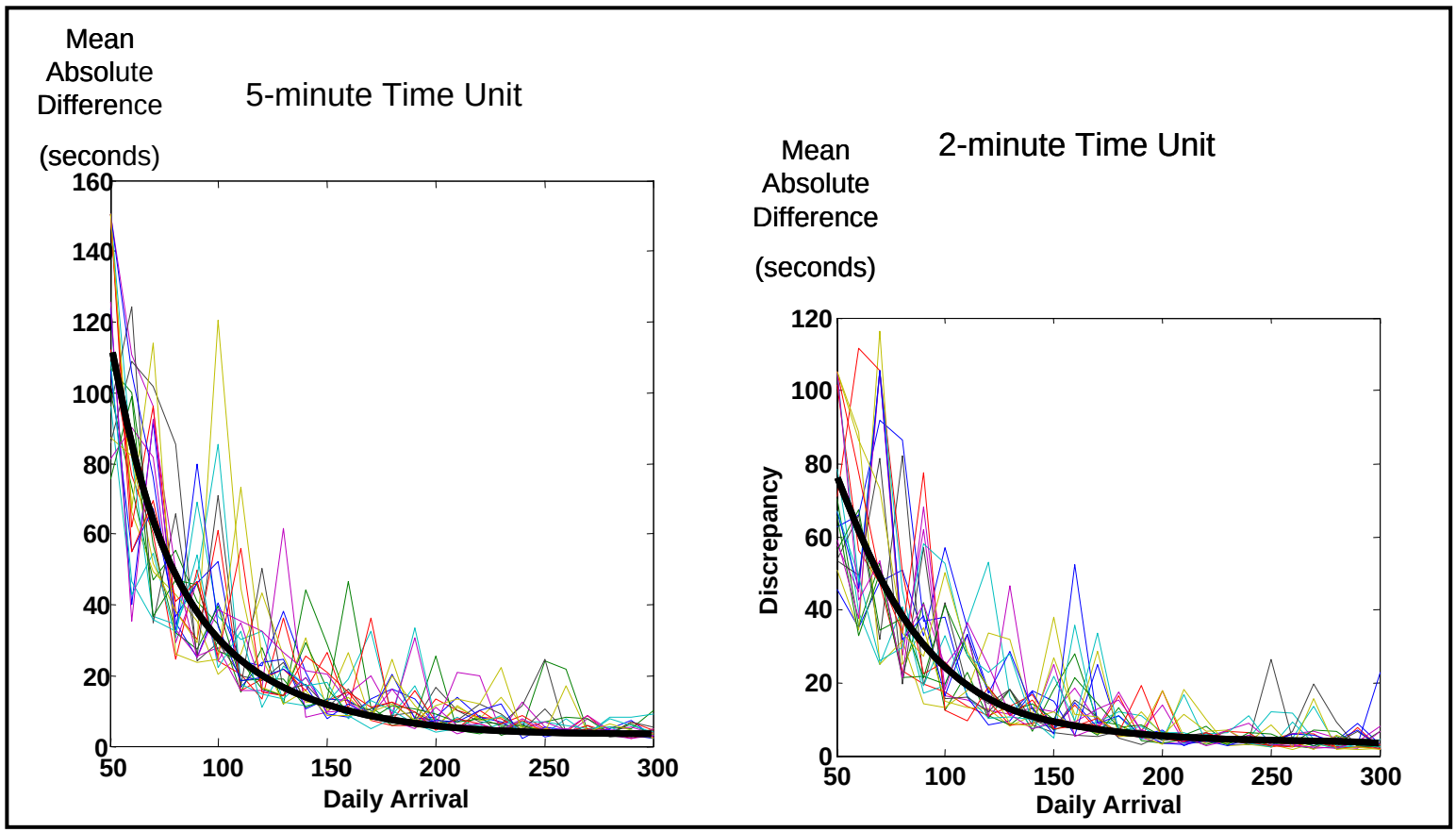
Delay Continuous Approximation

$$w_k = \min\left(\max\left(0, \frac{D_k}{c_I} - t_k \right), \max\left(0, \frac{D_k - c_I T_I}{c_V} - (t_k - T_I) \right) \right)$$

$$w_k = \max\left\{ 0, \frac{D_k - c_I T_I}{c_V} + T_I - t_k \right\}$$



Test the Performance of Delay Continuous Approximation



Constraints

$$x_{ij} = 0 \quad \forall \Lambda_{ij} = 0$$

$$\sum_{j} x_{ij} \leq 1 \quad \forall i \in \mathrm{I}$$

$$\sum_{i} x_{ij} \leq M \cdot y_j \quad \forall j \in \Gamma$$

$$\sum_{i \in \{\mathrm{I} | n-1 \leq HSA_i < n\}} x_{ij} \leq ECap_{nj} \quad \forall j \in \Gamma \forall n \in \mathrm{N}$$

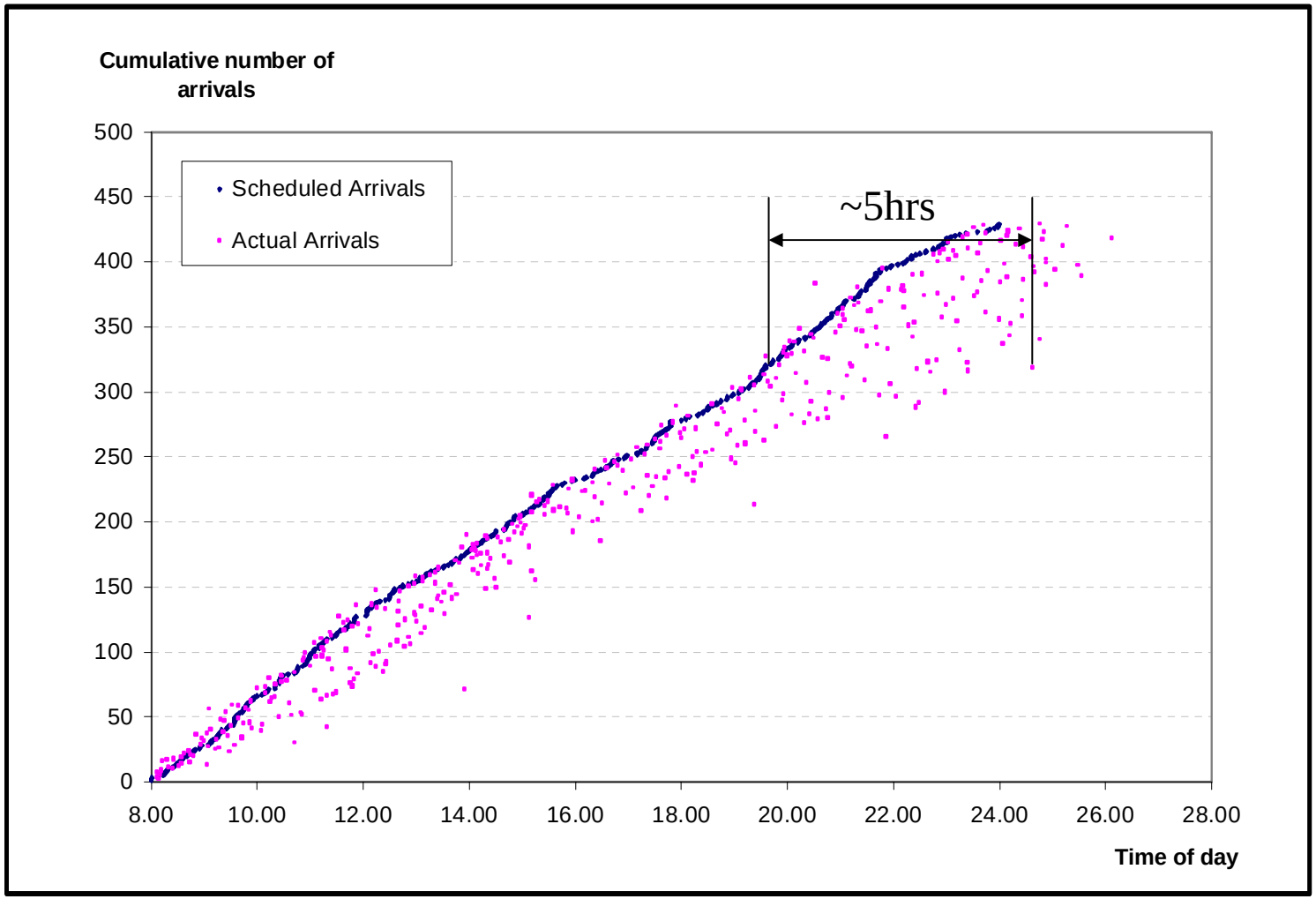
If runway length at alternative hub is too short for flight i, $x_{i,j} = 0$.

Flight i can only be diverted to at most one alternative hub.

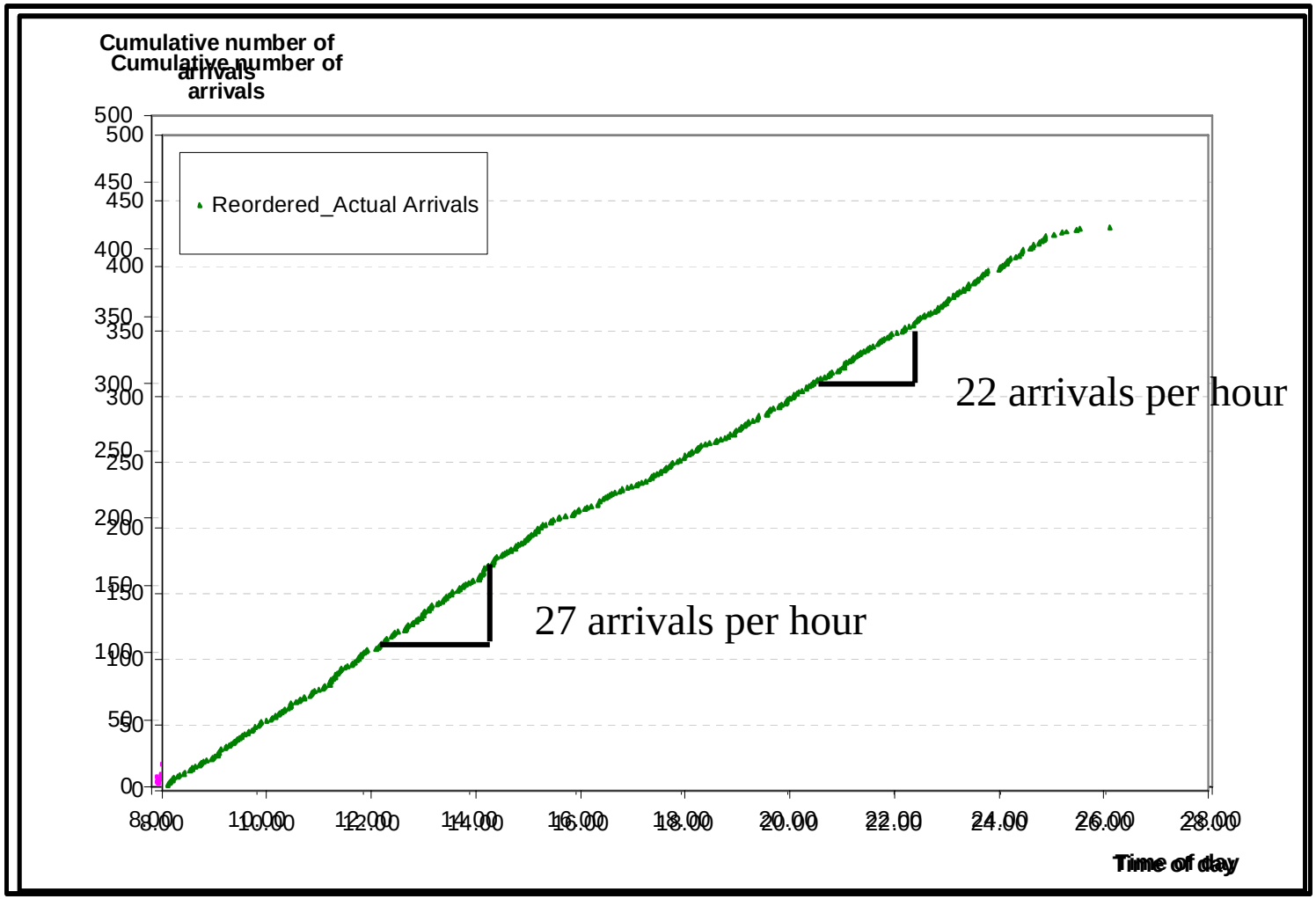
Flight divert to an airport only when it is used as an alternative hub.

Alternative hub capacity constraint

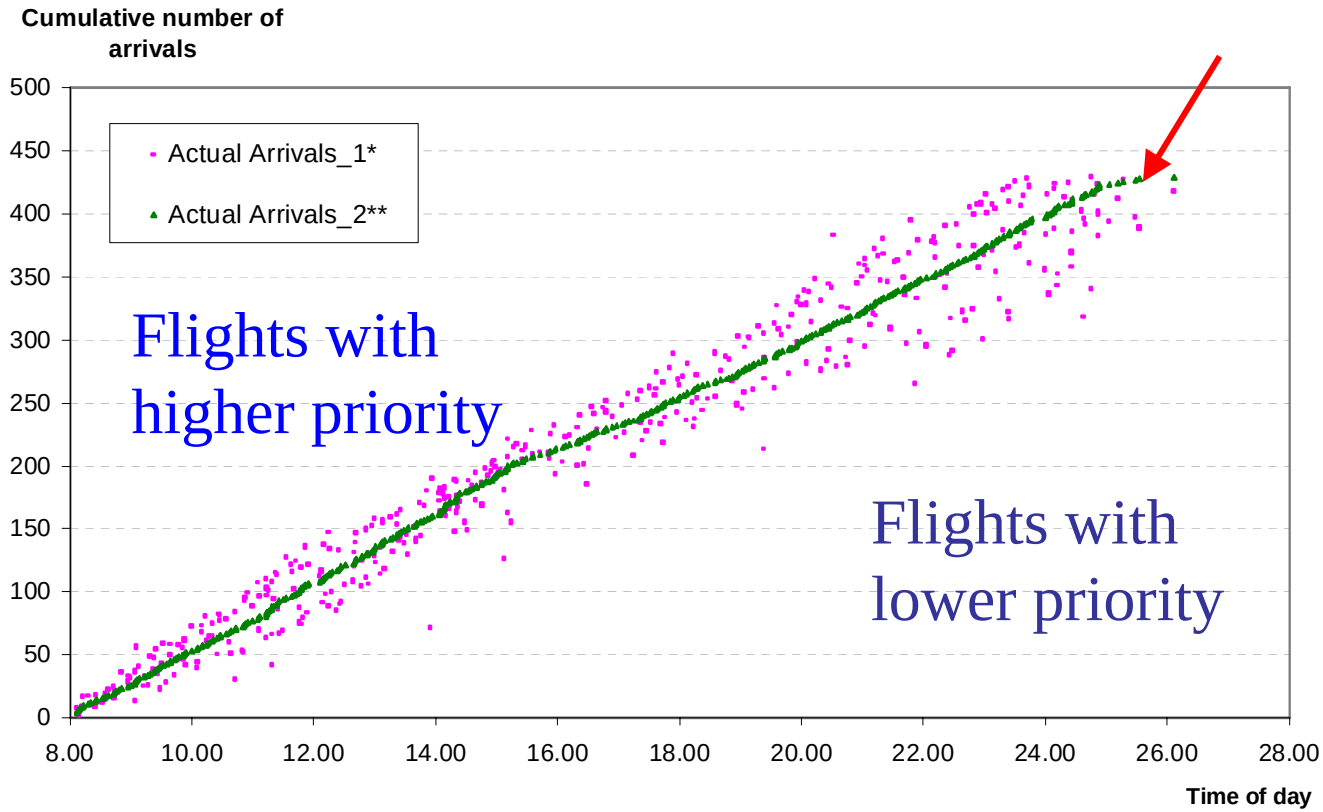
Case Study (SFO, 06/25/08): Scheduled arrival vs. Actual Arrival



Case Study: Obtaining Arrival Capacity Profile



Case Study: Define flight diversion costs



*Flight sequence follows scheduled arrival times
**Flight sequence follows actual arrival times

Results of the Case Study

- The optimization of the mathematical programming model suggests 45 flights being diverted to OAK, thus a Regional GDP is suggested.
- Actual longest delay was about 5 hours. In comparison, the longest flight delay after diverting the 49 flights is half an hour .

Implementation Issues

- Security issues
- Passenger acceptance and communication
- Airport ground facility requirement and funding source

Conclusions

- Regional GDP is a collaborative resource allocation method for regional airport system achieving system efficiency.
- Real-time intermodal transportation need to be designed and operated in making Regional GDP viable.
- Echoes the metroplex airspace management research that promoted by NASA.

Questions? Comments? Thanks.

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