Inter-modal Substitution (IMS) in Airline Collaborative Decision Making

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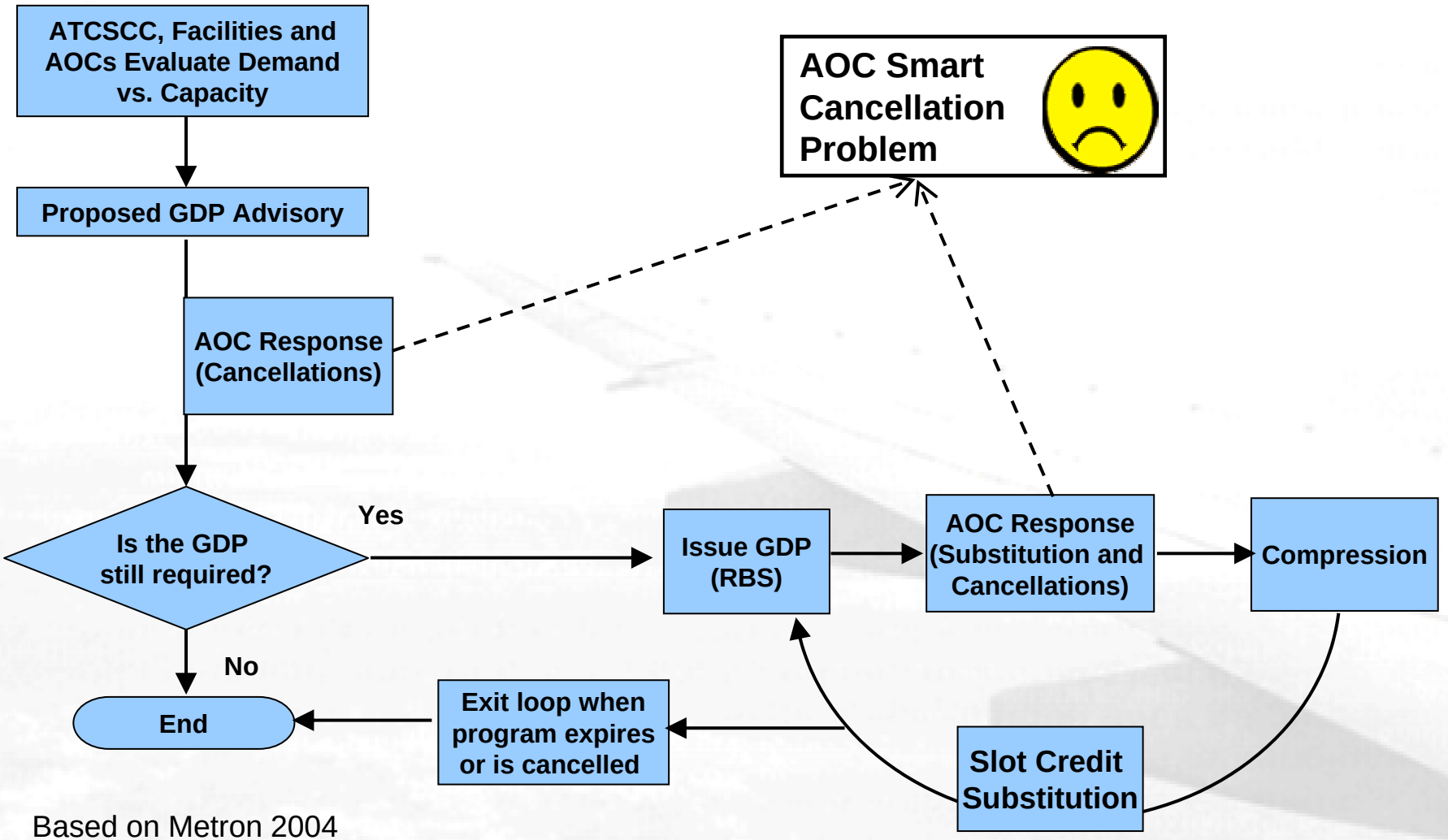
Road Map

- Introduction
  - Delay In National Airspace System (NAS)
  - Idea of Inter-modal Substitution (IMS)
- Objectives
- Inter-modal Traffic Assignment Model
- Jointly Optimization of Air and Surface Transportation
- Future Work

Introduction — Delay in NAS

- Adverse weather and other transient events
- Serious problem at hub airports
  - Passenger misconnections
  - Delay propagation
- Substantial number of short-haul flights

Introduction — Procedure of CDM



Based on Metron 2004

Idea

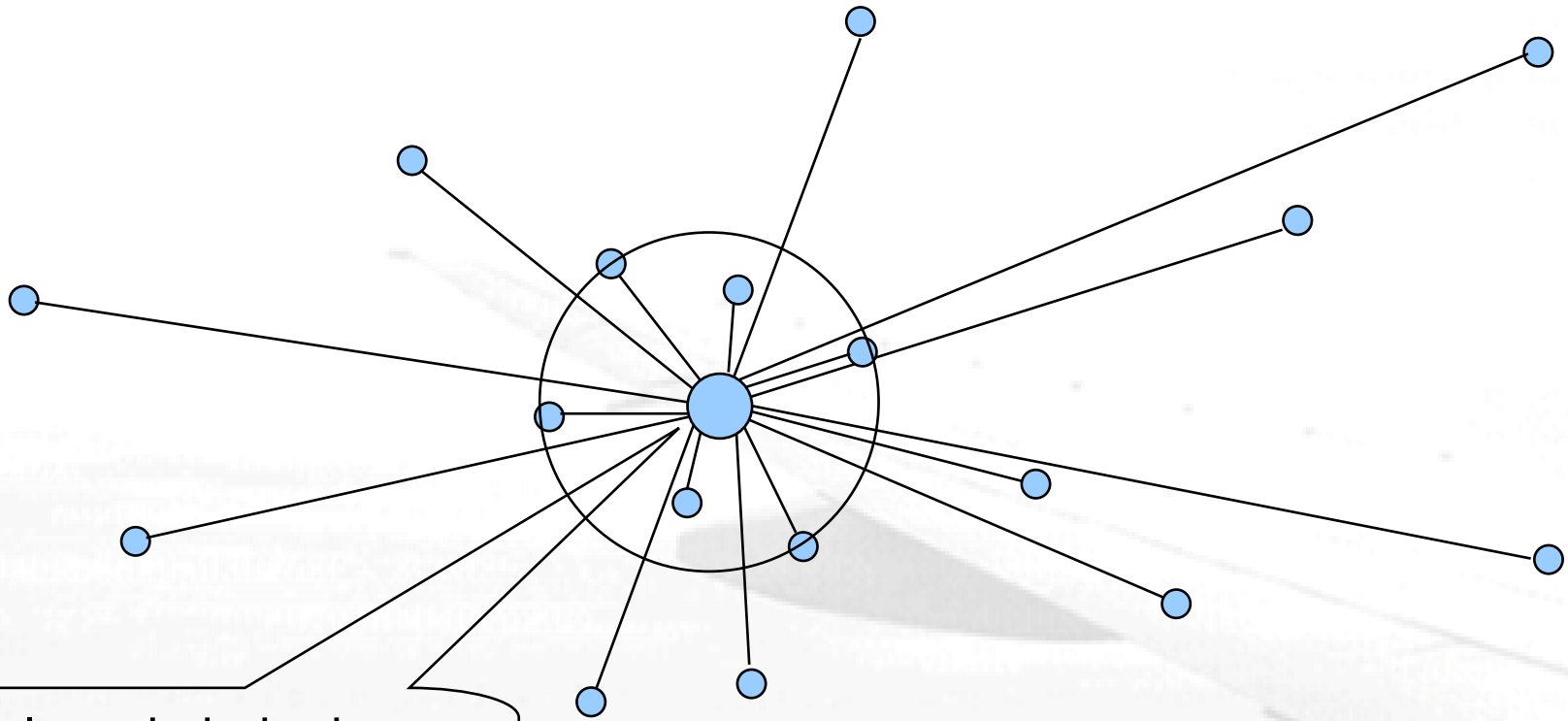
Substitute short-haul flights with surface transport when capacity temporarily drops at hub airports

Inter-modal Substitution (IMS)

Objectives

- Access the potential benefits of implementing this inter-modal substitution (IMS) system.
- Develop methodology for making optimal inter-modal substitution and flight cancellation decision.
- Explore the compatibility into Collaborative Decision Making (CDM)

Inter-modal Traffic Assignment Model — Network



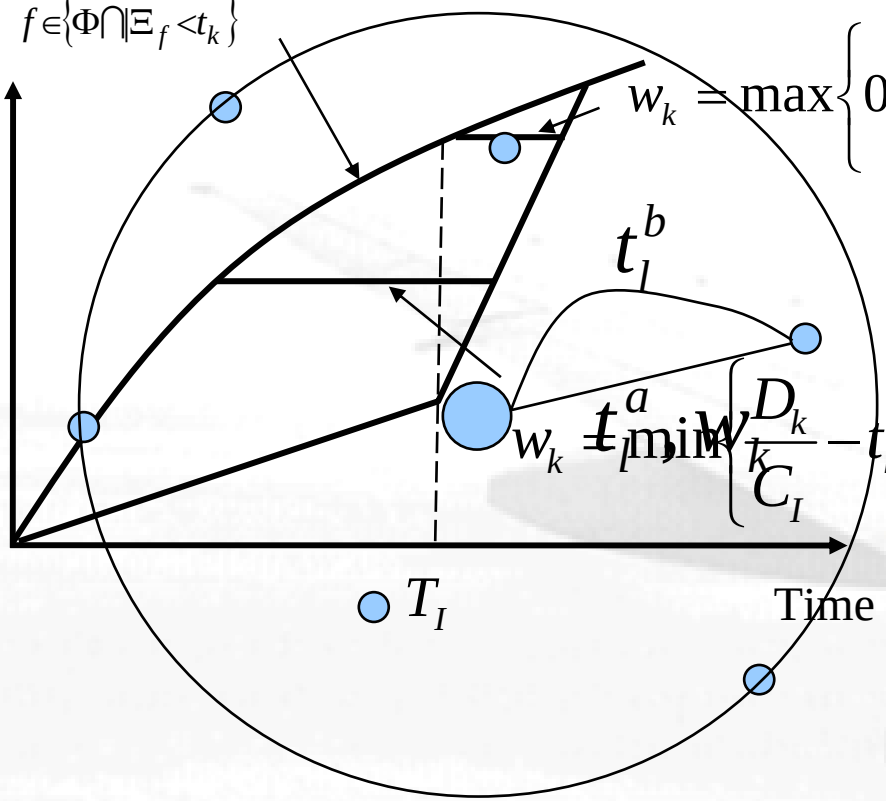
Bottleneck: hub airport with capacity constraints

Problem Definition

- In the case of transient capacity drop, choose appropriate transportation modes in order to minimize (maximize) airline's objective

Continuous Delay Approximation

$$\sum_{f \in \{\Phi \cap \Xi_f < t_k\}} x_f = D_k$$



Constraints

$$S.t. \qquad w_k = \min\left\{\frac{D_k}{C_I} - t_k, \frac{D_k - C_I T_I}{C_V} + T_I - t_k\right\} \qquad \forall t_k \le T_I$$

$$w_k = \max\left\{0, \frac{D_k - C_I T_I}{C_V} + T_I - t_k\right\} \qquad \forall t_k > T_I$$

$$\sum_{f \in \{\Phi \cap \Xi_f < t_k\}} x_f = D_k$$

C_I Reduced capacity

C_V Full capacity

T_I Length of reduced capacity

t_k k th discrete time period

D_k Cumulative number of flights at time period k

x_f Decision Variables, equal to 1 if flight f is not cancelled, 0 otherwise

Objective Function

$$Minimize \sum_{f \in \Phi} \left[x_f t_f^a + \beta \times (1 - x_f) t_f^b \right] pax_f + \sum_{k=0}^{K} \sum_{f \in \{ f | \Xi_f \in [t_{(k-1)}, t_k] \}} \delta \times w_k pax_f$$

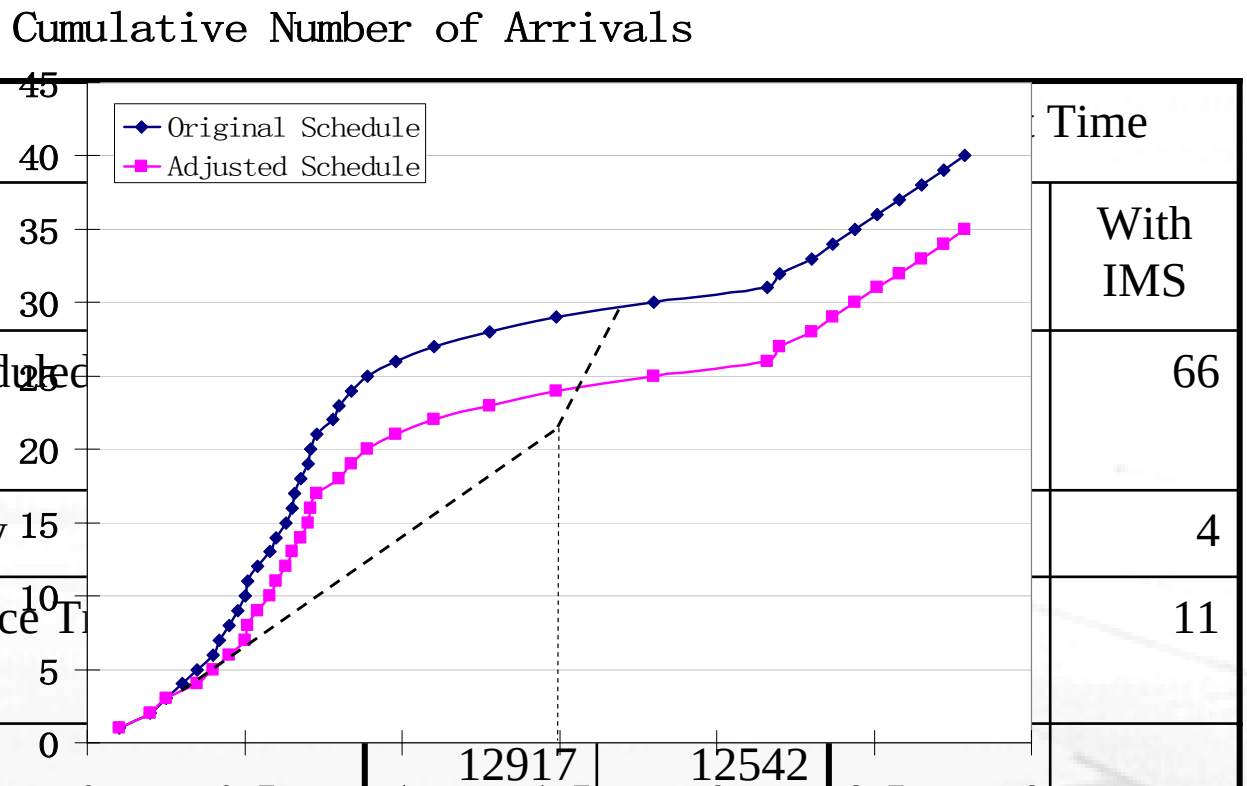
x_f	Decision Variables, equal to 1 if flight f is not cancelled, 0 otherwise
t_f^a	Flying time for flight f
t_f^b	Surface transportation time for flight f
w_k	Queuing delay for discrete time period k
pax_f	Passenger number on flight f
β	Weight of surface transportation time
δ	Weight of delay time

Inter-modal Traffic Assignment Model

Numerical Example

- Data
  - 40 flights in 3 hours
  - Region: 110 miles to 2000 miles
  - Dropped capacity: 10 flights per hour
  - Regular capacity: 30 flights per hour
  - Duration of capacity dropping: 1.5 hours
- Solution Methods
  - AMPL: Branch and Bound
  - C: Enumeration

Numerical Example Results



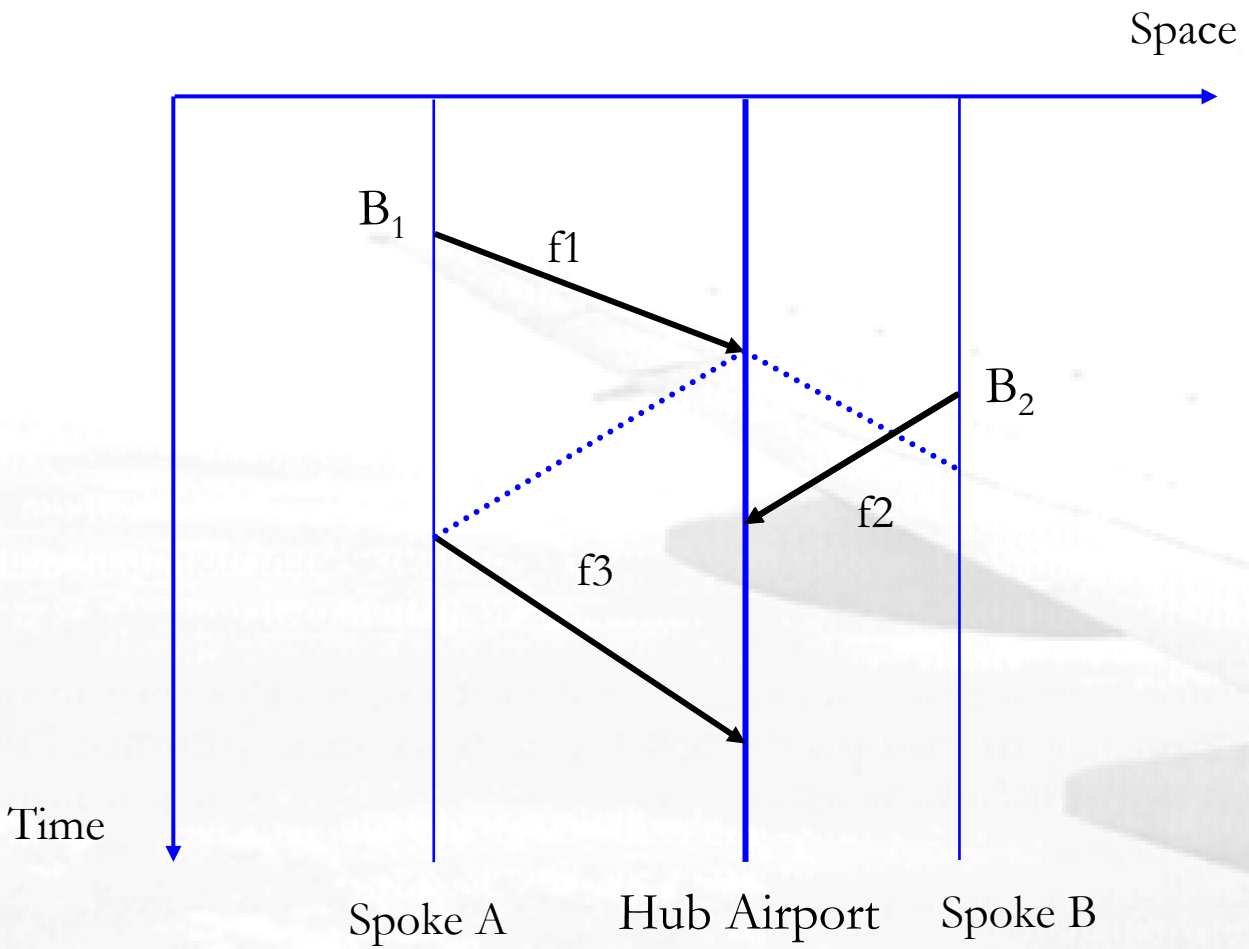
			Time
			With IMS
Scheduled time			66
Delay			4
Surface Time			11
Total		12917	12542
Benefit		-375 (pax.hr)	

Inter-modal Traffic Assignment Model

Alternative Objective Functions

- Varied weights or monetary coefficients for different time: flying time, surface transportation time, and delay time
- Including estimated passenger delay time with reassignment
- Considering airlines' operating costs
- Etc.

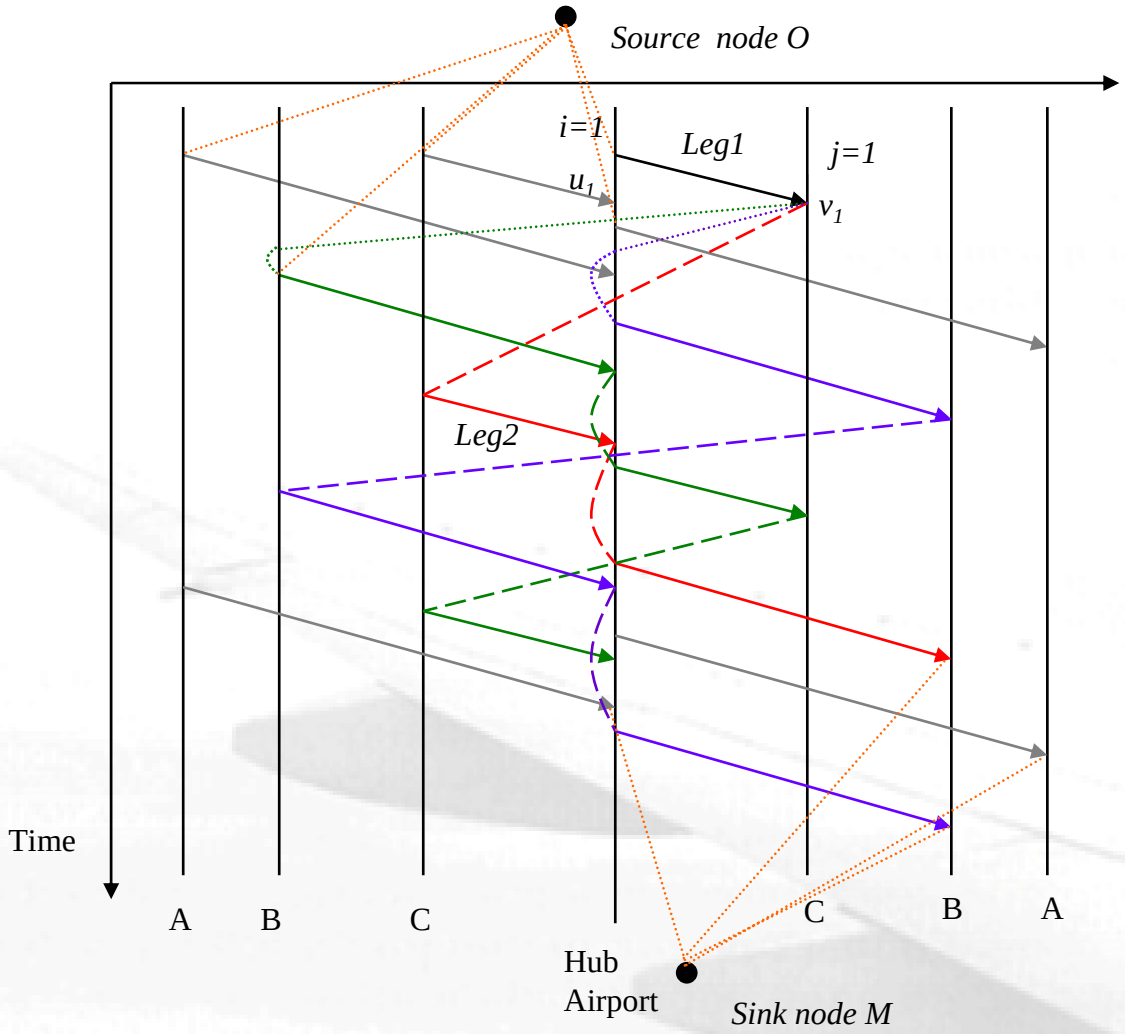
Jointly Optimization of Air and Surface Transportation



Transporting passengers

Waiting at the terminal

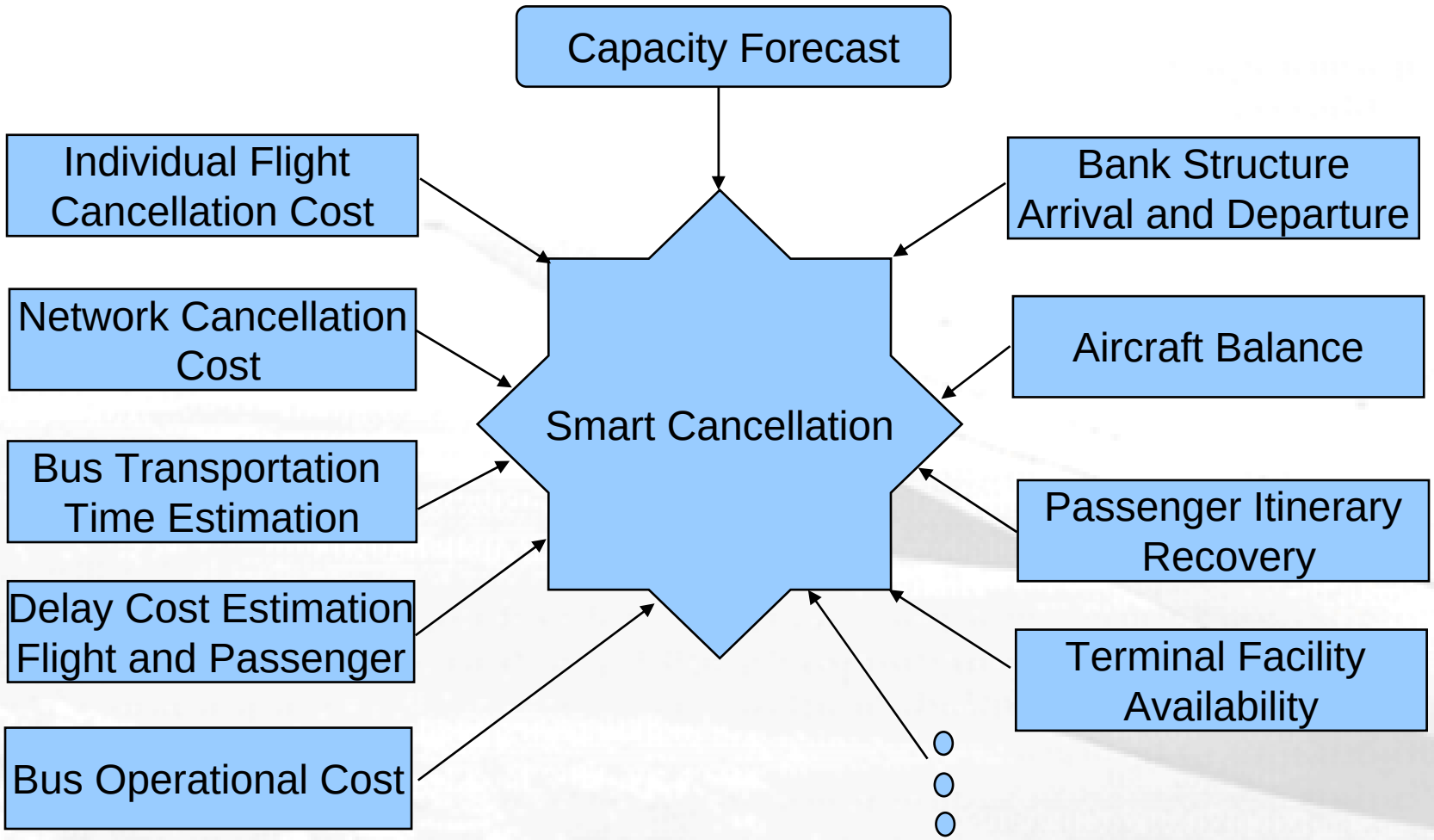
Dead-heading to another airport or central airport



Questions Answered

- How many flights will be cancelled, and which one should be cancelled?
- How many vehicles (charter buses) are needed?
- How to dispatch those vehicles?
- What is the passenger delay?
- What is the flight delay?
- What is the other objective that airlines interested in?

Smart Cancellation— Complete Version



Future Work

- Extension of Inter-modal Traffic Assignment Model
- Formulation and numerical examples of Joint optimization of air and surface transportation
- Capacity Uncertainty
- Integration of Different Modes
- Cooperation among Airlines

Thank you!