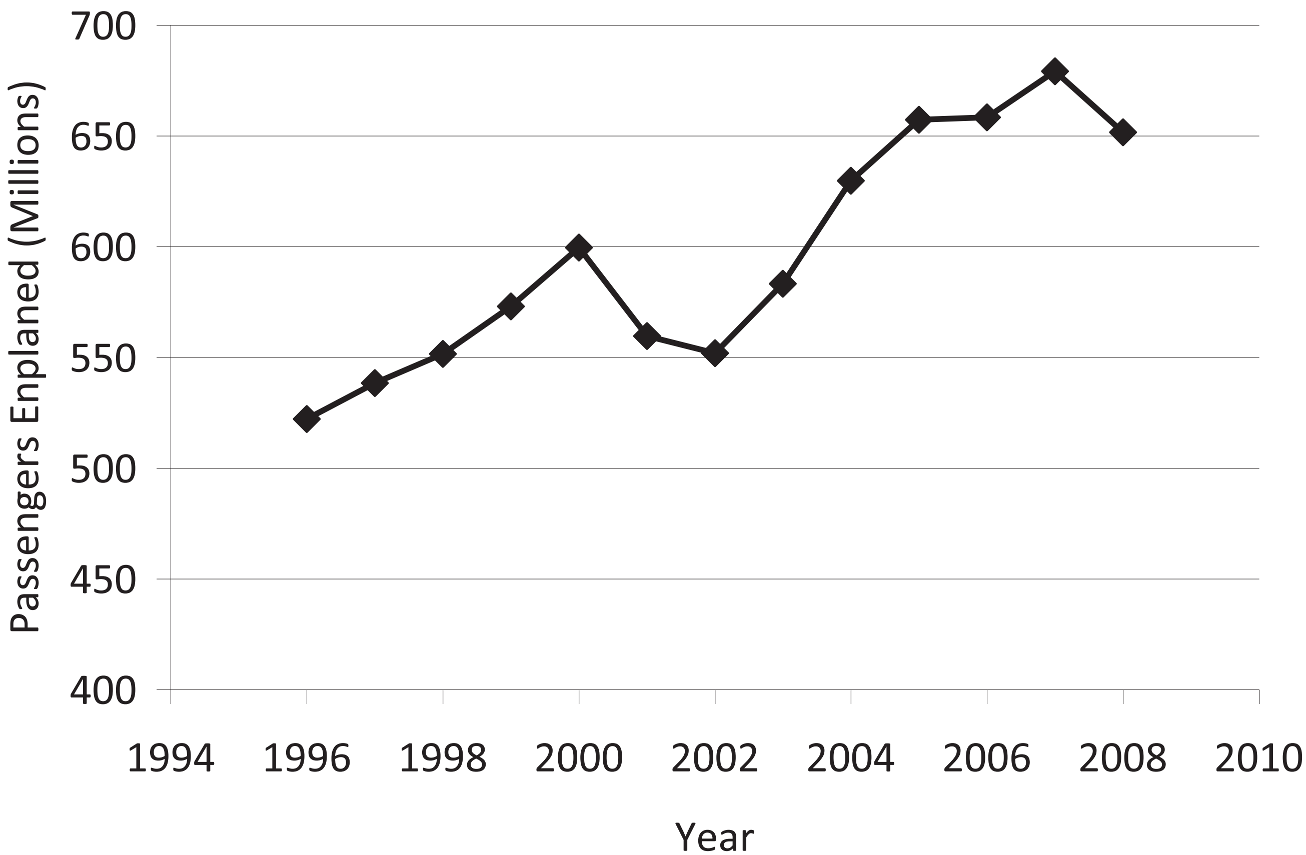
National airspace model: Optimization of flight frequencies after airport losses

Brian Levine • June 22, 2010

DOE CSGF Conference

Background & Motivation

- U.S. Aviation
  - Multi-billion dollar industry; Critical to economy



Over 600 million domestic passengers transported per year

Increase an average of 2% per year

Background & Motivation

- Consider a natural disaster or terrorist attack that shuts down an airport for an extended period of time
  - Reduced network capacity
  - Changes in passenger demand
- Goal: Comprehensive national airspace model
  - Individual airlines
  - Federal government (FAA)

Background & Motivation

Comprehensive National Airspace Model

Multiple Airlines

Continental Airlines

AA

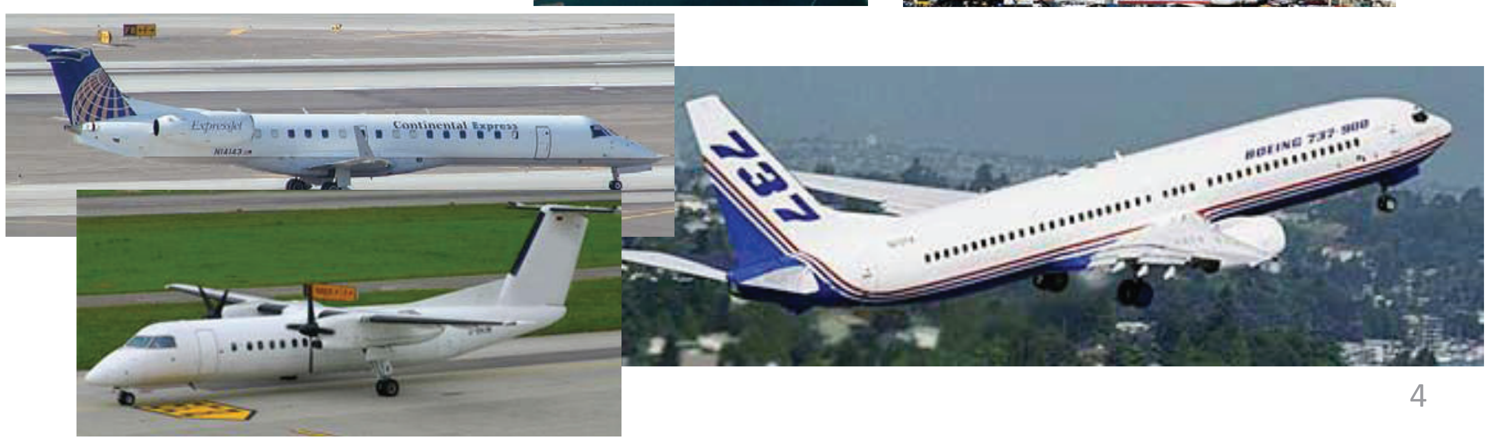
UNITED

jetBlue

SOUTHWEST AIRLINES

Airport Capacity

Multiple Aircraft



Model Formulation
Background

- Airline Scheduling
  - Single airlines, no capacity at airports (Jaillet, et.al. 1996)
  - Short term disruptions (Thengvall, et.al. 2001)
  - Discrete/unlimited capacities on flights (Aykin, 1994)
  - Small number of flight legs (Erdmann, et. al. 2002)

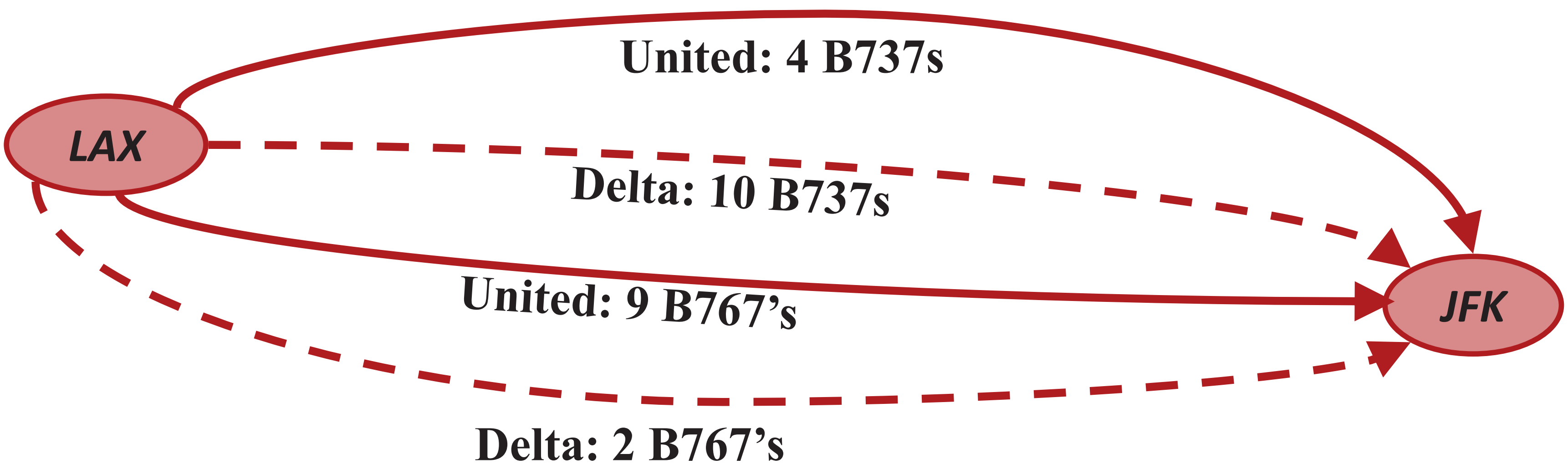
Nobody has solved a flight frequency problem for the entire national airspace system considering multiple carriers and capacity constraints at airports

- Facility Location
  - Heuristic methods yield good quality solutions (Daskin)
  - Need effective interchange heuristics (Aykin, 1995)

Model Formulation

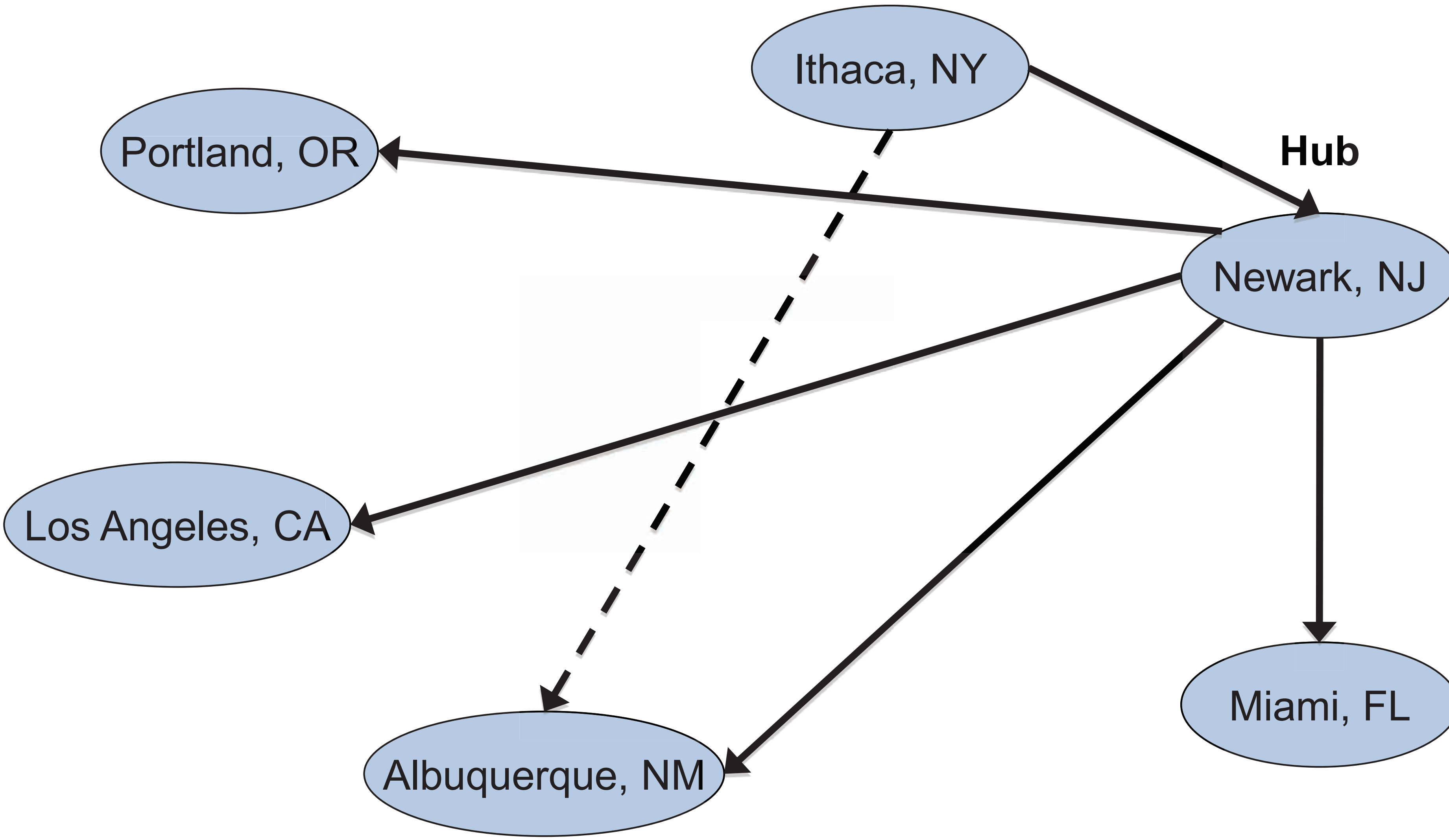
Description

- **Given**: Set of cities, aircraft types, carriers, and origin-destination passenger demand
- **Find**: Flight frequencies and passenger routing that minimizes total operating cost and satisfies as many passengers as possible



Model Formulation

Hub-and-Spoke Networks

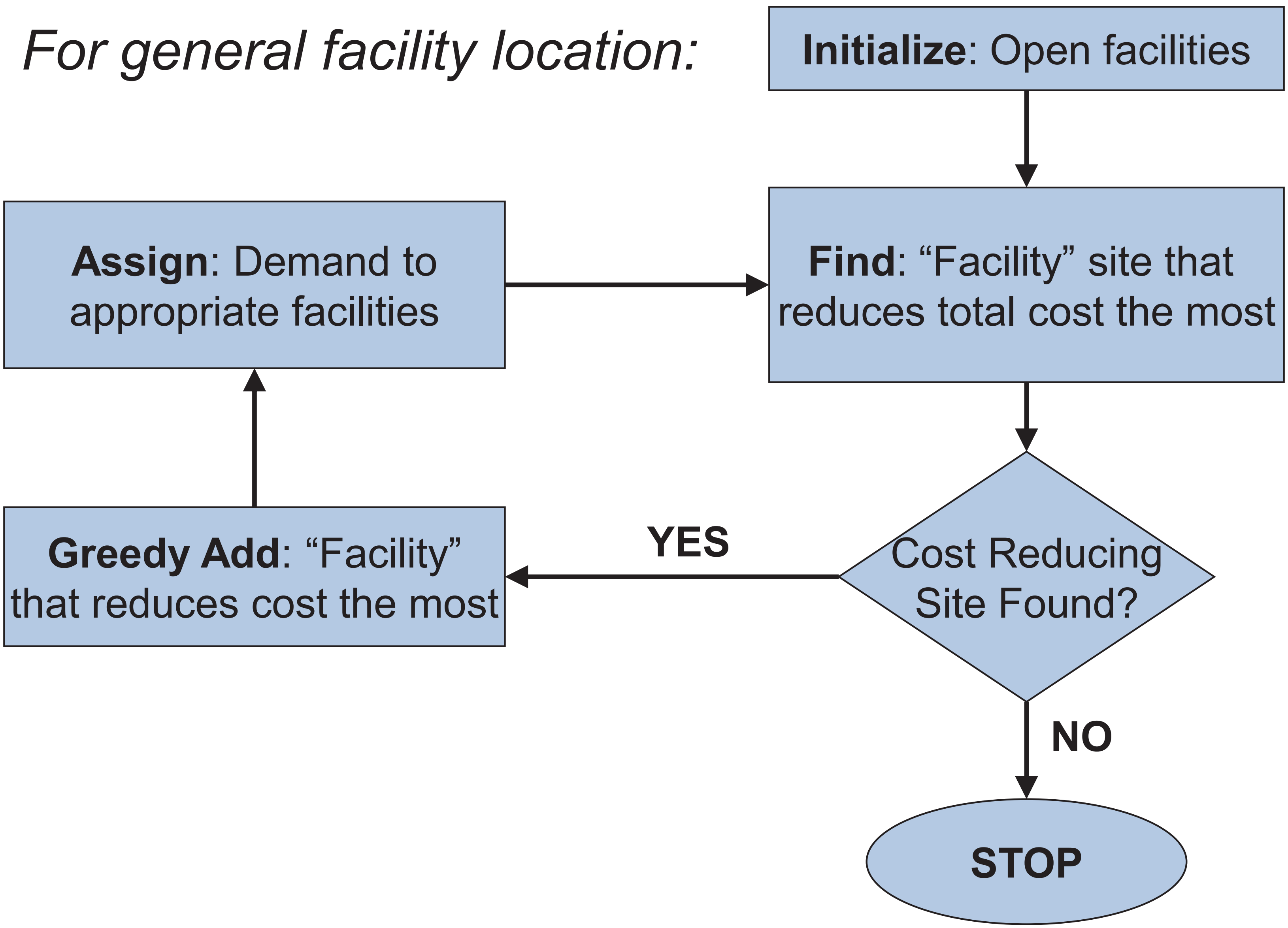


Model Formulation
Description

- Objective
  - Minimize total cost and fly as many passengers as is feasibly possible
- Constraints
  - Obey capacity on flight legs
  - Make sure passenger demand is satisfied
  - Have enough aircraft available to fly flights
  - Obey airport capacity (takeoffs/landings)
- Solution Method
  - Solve as a facility location problem

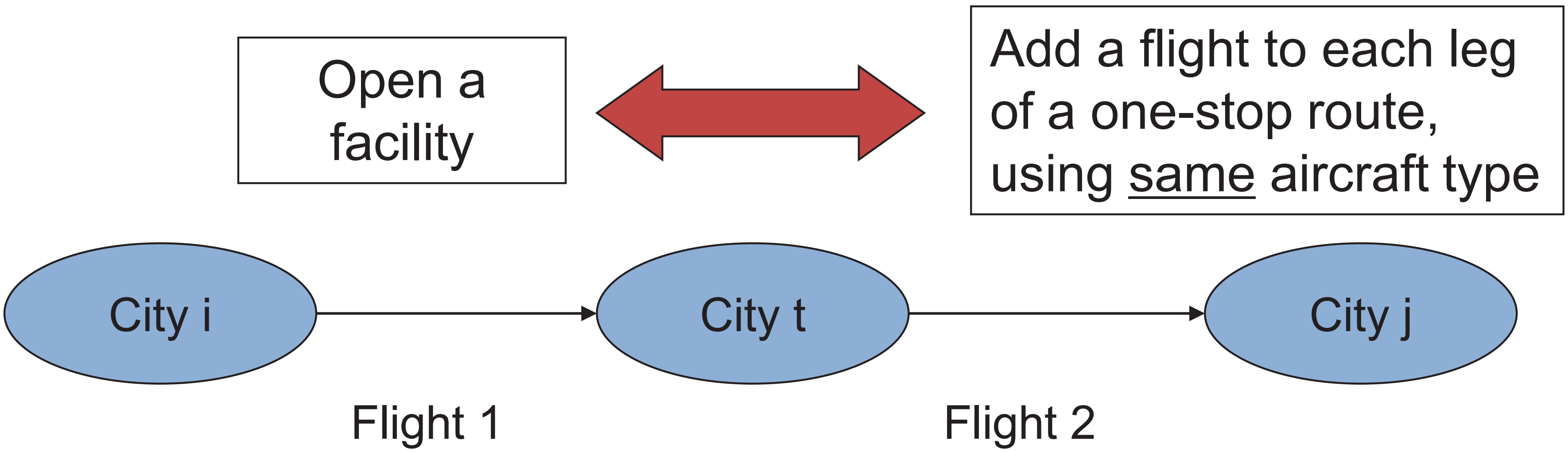
Heuristic Algorithm
Flow Chart: Greedy Add

For general facility location:



Heuristic Algorithm
Description: Greedy Add

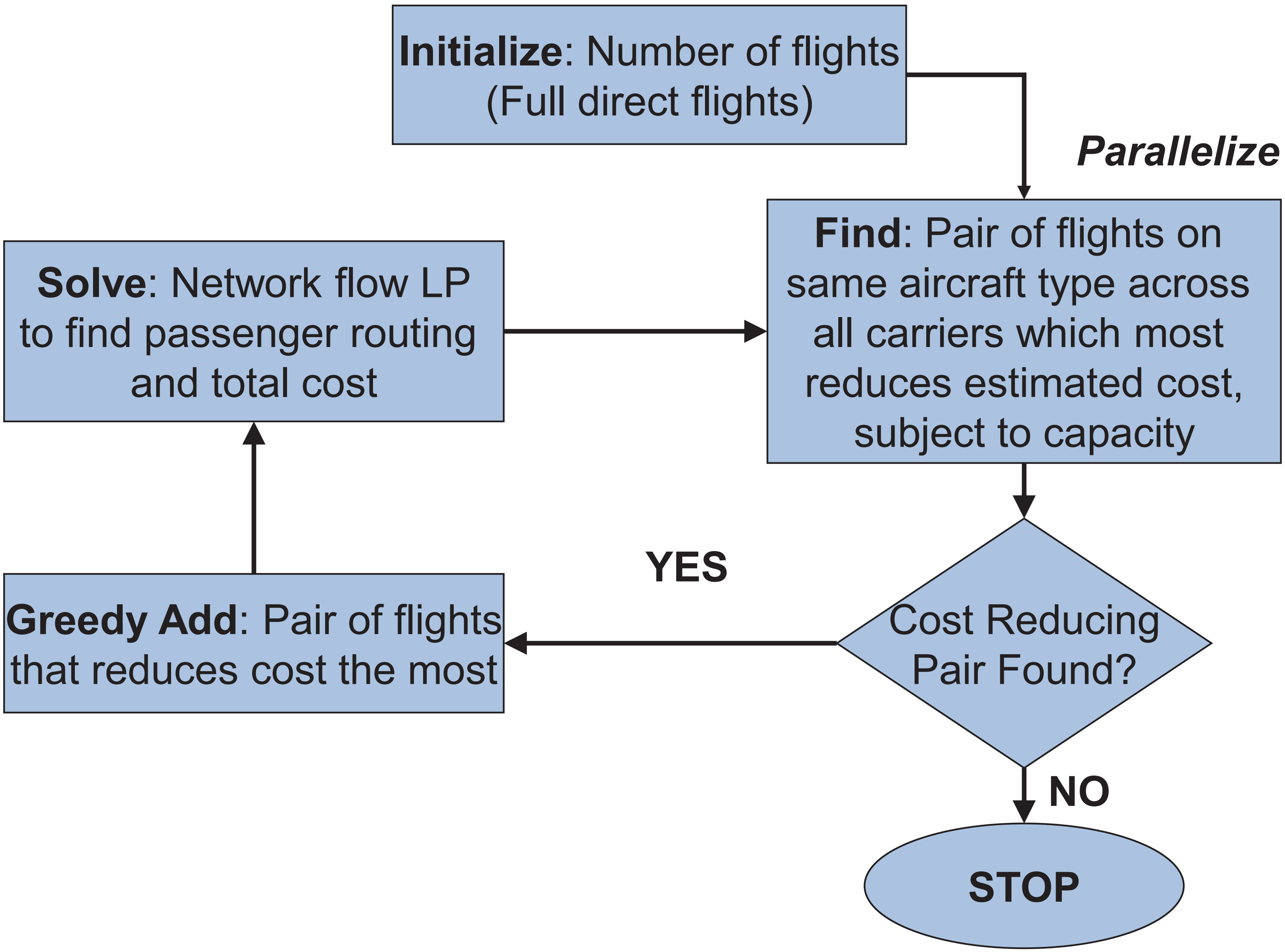
- Find Facilities



- Pair of flights across all carriers which most reduces estimated cost, subject to capacity constraints

Heuristic Algorithm

Flow Chart: Greedy Add

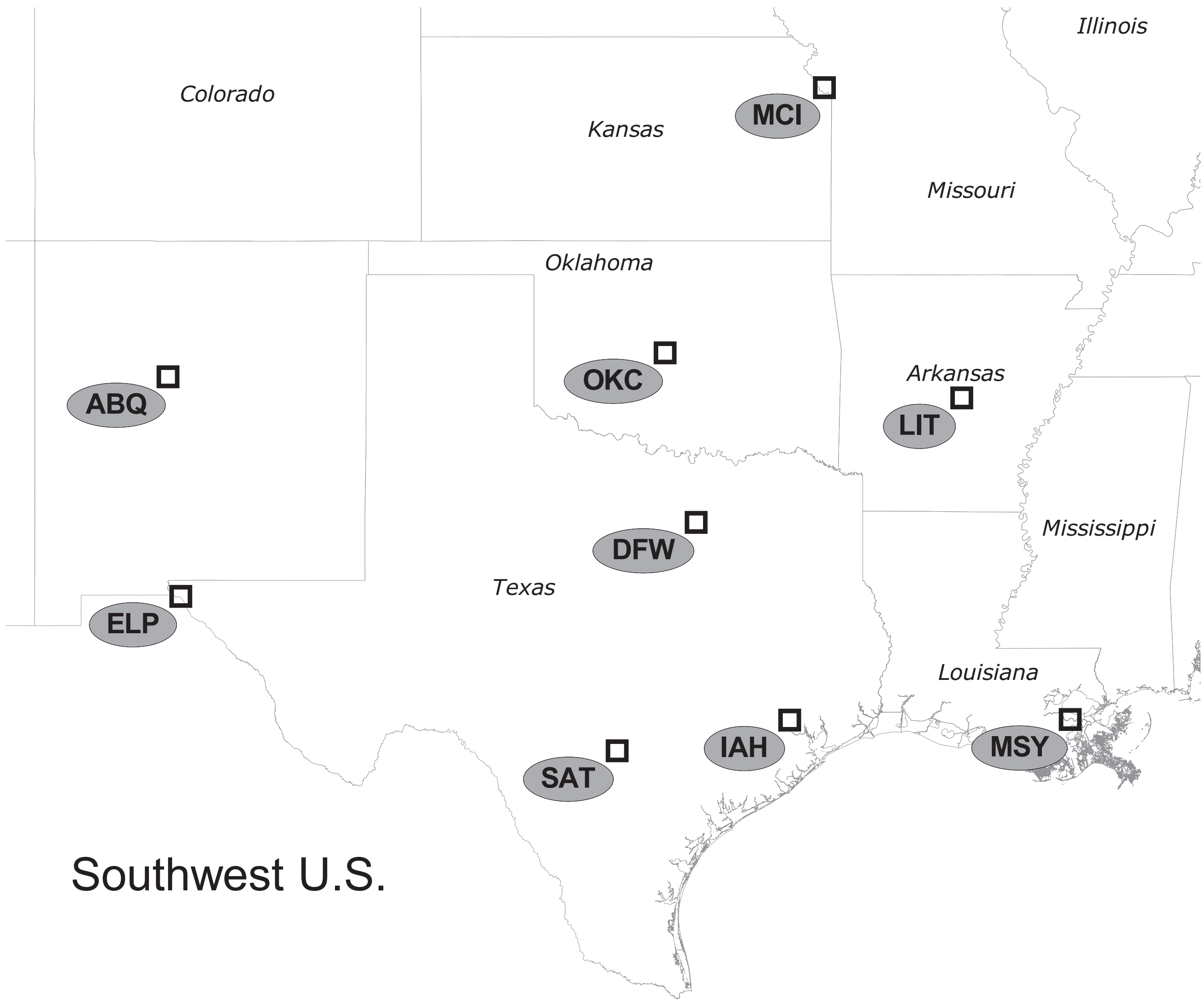


Heuristic Algorithm
Final Steps

- Swap Aircraft
  – Use more economical aircraft
- Add / Drop Single Flight
  – Add: Satisfy direct service passengers
  – Drop: Added capacity may be unnecessary
- Exchange / Interchange
  – Move flights around
  – Focus on parts of network at capacity

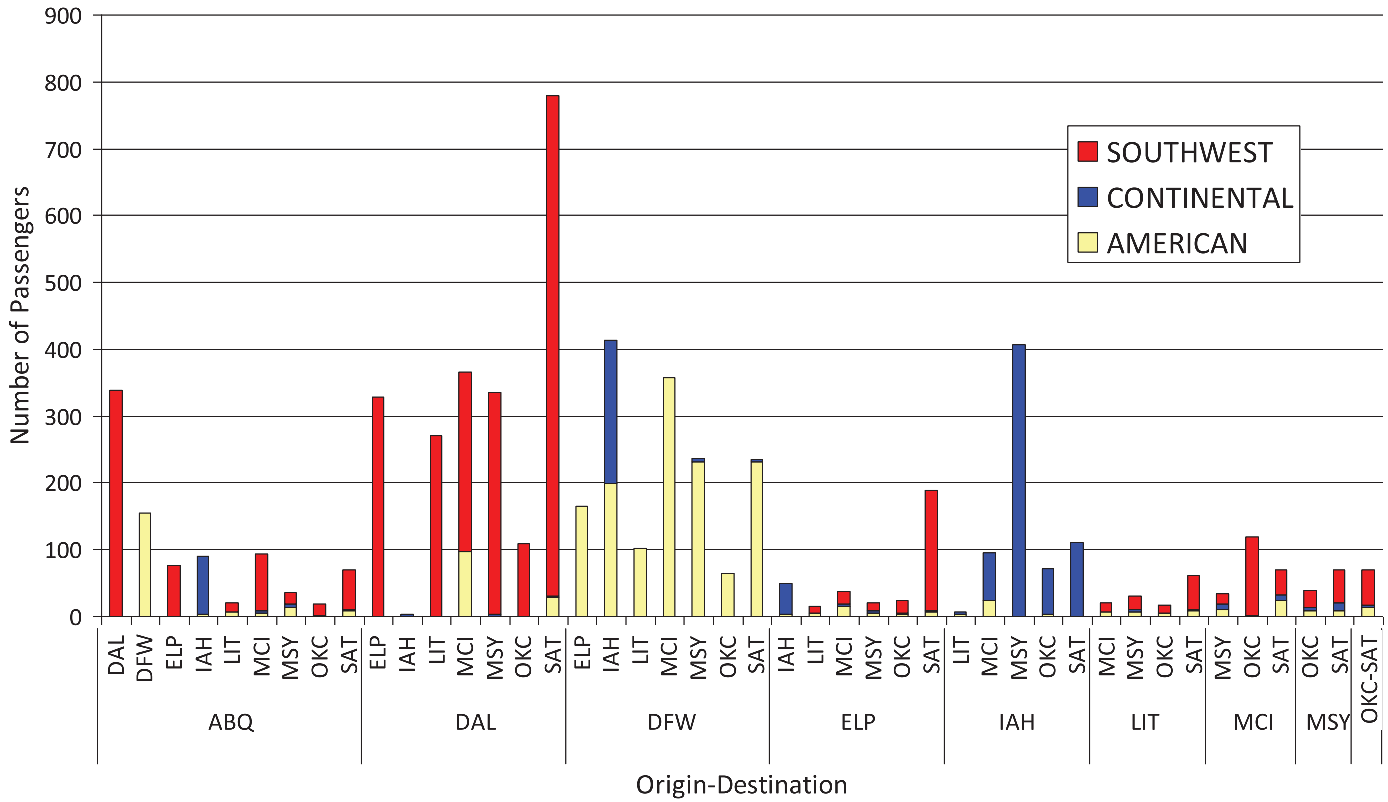
Application: 10 Node Network

Map of Cities



Application: 10 Node Network

Data



- Two aircraft types
  - Narrow Body & Regional Jet
  - Each has different capacities and costs

Application: 10 Node Network

Results

- Optimal IP Solution = $183,094 (total cost)

Solution Step	Cost	Gap
Initial Solution	$487,341	166.2%
Add Heuristic	$205,612	12.3%
Swap Aircraft	$204,551	11.7%
Add Single Aircraft	$194,814	6.4%
Subtract Single Aircraft	$193,793	5.8%
Exchange Heuristic	N/A	N/A

Application: 10 Node Network
Results

- Structure of solution
  - Heuristic: Fewer flights that cost more
  - IP Actual: More passengers transferring

	Heuristic	**IP Actual**
Transfers	758	1045
Unserved Passengers	49	40
Number of Flights	59 legs	61 legs
Cost of Flights	186,443	177,094

Conclusions & Future Research

- Come up with efficient exchange heuristic
- Use heuristic algorithm on larger network
- Begin from known (current) flight schedule

Acknowledgements

- Linda Nozick, Oliver Gao, Shane Henderson, *Cornell University*
- Dean Jones and the Operations Research & Computational Analysis (ORCA) group, *Sandia National Laboratories*
- *The Krell Institute*

Questions?