Evacuation Route Planning

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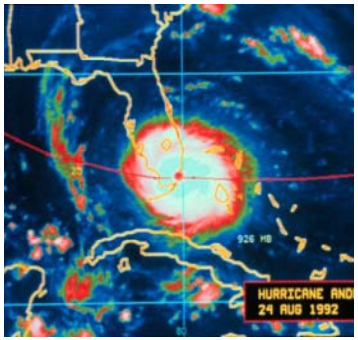
Large Scale Evacuation due Natural Events

Hurricane: Andrews, Rita

- Traffic congestions on all highways
  - E.g. 100-mile congestion (TX)
- Great confusions and chaos

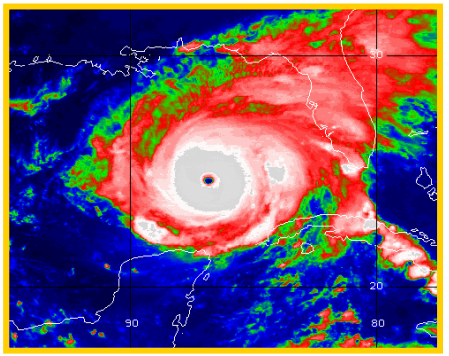
"We packed up Morgan City residents to evacuate in the a.m. on the day that Andrew hit coastal Louisiana, but in early afternoon the majority came back home. **The traffic was so bad that they couldn't get through Lafayette**."
Mayor Tim Mott, Morgan City, Louisiana
(http://i49south.com/hurricane.htm)

Florida, Lousiana (Andrew, 1992)



(National Weather Services)

Houston (Rita, 2005)



(National Weather Services)

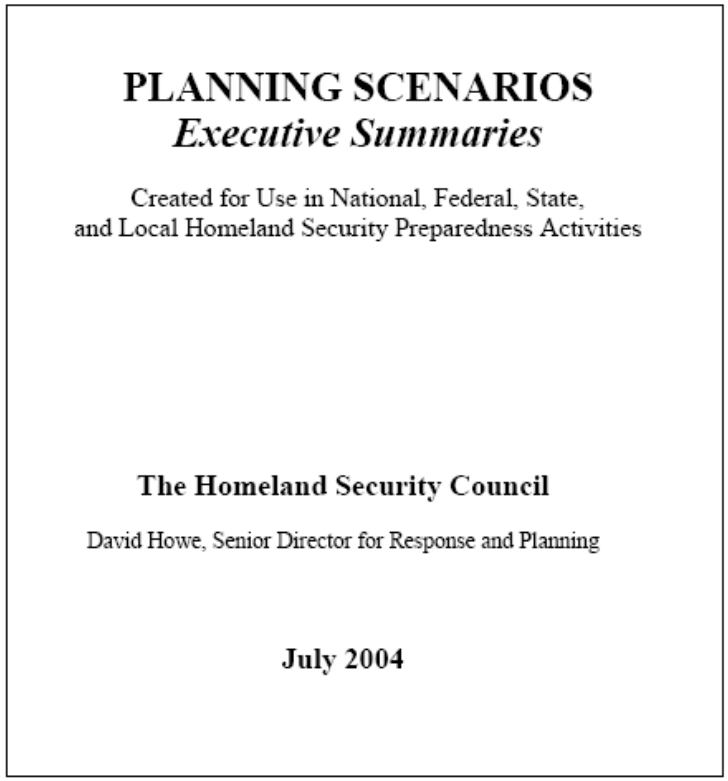
(www.washingtonpost.com)

I-45 out of Houston

(FEMA.gov)

Homeland Defense & Evacuation Scenarios

- Preparation of response to an attack
- Plan evacuation routes and schedules
- Help public officials to make important decisions
- Guide affected population to safety
- Reverse Evacuation: Mass vaccinations ?



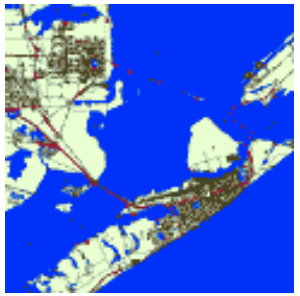
PLANNING SCENARIOS
Executive Summaries

Created for Use in National, Federal, State,
and Local Homeland Security Preparedness Activities

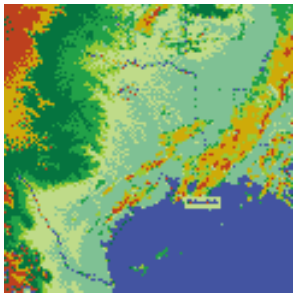
The Homeland Security Council

David Howe, Senior Director for Response and Planning

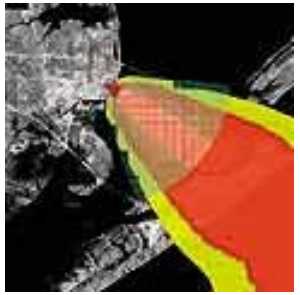
July 2004



Base Map



Weather Data



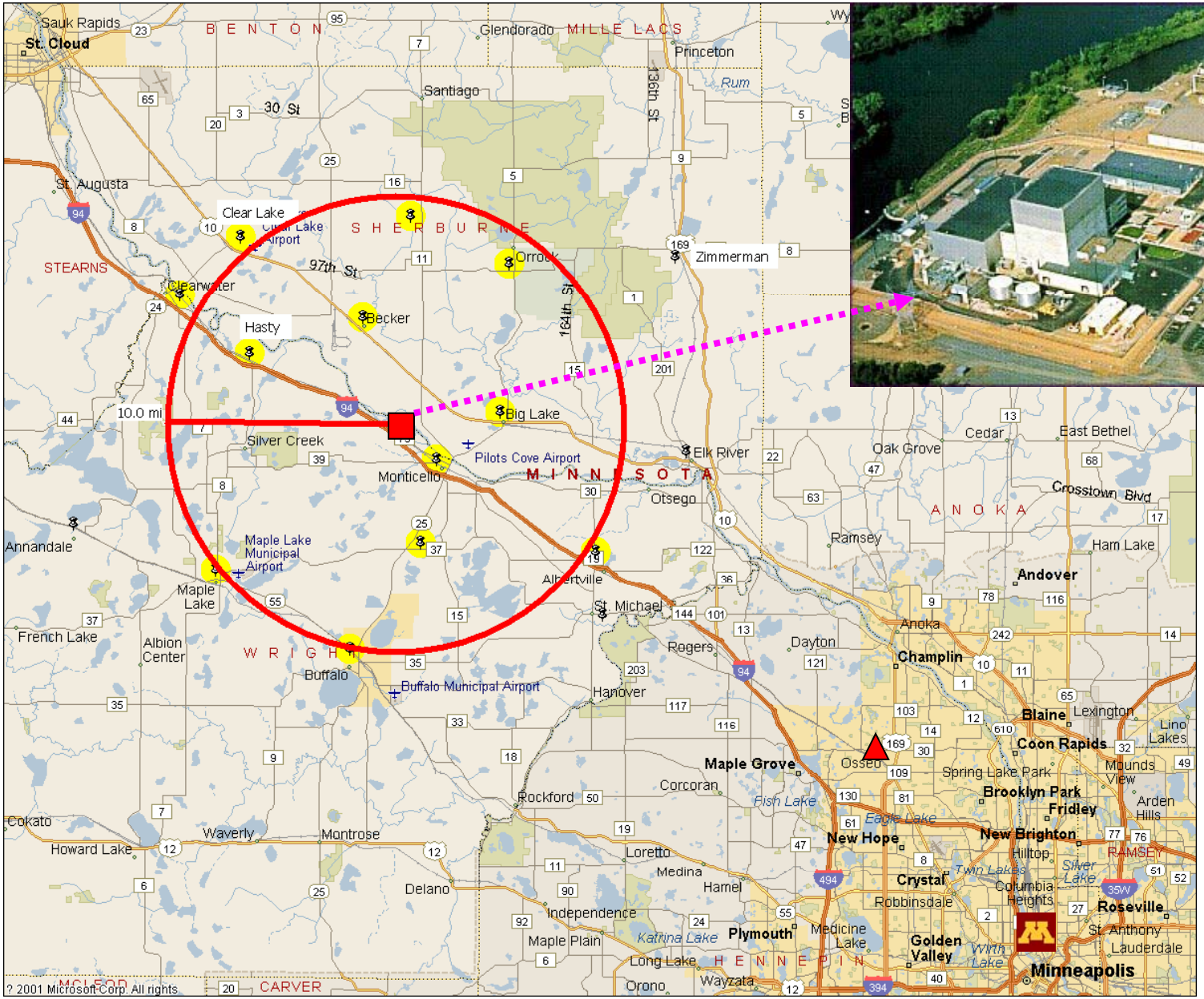
Plume Dispersion

Demographics Information

Transportation Networks

(*Images from www.fortune.com*)

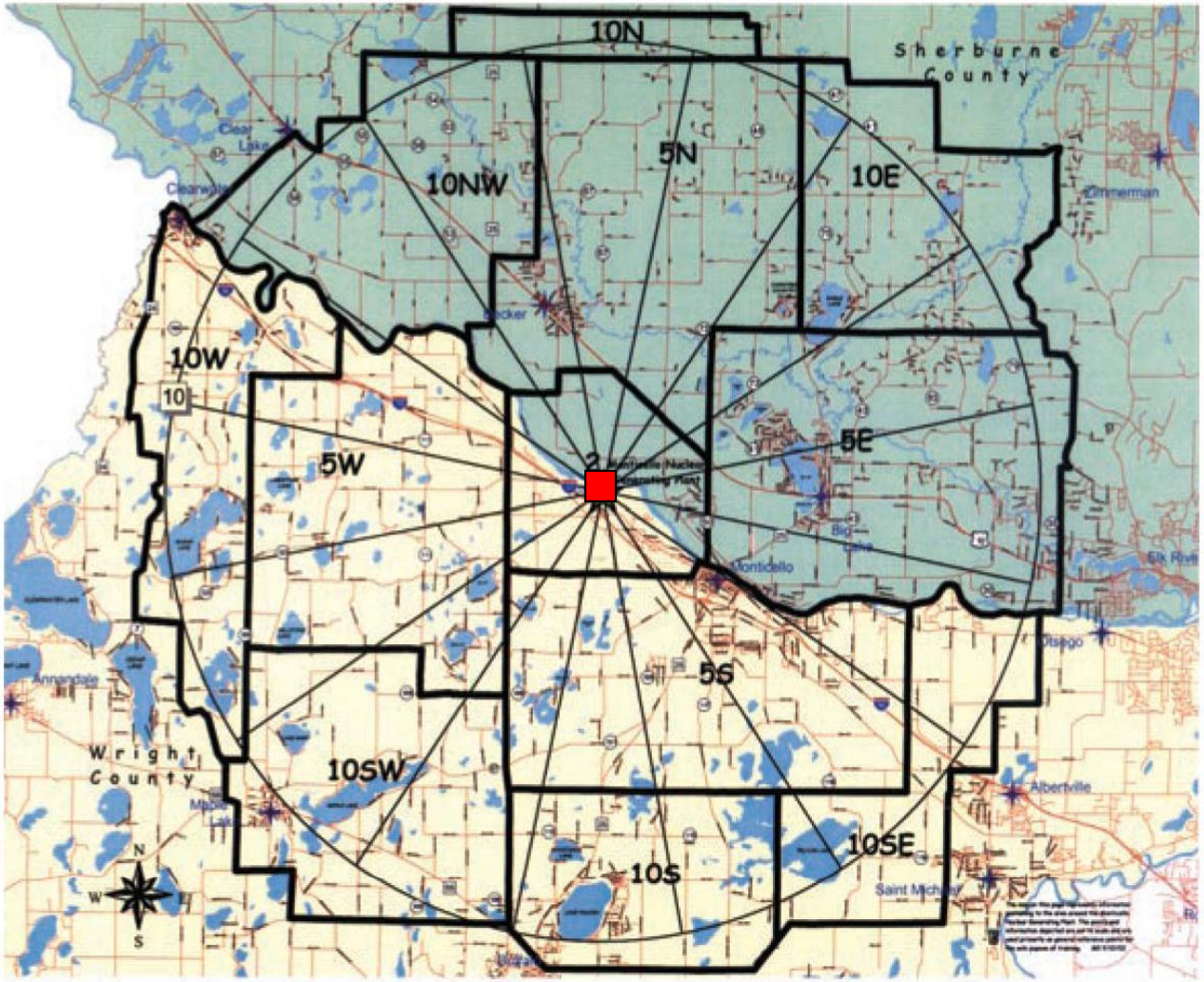
A Real Scenario: Montecillo Nuclear Power Plant



- Monticello Power Plant
- Affected Cities
- Evacuation Destination
- University of Minnesota

A Real Scenario: Monticello Emergency Planning Zone and Population

Emergency Planning Zone (EPZ) is a 10-mile radius around the plant divided into sub areas.



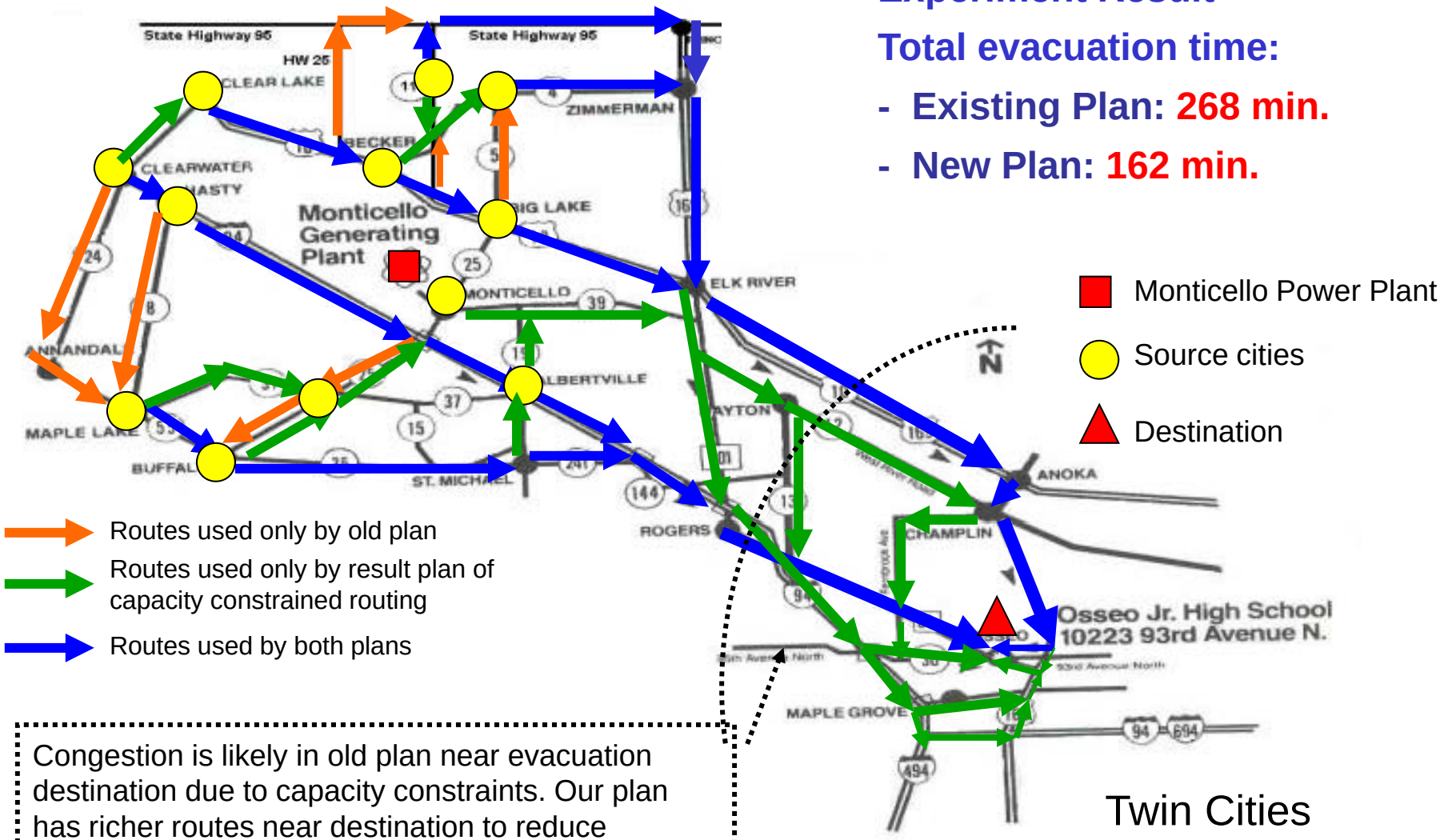
Monticello EPZ

Subarea	Population
2	4,675
5N	3,994
5E	9,645
5S	6,749
5W	2,236
10N	391
10E	1,785
10SE	1,390
10S	4,616
10SW	3,408
10W	2,354
10NW	707
Total	**41,950**

Estimate EPZ evacuation time:
Summer/Winter(good weather):
3 hours, 30 minutes
Winter (adverse weather):
5 hours, 40 minutes

Data source: Minnesota DPS & DHS
Web site: http://www.dps.state.mn.us
http://www.dhs.state.mn.us

A Real Scenario : New Plan Routes



Experiment Result

Total evacuation time:

- **Existing Plan: 268 min.**
- **New Plan: 162 min.**

Congestion is likely in old plan near evacuation destination due to capacity constraints. Our plan has richer routes near destination to reduce congestion and total evacuation time.

Summary of Related Works & Limitations

A. Capacity-ignorant Approach

- Simple shortest path computation, e.g. A*, Dijktra's, etc.
- e.g. EXIT89 (National Fire Protection Association)

Limitation: Poor solution quality as evacuee population grows

B. Operations Research: Time-Expanded Graph + Linear Programming

- Optimal solution, e.g. EVACNET (U. FL), Hoppe and Tardos (Cornell U).

Limitation: - High computational complexity => Does not scale to large problems

- Users need to guess an upper bound on evacuation time

Inaccurate guess => either no solution or increased computation cost!

Number of Nodes	50	500	5,000	50,000
EVACNET Running Time	0.1 min	2.5 min	108 min	> 5 days

C. Transportation Science: Dynamic Traffic Assignment

- Game Theory: Wardrop Equilibrium, e.g. DYNASMART (FHWA), DYNAMIT(MIT)

Limitation: Extremely high compute time

- Is Evacuation an equilibrium phenomena?

Performance Evaluation : Experiment Results 3

Experiment 3: Effect of Network Size

Setup: fixed number of evacuees = 5000, fixed number of source nodes = 10 nodes, number of nodes from 50 to 50,000.

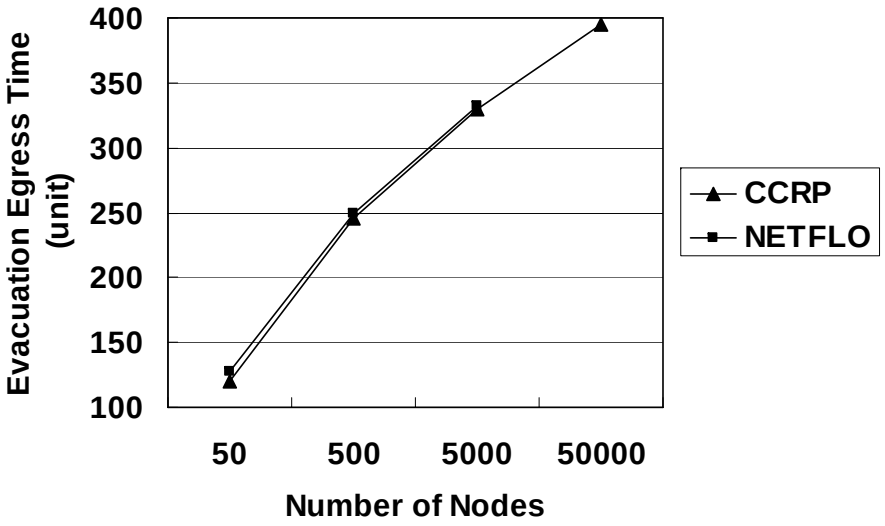
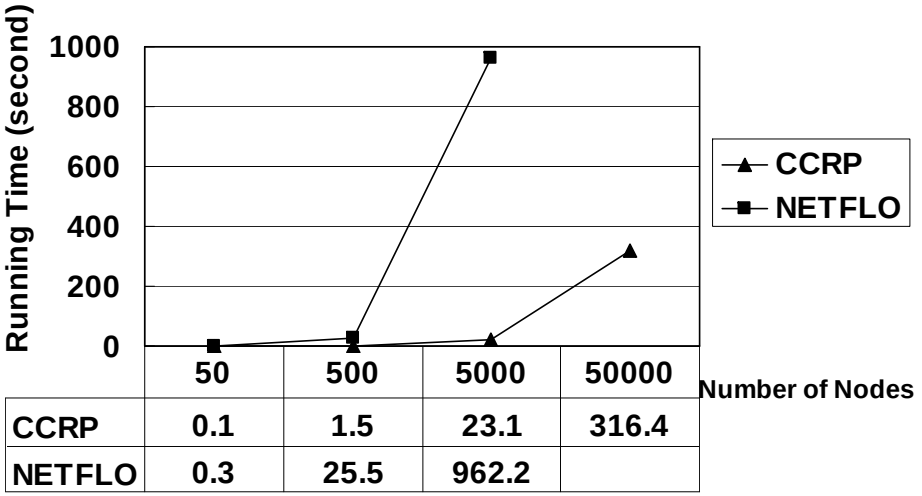


Figure 1 Quality of solution



	50	500	5000	50000
CCRP	0.1	1.5	23.1	316.4
NETFLO	0.3	25.5	962.2	

Figure 2 Run-time

- CCRP produces high quality solution, solution quality increases as network size grows.
- Run-time of CCRP is scalable to network size.

Current Limitations & Future Work

- Evacuation time estimates
  - Approximate and optimistic
  - Assumptions about available capacity, speed, demand, etc.
  - No model for pedestrians, bikes, public transportation, etc.
- Quality of input data
  - Population and road network database age!
    - Ex.: Rosemount scenario – an old bridge in the roadmap!
  - Data availability
    - Pedestrian routes (links, capacities and speed)
- On-line editing capabilities
  - Taking out a link (e.g. New Orleans bridge flooding) !

Future Work Across Disciplines

- Data Availability
  - Estimating evacuee population, available transport capacity
  - Pedestrian data: walkway maps, link capacities based on width
- Transportation
  - Link capacity depends on traffic density
  - Modeling traffic control signals, ramp meters, contra-flow, …
- Evacuee Behavior
  - Unit of evacuation: Individual or Household
  - Heterogeneity: by physical ability, age, vehicle ownership, language, …
- Policy Decisions
  - How to gain public's trust in plans? Will they comply?
  - When to evacuate? Which routes? Modes? Shelters? Phased evacuation?
  - Common good with awareness of winners and losers due to a decision
- Science
  - How does one evaluate an evacuation planning system ?
  - How do we caliberate parameters?