Infrastructure System Restoration Planning Using Evolutionary Algorithms

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Problem Statement

- Restoration in the aftermath of large-scale disasters creates complex restoration problems across virtually all urban systems.

- Tools are necessary to manage the large amounts of data involved in the restoration.

Damage Due to Extreme Events – Hurricane Katrina

- **"Nine Years After Katrina, Coastal Restoration Plans Remain Distant Dream for New Orleans." Over 10% of the production capacity is still non-operational.** *(http://www.desmogblog.com/2014/08/31/nine-years-after-katrina-coastal-restoration-plans-distant-dream-new-orleans)*(Kivanc and Michelle, 200

Hurricane Katrina debris (Wikipedia commons)

Interacting with the Data

- Estimation of resources required for restoration is critical to start a successful restoration process

- Interactions between the elements to be restored must be understood to make a good approximation

Capturing Interactions

- An application of the systems engineering approach to designing restoration schemes requires an understanding of the sub-system interactions within a city
- Mathematical modeling for restoration planning started with identifying the necessary facilities for a city to be brought back to normal operation
- Right now, twenty-six facility types have been identified, for which mathematical relationships have been studied

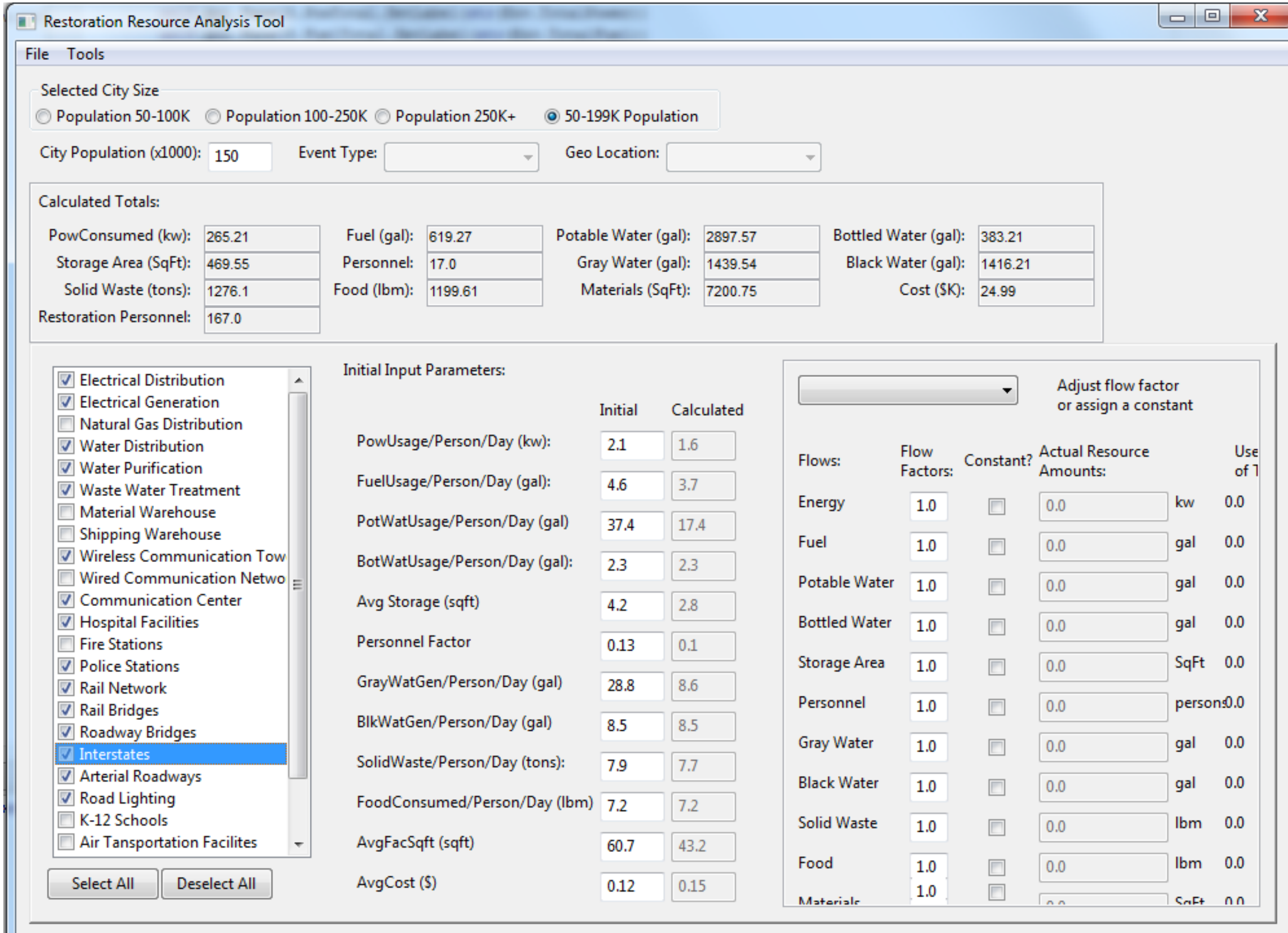
Capturing Interactions

- The main intent of these mathematical relationships is to estimate the numbers required to support a city of 150,000 people with necessary support to restore capacity
- Consumption/Generation numbers are taken from publically available sources and information provided by the government agencies, and the other numbers are filled in the model by way of ‘good educational guesses’ based on information from Saint Louis Area
- Results are being evaluated iteratively to improve accuracy

Capturing Interactions

1. Power Usage/Person/day (Watts): The total electricity that will be consumed
2. Fuel/Person/day (gal): The total fuel required
3. Potable Water/Person/day (gal): Total potable water consumed
4. Bottled Water/Person/day (gal): Total bottled water consumed
5. Average Storage (Sq. ft.): Storage space used during restoration
6. Restoration Personnel (Number): Number of restoration personnel required
7. Gray Waste Water/Person/day (gal): Waste water (Gray) generated from the restoration
8. Black Waste Water/Person/day (gal): Waste water (Black) generated from the restoration
9. Solid Waste/Person/day (lbm): Total solid waste generated from the restoration
10. Food Consumed/Person/day(lbm): Food consumed per day
11. Average Area (Sq. ft.): Total footprint area
12. Average Cost ($): Total Cost for restoring all the facilities

Calculator Interface



Determining Restoration Order

- The calculator provides a rough estimate of what is needed and what must be disposed of

- These values can be reduced using planning tools

Determining Restoration Order

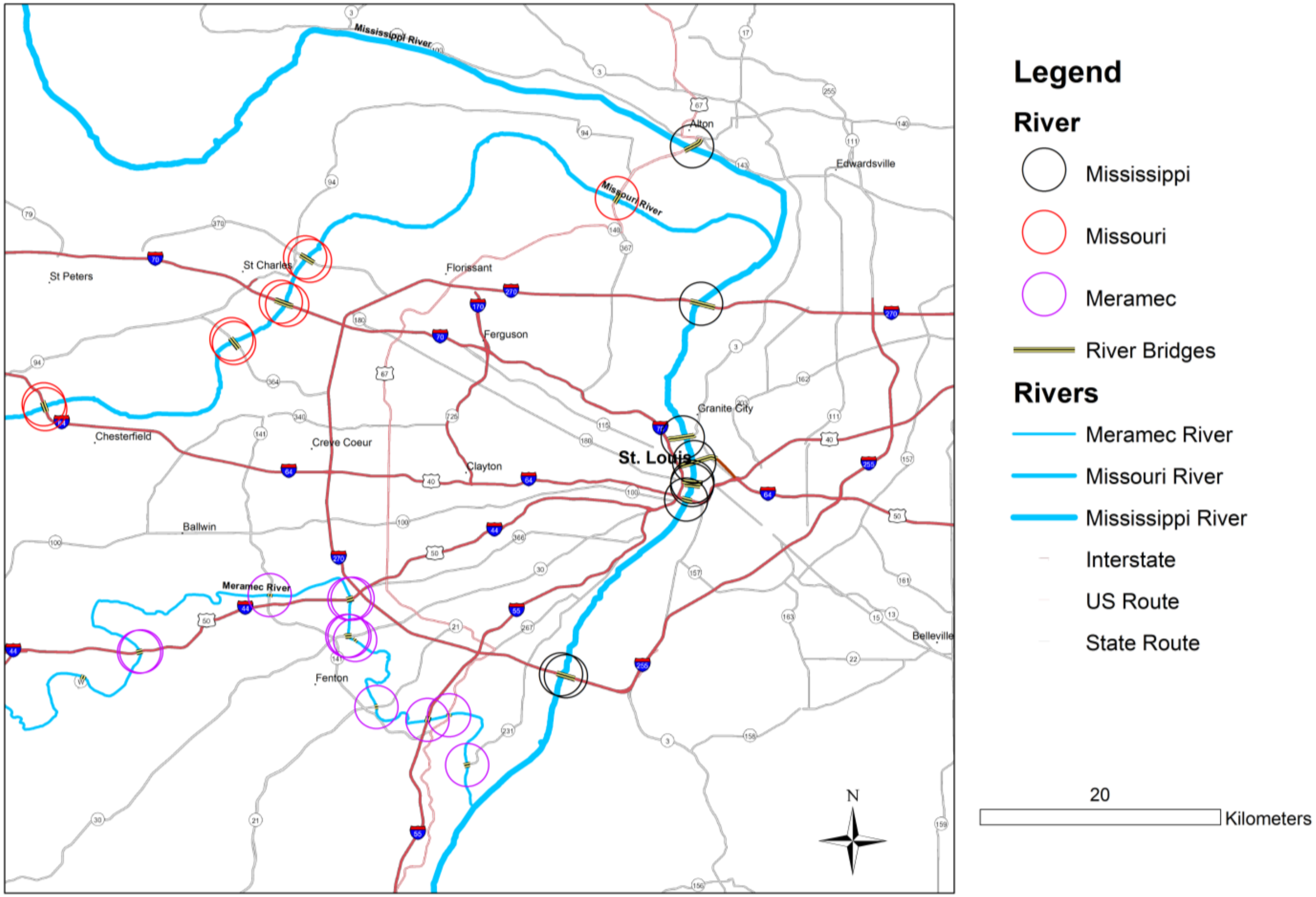
- Restoration of supply chain infrastructure capacity is critical to restoring all services
  - Reduces indirect costs

- Restoration order has an impact on the rate at which this capacity is restored

Saint Louis River Bridges

- Three major rivers to cross
- Four Interstates
- Thirty-one bridges under consideration

Saint Louis River Bridges



Saint Louis River Bridges

- Order of bridge restoration affects rate of restoration for:
  - Interstate transportation through St. Louis
  - Local traffic
  - Access for local industry

Restoration Planning

- Restoration order determined using Evolutionary Algorithm:
  - Scalable
  - Can be used for non-linear relationships
  - Allows for multiple parameters

Restoration Planning

- Cost for restoring bridges used as basis for indirect costs
- Cost is incurred while bridge is out of commission
- Restoration of infrastructure connectivity also rewarded
  - River crossings
  - Number of lanes crossing river

Restoration Planning

- Results of Evolutionary Algorithm compared to greedy algorithm
  - Adjusted to enforce alternating rivers
- Evolutionary algorithm reduced indirect costs by 12.4%

Restoration Planning

- Algorithms being developed for other infrastructure elements
- Algorithms also being developed to manage interfaces between the infrastructure systems

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- Questions?
- For more information contact:

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