Optimal Resource Allocation and Evacuation in Urban Crises

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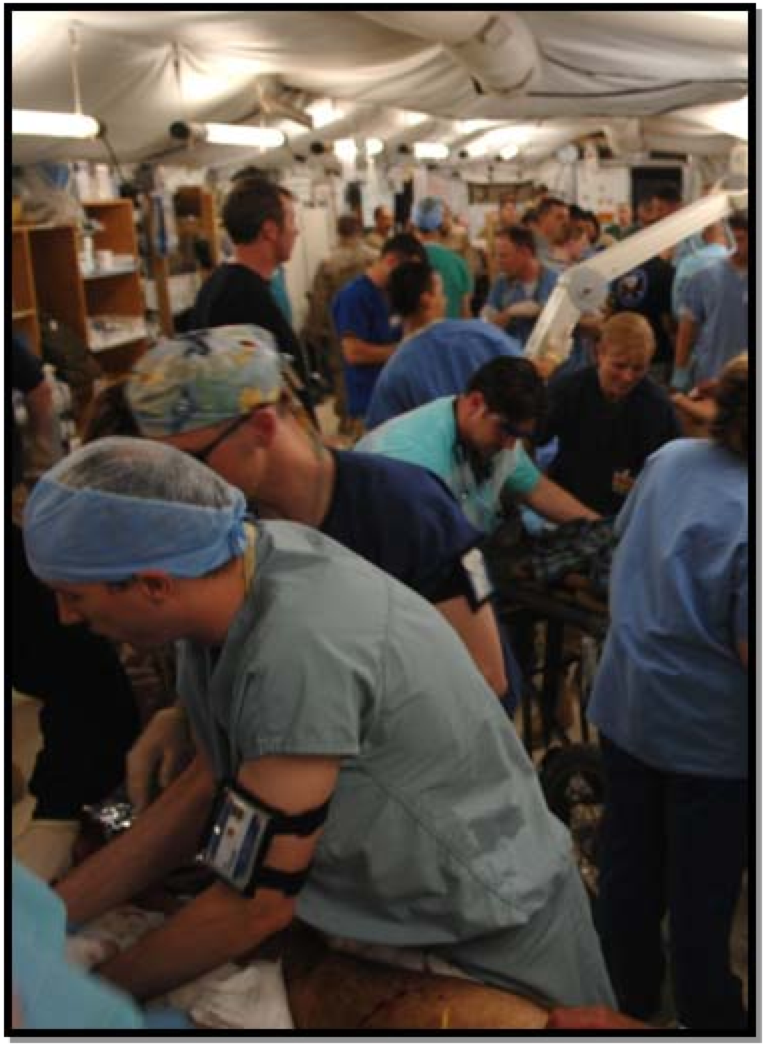
Scenario

- Crises in an urban center
  - Infectious disease outbreak
  - Extreme heat wave
- Spike in demand for medical treatment overwhelms currently available resources
  - Hospitals
  - Pool of trained medical personnel



Scenario

- Convert various public facilities for use as temporary medical centers
- Constraints
  - Trained medical personnel
  - Medical supplies
  - Capacities of buildings

Scenario

- Convey good information to public
  - When to seek treatment
  - Where to seek treatment

- Public Response
  - Ability to learn directives
  - Adherence to directives
    - Willingness to comply
    - Ability to comply

Scenario

- Two-fold problem
  - Which facilities to convert?
    - Includes types of supplies to allocate to each
  - How to route population most efficiently?
- Goal: Minimize loss of life

Approach

Approach

- LP formulation
  - Provides optimal solution with respect to facility location and population routing algorithm
  - Solution not easily transmissible to general public
  - Computationally difficult to solve
  - People aren't (usually) continuous
  - No real-time updates

Approach

- Simulation
  - Construct an individual-based model to simulate the crisis situation
  - Test outcomes associated with
    - Routing algorithms that are easily conveyable to a large population
    - Facility allocations that work well in combination with these algorithms
  - Model behavioral response of public

Approach

- Input to model
  - An explicit spatial map of the urban center
  - Demographic information about the population
    - Age, Gender, Socioeconomic status
  - List of suitable and available public facilities
    - Locations and capacities
  - Limited pool of medical personnel and supplies

Approach

- Minimize loss of life with proper combination of:
  - Allocation of supplies and personnel to facilities designated for temporary care provision
  - Easily dispersible and generally understandable routing algorithm
  - Compare result to optimal result obtained through LP formulation of problem.

A First Implementation

A First Implementation

- Extreme heat events
  - CDC defines as "*summertime temperatures that are substantially hotter and/or more humid than average for location at that time of year*"

- Multiple components to our model
  - Travel and contact network
  - Individual (behavioral) processes
  - Disease process
    - Non-infectious, exposure-based

A First Implementation

- Categorized health impacts from overexposure to heat
  - Dehydration, Respiratory, Cardiovascular
- Treatment centers able to treat a subset of these categories depending upon the medical supplies provided to that site

A First Implementation

- Triage system
  - Most serious cases need most serious care
    - i.e. more highly skilled medical personnel, etc.
  - Routing should be done so that the resources of the centers are used appropriately

A First Implementation

- Simple routing algorithms
  - Easily interpreted by general public
  - Widely transmissible
- Examples
  - Nearest center
  - Nearest appropriate center
  - Pre-assigned center

Future Directions

Future Directions

- Algorithms for generating locations of temporary facilities
  - Maximize coverage
  - Maximize capacity
  - Minimize potential traffic bottlenecks in the travel network
    - Dynamic Capacitated Arc Routing Problem for Optimal Evacuation Strategies in Disasters

Future Directions

- Infectious Disease
  - Pneumonic plague
    - Potential bio-weapon
    - Highly contagious
    - Symptoms similar to flu
    - Delay between exposure and onset of symptoms
    - High risk of death if left untreated
  - Emergency Triage Procedure

Future Directions

- Additional routing algorithms
  - "Radio traffic"
    - Radio broadcast of current wait times at each center; individual discounts wait time by distance from current position (and by treatment capabilities of center)
  - "Bring out your dead"
    - Individuals exhibiting symptoms self-quarantine until medical transportation arrives to take them to the appropriate center

Future Directions

- Additional routing algorithms
  - “Friendly warning”
    - Individuals receive information via cell phone from friends and/or relatives who are currently stuck in a long wait at a particular center.

Future Directions

- Behavioral components
  - Willingness to comply to suggested routing algorithm
    - Initial defiance
    - Break from orders due to extenuating circumstances
  - “Worried well” – pre-emptive seeking of treatment
  - Ability to self-diagnose

Concluding Thoughts

Academically Interesting

- Self-organization of a social network into triage by dissemination of general guidelines
  - How does the structure of the network change over time?
  - Does the layout of the information network determine the best solution?
  - What advantages/disadvantages does empirical simulation provide over a mathematical generalization of the problem?

Practical Applications

"Protecting the public from health threats involves *public health preparedness* as well as *medical preparedness*. Both are essential for national health security and, hence, to the overall preparedness of the nation."

- CDC Emergency Preparedness And Response Website

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CCICADA
Command, Control, and Interoperability Center for Advanced Data Analysis
A Department of Homeland Security Center of Excellence

DIMACS
Center for Discrete Mathematics & Theoretical Computer Science
Founded as a National Science Foundation Science and Technology Center

CDC
Centers for Disease Control and Prevention

U.S. Department of Homeland Security

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Questions?